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# A Review of the Environmental Survivability of Telerobotic Control Sensor Systems for Use in Nuclear Waste Tanks

D. E. Holcomb
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May 1994

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# A Review of the Environmental Survivability of Telerobotic Control Sensor Systems for Use in Nuclear Waste Tanks

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## ABSTRACT

This report was prepared by the Oak Ridge National Laboratory (ORNL) and funded by the Department of Energy (DOE) Office of Technology Development (OTD) Robotics Technology Development Program (RTDP). During the next few years field deployment of remotely operated systems in nuclear waste cleanup operations will increase dramatically as DOE strives to efficiently and safely remediate the many waste storage sites. Typically, the most fragile components in remote systems are the sensors that provide feedback to the operators or to computer control algorithms. The purpose of this review is to determine the availability of environmentally hardened sensors to support control of a manipulator or vehicle system in a waste tank environment.

The emphasis of the report is on the environmental ruggedness of currently available sensors. For the purpose of this review a set of nominal requirements for survivability were adopted conditions in the single-shell tanks at Hanford. This report is designed to be a practical guide to the state of the art in commercially available environmentally tolerant sensors for use with robotic systems. It is neither intended to be an exhaustive review of the technical literature on potential measurement techniques nor a complete physical review of the functioning of particular sensor systems. This report is intended to be a living document. As additional, corrected, or updated information is received from sensor manufacturers, it will be incorporated into the report database. The physical report will then be periodically revised and released in updated format. The authors wish to apologize to any sources of environmentally hardened sensors that were omitted during this review and encourage submission of new or updated data.

# 1. INTRODUCTION

During the next few years field deployment of remotely operated systems in nuclear waste cleanup operations will increase dramatically as the U.S. Department of Energy (DOE) strives to efficiently and safely remediate the many waste storage sites. One of the largest volume and most challenging waste problems that DOE faces is the retrieval and treatment of waste stored in large underground storage tanks like the single-shell tanks (SST) at Hanford, K-65 silos at Fernald, and gunite tanks at Oak Ridge National Laboratory (ORNL). Each site has a unique set of challenges depending on the waste properties and storage facility specifics. However, because of the number of SSTs and sheer volume of waste, the Hanford site offers the greatest payback for development of a robotics-based waste retrieval system that can be ported from tank to tank and reused multiple times. Design of these systems for extended useable lifetimes, in spite of the harsh conditions in the SSTs, allows maximum leveraging of the initial system development and procurement costs. Typically, the most fragile components in remote systems are the sensors that provide feedback to the operators or to computer control algorithms. This review discusses the availability of environmentally hardened sensors to support control of a manipulator or vehicle system in a waste tank environment.

Emphased in this report is on the environmental ruggedness of currently available sensors. For the purpose of this review, nominal requirements for survivability were adopted from documentation prepared for a robotic characterization and inspection system being developed by the DOE Office of Technology Development, Underground Storage Tank Integrated Demonstration. These environmental conditions were obtained from the "Operational and Interface Requirements for Characterization Sensors and End Effectors for the Light Duty Utility Arm," authored by Westinghouse Hanford Company [1]. These conditions include an operational temperature range of 21° to 65°C, up to 100% relative humidity, up to 10 Gy/h gamma dose rate, total accumulated gamma dose of 10,000 Gy, an operational pH of up to 12, an explosive hydrogen environment, and either a water- or carbon dioxide-based decontamination spray wash.

This report is designed to be a practical guide to the state-of-the-art in commercially available, environmentally tolerant sensors for use with robotic systems. It is not intended to be an exhaustive review of the technical literature on potential measurement techniques or a complete physical review of the functioning of particular sensor systems. It is intended to be a "living" document. As additional, corrected, or updated information is received from sensor manufacturers, it will be incorporated into the report database. The physical report will then be periodically revised and released in updated format. The authors apologize to any sources of environmentally hardened sensors that were omitted during this review and encourage submission of new or updated data.

The first step in the review was to identify candidate sensors and likely commercial vendors from the Sensors 1994 Buyer's Guide[2] and the AIP Handbook of Modern Sensors[3]. For each candidate sensor type several commercial vendors

were then contacted, and the relevant technical information was requested. In cases where off-the-shelf technology is not immediately available, the technical literature was searched for relevant data on potentially useful sensors.

This report is divided into sections on a technological basis. Each section contains, first, a basic description of the physical operating principles and known limitations of the sensor technology. Next, particular companies that sell environmentally tolerant versions of the sensor technology are identified, and their particular sensor systems are reviewed. The review includes general performance specifications and known limitations, rough cost estimation, sensor size and weight (when relevant), and finally (in an appendix) vendor data sheets. Also included with each sensor technology is a conclusion categorizing sensors into four groups: (1) sensors that will survive the Hanford waste tank environment and are currently commercially available, (2) commercially available sensors that will potentially survive the environment but have not yet been sufficiently tested, (3) prototype (but not standard commercial) sensors that are available and which will potentially survive the environment, and (4) the type of sensing that is impractical to perform in the waste tank environment.

## 2. FIBER OPTICS

Fiber optics are an enabling technology for several of the sensor types described in this report. Physically, an optical fiber is composed of an inner optically waveguiding core and cladding encased by a buffer and a protective sheath. An inert fluorocarbon will likely be suitable for use as a sheathing material (e.g., Hypalon™ or Tefzel™) in Hanford's harsh chemical and radiation environment. The combined requirements for high radiation and temperature tolerance makes the various plastic optical fibers unsuitable for use in the waste tanks. The most radiation tolerant varieties soften at ~85°C, while the high-temperature suitable acrylics brown before reaching 10,000 Gy.

Because the radiation performance of glass optical fibers is determined chiefly by its dopants, the fiber core should be composed of undoped silica glass, and the cladding should be of fluorosilica for optimal radiation hardness. Silica glass fiber's response to radiation is not uniform across its transmission band. Within the communication wavelength region (1 to 2 mm) any radiation-induced performance changes will be virtually undetectable. However, within the visible at 10,000 Gy the radiation-induced optical attenuation of a pure silica glass fiber will be of the order of 1 dB/m[4].

If optical fibers must be connected within the waste tank (e.g., for arm segmentation) additional components whose radiation performance is less well known will be introduced into the line. The radiation performance, as well as chemical resistance of the epoxies and plastic ferrules used with many mechanical fiber optic connectors, have not yet been determined.

Overall, suitable environmentally tolerant fiber optics are available from many manufacturers. Among them are 3M Specialty Fibers [Hugh Doherty (908) 521-2809], Ensign-Bickford (203) 678-0371, and Mitisubishi Cable (212) 888-2270.

## 3. LASER DIODES

The primary effect of irradiation of laser diodes (LDs) is to decrease the minority carrier lifetime. This results in a decrease in output power and an increase in the lazing threshold. A recent study of low-power LD performance shows that these LDs show no significant reduction in light output up to total gamma doses of $\leq 5 \times 10^5$ Gy.[5] The study cautions that the LDs must be run in current stabilization mode because of the radiation sensitivity of the integrated monitor PIN diodes. Also, the laser diode driving circuits used in AT&T transmission links have been shown to perform well up to doses of 1 MGy.[6]

Initial data from recent testing of the higher power LDs expected to be used in the laser rangefinders performed by ORNL and Ohio State University [Mardi Hastings (614) 292-2271] indicates that neither the LD output power nor its far-field beam pattern is adversely affected by a 10,000 Gy gamma dose. Moreover, the integrated monitor photodiode currents varied by less than 1% for 10,000 Gy gamma dose radiation.

## 4. CAMERAS

Electronic cameras are conventionally divided into three main classes—charge-coupled devices (CCDs), charge injection devices (CIDs), and photoconductive devices.

### 4.1 CCD

CCD cameras are based on an array of MOS capacitors in which charge is generated optically and read by transferring charge from one MOS capacitor to its neighbor under the control of clock pulses. CCDs are NMOS-based devices, which are the most radiation sensitive variety of MOS device: failures occur in the 7 to 70-Gy (Si) range.[7] It is possible, however, to greatly increase the radiation tolerance of CCD cameras through extensive shielding.

R. J. Electronics [Roy Bennett (503) 743-3709] sells CCD-based "Radiation Tolerant Zoom Color Television Cameras" that they claim are radiation hard to 4600-Gy accumulated dose (1 MeV equivalent) or $5.9 \times 10^5$ Gy (0.5 MeV equivalent). The company claims that the actual CCD array (Sony image sensor) survives to 100 to 1000 Gy (200 Gy nominally). Camera housing length is approximately 25 cm; diam is 12 cm. Tube mass is 30 kg, and operating temperatures are limited to < 40°C. Some care must be taken with the camera model specification in that the RC-510 series is designed for viewing spent fuel elements from one direction and thus is shielded for only approximately one-third of its circumference. Heavier models that are fully shielded are available and are currently in use in the Hanford 101 and 103 tanks. Also, the sealed cameras use a constant nitrogen purge to cool the electronics (increasing the operating range to 50°C) and ensure a nonoxygen (nonexplosive) atmosphere.

### 4.2 CID

PMOS-based CID technology is somewhat more radiation hard. An additional CID advantage is that the technology allows a contiguous pixel structure facilitating superior image quality. However, current CID technology allows only monochromatic imaging.

CIDTEC [Anthony Chapman (315) 451-9410] sells a range of radiation tolerant CID-based cameras. Current models operate up to doses of a few thousand Gray. The company plans to introduce in 1994 a product line approximately 100 times as radiation hard. The new design is based on military work that has been done with General Electric (GE)—the company is a GE spin-off. The company also has done radiation testing with COGEMA, Ontario-Hydro, and the National Institute of Standards and Technology.

## 4.3 PHOTOCONDUCTIVE

Photoconductor-based cameras are by far the most radiation tolerant cameras currently available. Image quality is available from 500 to 800 horizontal television lines.

Rees Instruments, Inc. [Jess Johns (404) 433-9991] manufacturers a wide variety of radiation tolerant photoconductor-based cameras. Vidicon ($Sb_2S_3$) tubes are available that will survive 2 MGy. Typical tube dimensions are 25 cm in length and 4.0 cm diam. Tube mass without head or lens body is ~1.25 kg. Electrical power requirements are approximately 3 W. An entry-level system costs ~$20,000. Operational temperature is limited to < 55°C for the Vidicon tubes and < 70°C for the Chalnicon (CdTe) tubes. The main limitations of photoconductor-based cameras are their price, their size, and their physical fragility due to use of vacuum tube technology.

# 5. ANGULAR POSITION MEASUREMENT SYSTEMS

## 5.1 OPTICAL ENCODERS

Optical encoders are based on interruption of a light beam (or beams) by an encoder disk that has precisely placed transparent sections corresponding to particular angular positions. The major advantages of optically based systems are high accuracy and precision as well as small physical size. The main limitation of optical encoder systems is cost—few standard systems are designed for adverse environments.

BEI Motion Control Systems [Tim Malcolm (501) 851-4000, ext. 5467] makes a variety of radiation-hardened optical encoder systems. In particular, BEI has a 15-bit encoder with integral electronics (provides digital output directly) available for ~$7000 (additional units ~$5000). This unit has a diam of 8.85 cm and masses 0.9 kg. This unit will operate at 100°C, 100% relative humidity, and in chemically corrosive environments.

Computer Optical Products, Inc. [Lou Rosinski (818) 882-0424] makes an optical fiber–based optical encoder that they claim is radiation hard. Although conceptually their technology appears to be radiation hard, no testing data are available. In this particular fiber optic design a bulk cable is used to illuminate a reflective encoder plate, and the reflected light is guided back to remote detectors—maximum fiber length is 6 m. The sensors will operate in temperatures up to 125°C (optionally up to 300°C). Resolution is limited to 12 bits. A great deal of redundancy is provided in the fiber optic cable bundle. Typical dimensions are 8 cm in length and 8 cm in diam.

## 5.2 INDUCTOSYNS®

In an Inductosyn® the physical quantity that varies with angular positioning is the inductive coupling between two sets of electrical conductors. The conductors are printed on parallel, opposing insulative plates. The rotor plate has a fine, continuous pattern of radially printed conductors, while the stator plate is composed of several sets of conductors. The patterns on the rotor and stator are designed so that the inductive coupling varies sinusoidally with angular position.

Farrand Controls [Paul Valanti (914) 761-2600] makes a range of Inductosyns ® that they describe as "unaffected by dust, oil films, vapors, sea water, light, radiation, extreme pressure, temperature from 10°K to 150°C." However, they do not have specific test data showing the level of radiation tolerance—the company quotes several military examples of their use, and it is likely the units have survived some radiation testing. The company has indicated that they are willing to provide a unit to ORNL for radiation testing in return for testing data. The approximate price for a 16-bit accurate system is $5000. The electronics for the unit can be remoted up to 10 m (standard unit limited to 3 m). Sixteen-bit accurate units have 30-cm-diam plates, and smaller plates (8 cm) are available for lower accuracy measurements.

## 5.3 RESOLVERS

Resolvers resemble small cylindrical alternating current (AC) motors. They employ single winding rotors that revolve within fixed stators which have two windings oriented at 90°. Resolver operation resembles a rotating transformer. The rotor winding is excited by an AC voltage. The magnitude of the voltage induced in any stator winding is proportional to the cosine of the angle between the rotor coil axis and the stator coil axis.

Astrosystems, Inc. [Mike Goldstein (516) 328-1600] manufactures a line of environmentally tolerant resolvers. This line includes models that are explosion proof, radiation tolerant to 10 MGy, operational from −20° to +85°C, and have accuracies (single turn) of 0.088°. Resolver sizes vary from a few centimeters to more than 10 cm in diam and mass from 0.11 to 1.25 kg.

## 6. RADFETs

Radiation Sensitive Field Effect Transistors (RADFETs) are based on using the shift in threshold voltage of a radiation soft, p-channel MOSFET as a radiation sensor. Physically, radiation produces trapped charge in the oxide layer of the MOSFET inhibiting the gate from creating a channel between the source and drain electrodes. Advantages of RADFETs include very small size (< 1 $mm^2$), giving total integrated ionizing dose directly, wide variation in sensitivity available, and physical simplicity. Limitations of RADFETs are limited commercial availability, lack of spectral information, lack of individual event information, slow drift in the threshold voltage when switching on the read-out circuit, and long-term fading. The slow drift problem is typically addressed by always performing the read-out at the same time after turning on the reader.

Sandia National Laboratories (SNL) [Daniel Moreno (505) 844-6860 or Bob Hughes (505) 844-8172] has produced a dual layer (i.e., oxide and nitride) RADFET that they claim allows it to maintain its radiation-induced threshold voltage drift indefinitely. A commercial source for RADFETs is Andrew Holmes-Siedle at REM; 64a Acre End St.; Eynsham, Oxford OX8 IPD, England.

# 7. PROXIMITY DETECTORS

## 7.1 CAPACITIVE PROXIMITY DETECTORS

Capacitive proximity detectors are based on changing the geometry between capacitive plates. One of these plates is the active sensing region of the probe; the other, the target object. Capacitive probes are short distance proximity measurement systems. Their effective range depends on the particular material being sensed. For detecting grounded metals the sensors act in an inductive manner producing eddy currents in the conductors, and the effective range of the sensor is roughly 3 cm. In contrast, detecting dielectrics depends on the material dielectric constant and can only be done at shorter distances—polyethylene (k = 2.0) at 0.2 cm.[8] Fundamentally, capacitive proximity detectors should be quite radiation hard as their only required exposed components are a metal plate and a shielded signal line. One limitation of most capacitive proximity detectors is the parasitic capacitance of the signal lines that limits the distance the electronics can be remoted from the probe head.

Capacitec [Bob Foster (508) 772-6033] makes a line of capacitive proximity sensors that have been tested for radiation tolerance at ORNL.[9] In the Oak Ridge tests the sensor systems survived doses of 4 MGy. Capacitec's standard probes will operate up to 150°C and are housed in a stainless steel enclosure. Probe diameters vary from 0.1 to 1.3 cm. The Capacitec probes operate at 15 to 20 kHz and in standard configuration can be remoted 10 m from the electronics. Rack-mounted electronics that will control up to four probes cost ~$2500. Sensor heads cost ~$300, and radiation-hardened cabling (IR2 model) costs ~$200 per probe. One limitation of the Capacitec design is its sensitivity to deposition on the sensor face (e.g., dust, dirt, and water). Some form of a cleaning flow (e.g., a nitrogen line) would be required if sensor fouling is anticipated.

## 7.2 ACOUSTIC PROXIMITY DETECTORS

Ultrasonic proximity detectors are based on generating high-frequency sound waves and measuring the time delay of the reflected echo signal to detect the presence of an object and its range. To generate ultrasonic waves, the movement of a surface is required. This is most commonly accomplished using a piezoelectric diaphragm that flexes in response to an electrical signal. Important considerations when considering ultrasonic proximity sensors include (1) dead zone (minimum detection range), (2) beam cone angle, (3) maximum sensing range, (4) inclination of smooth targets, and (5) variation of the air temperature. Ultrasonic sensors exhibit a minimum detection range—if a target is located closer to the transceiver than the dead zone, the reflected signal will return before the diaphragm has completed its ringing from the output pulse. Smooth, flat targets can reflect incident ultrasonic pulses away from the transceiver unit—this is not a problem with coarse surface material. Also large temperature variations of the air in the beam path will cause dispersion and refraction of the ultrasonic signal.

A wide variety of polymers and ceramics exhibit a piezoelectric effect. However, comprehensive environmental survivability data have been published only for Lithium Niobate ($LiNbO_3$) crystals.[10,11,12] Lithium Niobate has been shown to perform as a piezoelectric material with no significant changes at temperatures exceeding 500°C and for $^{60}Co$ doses of 40 MGy.

Panametrics, Inc. [Larry Linworth (800) 833-9438] has a radiation tolerant, high-temperature, environmentally ruggedized line of ultrasonically based flowmeters incorporating Lithium Niobate crystals. The same general technology is directly applicable to proximity detection. The major limitation of this approach is that since the technology used is not off-the-shelf, the first Lithium Niobate–based ultrasonic proximity detector would cost ~$10,000 because of one-time engineering costs. Minimum detection distance with this sensor system would be ~0.1 m, maximum range would be ~10 m, and virtually any desired beam angle could be obtained. Physical size of the transceiver unit would be ~5 cm diam. All required electronics would be remotely located.

Several other less expensive ultrasonic sensor systems (<$1000) may be suitable (no obvious inherent reason exists for a variety of piezoelectric crystals not to be radiation tolerant) for use in the waste tank environment. Further investigation of other manufacturers' products would be advantageous, especially if they are competitive in cost and performance with Lithium Niobate systems from Panametrics.

## 7.3 OPTICAL PROXIMITY DETECTORS

In optical proximity detectors (also known as diffuse scan photoelectric sensors) a light beam is projected out of the transceiver head, and the intensity of returning light indicates the presence of an object within the sensing range. The light beam is typically generated either by a light-emitting diode (LED) or an LD and light detection is performed with a PIN photodiode. The only other electronics normally contained in the sensor head are the PIN preamplifier circuitry and perhaps the light source controlling circuitry. Off-the-shelf, optical proximity detector systems are available in red and near infrared wavelength ranges.

Apparently, no radiation testing on optical proximity detector systems has been done. However, as is indicated in the earlier section on LDs, testing has been performed on all of the critical components of optical proximity detectors (i.e., light sources, lenses, PIN diodes, and preamplifier circuits)–all of which may be chosen such that doses well in excess of 10 kGy may be survived. Two companies that sell environmentally hardened (although not radiation-tested) optical proximity detector systems are Aromat Corp. [Tom Steele (800) 228-2350 and Micro Switch—a Honeywell Division (800) 537-6945]. Both of these companies also sell a fiber optic–based version of their optical proximity detectors. In these systems the electronics are located remotely from the adverse environment, and only an optical fiber and lens system are exposed to the radiation field.

The effective range of diffuse scan photoelectric sensors is typically from near 0 to ~50 cm. For unknown target types, the sensors give only a presence or absence indication rather than a target range. The overall recommendation for this sensor system type is that, if needed in a radiation environment, off-the-shelf systems should first be radiation-tested to determine their survivability; if they prove inadequate, a radiation tolerant system should then be engineered.

## 8. LASER RANGEFINDERS

The function of a laser rangefinding camera is to create a three-dimensional map of a surface. Three different techniques are available for creating these maps. Triangulation-based systems use an LD beam and then position the LD's diffusely reflected spot (relative to the spot's position for a calibration surface) to determine the coordinates of a point on an object's surface. Amplitude-modulated laser rangefinders use the phase difference between the "send" and "return" light beams of an amplitude modulated laser to obtain surface coordinates. In frequency-modulated laser rangefinders the output of a frequency-modulated, long-coherence-length laser is split into a reference leg and a signal leg. As the laser frequency range is being swept, the signal leg is reflected off the object's surface and recombined with the reference leg to obtain a heterodyne-type interference pattern. The difference frequency (i.e., the heterodyne beat pattern frequency) is proportional to range.

### 8.1 TRIANGULATION

Spar Aerospace Limited (SPAR) [Cor van Kemenade (416) 790-2800, ext. 4707] makes a triangulation-based laser rangefinder. Although no system deployment data are available yet, the company claims that their system will survive 10,000 Gy. The system used by SPAR was developed by the National Research Council of Canada.[13,14] The sensor head will be approximately 27 x 10 cm in cross section and 23 cm in depth. The image acquisition system is based on a shielded CCD array (512 x 512 pixel). The system field of view will be 30° X and 50° Y. Image acquisition time is nominally 5 s. Minimum and maximum range are 0.6 m and 10 m respectively. The stated precision is 0.02 cm at 0.6 m and 2.5 cm at 10 m. The device accuracy is claimed to be ≤ 5 times the precision. The camera mass is approximately 4 kg. The electronics can be remoted at least 10 m from the detector head (25-m goal). The total radiation tolerance will be at least 10 kGy(Si) [1 MGy (Si) goal]. The system is still experimental; thus no firm price exists. Current estimates are $100,000 to $150,000.

### 8.2 AMPLITUDE MODULATION

Perceptron Inc. [Leo VanWezel (313) 478-7710] makes an amplitude modulation–based laser rangefinder. Perceptron is using a 50-mW laser diode (Spectra Diode SDL-5412-H1; 835 nm; 100 mW peak). The product was developed under a National Aeronautics and Space Administration Small Business Innovative Research contract. The sensor head also contains aluminum mirrors (silver/magnesium fluoride coated); bare, gold-coated lenses; analog bipolar amplifiers, a direct current brushless motor, a galvanometer, and an avalanche photodiode. More detailed information about their system is proprietary. Perceptron has not performed any radiation testing on their system; however, no immediately apparent radiation-sensitive components are required to be used in their sensor head. Therefore, proper system testing should be conducted to determine if the Perceptron laser

range-finder will survive the waste tank environment. All controller electronics are located remotely. The sensor head mass is 8 kg The sensor head is roughly 14 x 20 cm in cross section and 20 cm in depth. The minimum sensor has minimum and maximum ranges of 0 and 40 m. The sensor accuracy depends on target characteristics and range. Perceptron does not currently have quantitative precision and accuracy numbers. Amplitude modulation-based systems suffer from accuracy limitations due to target characteristics (i.e., dark areas look closer than bright areas)—this is likely to be a significant limitation to accurate surface mapping. Data acquisition can be up to 1024 x 1024 pixels in a 60° x 60° field of view with a repeatability of 0.5 pixel. A 1024 x 1024 image can be obtained in 7 s; and a 256 x 256, image in 0.5 s. The data collection rate is on the order of $5 \times 10^5$ samples per second. System price is $50,000 to 60,000. Odetics, Inc. [Robert Carlton (714) 758-0100, ext. 6943] is another commercial source for laser imaging scanners.

## 8.3 FREQUENCY MODULATION

Coleman Research Corporation [Steve Webber or Richard Sebastian (703) 719-9200] makes a fiber optic–coupled, frequency-modulated, continuous wave laser radar. Coleman's system uses a long-coherence-length, 1-mW laser diode frequency-modulated at 70 GHz. Data acquisition rate for Coleman's system is 1000 points per second—faster systems are possible using higher performance processors. The sensor head is ~25 cm in diam and masses ~5 kg. This technology is inherently more accurate than the approaches described above. Uncertainties are on the order of 1 mm. The main system limitations are price (current system costs are unknown) and possibly survivability. Further detailed analysis and component testing would be required to determine whether the system would survive the radiation, chemical, and temperature environments. The system relies on a precision light direction system that uses state-of-the-art components which have not yet been tested for radiation hardness and would be expensive to test to failure. The currently available Coleman system uses a rotating mirror system for light redirection, while their development system is based on a high-speed fiber optic switching system.

## 8.4 STRUCTURED LIGHT

Structured light is an approach that combines several of the components described above to form a surface-mapping system. The key components are a laser source such as an LD, camera, and rotating mirrors or high-precision rotary stages. ORNL and SNL have both been recently involved in structured light system development and demonstration. A mapping system developed by ORNL in 1991 was used in a hot-field deployment at Fernald. Mechanical Technology Incorporated (MTI) [John Wagner (518) 785-2800] worked with ORNL and SNL through Cooperative Research and Development Agreements (CRADAs) to transfer DOE-structured light technology from the national laboratories to the commercial sector. The emphasis of the CRADA between ORNL and MTI was design and

demonstration of a structured light system appropriate for use in the Hanford SSTs. This project was completed early in 1994. This system is designed to survive the radiation, humidity, and temperature ranges described in ref. 1. Mapping accuracies are about 6 mm for ranges up to 15 m.

## 9. ACCELEROMETERS

Ruggedizied, radiation-hardened accelerometers are standard commercial products. The current generation of this technology is piezoelectrically based. Piezoelectric accelerometers use a spring-and-mass system to couple a force proportional to the amplitude and frequency of vibration to a piezoelectric crystal.

Endevco Corporation [Jim Jones (800) 982-6732] makes a wide variety of radiation-hardened accelerometers. Their product line includes sensors of less than 0.1 g, hermetically sealed systems (to 24 MPa), operation to 350°C, radiation tolerance to 620 MGy, and extreme maximum shock limits.

## 10. STRAIN GAUGES

A strain gauge is essentially a resistor whose resistance is a function of its deformation. Metal foil strain gauges are a standard type of strain gauge and have been extensively tested for radiation performance.[15] Properly designed, conventional metal foil, polyimide-backed, epoxy-bonded strain gauge technology will survive at least 1 GGy. Constantan metal foil strain gauges are available that have essentially identical radiation performance changes; thus when they are used in a Wheatstone bridge, bridge balance is maintained.

Industrial Sensors and Instruments [Bud Dublin (512) 255-3790] has experience with radiation resistant, high-temperature (≥ 260°C), chemically resistant strain gauges. Their strain gauges are available in a wide variety of sizes and packages.

## 11. FORCE/TORQUE SENSORS

The function of force/torque sensing systems is to provide simultaneous multiaxis (up to six) indication of the force and torque acting on the sensor, which completely defines the loading acting on the sensor. This is accomplished using mechanically and electrically balanced sets of strain gauges.

JR3 Inc.'s [Wayne Johnson (916) 661-3677] primary product line is multiaxis load-sensing systems. JR3's sensor line is based on metal foil strain gauge technology. JR3 is currently involved in radiation performance testing its sensors with the Belgian nuclear authority. Although test results are not yet available, metal foil strain gauge technology has previously been shown to be very radiation hard.[15] The controlling electronics can be remotely located from the sensor head. Sensor-sealing methods are available to withstand aggressive chemical environments. Sensor-rated loads are available from 6.7 to 11,000 N. Typical sensor head sizes are 9 cm OD and 4 cm in depth. Digital sample rates of all six axes are standardly available up to 350 Hz. Typical stock sensor system prices are slightly more than $5000.

Assurance Technologies, Inc. [Cathy Knight (919) 772-0115, ext. 134] manufactures multiaxis load-sensing systems. Assurance's product line is based on silicon strain gauge technology. Assurance's sensor heads have been tested in radiation environments by Harwell Labs (England). Assurance's standard stainless steel sensor body with silicon strain gauges and standard resident electronics have survived off-line irradiation of 300 kGy with minimal changes (<1% accuracy decrease). Assurance's standard temperature-compensated model will operate from –40°C to +76°C. Assurance provides stock systems with rated sensing ranges from 66.7 to 667 N. Force resolution in the X or Y axis varies from 0.05 to 0.56 N with the sensing range; correspondingly, the force resolution in the Z axis varies from 0.11 to 1.1 N. Typical sensing heads are 9 cm in diam by 5 cm in depth. The maximum six-axis data rate standardly available is 1000 Hz. Stock sensor system prices are in the $6000 to $8000 range, and specially modified systems are available for ~$15,000.

## 12. TACTILE SENSORS

The function of tactile sensors is through contact to provide information on an object's shape, orientation, texture, hardness, weight, and temperature. The object's tactile information is then used to determine the amount of force/torque required to manipulate it without slippage. To accomplish this, two dimensional arrays of force-sensing elements are located on gripping elements. Although a wide variety of sensing techniques have been investigated in the laboratory (i.e., optical, resistive, capacitive, inductive, and piezoelectric), no robust, two-dimensional tactile sensor is yet available that can effectively mimic the human hand.[16]

One potentially promising technology is that manufactured by Bonneville Scientific at (801) 359-0402. This sensor is based on the piezoelectric properties of polyvinylidene fluoride polymer (PVDF). Bonneville's sensor consists of a two-dimensional array of PVDF transceivers mounted on a rigid substrate and overlaid by a thin rubber pad. The sensor operates by transmitting an ultrasonic pulse from each taxel (i.e., tactile element) and measuring the time of flight for the reflection of the pulse from the top surface of the rubber. The time of flight is proportional to the rubber thickness, which is in turn related to the incident force and stiffness of the rubber. PVDF is mechanically and chemically robust, possesses a large piezoelectric coefficient, excellent linearity, low hysteresis, and long-term survivability in temperatures of up to 60°C.[16] Radiation performance data on Bonneville's sensor system is not available; however, this appears to be a technology worth further investigation. One limitation of PVDF is its cross-sensitivity to temperature due to its inherent pyroelectric response. Bonneville's standard product is a 16 x 16 array of taxels, each of which is 0.152 cm across and separated by 0.025 cm. The price is ~$5,000.

## 13. INCLINOMETERS

Inclination detectors measure the angle of the sensor from the direction of the center of the earth. Mercury switches are the traditional method for electrically determining inclination. However, because of the toxicity of mercury and the resulting environmental regulation, sources of precision mercury switches are becoming rare. Spirit levels that are read optically are a potential solution to this problem. These sensors consist of an LED located above a hemispherical level mounted on a quadrant PIN photodetector.[17] The relative output signal of the four photodetectors yields the location of the bubble in the spirit level and hence the sensor inclination. In the configuration described the hemisphere is 1.7 cm in diam, and the distance of the LED from the photodiodes is 5.0 cm. Although no environmental tolerance information is available about this sensor as a whole, all of its internal components (i.e., LED, glass, epoxy, liquid, and PIN photodiode) are available in forms that have been previously demonstrated to tolerate radiation environments.

## 14. SIGNAL PROCESSORS

Amplifying the analog signals produced by sensor elements, converting them from analog to digital locally, and multiplexing these digital signals onto a communications network would significantly reduce the cabling difficulties in adverse environments for robotic systems. However, the typical radiation effect threshold for several of these devices is quite low, and significant design effort is required to obtain an acceptably radiation hardened system. Moreover, for some sensor systems very precise, state-of-the-art electronics are required to detect and to analyze the sensor signal; these electronics are not available in a radiation-hardened form.

Radiation failure data for analog-to-digital converters shows that they are available with ionizing dose failure thresholds above 10,000 Gy.[18] It has also recently been demonstrated that with proper circuit design, "it is possible to construct a radiation-hardened processor that can implement a useful degree of intelligence and computational power in a radioactive environment."[19] Radiation-hardened [50,000 Gy (Si)] microprocessors (both CMOS and bipolar amplifier based) are available.[20] Research in developing radiation-hardened real-time signal processing is ongoing, and radiation-hardened signal processing is likely in the next few years to move from the realm of the research laboratory to the commercial production environment.[21]

The general conclusions as to the design of sensor signal processors for radiation environments are that (1) for most sensor systems it is possible to design and to fabricate suitable radiation-hardened (to 10,000 Gy) signal-processing electronics, (2) radiation-hardened signal processor system design requires considerable engineering time and effort, and (3) considerable research still needs to be done to develop inexpensive, off-the-shelf, radiation-hardened signal-processing technology.

## 15. CONCLUSIONS AND RECOMMENDATIONS

Properly designed, ruggedizied versions of all of the sensing functions described suitable for application in the Hanford SSTs can be obtained or developed with a nominal effort using currently available technology. However, for several of the sensor systems identified, only limited environmental performance data are available (i.e., optical proximity detectors, laser rangefinders, tactile sensors, piezoelectric crystals, and optical encoders). Before sensor systems utilizing these components are deployed in the waste tank environment, their environmental tolerance should be more fully determined and documented. In addition, if signal processing is to be performed within the waste tank, the necessary effort should be expended to test candidate processors for survival in the waste tank environment.

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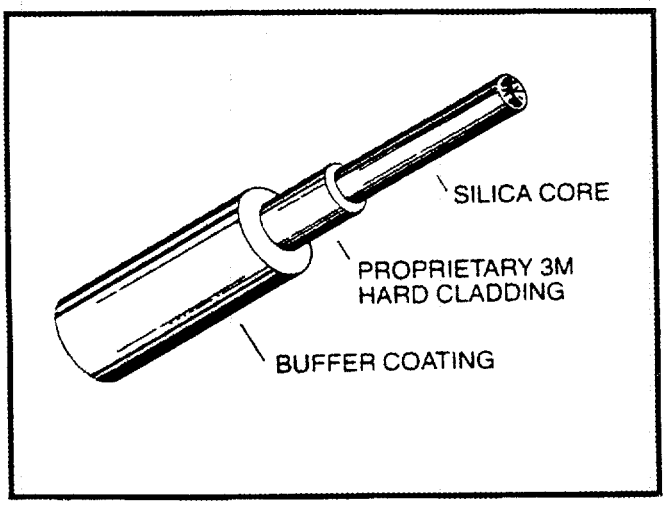
# APPENDIX A
# FIBER OPTICS

# Power-Core Fiber
## 0.48-NA TECS™ Hard-Clad Fiber




TECS™ Hard-Clad Fiber Construction

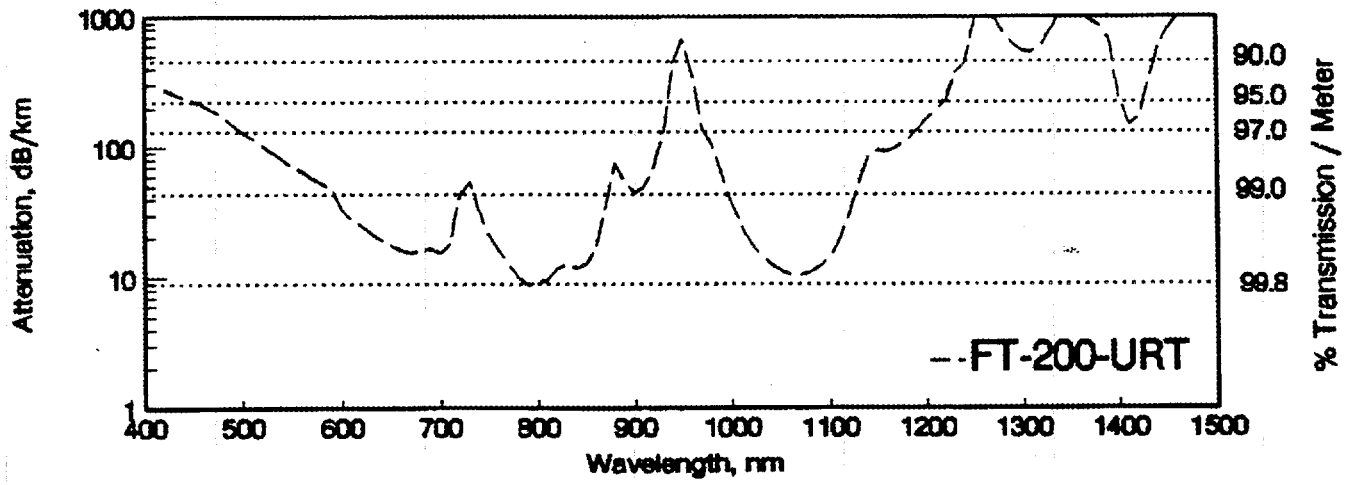
**Applications**

- Illumination Systems
- Sensing Systems
  - Medical
  - Industrial
- Laser Delivery Systems
- Laser Diode Systems
- Short-Haul Data and Video Communications

**Advantages**

- High numerical aperture:
  - Couples over 50% more power than standard polymer-clad fibers.
  - Couples over 370% more power than standard silica-clad fibers.
  - Less critical fiber alignment requirements.
  - Reduced bending losses.
- Hard cladding yields increased fiber strength and reduced static fatigue. It also protects the fiber during buffer stripping to prevent fiber breakage.
- High core-to-clad bonding prevents pistoning and provides more stable crimp-and-cleave or epoxy terminations.
- Small overall fiber size for small size constraints.
- Silica core has low-loss transmission over a broad spectral range.
- High concentricity and core-to-clad ratio for excellent connection alignment, fiber core positioning and high transmission bundles.
- Variety of connectors and assemblies available:
  - High-power SMA 905 assemblies.
  - 3M FC and ST*-compatible ceramic ferrule connectors and assemblies for high-precision applications.
  - SMA 905 crimp-and-cleave connector system for user-friendly, high-quality, repeatable terminations.
  - No epoxy, reusable 3M mechanical splice.

**Typical Spectral Response**




3M

# 0.48-NA TECS™ Hard-Clad Fiber

| Part Number | Unit | FT-125-URT | FT-200-URT | FT-400-URT | FT-600-URT | FT-1.0-URT |
|---|---|---|---|---|---|---|
| Core Diameter | µm | 125 ± 5 | 200 ± 5 | 400 ± 8 | 600 ± 10 | 1000 ± 15 |
| Clad Diameter | µm | 140 +2,-5 | 230 +0,-10 | 430 +5,-15 | 630 ± 10 | 1035 ± 15 |
| Buffer Diameter[1] | µm | 250 +50,-0 | 500 ± 30 | 730 ± 30 | 1040 ± 30 | 1400 ± 50 |
| Maximum Attenuation @ 820nm | dB/km | 14 | 12 | 12 | 12 | 12 |
| Typical Attenuation @ 420nm | dB/km | 280 | 280 | 280 | 280 | 280 |
| Maximum Core Offset | µm | 5 | 5 | 7 | 9 | 10 |
| Numerical Aperture[2] | | 0.48 ± 0.03 | 0.48 ± 0.03 | 0.48 ± 0.03 | 0.48 ± 0.03 | 0.48 ± 0.03 |
| Acceptance Angle (Full) | | 57° | 57° | 57° | 57° | 57° |
| Peak Optical Power Capability[3] | MW | 0.6 | 1.6 | 6.3 | 14.0 | 64.3 |
| Operating Temperature Range | °C | -65 to +125 | -65 to +125 | -65 to +125 | -65 to +125 | -65 to +125 |
| Proof Test Level | kpsi | 100 | 100 | 50 | 50 | — |
| Minimum Bend Radius | | | | | | |
| — Recommended Short Term | mm | 8 | 13 | 53 | 80 | 133† |
| — Recommended Long Term | mm | 13 | 20 | 80 | 120 | 180 |
| — Absolute Short Term† | mm | 3 | 5 | 12 | 18 | 30 |
| — Absolute Long Term† | mm | 7 | 10 | 20 | 30 | 60 |
| Standard Length | m | 1100 | 1100 | 500 | 300 | 50 |

[1] Standard buffer coating is Tefzel® 210
[2] meters, 50% intensity
[3] Based on 5 GW/cm² for 1064nm Nd:YAG laser with 10 nsec. pulse length.
† Determined statistically for short gauge length.

**Special Note:**
This product is experimental: It may be subject to modification, production limitations or cancellation by the manufacturer. Contact 3M regarding current status of this product before including it in any Specification.

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**3M Specialty Optical Fibers**

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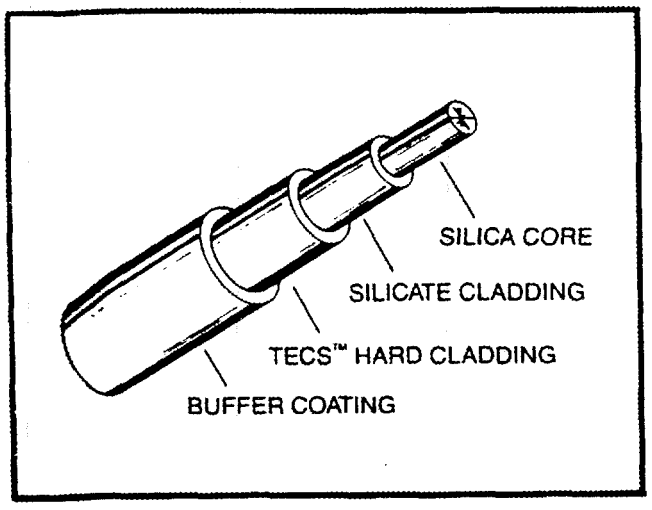
(203) 934-7961

# Power-Core Fiber

## TECS™ - Coated Silica/Silica



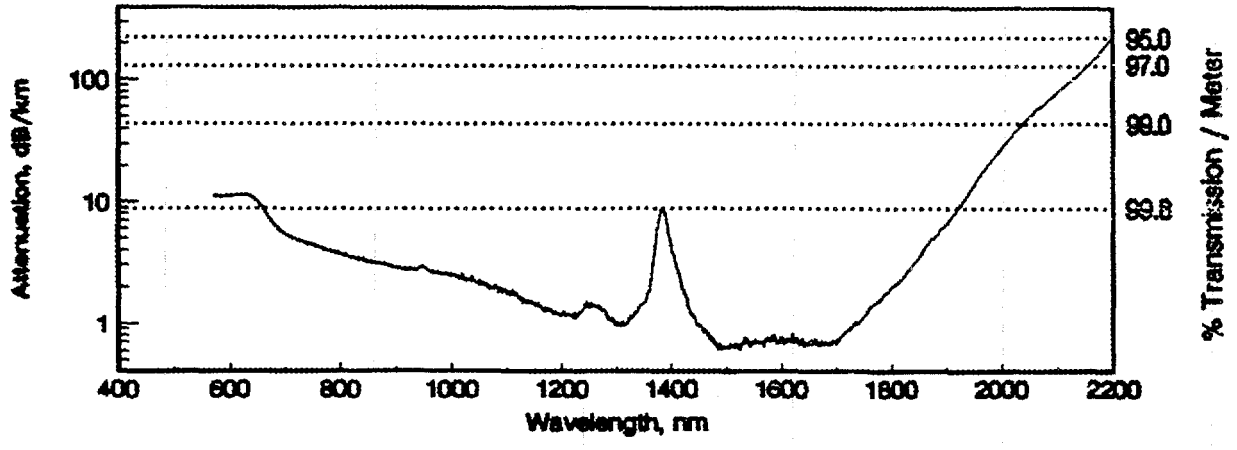

**Applications**

- High-Power Near-IR Laser Delivery Systems
  - Ho:YAG at 2100nm
  - Nd:YAG at 1440nm
- Ordnance Initiation
- Spectroscopy

**Advantages**

- Stability of silicate cladding allows for high power-handling capability and laser misalignment.
- Low-index fluorine-doped silicate cladding design provides superior near-IR transmission compared to polymer-clad fibers and borosilicate-doped silica/silica fibers.
- High concentricity and core-to-clad ratio for excellent connector alignment and small overall fiber size.
- TECS™ hard-polymer cladding yields increased fiber strength and reduced static fatigue. Also protects the fiber during stripping to prevent fiber breakage.
- Secondary 3M hard cladding provides a dual waveguide design, resulting in improved bend performance and power coupling.
- Strong bonding of silicate to 3M hard cladding prevents pistoning and provides more stable terminations.
- Core, cladding and buffer are USP Class VI approved for non-toxicity and biocompatibility.
- Sterilizable (EtO and Steam)
- Custom fiber sizes, core-to-clad ratios, and coatings available for specific applications.
- 3M High-Power SMA 905 assemblies available.

**Typical Spectral Response**




Manufactured in the U.S.A.

3M

# TECS™ - Coated Silica/Silica

| Part Number | Unit | FG-200-LCR | FG-365-LER | FG-550-LER |
|---|---|---|---|---|
| Core Diameter | μm | 200 ± 5 | 365 ± 8 | 550 ± 12 |
| Clad Diameter | μm | 240 ± 5 | 400 ± 8 | 600 ± 10 |
| Coating Diameter | μm | 260 ± 6 | 430 +5,-15 | 630 ± 10 |
| Buffer Diameter[1] | μm | 400 ± 30 | 730 ± 30 | 1040 ± 30 |
| Maximum Attenuation @ 820nm | dB/km | 8 | 8 | 8 |
| Typical Transmission @ 2100nm | /m | 98% | 98% | 98% |
| Maximum Core Offset | μm | 5 | 7 | 9 |
| Numerical Aperture[2] | | 0.22 ± 0.02 | 0.22 ± 0.02 | 0.22 ± 0.02 |
| Acceptance Angle (Full) | | 25° | 25° | 25° |
| Peak Optical Power Capability | MW | 1.6 | 5.2 | 11.9 |
| Operating Temperature Range | °C | -60 to +125 | -60 to +125 | -60 to +125 |
| Proof Test Level | kpsi | 100 | 50 | 50 |
| Minimum Bend Radius | | | | |
| — Recommended Short Term | mm | 16 | 53 | 80 |
| — Recommended Long Term | mm | 24 | 80 | 120 |
| — Absolute Short Term† | mm | 6 | 12 | 18 |
| — Absolute Long Term† | mm | 12 | 20 | 30 |
| Standard Length | m | 1100 | 500 | 300 |

[1] Standard buffer coating is Tefzel® 210.
[2] 2 meters, 50% intensity.
† Determined statistically for short gauge length.

**Important Notice to Purchaser:**
All statements, technical information and recommendations related to the Seller's products are based on information believed to be reliable, but the accuracy or completeness thereof is not guaranteed. Before utilizing the product, the user should determine the suitability of the product for its intended use. The user assumes all risks and liability whatsoever in connection with such use.

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# TECS™ Hard-Clad Fiber
# Specification Addendum

| Part Number | Unit | FT-1.5-UMT |
|---|---|---|
| Core Diameter | μm | 1500 ± 30 |
| Clad Diameter | μm | 1550 ± 31 |
| Buffer Diameter[1] | μm | 2000 ± 100 |
| Maximum Attenuation @ 820nm | dB/km | ≤ 18 |
| Maximum Core Offset | μm | ≤ 15 |
| Numerical Aperture | | 0.39 ± 0.02 |
| Acceptance Angle (Full)[2] | | 46° |
| Peak Optical Power Capability[3] | MW | 88 |
| Operating Temperature Range | °C | -65 to +125 |
| Minimum Bend Radius[4] | | |
| — Recommended Short Term | mm | 200 |
| — Recommended Long Term | mm | 300 |
| Standard Length | m | 2 |

[1] Standard buffer coating is Tefzel® 210
[2] 2 meters, 50% intensity
[3] Based on 5 GW/cm$^2$ for 1064nm Nd:YAG with 10 nsec pulse length.
[4] Determined statistically for short gauge length.

**Note:**
This product is experimental: It may be subject to modification, production limitations or cancellation by the manufacturer. Contact 3M regarding current status of this product before including it in any specification.

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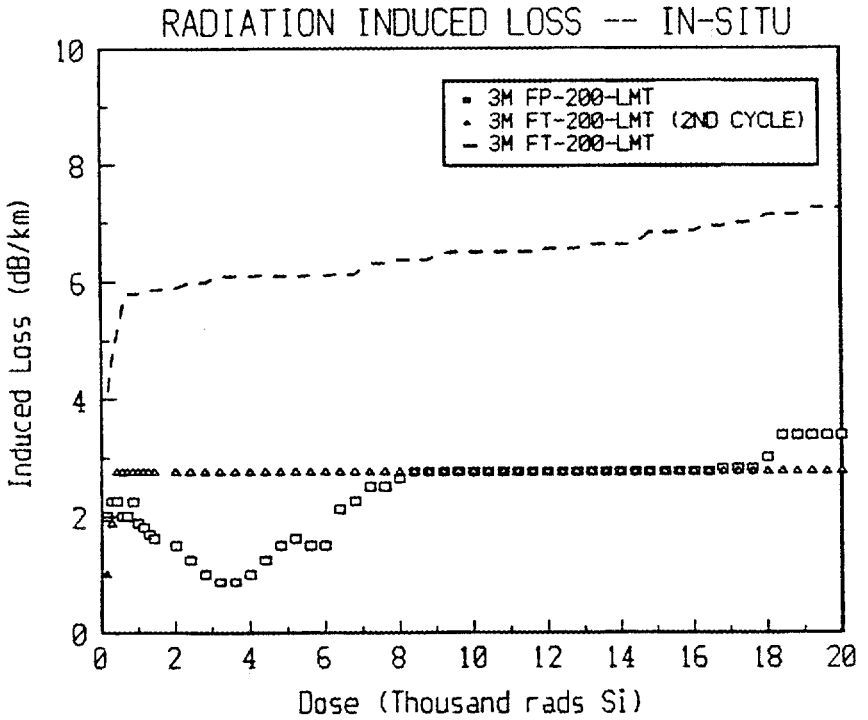
# Radiation Performance

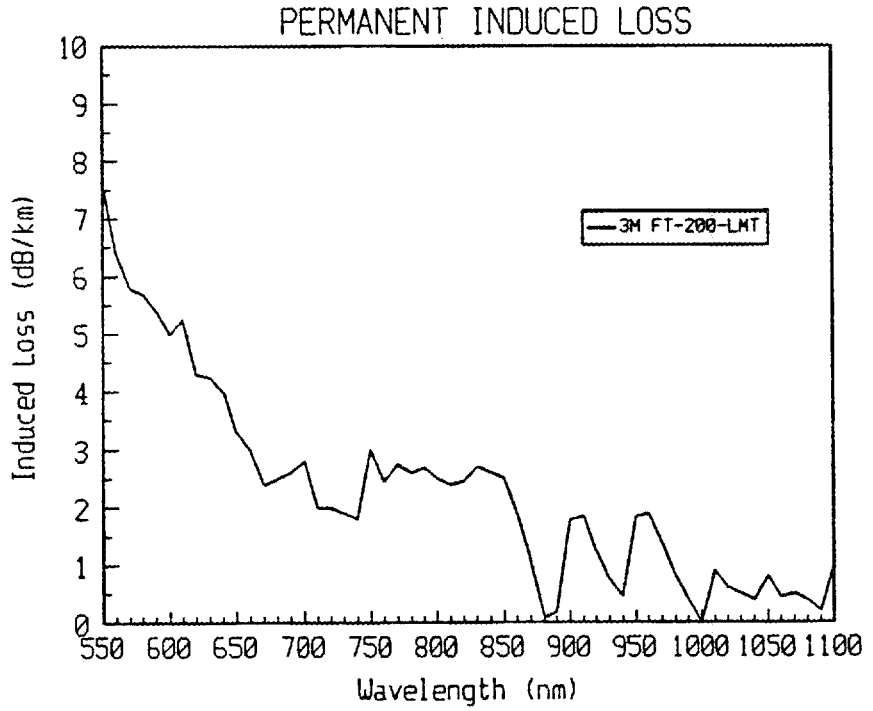



**Environment**

γ Radiation — $Co_{60}$
Dose Rate: 420 Rads/min.
Wavelength: 820 nm

**Fiber Samples**

| | |
|---|---|
| 3M Plastic-Clad Silica: | FP-200-LMT |
| 3M TECS™ Hard-Clad: | FT-200-LMT |




**Environment**

γ Radiation — $Co_{60}$
Dose Rate: 420 Rads/min.
Total Dose: 20,000 Rads

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# Catalog Addendum
# Low-Stress Polarization-Maintaining Single-Mode Fiber

| Part Number | Unit | FS-CP-4611 | FS-CP-6621 | FS-CP-7621 |
|---|---|---|---|---|
| Operating Wavelength | nm | 820 | 1300 | 1550 |
| Mode Field Diameter | μm | 5.3 ± 0.5 | 8.0 ± 0.5 | 9.5 ± 0.5 |
| Second Mode Cutoff | nm | <780 | <1270 | <1500 |
| Nominal Numerical Aperture[1] | | 0.13 | 0.13 | 0.13 |
| Maximum Attenuation | dB/km | 6.0 @ 820nm | 3.0 @ 1300nm | 3.0 @ 1550nm |
| Fiber Diameter | μm | 80 ± 2 | 125 +1,-3 | 125 +1,-3 |
| Maximum Core/OD Offset[2] | μm | 1.0 | 1.0 | 1.0 |
| Coating Diameter | μm | 200 ± 15 | 250 ± 15 | 250 ± 15 |
| Maximum Beatlength | mm | 5.0 @ 630nm | 5.0 @ 630nm | 5.0 @ 630nm |
| Coating Type | | Soft Primary/Acrylate | Soft Primary/Acrylate | Soft Primary/Acrylate |
| Operating Temperature Range | °C | -55 to +85 | -55 to +85 | -55 to +85 |
| Proof Test Level[3] | kpsi | 50 | 50 | 50 |
| Standard Length | m | 1100 | 1100 | 1100 |

[1] Calculated from mode field diameter (Petermann approximation).
[2] Tighter tolerance can be provided.
[3] Fiber with higher tensile level can be provided.

**Note:**
This product is experimental: It may be subject to modification, production limitations or cancellation by the manufacturer. Contact 3M regarding current status of this product before including it in any specification.

Rev: 1/5/94

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# Single-Polarization (Polarizing) Fiber

3M has developed a true single-polarization fiber, the first such product in the industry. Unlike the more common polarization-maintaining fibers, this fiber guides *one and only one* polarization of light. Short lengths may be coiled to form high-extinction polarizers (better than 40 dB extinction for 3 meters, typical) or longer lengths may be used as a transmission medium in polarization-sensitive communication systems. The fiber is available at three wavelengths: 820nm, 1300nm and 1550nm.

## The Fiber Design

3M™ polarizing (PZ) fiber is very similar to 3M™ polarization-maintaining (PM) fiber. Like its sibling, the fiber has a circular core and barrier surrounded by an elliptical stress-applying region; resulting in high modal birefringence. In addition, the PZ fiber has a thin, low-index ring between its core and cladding. (See Figure 1)

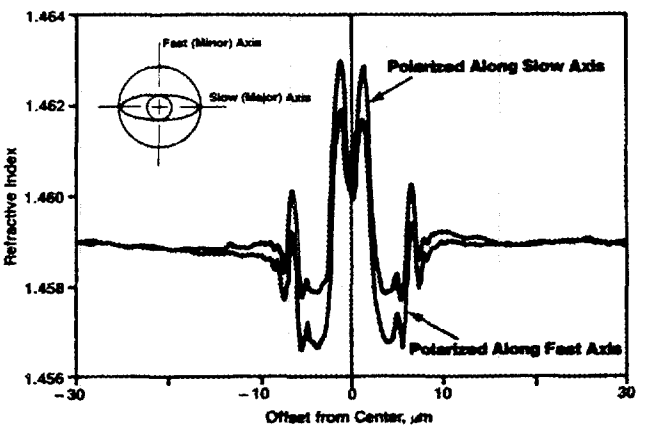


**Figure 1.** Refractive-index profiles of PZ fiber using linearly polarized light along the polarization axes.

In operation, the fundamental mode of the fiber tunnels across the added layer, and since the fiber is birefringent, the tunneling occurs at a shorter wavelength for one polarization than it does for the other. Operating at an intermediate wavelength, propagates only the guided polarization mode and allows the fiber to act as a polarizer[1]. See Figure 2.

The design of the 3M PZ fiber results in a fiber offering superb performance in:

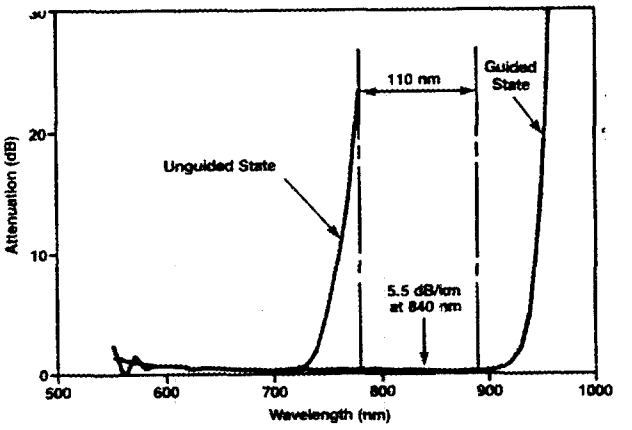


**Figure 2.** Spectral attenuation of the guided and unguided polarization states. Sample length is 40 meters.

- extinction (better than 40 dB)
- insensitivity to microbends
- the width of the polarizing band (more than 12% of the operating wavelength)

## Fiber Polarizers for Sensors and Device Pigtails

The 3M PZ fiber is remarkably versatile and will polarize light whether it is held straight or coiled. The length of fiber required to achieve good extinction is minimized, though, by coiling. When wound to a 3-inch diameter, only 3 meters of fiber are needed to achieve better than 40 dB extinction (typical). This small package is ideal for sensor applications. If desired, a smaller or larger coil diameter can be chosen to match the size requirements of a particular sensor. Note, however, that the extinction rate and the placement and width of the extinction band change with coil diameter. (See Figure 3)

## Long-Length PZ Fiber for Transmitting Coherent Light

Polarization-maintaining fiber has proven to be indispensable in a number of long-length sensor applications, most notably in the fiber optic gyroscope. Although PM fibers carry the initial polarization signal with low loss, they still carry and

transmit both polarization modes. Problems can arise when using PM fibers to transmit light from high-coherence sources (such as lasers), problems not encountered with the low-coherence sources found in gyroscopes. The PZ fiber solves this problem by rejecting one of the polarization modes, making it much more attractive for polarization-dependent communications schemes.

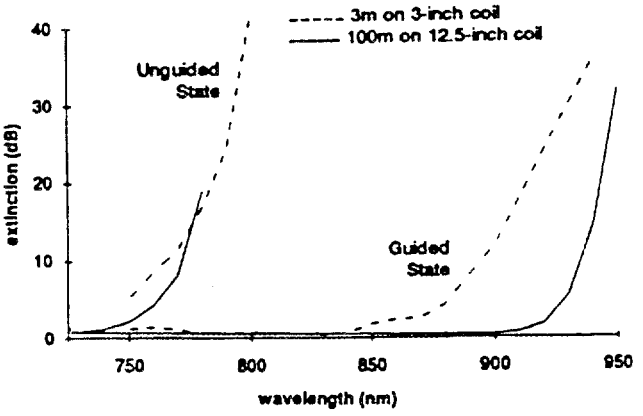


**Figure 3.** Spectral attenuation of the guided and unguided polarization states on 3-inch and 12.5-inch diameter coils.

A second advantage of 3M PZ fiber is seen when aligning the polarization of the source to the fiber's stress axes. The task is straightforward with an incoherent source such as an LED, but is much more involved when the source is a laser[2]. With the PZ fiber alignment is simple — rotate the polarization of the source until the transmitted power is maximized.

The third advantage of PZ fiber is more subtle. In long-length communication lines, it is inevitable that a small amount of light carried in a PM fiber will be coupled from the launched polarization to the unlaunched polarization, then back again. With coherent light, the twice-coupled light can interfere with the launched light, adding to the system noise. With the 3M PZ fiber, however, the noise is greatly reduced because light coupled to the unlaunched polarization is swept out of the fiber before it has a chance to couple back and cause interference.

## Operating Principle

3M polarizing fiber utilizes a depressed-well cladding or W-type refractive index profile. Careful design of the various fiber structures results in polarized light "seeing" the different refractive index profiles shown in Figure 1. Under these conditions, one polarization mode is cut off where the other orthogonal state is guided for a fairly wide wavelength band.

For an in-depth description of the operating principle, please contact 3M Specialty Optical Fibers for a copy of "A Broad-Band Single Polarization Optical Fiber" as published in the Journal of Lightwave Technology (see Footnote 1).

## Using 3M Single-Polarization Fiber

As with standard telecommunications fibers, the PZ fibers have excellent mechanical strength characteristics. Therefore, standard handling practices are sufficient when stripping, bending, and winding.

The 3M PZ Series single-polarization fibers are mechanically matched to 3M PM Series polarization-maintaining fibers for ease in fiber-to-fiber splicing. In aligning the fiber to other fibers and devices, simply rotate the fiber and monitor its output power until maximum is reached.

By design, 3M single-polarization fibers do not require bending for operation as in conventional fiber polarizers. However, under tight bends the guided mode cutoff edges toward the shorter wavelength, reducing the operational bandwidth. This effect is shown in Figure 3 and should be taken into consideration when using 3M PZ fiber.

## Additional Information

The following references describe theory and performance of 3M single-polarization fiber and some of its applications. For additional assistance, please consult 3M Specialty Optical Fibers.


1 Messerly, M.J., Mikkelson, R.C., Onstott, J.R., "A Broad-band Single Polarization Optical Fiber." Journal of Lightwave Technology Vol. 9, No. 7, (July 1991).

2 Rashleigh, S.C., Burns, W.K., Moeller, R.P., and Ulrich, R., "Polarization holding in birefringent single-mode fibers." Optics Letters Vol. 7, No. 1, (1982).


## Special Note

This product is experimental: It may be subject to modification, production limitations or cancellation by the manufacturer. Contact 3M regarding current status of this product before including it in any specification.

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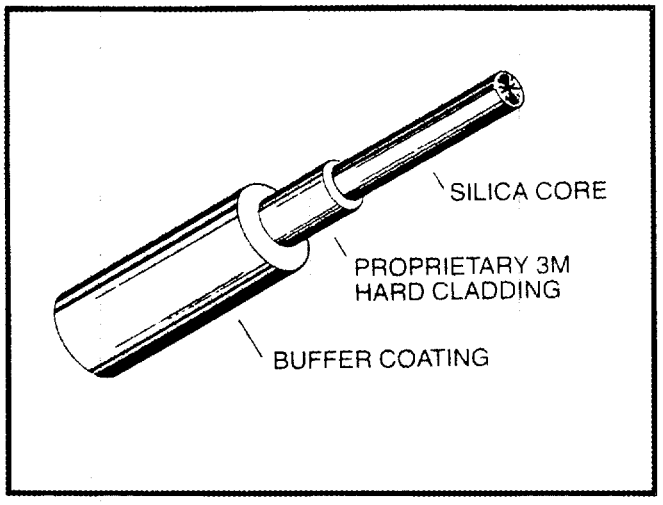
# Power-Core Fiber

## TECS™ Hard-Clad Fiber




TECS™ Hard-Clad Fiber Construction

TECS™ Hard-Clad Fiber is ideal for use in medical laser delivery systems.

### Applications

- Laser Delivery Systems
  - Medical
  - Industrial
  - Ordnance Initiation
- Short-Haul Data and Video Communications
- Illumination Systems
- Sensing Systems
  - Medical
  - Industrial
  - Spectroscopy

### Advantages

- Hard cladding yields increased fiber strength and reduced static fatigue in humid environments. Also protects the fiber during buffer stripping to prevent fiber breakage.
- Efficient light coupling and superior transmission in tight bends due to high numerical aperture.
- High core-to-clad bonding prevents pistoning and provides more stable crimp-and-cleave or epoxy terminations.
- Small overall fiber size for small size constraints.
- High concentricity and core-to-clad ratio for excellent connection alignment, fiber core positioning and high transmission bundles.
- Both Low- and High-OH fiber designs available, providing a broad spectral transmission range from 220nm to 2400nm.
- New DMT Series Low-OH fibers are a highly economical alternative to the LMT Series fibers — without compromising performance in most applications.
- LMT Series Low-OH fibers offer superior radiation resistance in $Co_{60}$ environments.
- Core, 3M hard cladding, and buffer are USP Class VI approved for non-toxicity and biocompatibility.
- Sterilizable (Radiation, EtO, Steam)
- Variety of connectors and assemblies available:
  - High-power SMA 905 assemblies
  - 3M FC and ST*-compatible ceramic ferrule connectors and assemblies
  - SMA 905 crimp-and-cleave termination kit
  - No epoxy, reusable 3M mechanical splice

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# TECS™ HARD-CLAD FIBER SPECIFICATIONS

## LOW-OH FIBER — Designed for Visible to Near-IR Transmission

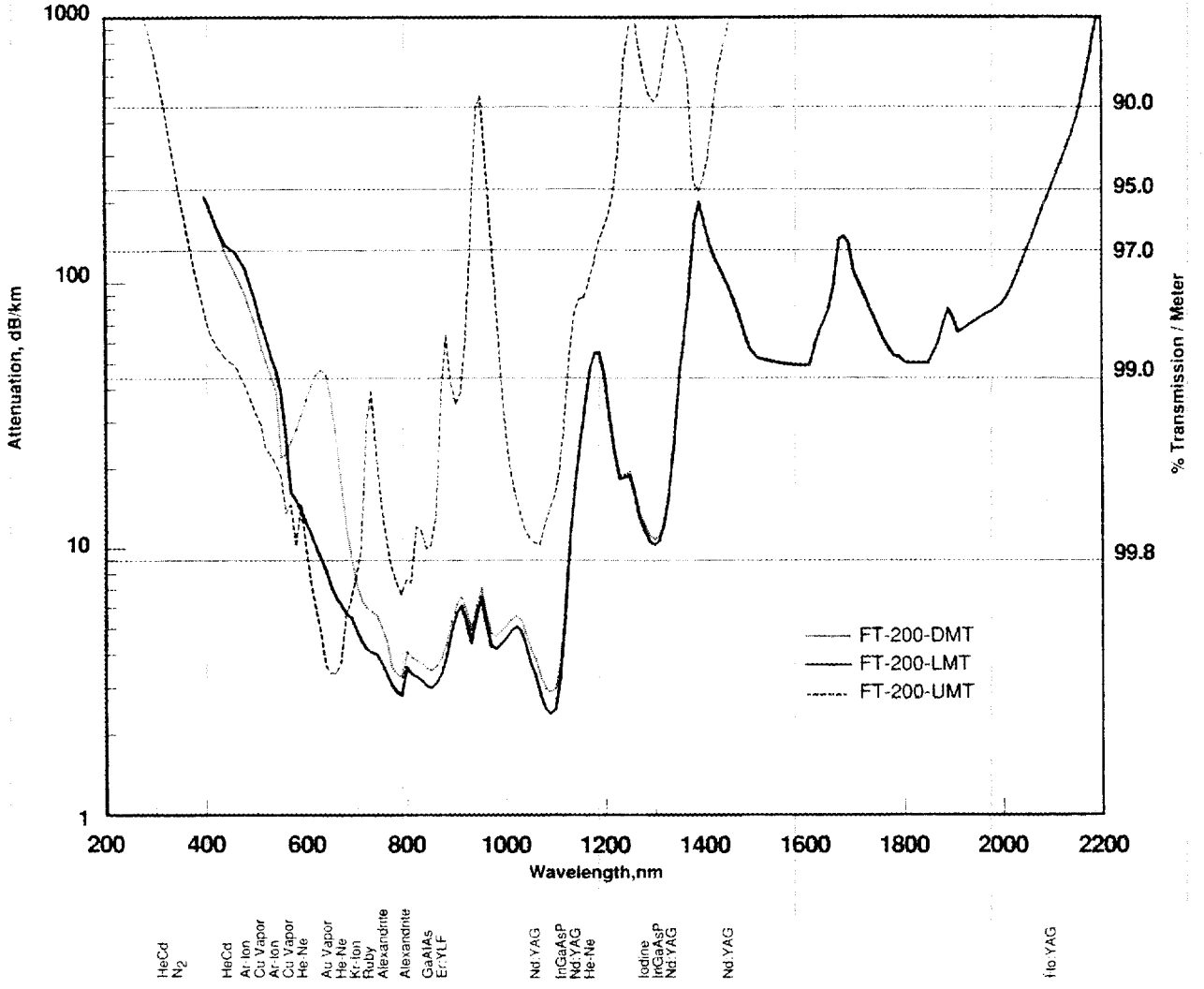
| **Standard Performance Fiber**[1] Attenuation @ 630nm ≤ 50 dB/km Part Number → | Unit | FT-200-DMT | FT-300-DMT | FT-400-DMT | FT-600-DMT | FT-800-DMT | FT-1.0-DMT |
|---|---|---|---|---|---|---|---|
| **Premium Performance Fiber** Attenuation @ 630nm ≤ 10 dB/km Part Number → | | FT-200-LMT | FT-300-LMT | FT-400-LMT | FT-600-LMT | FT-800-LMT | FT-1.0-LMT |
| Core Diameter | µm | 200 ± 5 | 300 ± 6 | 400 ± 8 | 600 ± 10 | 800 ± 10 | 1000 ± 15 |
| Clad Diameter | µm | 230 +0,-10 | 330 +5,-15 | 430 +5,-15 | 630 ± 10 | 830 ± 10 | 1035 ± 15 |
| Buffer Diameter[2] | µm | 500 ± 30 | 650 ± 30 | 730 ± 30 | 1040 ± 30 | 1040 ± 30 | 1400 ± 50 |
| Maximum Attenuation @ 820nm | dB/km | 6 | 6 | 8 | 8 | 8 | 8 |
| Bandwidth | MHz-km | 20 | 15 | 13 | 9 | — | — |
| Maximum Core Offset | µm | 5 | 5 | 7 | 9 | 9 | 10 |
| Numerical Aperture[3] | | 0.39 ± 0.02 | 0.39 ± 0.02 | 0.39 ± 0.02 | 0.39 ± 0.02 | 0.39 ± 0.02 | 0.39 ± 0.02 |
| Acceptance Angle (Full) | | 46° | 46° | 46° | 46° | 46° | 46° |
| Peak Optical Power Capability[4] | MW | 1.6 | 2.8 | 6.3 | 14.0 | 25.0 | 64.3 |
| Operating Temperature Range | °C | -65 to +125 | -65 to +125 | -65 to +125 | -65 to +125 | -65 to +125 | -65 to +125 |
| Proof Test Level | kpsi | 100 | 100 | 50 | 50 | — | — |
| Minimum Bend Radius | | | | | | | |
| — Recommended Short Term | mm | 13 | 20 | 53 | 80 | 106† | 133† |
| — Recommended Long Term | mm | 20 | 30 | 80 | 120 | 160† | 180 |
| — Absolute Short Term† | mm | 5 | 8 | 12 | 18 | 20 | 30 |
| — Absolute Long Term† | mm | 10 | 15 | 20 | 30 | 40 | 60 |
| Standard Lengths | m | 1100, 2200 | 500 | 500 | 300 | 100 | 50 |

## HIGH-OH FIBER — Designed for UV to Visible Transmission

| Part Number | Unit | FT-200-UMT | FT-300-UMT | FT-400-UMT | FT-600-UMT | FT-800-UMT | FT-1.0-UMT |
|---|---|---|---|---|---|---|---|
| Core Diameter | µm | 200 ± 5 | 300 ± 6 | 400 ± 8 | 600 ± 10 | 800 ± 10 | 1000 ± 15 |
| Clad Diameter | µm | 230 +0,-10 | 330 +5,-15 | 430 +5,-15 | 630 ± 10 | 830 ± 10 | 1035 ± 15 |
| Buffer Diameter[2] | µm | 500 ± 30 | 650 ± 30 | 730 ± 30 | 1040 ± 30 | 1040 ± 30 | 1400 ± 50 |
| Maximum Attenuation @ 820nm | dB/km | 12 | 12 | 12 | 12 | 12 | 12 |
| Typical Attenuation @ 400nm | dB/km | 75 | 75 | 75 | 75 | 75 | 75 |
| Bandwidth | MHz-km | 20 | 15 | 13 | 9 | — | — |
| Maximum Core Offset | µm | 5 | 5 | 7 | 9 | 9 | 10 |
| Numerical Aperture[3] | | 0.39 ± 0.02 | 0.39 ± 0.02 | 0.39 ± 0.02 | 0.39 ± 0.02 | 0.39 ± 0.02 | 0.39 ± 0.02 |
| Acceptance Angle (Full) | | 46° | 46° | 46° | 46° | 46° | 46° |
| Peak Optical Power Capability[4] | MW | 1.6 | 2.8 | 6.3 | 14.0 | 25.0 | 64.3 |
| Operating Temperature Range | °C | -65 to +125 | -65 to +125 | -65 to +125 | -65 to +125 | -65 to +125 | -65 to +125 |
| Proof Test Level | kpsi | 100 | 100 | 50 | 50 | — | — |
| Minimum Bend Radius | | | | | | | |
| — Recommended Short Term | mm | 13 | 20 | 53 | 80 | 106† | 133† |
| — Recommended Long Term | mm | 20 | 30 | 80 | 120 | 160† | 180 |
| — Absolute Short Term† | mm | 5 | 8 | 12 | 18 | 20 | 30 |
| — Absolute Long Term† | mm | 10 | 15 | 20 | 30 | 40 | 60 |
| Standard Lengths | m | 1100, 2200 | 500 | 500 | 300 | 100 | 50 |

[1] Not recommended for radiation environments.
[2] Standard buffer coating is Tefzel® 210
[3] 2 meters, 50% intensity
[4] Based on 5 GW/cm² for 1064nm Nd:YAG laser with 10 nsec. pulse length.
† Determined statistically for short gauge length.

# TYPICAL SPECTRAL RESPONSE

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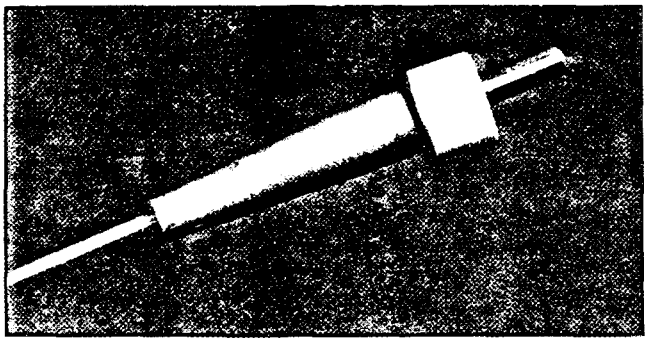
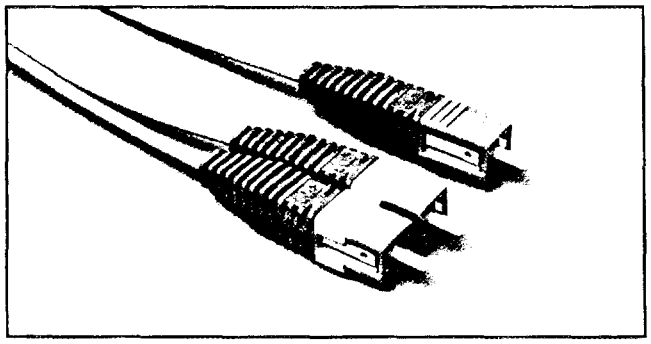
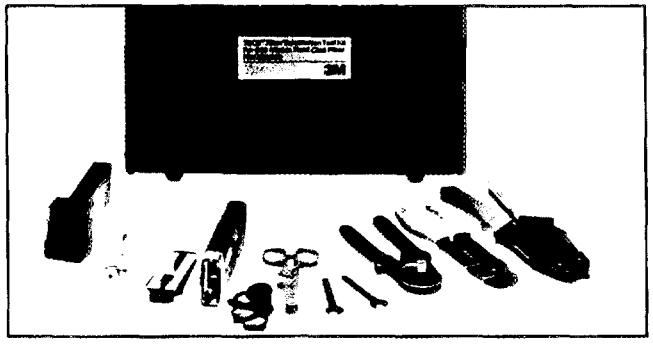
# TECS™ HARD-CLAD FIBER ACCESSORIES



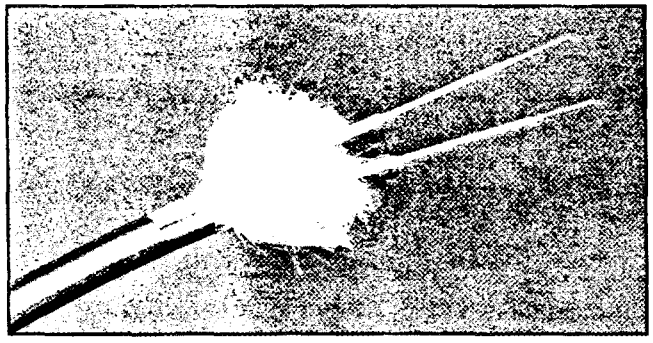
**3M High-Power SMA 905 Assemblies.** Proprietary 3M connector was designed for applications using high peak energy lasers, high average power pulsed lasers, and high-power CW lasers. Connector is available on factory-mount fiber assemblies.



**3M FC, ST* and ST* Push-Pull Connectors.** For high-precision applications, 3M FC and ST*-compatible ceramic ferrule connectors and assemblies are available. The 3M Push-Pull ST* connector has a rectangular push-pull coupling mechanism that provides easy insertion, high repeatability, and excellent stability. The connector's pull-proof and side-pull-resistant design helps prevent accidental movement of the ferrule in a connection.



**3M TECS™ Crimp-and-Cleave SMA 905 Termination Kit.** All the tools necessary to install an SMA-style crimp-and-cleave TECS™ 200 micron connector are contained in this kit. This no-epoxy, no-polish termination method means quick and easy, high-quality terminations in almost any environment.



**Simplex and Duplex-Oval Plenum and UL Cables.** Two cable designs are available: 1) loose tube to protect the fiber, or 2) no tube for a low-cost alternative. Both designs have a meshed aramid strength member and a PVC over-jacket. No breakout kit is required.

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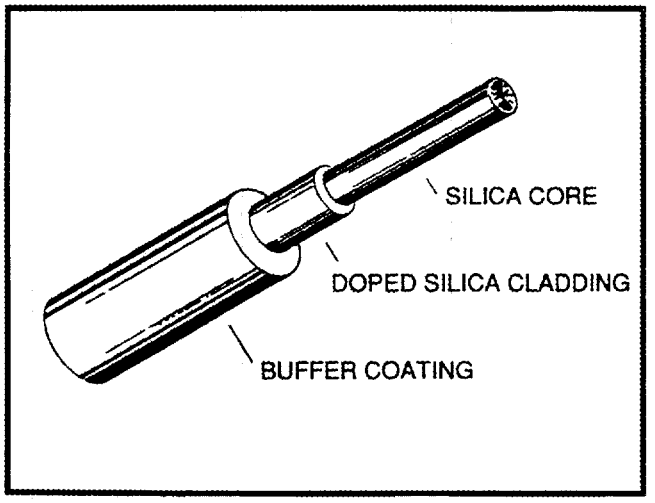
# Power-Core Fiber

## High-NA Silica/Silica




High-NA Silica/Silica Fiber Construction

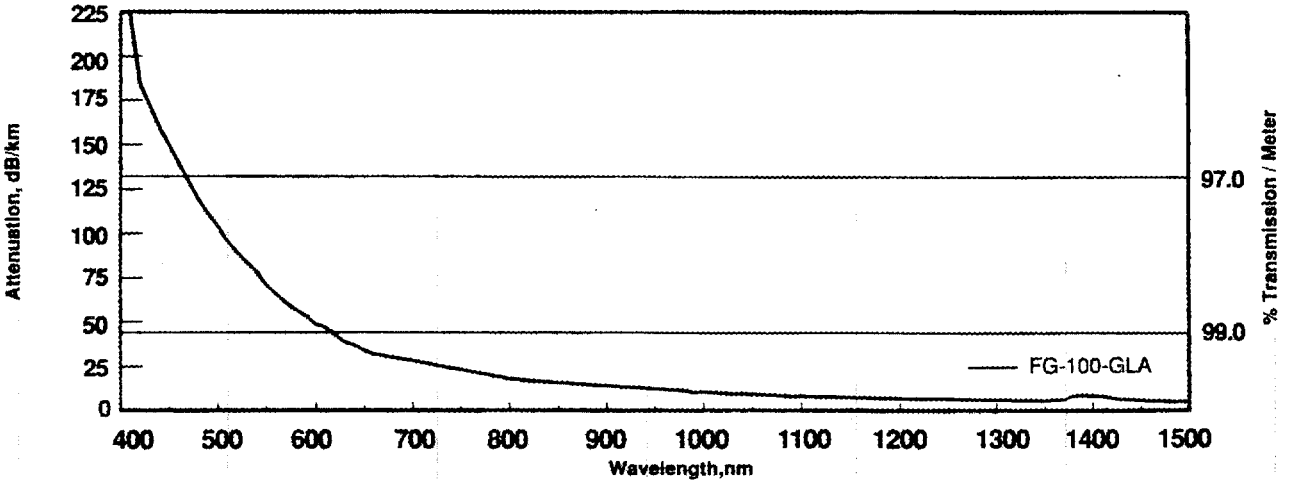
**Applications**

- Laser Diode Pigtails
- Medical Sensing Systems
- Data Communications
- Single-Fiber Illumination Systems

**Advantages**

- High numerical aperture:
  - Couples over 75% more power than conventional 50/125 and 100/140 fibers, respectively.
  - Less critical fiber alignment requirements.
  - Reduced bending losses.
- Step-index fiber design for maximum power delivery.
- Silica cladding material offers stable temperature performance and allows metalized packaging.
- Core, cladding and buffer are USP Class VI approved for non-toxicity and biocompatibility.
- EtO and autoclave sterilizable.
- Fiber dimensions are compatible with standard connectors and splicing systems.
- Pre-terminated pigtails and assemblies available.

**Typical Spectral Response**




Manufactured in the USA

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# High-NA Silica/Silica

| Part Number | Unit | FG-050-GLA | FG-100-GLA |
|---|---|---|---|
| Core Diameter | µm | 50 ± 3 | 100 ± 4 |
| Clad Diameter | µm | 125 ± 2 | 140 ± 3 |
| Buffer Diameter | µm | 250 ± 15 | 250 ± 15 |
| Maximum Attenuation @ 820nm | dB/km | 20 | 20 |
| @ 1300nm | dB/km | 8 | 8 |
| Nominal Concentricity — Core-to-Clad | µm | Offset ≤ 3 | Offset ≤ 3 |
| — Fiber-to-Buffer | % | ≥70 | ≥70 |
| Numerical Aperture[1] | | 0.365 ± 0.015 | 0.365 ± 0.015 |
| Acceptance Angle (Full) | | 21.4° | 21.4° |
| Operating Temperature Range | °C | -60 to +85 | -60 to +85 |
| Proof Test Level | kpsi | 50 | 50 |
| Minimum Bend Radius | | | |
| — Recommended Short Term | mm | 16.5 | 18.5 |
| — Recommended Long Term | mm | 24.5 | 28.5 |
| — Absolute Short Term† | mm | 8 | 9 |
| — Absolute Long Term† | mm | 13 | 15 |
| Coating Type | | Acrylate | Acrylate |
| Standard Length | m | 110 | 110 |

[1] 2 meters, 50% intensity
† Determined statistically for short gauge length.

**Special Note:**
This product is experimental: It may be subject to modification, production limitations or cancellation by the manufacturer. Contact 3M regarding current status of this product before including it in any Specification.

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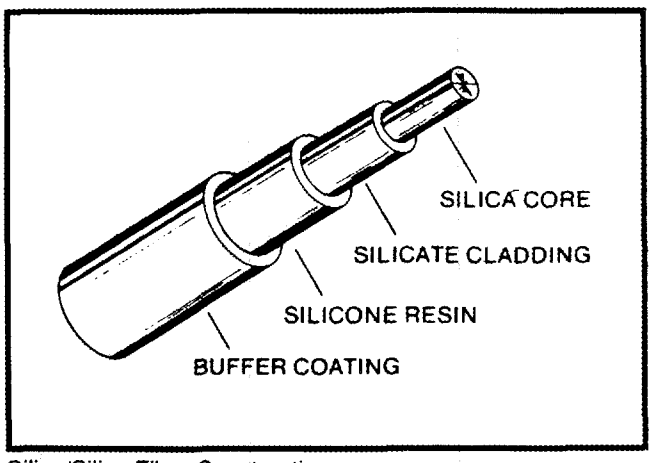
# Power-Core Fiber

## GLPC -- Silica/Silica




Silica/Silica Fiber Construction

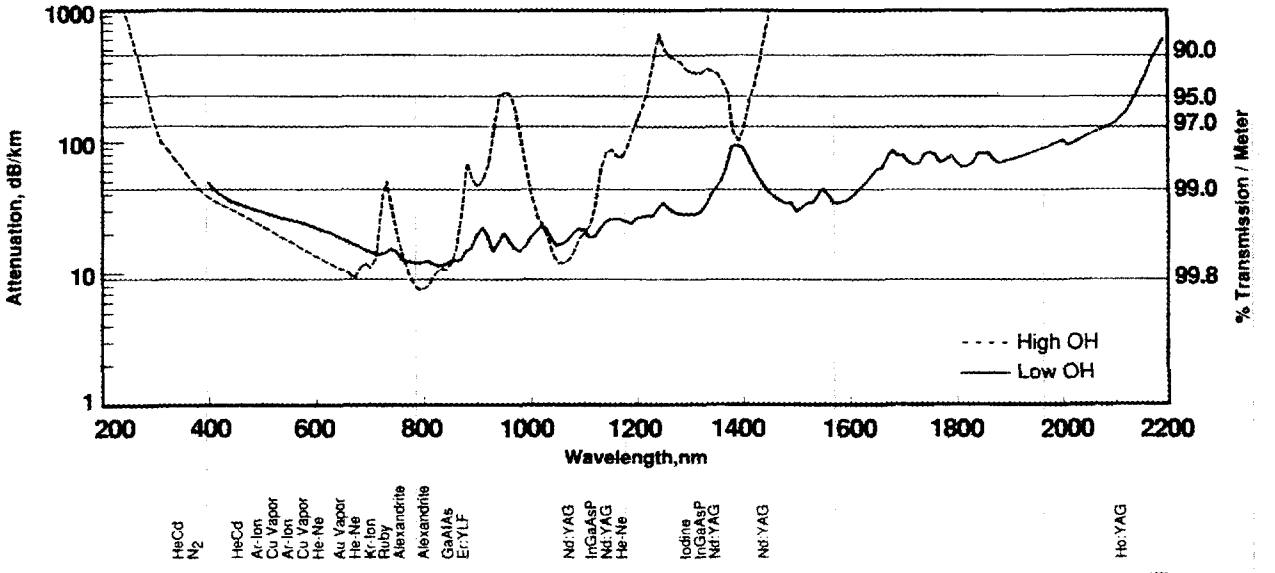
**Applications**

- High-Power Laser Delivery Systems
  - Medical
  - Industrial
  - Ordnance Initiation
- Short-Haul Data and Video Communications in Extreme Temperature Environments
- Illumination Systems
- Sensing Systems
  - Medical
  - Industrial
  - Spectroscopy

**Advantages**

- Glass-cladding stability allows for high power-handling capability and laser misalignment.
- Glass-clad design provides superior UV and near-IR transmission compared to polymer-clad fibers.
- Low numerical aperture provides a low beam divergence and uniform spot size.
- High concentricity and core-to-clad ratio for excellent connector alignment and small overall fiber size.
- Both Low- and High-OH fiber designs available, providing a broad spectral transmission range from 220nm to 2400nm.
  - High-OH version provides superior radiation resistance in $Co_{60}$ environments.
- Reduced microbend sensitivity in rugged environments due to dual coating of silicone and Tefzel®.
- Core, cladding and buffer are USP Class VI approved for non-toxicity and biocompatibility.
- Sterilizable (Radiation, EtO, Steam)
- Temperature range of -65° to +150°C meets military specifications.
- Custom fiber sizes, core-to-clad ratios, and coatings available for specific applications.
- 3M FC and ST*-compatible ceramic ferrule connectors and assemblies available for high-precision applications.

**Typical Spectral Response**




Manufactured in the USA

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# GLPC -- Silica/Silica

## LOW-OH FIBER — Designed for Visible to Near-IR Transmission

| Part Number | Unit | FG-200-LAT | FG-400-LAT | FG-600-LAT | FG-1.0-LAT |
|---|---|---|---|---|---|
| Core Diameter | µm | 200 ± 5 | 400 ± 8 | 600 ± 10 | 1000 ± 25 |
| Clad Diameter | µm | 250 ± 5 | 500 ± 10 | 750 ± 15 | 1250 ± 25 |
| Buffer Diameter[1] | µm | 600 ± 30 | 1000 ± 30 | 1250 ± 30 | 1850 ± 50 |
| Maximum Attenuation @ 820nm | dB/km | 8 | 8 | 8 | 10 |
| Numerical Aperture[2] | | 0.16 ± 0.02 | 0.16 ± 0.02 | 0.16 ± 0.02 | 0.16 ± 0.02 |
| Nominal Concentricity | % | 95 | 95 | 85 | 80 |
| Acceptance Angle (Full) | | 19° | 19° | 19° | 19° |
| Peak Optical Power Capability[3] | MW | 1.6 | 6.3 | 14.0 | 64.3 |
| Operating Temperature Range | °C | -65 to +150 | -65 to +150 | -65 to +150 | -65 to +150 |
| Proof Test Level | kpsi | 50 | 20 | 15 | — |
| Minimum Bend Radius | | | | | |
| — Recommended Short Term | mm | 33 | 66† | 99† | 166† |
| — Recommended Long Term | mm | 50 | 100† | 150† | 180 |
| — Absolute Short Term† | mm | 12 | 20 | 32 | 65 |
| — Absolute Long Term† | mm | 25 | 40 | 65 | 140 |
| Standard Length | m | 500 | 100 | 50 | 20 |

## HIGH-OH FIBER — Designed for UV to Visible Transmission

| Part Number | Unit | FG-200-UAT | FG-400-UAT | FG-600-UAT | FG-1.0-UAT |
|---|---|---|---|---|---|
| Core Diameter | µm | 200 ± 5 | 400 ± 8 | 600 ± 10 | 1000 ± 25 |
| Clad Diameter | µm | 250 ± 5 | 500 ± 10 | 750 ± 15 | 1250 ± 25 |
| Buffer Diameter[1] | µm | 600 ± 30 | 1000 ± 30 | 1250 ± 30 | 1850 ± 50 |
| Maximum Attenuation @ 820nm | dB/km | 12 | 12 | 12 | 14 |
| Typical Attenuation @ 400nm | dB/km | 40 | 40 | 40 | 40 |
| Nominal Concentricity | % | 95 | 95 | 85 | 80 |
| Numerical Aperture[2] | | 0.16 ± 0.02 | 0.16 ± 0.02 | 0.16 ± 0.02 | 0.16 ± 0.02 |
| Acceptance Angle (Full) | | 19° | 19° | 19° | 19° |
| Peak Optical Power Capability[3] | MW | 1.6 | 6.3 | 14.0 | 64.3 |
| Operating Temperature Range | °C | -65 to +150 | -65 to +150 | -65 to +150 | -65 to +150 |
| Proof Test Level | kpsi | 50 | 20 | 15 | — |
| Minimum Bend Radius | | | | | |
| — Recommended Short Term | mm | 33 | 66† | 99† | 166† |
| — Recommended Long Term | mm | 50 | 100† | 150† | 180 |
| — Absolute Short Term† | mm | 12 | 20 | 32 | 65 |
| — Absolute Long Term† | mm | 25 | 40 | 65 | 140 |
| Standard Length | m | 500 | 100 | 50 | 20 |

[1] Standard buffer coating is Tefzel® 210
[2] 2 meters, 50% intensity
[3] Based on 5 GW/cm² for 1064nm Nd:YAG laser with 10 nsec. pulse length.
† Determined statistically for short gauge length.

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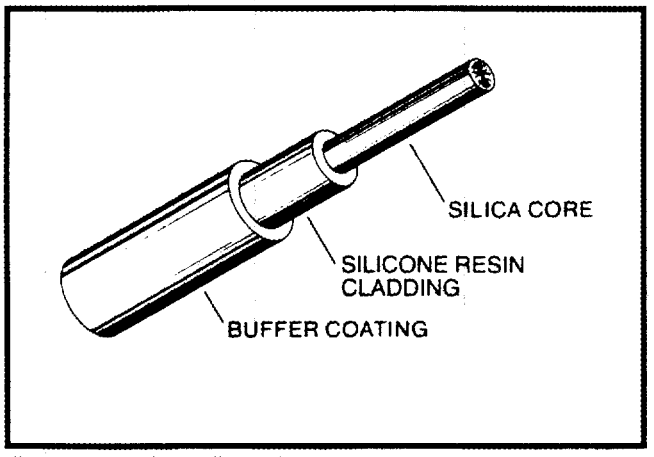
# Power-Core Fiber

## PCS -- Plastic-Clad Silica




Plastic-Clad Silica Fiber Construction

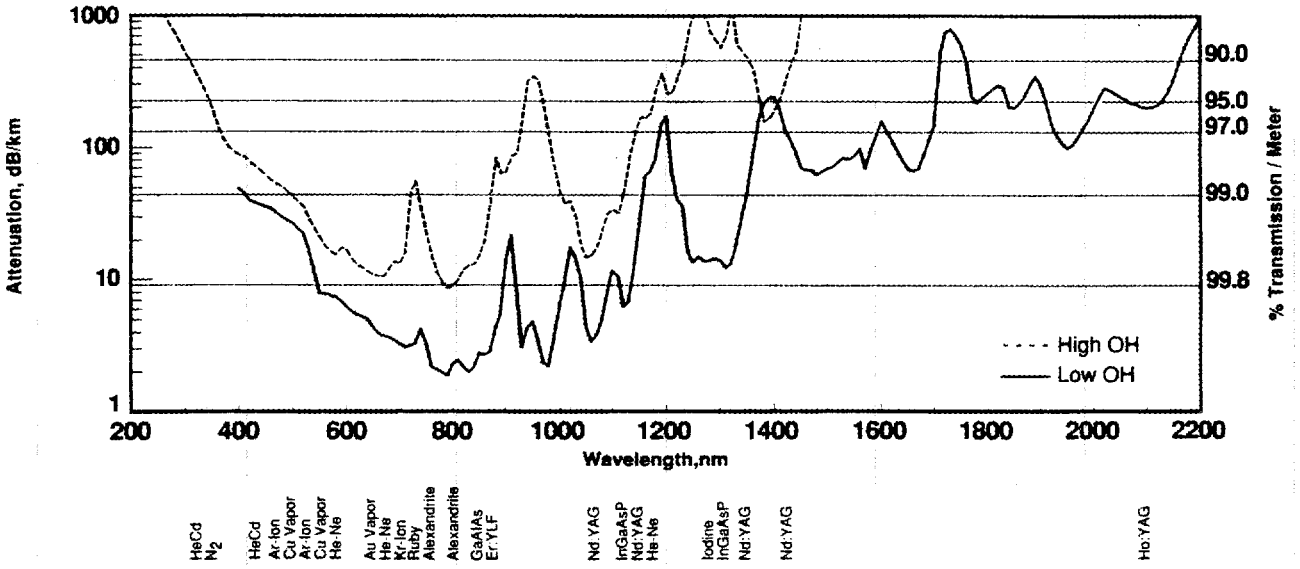
**Applications**

- Laser Delivery Systems
  - Medical
  - Industrial
  - Ordnance Initiation
- Short-Haul Data and Video Communications
- Illumination Systems
- Sensing Systems
  - Medical
  - Industrial
  - Spectroscopy

**Advantages**

- Two cladding types available:
  - Non-mechanically strippable clad fiber has a -35°C temperature capability and provides a stable termination with less pistoning. Recommended for crimp-and-cleave termination systems.
  - Mechanically strippable clad fiber has a -25°C temperature capability and provides easy cladding removal.
- Easy light coupling and low microbend loss due to high numerical aperture.
- Silicone-clad design provides low-cost UV performance superior to hard-clad polymer fibers.
- Both Low- and High-OH fiber designs available, providing a broad spectral transmission range from 220nm to 2400nm.
  - High-OH version provides superior radiation resistance in $Co_{60}$ environments.
- Core, cladding and buffer are USP Class VI approved for non-toxicity and biocompatibility.
- Sterilizable (Radiation, EtO, Steam)
- Custom fiber sizes and coatings are available for specific applications.

**Typical Spectral Response**




Manufactured in the USA

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# PCS -- Plastic-Clad Silica

## LOW-OH FIBER — Designed for Visible to Near-IR Transmission

| Part Number | Unit | FP-200-LMT | FP-400-LHT | FP-600-LHT | FP-1.0-LHT |
|---|---|---|---|---|---|
| Core Diameter | µm | 200 ± 5 | 400 ± 8 | 600 ± 10 | 1000 ± 20 |
| Clad Diameter | µm | 380 ± 20 | 600 ± 30 | 830 ± 30 | 1400 ± 50 |
| Buffer Diameter[1] | µm | 600 ± 30 | 750 ± 30 | 1050 ± 30 | 1600 ± 50 |
| Maximum Attenuation @ 820nm | dB/km | 6 | 8 | 8 | 8 |
| Bandwidth | MHz-km | 20 | 13 | 9 | — |
| Nominal Concentricity | % | 95 | 95 | 85 | 80 |
| Numerical Aperture[2] | | 0.40 ± 0.02 | 0.40 ± 0.02 | 0.40 ± 0.02 | 0.40 ± 0.02 |
| Acceptance Angle (Full) | | 47° | 47° | 47° | 47° |
| Peak Optical Power Capability[3] | MW | 1.6 | 6.3 | 14.0 | 64.3 |
| Operating Temperature Range | °C | -35 to +150 | -25 to +150 | -25 to +150 | -25 to +150 |
| Proof Test Level | kpsi | 50 | 40 | 25 | — |
| Minimum Bend Radius | | | | | |
| — Recommended Short Term | mm | 26 | 75 | 100† | 150† |
| — Recommended Long Term | mm | 40 | 100 | 140† | 180 |
| — Absolute Short Term† | mm | 10 | 15 | 25 | 35 |
| — Absolute Long Term† | mm | 20 | 30 | 45 | 85 |
| Standard Lengths | m | 1100, 2200 | 500 | 300 | 50 |

## HIGH-OH FIBER — Designed for UV to Visible Transmission

| Part Number | Unit | FP-200-UHT | FP-400-UHT | FP-600-UHT | FP-1.0-UHT |
|---|---|---|---|---|---|
| Core Diameter | µm | 200 ± 5 | 400 ± 8 | 600 ± 10 | 1000 ± 20 |
| Clad Diameter | µm | 380 ± 20 | 600 ± 30 | 830 ± 30 | 1400 ± 50 |
| Buffer Diameter[1] | µm | 600 ± 30 | 750 ± 30 | 1050 ± 30 | 1600 ± 50 |
| Maximum Attenuation @ 820nm | dB/km | 12 | 12 | 12 | 12 |
| Typical Attenuation @ 400nm | dB/km | 40 | 40 | 40 | 40 |
| Nominal Concentricity | % | 95 | 95 | 85 | 80 |
| Numerical Aperture[2] | | 0.40 ± 0.02 | 0.40 ± 0.02 | 0.40 ± 0.02 | 0.40 ± 0.02 |
| Acceptance Angle (Full) | | 47° | 47° | 47° | 47° |
| Peak Optical Power Capability[3] | MW | 1.6 | 6.3 | 14.0 | 64.3 |
| Operating Temperature Range | °C | -25 to +150 | -25 to +150 | -25 to +150 | -25 to +150 |
| Proof Test Level | kpsi | 50 | 40 | 25 | — |
| Minimum Bend Radius | | | | | |
| — Recommended Short Term | mm | 26 | 75 | 100† | 150† |
| — Recommended Long Term | mm | 40 | 100 | 140† | 180 |
| — Absolute Short Term† | mm | 10 | 15 | 25 | 35 |
| — Absolute Long Term† | mm | 20 | 30 | 45 | 85 |
| Standard Lengths | m | 1100, 2200 | 500 | 300 | 50 |

[1] Standard buffer coating is Tefzel® 210
[2] 2 meters, 50% intensity
[3] Based on 5 GW/cm² for 1064nm Nd:YAG laser with 10 nsec. pulse length.
† Determined statistically for short gauge length.

**Important Notice to Purchaser:**
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**3M Specialty Optical Fibers**

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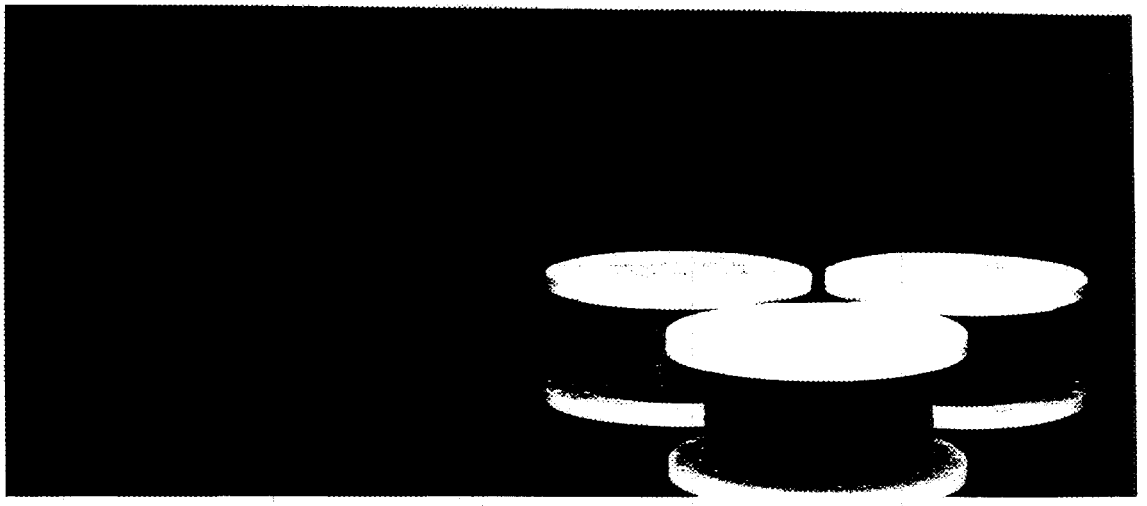
West Haven, CT 06516-4190 USA
(203) 934-7961

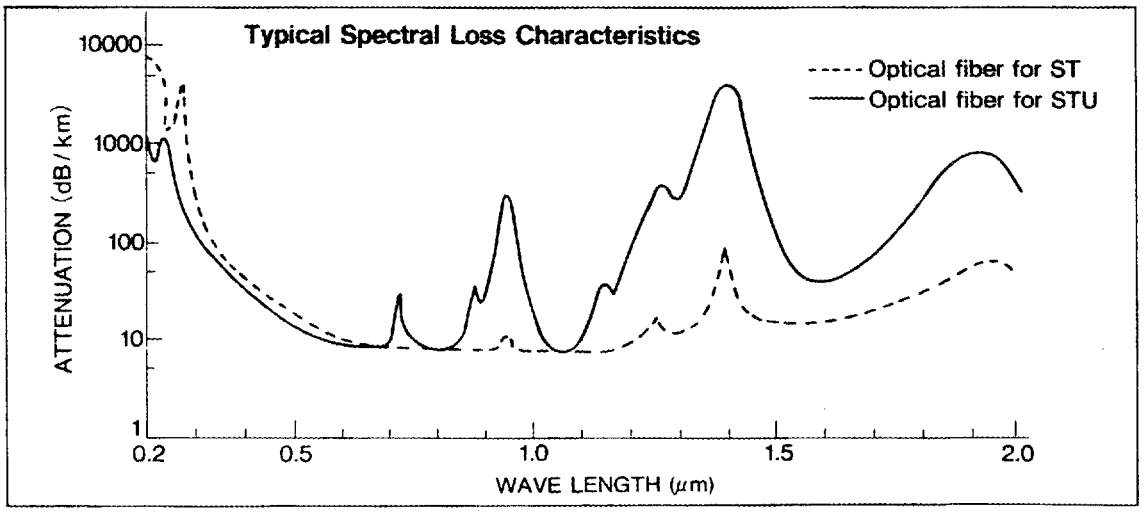


# DIAGUIDE® ST SERIES STEP INDEX MRT OPTICAL FIBER

**Diaguide ST series MRT optical fibers are made of silica glass and manufactured by the MRT (Modified Rod-in-Tube) process originally developed by Mitsubishi Cable Industries., Ltd. This fiber features a high purity silica glass core and large range of fiber size. Our large core-fibers are especially well suited to such applications as high power laser beam guides or optical measuring devices. Also, STR series with excellent radiation resistance and STU series for ultraviolet transmission are available.**

## ■Features

* Wide range of spectral transmission
  (ST :500～2100nm)
  (STU:200～600nm)
* High power transmission
  ($10^6$ W/mm$^2$ for pulsed 1060nm)
  (2000W/mm$^2$ for CW 1060nm)
* Core diameter of 50 $\mu$m to 1000 $\mu$m)
* High radiation resistance
* Core and clad ratio (1:1.1 1:1.25)
* Numerical aperture 0.2 ± 0.02
* Special coating, jacketing and core-size available on request




MITSUBISHI CABLE INDUSTRIES, LTD.

## ■Standard VIS-IR Transmission Optical Fiber

(ST-SY Series,Nylon Jacketed Fiber)

| Type | | ST50A-SY | ST100B-SY | ST100C-SY | ST200D-SY | ST400E-SY | ST600F-SY | ST800G-SY | ST1000H-SY |
|---|---|---|---|---|---|---|---|---|---|
| Core diameter | μm | 50±3 | 100±3 | 100±3 | 200±10 | 400±20 | 600±30 | 800±40 | 1000±50 |
| Core non-circularity | % | ≦6 | | | ≦5 | | | | |
| Core concentricity error | % | ≦6 | | | ≦3 | | | | |
| Fiber diameter | μm | 125±3 | 140±3 | 150±3 | 250±12 | 500±25 | 750±37 | 1000±50 | 1250±62 |
| Fiber non-circularity | % | ≦2 | | | ≦5 | | | | |
| Outer diameter | mm | 0.9 | | | 1.0 | 1.3 | 1.7 | 2.0 | 2.3 |
| Numerical aperture | | 0.2 | | | 0.2 | | | | |
| Attenuation (0.85 μm) | dB/km | ≦3 | ≦6 | ≦5 | ≦10 | ≦15 | ≦20 | ≦20 | ≦20 |
| Band-width (0.85 μm) | MHz·km | ≧20 | | | – | | | | |
| Standard continuous lenghth | m | 1000 | | | 500 | 200 | 50 | 20 | 20 |

## ■Standard VIS-IR Transmission Optical Fiber Cord

(ST-FV Series, Kevlar Reinforced PVC Sheathed Fiber)

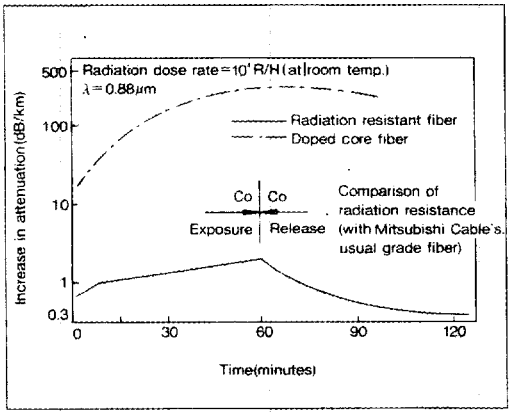
| Type | | ST50A-FV | ST100B-FV | ST100C-FV | ST200D-FV | ST400E-FV | ST600F-FV | ST800G-FV | ST1000H-FV |
|---|---|---|---|---|---|---|---|---|---|
| Type of optical fiber | | ST50A-SY | ST100B-SY | ST100C-SY | ST200D-SY | ST400E-SY | ST600F-SY | ST800G-SY | ST1000H-SY |
| Layer of reinforce filament | | Kevlar (registered trademark of Dupont Corporation) | | | | | | | |
| Sheath | | PVC | | | | | | | |
| Overall diameter | mm | Approx. 3 | | | | Approx. 4 | Approx. 5 | | |
| Tensile Strength | kg | ≧10 | | | | ≧15 | ≧20 | ≧30 | ≧40 |
| Standard continuous length | m | 1000 | | | 500 | 200 | 50 | 20 | 20 |
| Nominal weight | kg/km | 10 | | | | 20 | 30 | | |

## ■Radiation Resistant VIS-IR Transmission Optical Fiber

(ST-R Series, Nylon Jacketed Fiber)

| Type | | STR50A-SY | STR100B-SY | STR100C-SY |
|---|---|---|---|---|
| Core diameter | μm | 50±3 | 100±3 | 100±3 |
| Core non-circularity | % | ≦3 | | |
| Core concentricity error | % | ≦6 | | |
| Fiber diameter | μm | 125±3 | 140±3 | 150±3 |
| Fiber non-circularity | % | ≦2 | | |
| Outer diameter | mm | 0.9 | | |
| Numerical aperture | | 0.2 | | |
| Attenuation (0.85 μm) | dB/km | ≦3 | ≦6 | ≦5 |
| Band-width (0.85 μm) | MHz·km | ≧20 | | |
| Standard continuous length | m | 1000 | | |

The core is made out of a high-purity silica glass which deteriorates little under radiation. Therefore, loss increasing is very slight under radiation in comparison with usual silica glass optical fiber, and loss characteristics recovers rapidly after stopping exposure.




Typical Radiation Resistivity

| Wavelength(μm) | Temp(℃) | Dose(R/H × time) | Optical Power(dBm) | Induced loss(dB/km) |
|---|---|---|---|---|
| 0.85 | 20 | $1\times10^5\times3$min | −20 | 10 |
| 0.85 | 20 | $1\times10^5\times3$min | −30 | 12 |
| 0.85 | 20 | $1\times10^4\times30$min | −20 | 3.5 |
| 0.85 | 20 | $1\times10^4\times30$min | −30 | 5 |
| 0.85 | −55 | $1\times10^4\times30$min | −20 | 14 |
| 0.85 | −55 | $1\times10^4\times30$min | −30 | 21 |

## ■Ultraviolet Transmission Optical Fiber

(STU-SY Series, Nylon Jacketed Fiber)

| Type | | STU50A-SY | STU100C-SY | STU200D-SY | STU400E-SY | STU600F-SY | STU800G-SY | STU1000H-SY |
|---|---|---|---|---|---|---|---|---|
| Core diameter | μm | 50±3 | 100±3 | 200±10 | 400±20 | 600±30 | 800±40 | 1000±50 |
| Core non-circularity | % | ≦6 | | ≦5 | | | | |
| Core concentricity error | % | ≦6 | | ≦3 | | | | |
| Fiber diameter | μm | 125±3 | 150±3 | 250±12 | 500±25 | 750±37 | 1000±50 | 1250±62 |
| Fiber non-circularity | % | ≦2 | | ≦5 | | | | |
| Outer diameter | mm | 0.9 | | 1.0 | 1.3 | 1.7 | 2.0 | 2.3 |
| Numerical aperture | | 0.2 | | | | | | |
| Attenuation | (0.35μm)dB/km | 80 (Transparency:98%/m) | | | | | | |
| | (0.26μm)dB/km | 600 (Transparency:87%/m) | | | | | | |
| Standard continuous length | | 1000 | | 500 | 200 | 50 | 20 | 20 |

## ■Ultraviolet Transmission Optical Fiber

(STU-M Series, UV Cured Acrylate-Jacketed Fiber)

| Type | | STU100M | STU200M | STU300M | STU400M | STU600M | STU800M | STU1000M |
|---|---|---|---|---|---|---|---|---|
| Core diameter | μm | 100±3 | 200±10 | 300±15 | 400±20 | 600±30 | 800±40 | 1000±50 |
| Core non-circularity | % | ≦5 | | | | | | |
| Core concentricity error | % | ≦3 | | | | | | |
| Fiber diameter | μm | 110±3 | 220±11 | 330±17 | 440±22 | 660±33 | 880±44 | 1100±55 |
| Fiber non-circularity | % | ≦5 | | | | | | |
| Outer diameter | mm | 200±20 | 345±15 | 505±15 | 627±17 | 847±17 | 1080±50 | 1310±60 |
| Numerical aperture | | 0.2 | | | | | | |
| Attenuation | (0.35μm)dB/km | 80 (Transparency:98%/m) | | | | | | |
| | (0.26μm)dB/km | 600 (Transparency:87%/m) | | | | | | |
| Standard continuous length | | 1000 | 500 | | 200 | 50 | 20 | 20 |

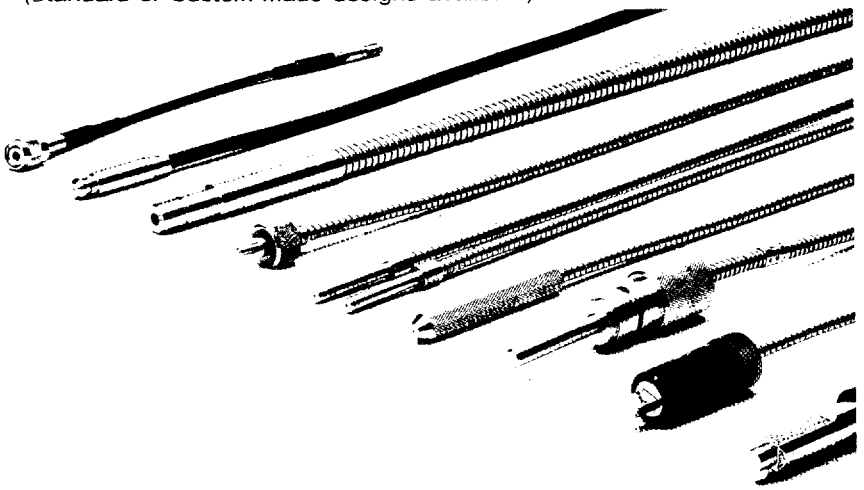
## ■Ultraviolet Transmission Optical Fiber Cord

(STU-FV Series, Kevlar Reinforced PVC Sheathed Fiber)

| Type | | STU50A-FV | STU100C-FV | STU200D-FV | STU400E-FV | STU600F-FV | STU800G-FV | STU1000H-FV |
|---|---|---|---|---|---|---|---|---|
| Type of optical fiber | | STU50A-SY | STU100C-SY | STU200D-SY | STU400E-SY | STU600F-SY | STU800G-SY | STU1000H-SY |
| Layer of reinforce filament | | Kevlar(registered trademark of Dupont Corporation) | | | | | | |
| Sheath | | PVC | | | | | | |
| Overall diameter | mm | Approx. 3 | | | Approx. 4 | Approx. 5 | | |
| Tensile strength | kg | ≧10 | | | ≧15 | ≧20 | ≧30 | ≧40 |
| Standard continuous length | m | 1000 | | 500 | 200 | 50 | 20 | 20 |
| Nominal weight | kg/km | 10 | | | 20 | 30 | | |

## ■Optical Fiber Bundle

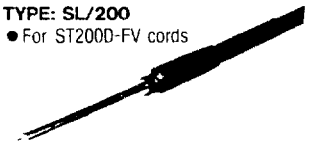
(Standard or Custom-made designs available)

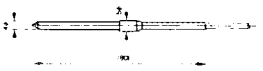


A wide variety of bundled fiber light guides with optically-ground ends are available. Light guides using high-purity silica core fibers feature particularly high light transmission efficiency and promise an extremely wide range of applications.

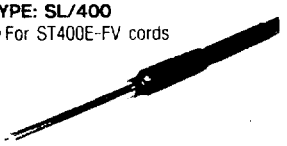
- Two types of silica fiber available, UV transmission or IR transmission, to best match your wavelength band.
- Please specify terminal fitting shape, fiber size, fiber terminal layout, etc.

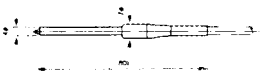
**TYPE: SL/200** (DWG No. FS244101A)
- For ST200D-FV cords



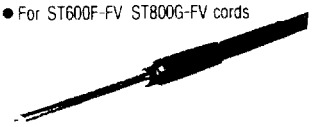


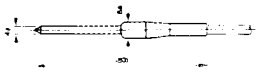
**TYPE: SL/400** (DWG No. FS244101A)
- For ST400E-FV cords



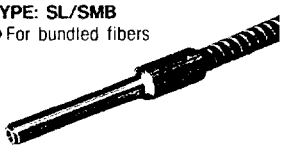


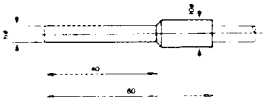
**TYPE: SL/800** (DWG No. FS244101A)
- For ST600F-FV ST800G-FV cords



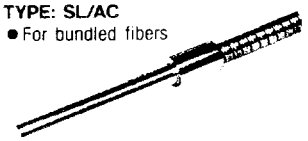


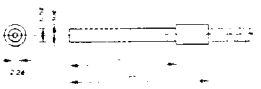
**TYPE: SL/SMB** (DWG No. FS249901)
- For bundled fibers



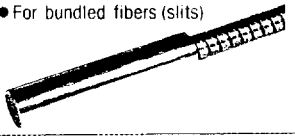


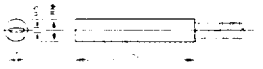
**TYPE: SL/AC** (DWG No. FS241402)
- For bundled fibers





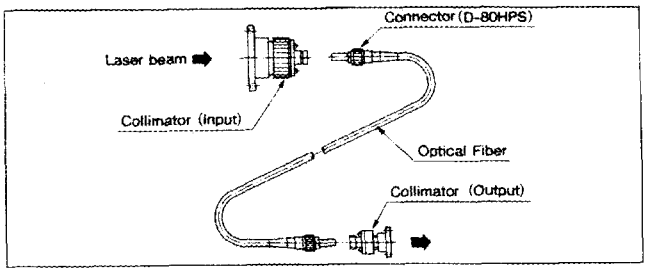
**TYPE: SL/AR** (DWG No. FS241402)
- For bundled fibers (slits)



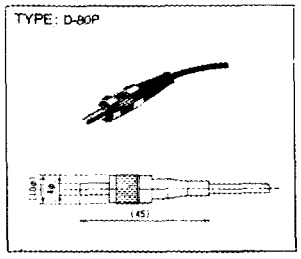


## ■Fiber Optic Laser Delivery System

Optical Fiber applied
※SY (Nylon Jacketed)
※FV (Kevlar reinforced PVC Sheathed)
※CSV (Anaconda tube for Fiber-Protection-Purpose)

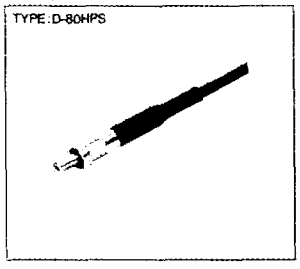



### CONNECTOR (For general use)



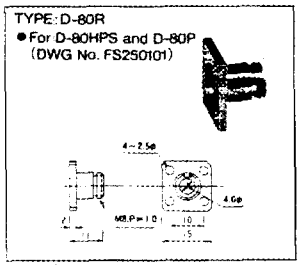

Connector, Type: D-80P, shall be mounted to both sides of the fiber cord to make a single-fiber cord set. (125, 150, 250, 500, 750, 1000 and 1250μm fiber diameter)

### CONNECTOR (For high power)




Connector, Type: D-80HPS, shall be mounted to both side of the fiber cord to make a single-fiber cord set. (500, 750, 1000 and 1250 μm fiber diameter)

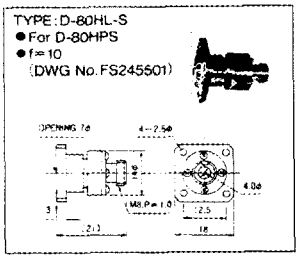
### RECEPTACLES



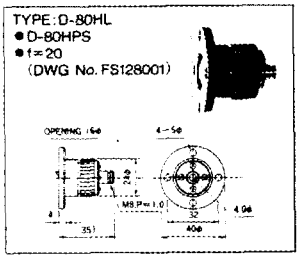

Receptacle, Type: D-80R excluding any lens can be connected with a single-fiber cord set (with D-80HPS connector)

①Lens assemblies are available with anti-reflection coating lens for the wavelength of 488nm, 510nm, 633nm and 1060nm
②Max. energy of continuous wave
250W : ST-400E
550W : ST-600F
1000W : ST-800G
1550W : ST-1000H

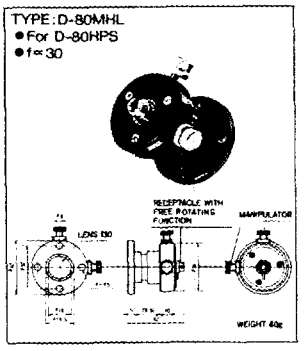
### COLLIMATORS



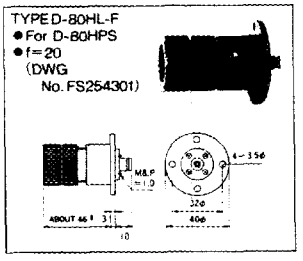

Collimator(Input), Type: D-80HL-S including a lens (D=8mmφ, f=10mm) can be connected with a single-fiber cord set (with D-80HPS connector).




Collimator(Input), Type: D-80HL, including a lens (D=19mmφ, f=20mm) can be connected with a single-fiber cord set (with D-80HPS connector).




Collimator(Input), Type: D-80MHL, including a lens (D=19mmφ, f=30mm) can be connected with a single-fiber cord set (with D-80HPS connector). The X axis and Y axis of the lens are adjustable and D-80MHL collimator is of a freerotating rotary type.




Collimator(Output), Type: D-80HL-F, including a lens (D=19mmφ, f=20mm or 30mm) can be connected with a single-fiber cord set (with D-80HPS connector).
D-80HL-F has a function to concentrate rays into a focus. The size of the focal point is almost the same as the core diameter of optical fibers.

For additional technical help or ordering information, please contact: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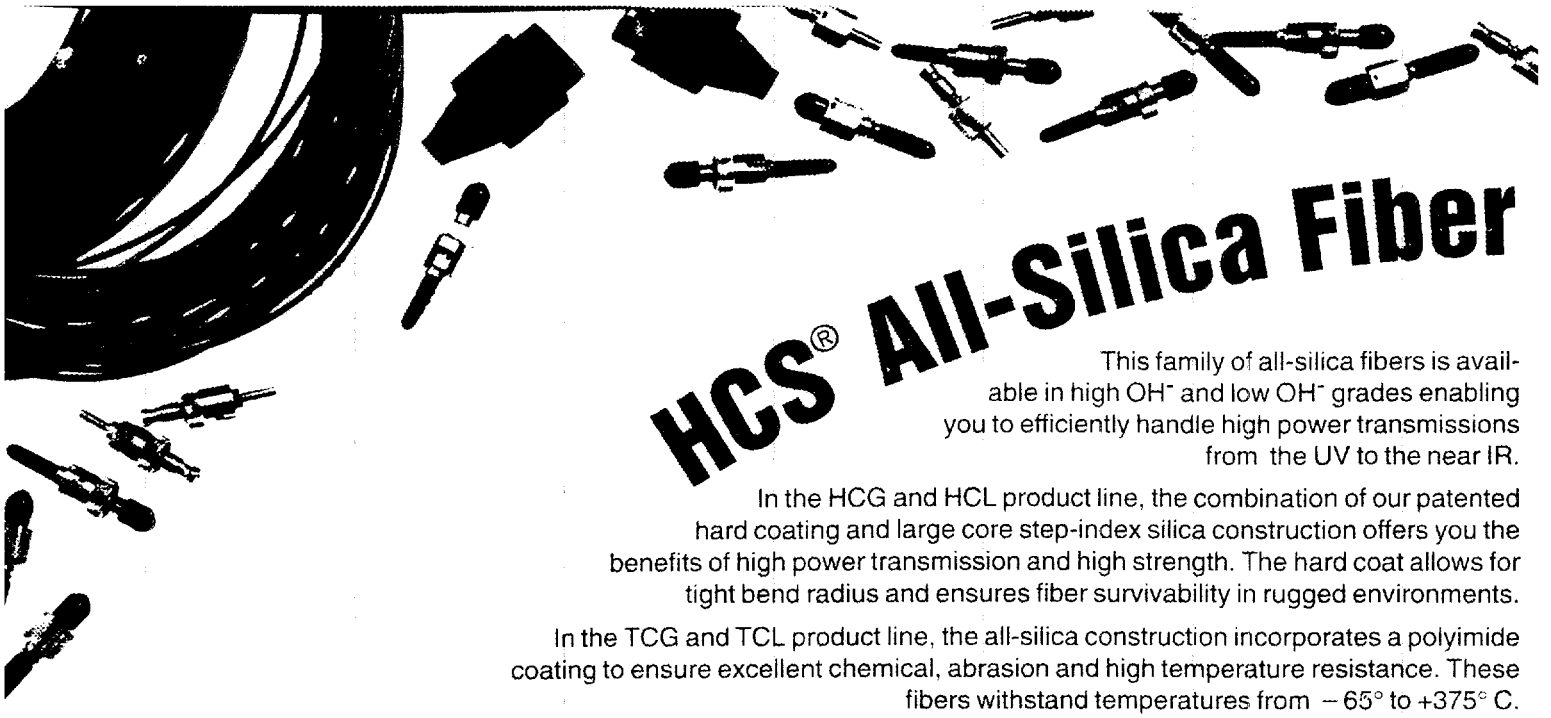
Fax (212)888-2276


No.6-103(91.03)



# HCS® All-Silica Fiber

This family of all-silica fibers is available in high $OH^-$ and low $OH^-$ grades enabling you to efficiently handle high power transmissions from the UV to the near IR.

In the HCG and HCL product line, the combination of our patented hard coating and large core step-index silica construction offers you the benefits of high power transmission and high strength. The hard coat allows for tight bend radius and ensures fiber survivability in rugged environments.

In the TCG and TCL product line, the all-silica construction incorporates a polyimide coating to ensure excellent chemical, abrasion and high temperature resistance. These fibers withstand temperatures from −65° to +375° C.

A variety of fiber constructions enables you to select the right all-silica product for your application.

## Features and Benefits

**High Power Laser Delivery.**
Peak power levels approaching 1 GWatt/cm$^2$ are possible with proper endface preparation.

**Excellent UV, Visible and Near IR Transmission.** Available in both high and low $OH^-$ to allow transmission over a broad spectral range.

**High Tensile Strength.**
Chemically bonded hard coating unique to Hard Clad Silica (HCS®) fibers ensures high strength and tight bend radius. Average tensile strength of 720 kpsi.

**High Temperature Resistance.**
Polyimide coating withstands temperatures from −65° to +375° C.

**Sterilizable.**
Steam, ETO, e-beam or gamma radiation methods.

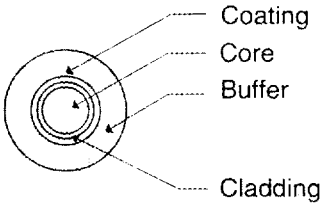
**Biocompatible Materials.**
All materials certified Class VI non-toxic and biocompatible.

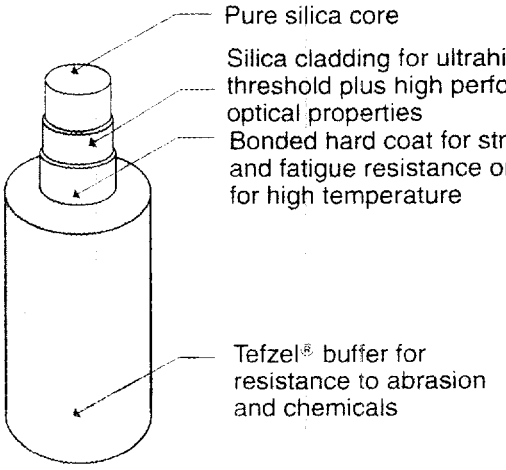
*Ensign-Bickford Optics products covered by one or more of the following US patents: 4,511,209, 4,599,098 4,707,076, 5,028,246, 5,108,021, 5,175,785.

## Applications

Laser Delivery Systems, Industrial and Medical
Spectroscopy
Sensors, Industrial and Medical
Radiation Analysis

Down Hole Well-Logging
Engine Controls
Laser Welding
Laser Ordnance Initiation
Illumination
Aircraft/Industrial Cabling



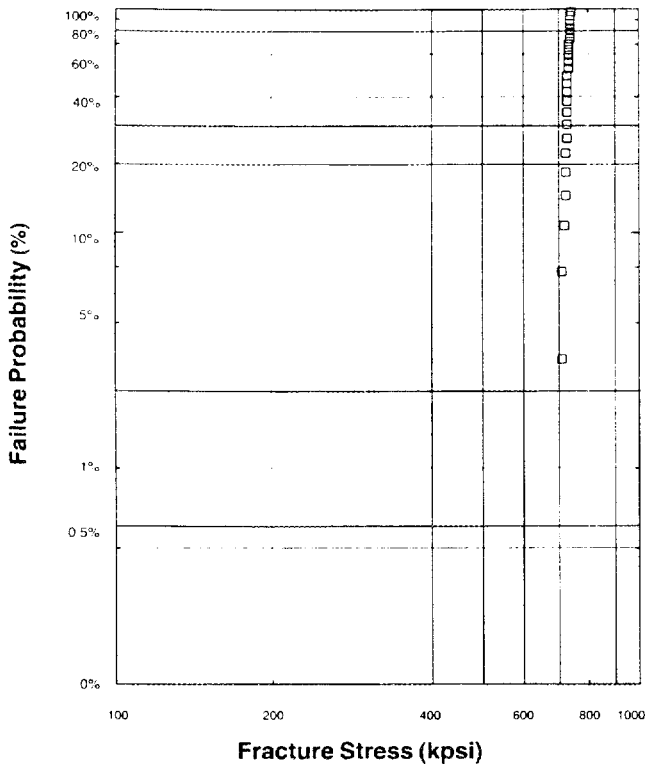





**Ensign-Bickford Optics Company** **The dynamic force in fiber.**

Ensign-Bickford Optics Company, 150 Fisher Drive, Box 1260, Avon, CT 06001-1260 USA
203/678-0371 Fax 203/674-8818

## Weibull Analysis of Tensile Strength For High Strength Fiber




### Power Delivery Facts

**Joule:** measure of energy

**Watt:** measure of power (1 Joule/second)

**Power Density:** Power per unit area (P/A)

**Feasible Limits for Laser Power Transmission**

P/A = ≤ 100 kW/cm$^2$ for CW Laser
P/A = > 1.5 GW/cm$^2$ for Pulsed Laser

**Recommended Laser Source Spot Size:**

≤ 2/3 fiber core diameter

**Recommended Laser Source NA:**

≤ 2/3 fiber NA

*Equation Example: transmit 5 watts of continuous laser power through a 200 µm core fiber*

*Fiber core diameter =*
*$2.0 \times 10^{-2}$ cm*
*Recommended laser spot diameter*
*2/3 fiber core = 2/3 ($2 \times 10^{-2}$cm) = $1.33 \times 10^{-2}$cm*
*Recommended laser spot area ($\pi r^2$)*
*$\pi [(1.33 \times 10^{-2}\text{cm})/2]^2 = 1.39 \times 10^{-4}\text{cm}^2$*
*Power density in fiber (P/A)*

## Part Numbering

**X C X - M X X X X X - X X**

**X C** - Coating Type H(High-Strength) or T (Polyimide)
**X** - Fiber Type G (High OH$^-$) or L (Low OH$^-$)
**M** - Medium NA (0.22)
**XXXX** - Core Diameter in microns
**X** - Outer Material: T (Tefzel®) H (Polyimide Coating)
**XX** - Maximum attenuation in dB/km @ 820 nm

All test methods are conducted with EIA guidelines for step-index fiber, subject to change without notice with issuance of new test standards from the EIA.

All specifications and tolerances are subject to change.

HCS is a registered trademark of Ensign-Bickford Optics Company.

Tefzel® is a registered trademark of DuPont.

Manufactured in the USA by Ensign-Bickford Optics Company.

Custom core materials, fiber sizes, core-to-clad ratios, and buffer types available. Contact our Sales Department for additional information.


**Ensign-Bickford Optics Company**

Ensign-Bickford Optics Company, 150 Fisher Drive, Box 1260, Avon, CT 06001-1260 USA
203/678-0371 Fax 203/674-8818


AS04/93

# TCL, Low OH⁻ Polyimide Coated Fiber

## Specifications:

| Product Code | Core Ø (µm) | Cladding Ø (µm) | Polyimide Coat Ø (µm) | Maximum Core-to-Coat Offset (µm) | Bandwidth (MHz-km) | Proof Test (kpsi) (100% tested) | Short-Term (60 mins.) Minimum Bend Radius (mm @ 23° C) †† | Long-Term (20 yrs.) Minimum Bend Radius (mm @ 23° C) †† | Typical Stock Lengths (m) ±5% |
|---|---|---|---|---|---|---|---|---|---|
| TCL-M0050H-14 | 50±2 | 55±2 | 66±2 | 2 | 25 | 100 | 6 | 10 | 1100 |
| TCL-M0100H-12 | 100±2 | 110±2 | 125±2 | 3 | 25 | 100 | 11 | 19 | 1100 |
| TCL-MA200H-08 | 200±3 | 220±3 | 240±3 | 3 | 25 | 100 | 22 | 37 | 1100 |
| TCL-M0200H-08 | 200±3 | 240±3 | 260±3 | 3 | 25 | 100 | 24 | 40 | 1100 |
| TCL-M0320H-08 | 320±5 | 385±5 | 415±4 | 3 | – | 100 | 39 | 64 | 500 |

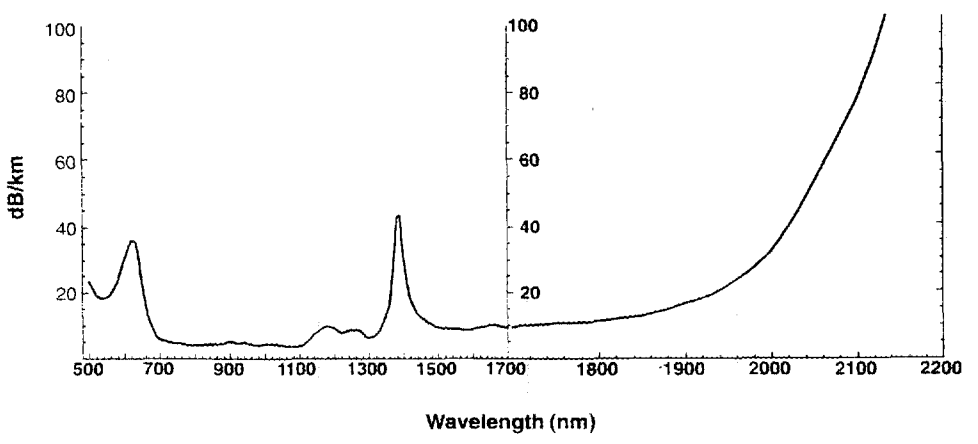
**Temperature Range for Continuous Usage: -65° C to +375° C**
**Numerical Aperture: 0.22 (2m 50% Far Field Intensity)**

Core sizes up to 600 µm available. Please consult factory.

### Spectral Attenuation (typical)

Fiber Transmission

| λ (nm) | | dB/meter |
|---|---|---|
| 532 | KTP | .018 |
| 755 | Alexandrite | .004 |
| 850 | LED | .004 |
| 1093 | Cr:MgF | .003 |
| 1300 | Diode Laser | .006 |
| 1550 | Diode Laser | .008 |
| 2010 | Thulium | .034 |
| 2100 | Ho:YAG | .075 |




†† Conditions are ambient
* Statistically Determined

# TCG, High OH⁻ Polyimide Coated Fiber

## Specifications:

| Product Code | Core Ø (µm) | Cladding Ø (µm) | Polyimide Coat Ø (µm) | Maximum Core-to-Coat Offset (µm) | Bandwidth (MHz-km) | Proof Test (kpsi) (100% tested) | Short-Term (60 mins.) Minimum Bend Radius (mm @ 23° C) †† | Long-Term (20 yrs.) Minimum Bend Radius (mm @ 23° C) †† | Typical Stock Lengths (m) ±5% |
|---|---|---|---|---|---|---|---|---|---|
| **TCG-M0050H-16** | 50±2 | 55±2 | 66±2 | 2 | 25 | 100 | 6 | 10 | 1100 |
| **TCG-M0100H-14** | 100±2 | 110±2 | 125±2 | 3 | 25 | 100 | 11 | 19 | 1100 |
| **TCG-MA200H-10** | 200±3 | 220±3 | 240±3 | 3 | 25 | 100 | 22 | 37 | 1100 |
| **TCG-M0200H-10** | 200±3 | 240±3 | 260±3 | 3 | 25 | 100 | 24 | 40 | 1100 |
| **TCG-M0320H-10** | 320±5 | 385±5 | 415±4 | 3 | – | 100 | 39 | 64 | 500 |

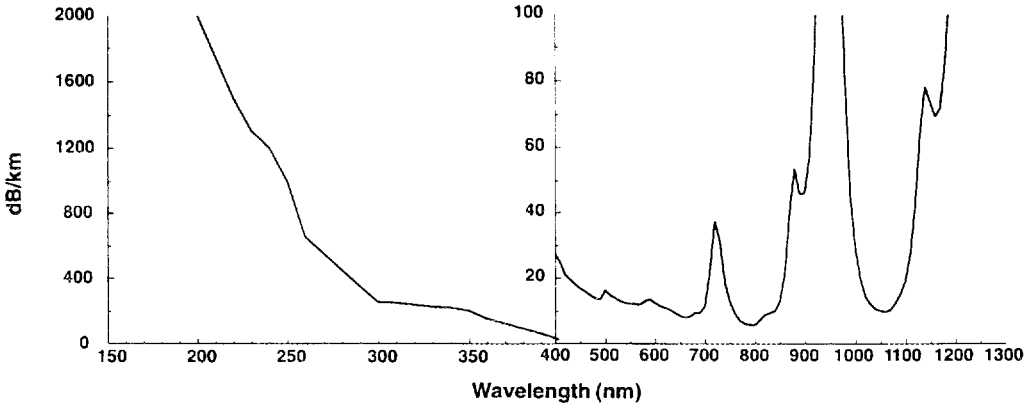
**Temperature Range for Continuous Usage: -65° C to +375° C**
**Numerical Aperture: 0.22 (2m 50% Far Field Intensity)**

Core sizes up to 600 µm available. Please consult factory.

### Spectral Attenuation (typical)

**Fiber Transmission**

| λ (nm) | | dB/meter |
|---|---|---|
| 248 | Kryton Fluoride | 1.1 |
| 308 | Excimer | .27 |
| 488 | Argon Blue | .013 |
| 515 | Argon Green | .014 |
| 532 | KTP | .013 |
| 647 | Kryton Red | .008 |
| 850 | LED | .013 |




†† Conditions are ambient
* Statistically Determined

# HCL, Low OH⁻ Fiber

## Specifications:

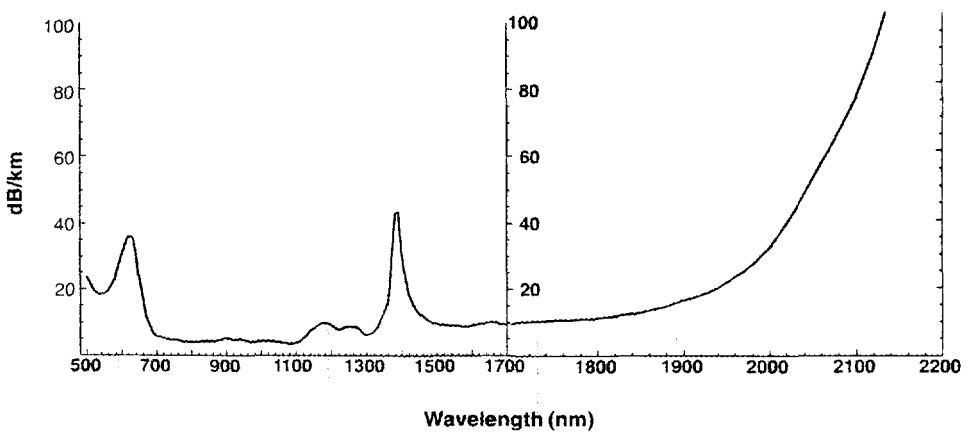
| Product Code | Core Ø (µm) | Cladding Ø (µm) | Hard Coat Ø (µm) | Buffer Ø (µm) | Maximum Core-to-Hard Coat Offset (µm) | Bandwidth (MHz-km) | Proof Test (kpsi) (100% tested) | Short-Term (60 mins.) Minimum Bend Radius (mm @ 23° C) †† | Long-Term (20 yrs.) Minimum Bend Radius (mm @ 23° C) †† | Typical Stock Lengths (m) ±5% |
|---|---|---|---|---|---|---|---|---|---|---|
| **HCL-M0100T-12** | 100±5 | 130±5 | 140±5 | 250-0/+50 | 6 | 25 | 200 | 5 | 7 | 1100 |
| **HCL-M0200T-08** | 200±5 | 240±5 | 260±5 | 375±30 | 7 | 25 | 200 | 9 | 14 | 1100 |
| **HCL-M0365T-08** | 365±10 | 400±10 | 430+5/-15 | 730±30 | 9 | 25 | 100 | 29 | 47 | 500 |
| **HCL-M0550T-08** | 550±12 | 600±10 | 630±10 | 750±30 | 8 | — | 75 | 58 | 94 | 200, 500 |
| **HCL-M0940T-10** | 940±15 | 1000±15 | 1035±15 | 1400±50 | 11 | — | — | *121 | *200 | 200 |

**Temperature Range for Continuous Usage: -65° C to +135° C**
**Suitable for Temperature Excursions up to 200° C**
**Numerical Aperture: 0.22 (2m 50% Far Field Intensity)**

### Spectral Attenuation (typical)

Fiber Transmission

| λ (nm) | | dB/meter |
|---|---|---|
| 532 | KTP | .018 |
| 755 | Alexandrite | .004 |
| 850 | LED | .004 |
| 1093 | Cr:MgF | .003 |
| 1300 | Diode Laser | .006 |
| 1550 | Diode Laser | .008 |
| 2010 | Thulium | .034 |
| 2100 | Ho:YAG | .075 |




†† Conditions are ambient
* Statistically Determined

# HCG, High OH⁻ Fiber

## Specifications:

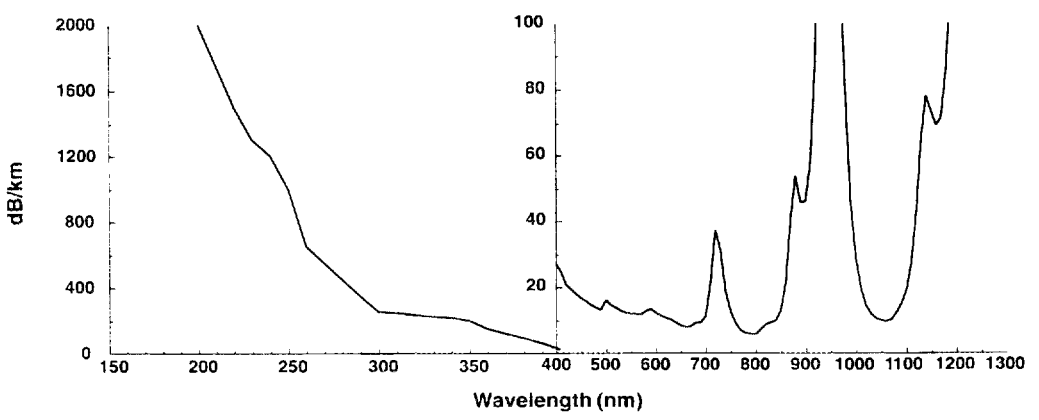
| Product Code | Core Ø (µm) | Cladding Ø (µm) | Hard Coat Ø (µm) | Buffer Ø (µm) | Maximum Core-to-Hard Coat Offset (µm) | Bandwidth (MHz-km) | Proof Test (kpsi) (100% tested) | Short-Term (60 mins.) Minimum Bend Radius (mm @ 23° C) †† | Long-Term (20 yrs.) Minimum Bend Radius (mm @ 23° C) †† | Typical Stock Lengths (m)±5% |
|---|---|---|---|---|---|---|---|---|---|---|
| **HCG-M0100T-14** | 100-0/+8 | 125±5 | 140±5 | 250-0/+50 | 6 | 25 | 200 | 5 | 7 | 1100 |
| **HCG-M0200T-10** | 200±5 | 240±5 | 260±5 | 375±30 | 7 | 25 | 200 | 9 | 14 | 1100 |
| **HCG-M0365T-10** | 365±10 | 400±10 | 430+5/-15 | 730±30 | 9 | — | 100 | 29 | 47 | 500 |
| **HCG-M0550T-10** | 550±12 | 600±10 | 630±10 | 750±30 | 8 | — | 75 | 58 | 94 | 200, 500 |
| **HCG-M0940T-10** | 940±15 | 1000±15 | 1035±15 | 1400±50 | 11 | — | — | *121 | *200 | 200 |

**Temperature Range for Continuous Usage: -65° C to +135° C**
**Suitable for Temperature Excursions up to 200° C**
**Numerical Aperture: 0.22 (2m 50% Far Field Intensity)**

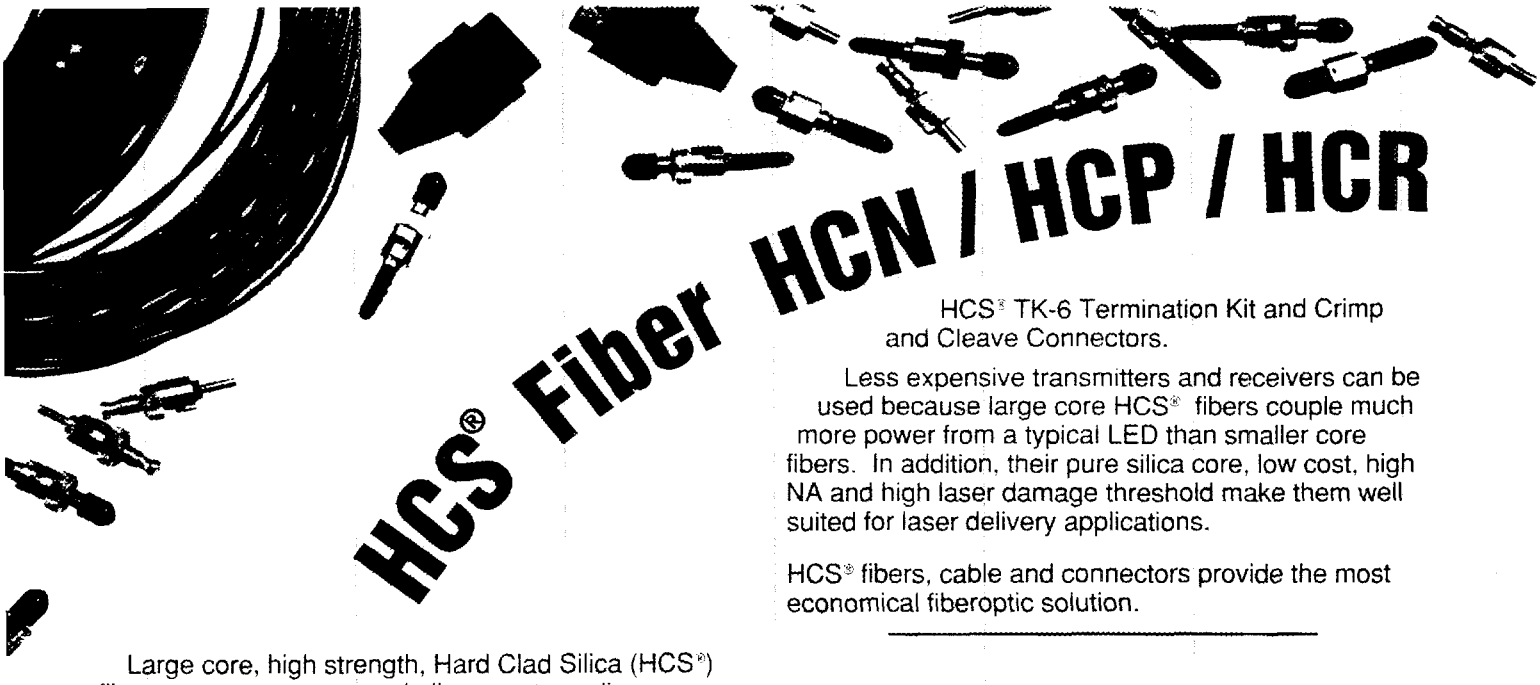
### Spectral Attenuation (typical)

**Fiber Transmission**

| λ (nm) | | dB/meter |
|---|---|---|
| 248 | Kryton Fluoride | 1.1 |
| 308 | Excimer | .27 |
| 488 | Argon Blue | .013 |
| 515 | Argon Green | .014 |
| 532 | KTP | .013 |
| 647 | Kryton Red | .008 |
| 850 | LED | .013 |




†† Conditions are ambient
* Statistically Determined



# HCS® Fiber HCN / HCP / HCR

Large core, high strength, Hard Clad Silica (HCS®) fibers arer easy to use and allow you to realize substantial cost savings.

Field termination of HCS® fibers, in 3 minutes or less, with minimal training and no consumables, is possible with our HCS® TK-6 Termination Kit and Crimp and Cleave Connectors.

Less expensive transmitters and receivers can be used because large core HCS® fibers couple much more power from a typical LED than smaller core fibers. In addition, their pure silica core, low cost, high NA and high laser damage threshold make them well suited for laser delivery applications.

HCS® fibers, cable and connectors provide the most economical fiberoptic solution.

## Features and Benefits

**Reliable, Easy Field Installation of Connectors.** Patented HCS® polymer technology permits direct crimping onto the cladding, utilizing the HCS® TK-6 Termination Kit and crimp and cleave SMA or ST® connectors.

**Enhanced Optical Budget.** HCS® fibers offer large core and a high numerical aperture (NA) of .37 which allow greater coupling efficiency. *A typical surface emitting LED will couple approximately 10 times more power into a typical HCS® 200 µm fiber than into 62.5 µm fiber (about 5 times more than 100 µm fiber).*

**Real Cost Savings.** The coupling efficiency of large core HCS® fibers allows for the use of less expensive transmitters and receivers. Field terminations are performed in 3 minutes or less, with minimal training and require no consumables. HCS® is available in three grades to allow you to make the most economical fiber selection.

**Tight Bend Radius.** Proof testing HCS® fiber to levels far exceeding industry standards (up to 600 kpsi, depending on core size) ensures the survivability of HCS® fibers in extreme conditions.

**Wide Selection of Cable Styles.** Fully dedicated cable department produces a variety of custom and standard cable designs.

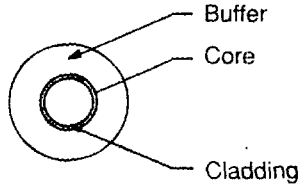
## Applications

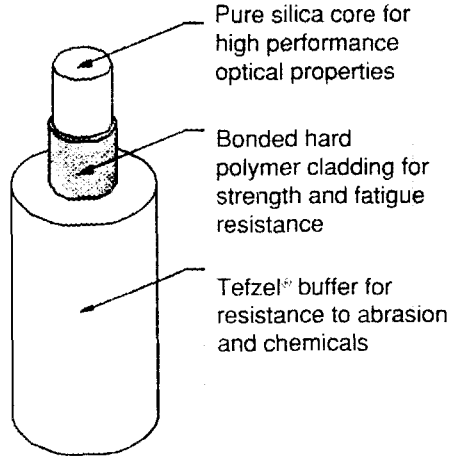
Disposable Medical Assemblies
Laser Power Delivery
Medical Sensors

Factory Automation Links
Industrial Sensors
High Voltage Environments
Illumination

Laser Ordnance
Avionics
Space Based Systems
Weaponry
Nuclear Reactor Systems

Point-to-Point Data Communication Links
Tapped Bus Networks




Ensign-Bickford Optics Company

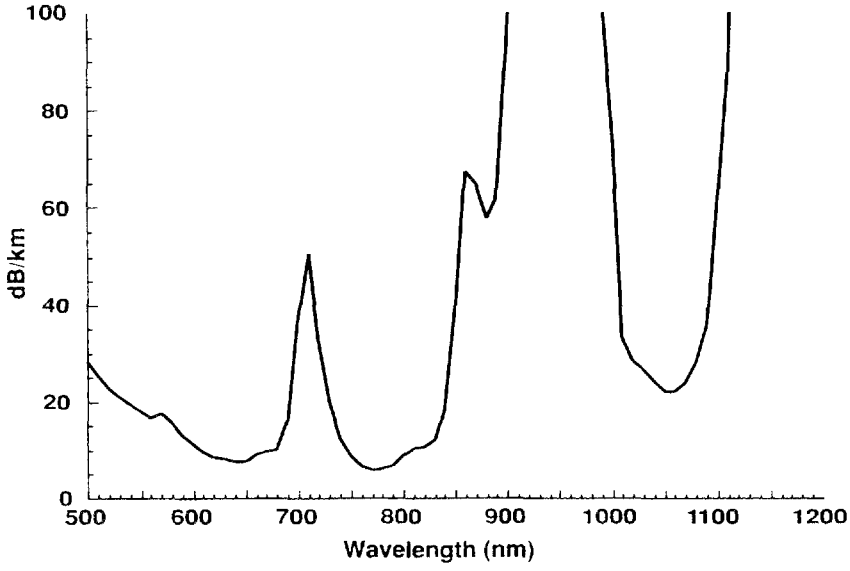
Ensign-Bickford Optics Company, 150 Fisher Drive, Avon, Connecticut 06001 USA
TEL 203-678-0371 FAX 203-674-8818

# HCN, the Short Haul HCS® Fiber

For low cost, short haul data or power transmission over distances from 1 m to 1000 m

| Specifications: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Product Code** | Core Ø (µm) | Cladding Ø (µm) | Buffer Ø (µm) | Maximum Core-to-Clad Offset (µm) | Nominal Bandwidth (MHz-km) | Proof Test (kpsi) [100% tensile proof tested] | Short-Term (60 mins.) Minimum Bend Radius (mm @ 23° C) †† | Long-Term (20 yrs.) Minimum Bend Radius (mm @ 23° C) †† | Typical Stock Lengths (m) ±5% |
| **HCN-M0110T-15** | 110±5 | 125+1/-5 | 250-0/+50 | 5 | 17 | 100 | 8 | 13 | 1100 |
| **HCN-M0125T-15** | 125±5 | 140+2/-5 | 250-0/+50 | 5 | 17 | 100 | 9 | 15 | 1100 |
| **HCN-M0200T-12** | 200±5 | 230+0/-10 | 500±50 | 5 | 17 | 100 | 15 | 24 | 2200 |
| **HCN-M0300T-14** | 300±6 | 330+5/-10 | 650±50 | 8 | 15 | 100 | 22 | 36 | 1100 |
| **HCN-M0400T-14** | 400±10 | 430+5/-10 | 730±50 | 9 | 13 | 50 | 58 | 95 | 1100 |
| **HCN-M0600T-14** | 600±10 | 630±10 | 1040±40 | 9 | 9 | 50 | 87 | 142 | 500 |
| **HCN-M0800T-14** | 800±15 | 830±15 | 1040±50 | 10 | -- | -- | *106 | *175 | 500 |
| **HCN-M1000T-14** | 1000±15 | 1035±15 | 1400±50 | 10 | -- | -- | *121 | *200 | 200 |
| **Temperature Range: -65° C to +125° C** | | | | | | | | | |

**Spectral Attenuation (typical)**




**Fiber Transmission**

| λ (nm) | | dB/km |
|---|---|---|
| 515 | Argon | 23 |
| 532 | KTP | 20 |
| 633 | Helium Neon | 8 |
| 660 | LED | 9 |
| 820 | LED | 11 |
| 1064 | Nd:YAG | 22 |

†† Conditions are ambient: 50% relative humidity, 23° C.
Static fatigue parameter: 24.
* Statistically determined

# HCP, the Low Loss HCS® Fiber

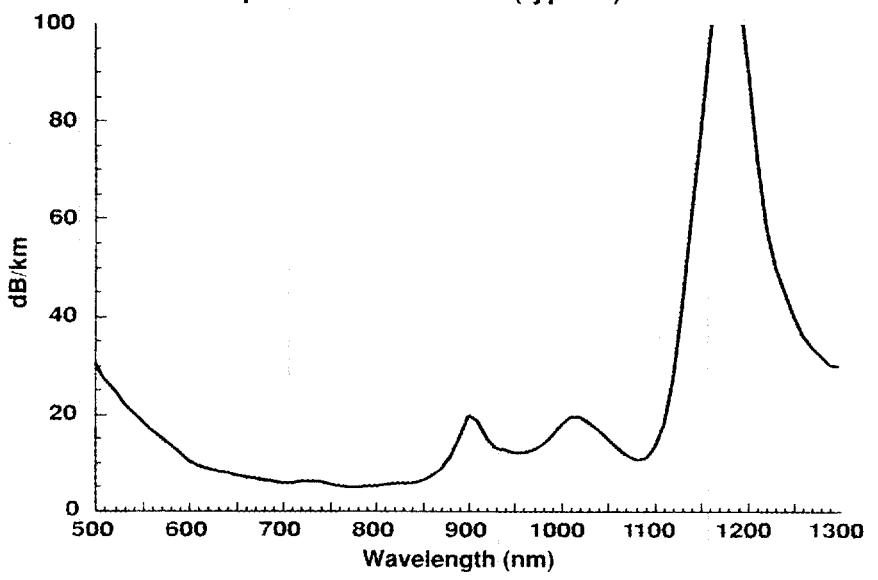
For medium haul (100 m to 3 km) data or power transmission and use in cabling systems

**Specifications:**

| Product Code | Core Ø (µm) | Cladding Ø (µm) | Buffer Ø (µm) | Maximum Core-to-Clad Offset (µm) | Nominal Bandwidth (MHz-km) | Proof Test (kpsi) [100% tensile proof tested] | Short-Term (60 mins.) Minimum Bend Radius (mm @ 23° C) †† | Long-Term (20 yrs.) Minimum Bend Radius (mm @ 23° C) †† | Typical Stock Lengths (m) ±5% |
|---|---|---|---|---|---|---|---|---|---|
| **HCP-M0110T-12** | 110±5 | 125+1/-5 | 250-0/+50 | 5 | 17 | 100 | 8 | 13 | 1100 |
| **HCP-M0125T-12** | 125±5 | 140+2/-5 | 250-0/+50 | 5 | 17 | 100 | 9 | 15 | 1100 |
| **HCP-M0200T-06** | 200±5 | 230+0/-10 | 500±50 | 5 | 17 | 100 | 15 | 24 | 2200 |
| **HCP-M0300T-08** | 300±6 | 330+5/-10 | 650±50 | 8 | 15 | 100 | 22 | 36 | 1100 |
| **HCP-M0400T-08** | 400±10 | 430+5/-10 | 730±50 | 9 | 13 | 50 | 58 | 95 | 1100 |
| **HCP-M0600T-08** | 600±10 | 630±10 | 1040±40 | 9 | 9 | 50 | 87 | 142 | 500 |
| **HCP-M1000T-10** | 1000±15 | 1035±15 | 1400±50 | 10 | -- | -- | *121 | *200 | 200 |

**Temperature Range: -65° C to +125° C**

**Spectral Attenuation (typical)**




**Fiber Transmission**

| λ (nm) | | dB/km |
|---|---|---|
| 633 | Helium Neon | 8 |
| 660 | LED | 7 |
| 820 | LED | 6 |
| 1064 | Nd:YAG | 12 |
| 1300 | Diode Laser | 30 |

†† Conditions are ambient: 50% relative humidity, 23 C.
Static fatigue parameter: 24.
* Statistically determined

# HCR, the Radiation Resistant HCS® Fiber

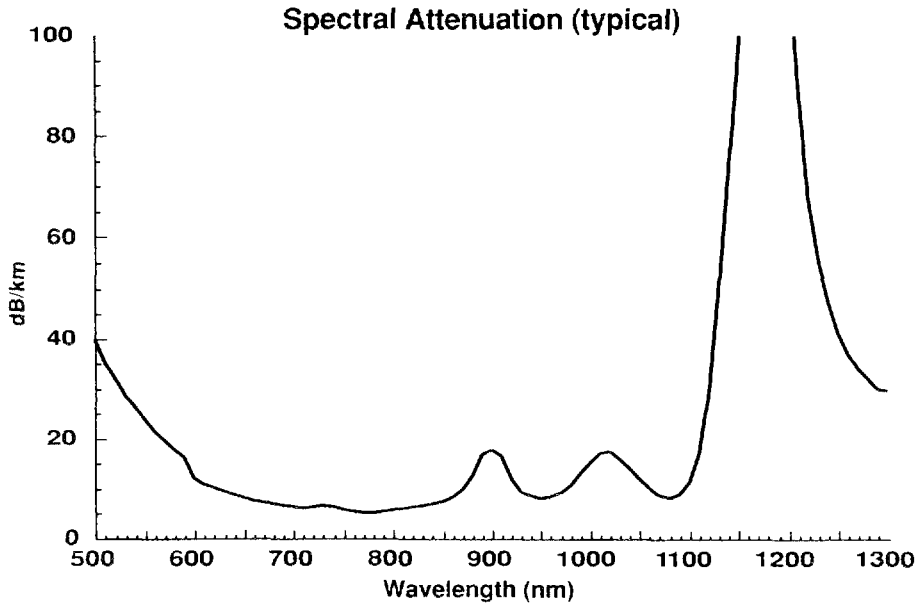
For use in radiation environments, both high dose and high dose rate

**Specifications:**

| Product Code | Core Ø (µm) | Cladding Ø (µm) | Buffer Ø (µm) | Maximum Core-to-Clad Offset (µm) | Nominal Bandwidth (MHz-km) | Proof Test (kpsi) [100% tensile proof tested] | Short-Term (60 mins.) Minimum Bend Radius (mm @ 23° C) †† | Long-Term (20 yrs.) Minimum Bend Radius (mm @ 23° C) †† | Typical Stock Lengths (m) ±5% |
|---|---|---|---|---|---|---|---|---|---|
| **HCR-M0110T-08** | 110±5 | 125+1/-5 | 250-0/+50 | 5 | 17 | 200 | 4 | 7 | 1100 |
| **HCR-M0125T-08** | 125±5 | 140+2/-5 | 250-0/+50 | 5 | 17 | 200 | 5 | 8 | 1100 |
| **HCR-M0200T-05** | 200±5 | 230+0/-10 | 500±50 | 5 | 17 | 200 | 8 | 12 | 2200 |
| **HCR-M0300T-06** | 300±6 | 330+5/-10 | 650±50 | 8 | 15 | 150 | 15 | 24 | 1100 |
| **HCR-M0400T-06** | 400±10 | 430+5/-10 | 730±50 | 9 | 13 | 100 | 29 | 47 | 1100 |
| **HCR-M0600T-06** | 600±10 | 630±10 | 1040±40 | 9 | 9 | 50 | 87 | 142 | 500 |
| **HCR-M1000T-06** | 1000±15 | 1035±15 | 1400±50 | 10 | -- | -- | *121 | *200 | 200 |

**Temperature Range: -65° C to +125° C**

**NOTE**: Additional radiation information available upon request

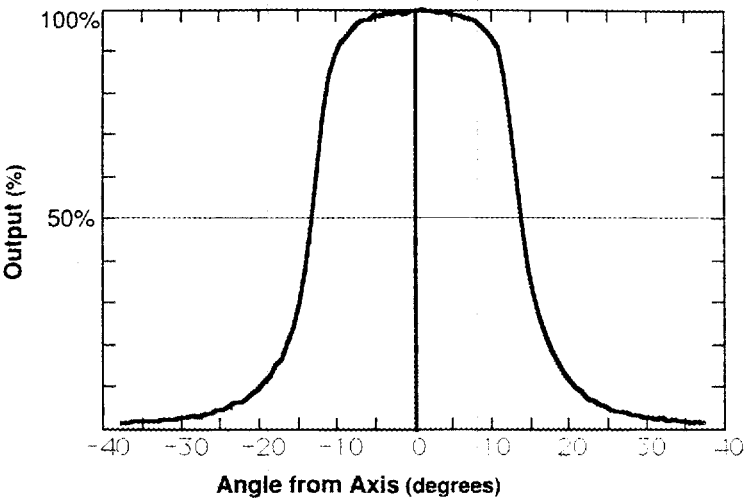



**Fiber Transmission**

| λ (nm) | | dB/km |
|---|---|---|
| 633 | Helium Neon | 8 |
| 660 | LED | 7 |
| 820 | LED | 6 |
| 1064 | Nd:YAG | 12 |
| 1300 | Diode Laser | 30 |

†† Conditions are ambient: 50% relative humidity, 23° C.
Static fatigue parameter: 24.
* Statistically determined

## Numerical Aperture Scan (nominal: 1km)

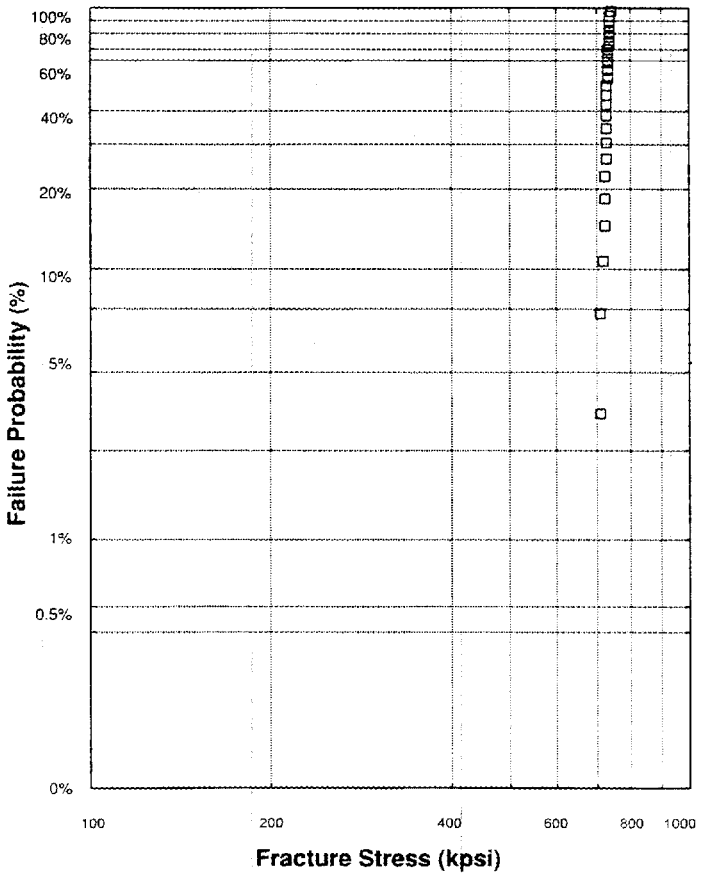



## PART NUMBERING

**H C X - M X X X X T - X X**

| | |
|---|---|
| **H C** | - Hard Clad |
| **X** | - Fiber Type (HCN, HCP, HCR) |
| **M** | - Medium NA (0.37) |
| **XXXX** | - Core Diameter in microns |
| **T** | - Tefzel® Buffer |
| **XX** | - Maximum attenuation in dB/km @ 820 nm |

## Weibull Analysis of Tensile Strength




Custom core materials, fiber sizes, core-to-clad ratios, NAs and buffer types available. Contact our Sales Department for additional information

Notes:

All test methods are conducted with EIA guidelines for step-index fiber, subject to change without notice with issuance of new test standards from EIA.

All specifications and tolerances are subject to change.

Kevlar and Tefzel are registered trademarks of Dupont. ST is a registered trademark of AT&T

Manufactured in the U.S.A. by Ensign-Bickford Optics Company

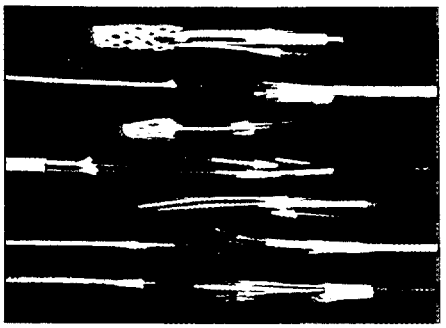
# We Are A Full Service Company. We Offer You....

## HCS® Fibers

**HCN, Short Haul**
**HCP, Low Loss**
**HCR, Radiation Resistant**

- High tensile strength
- Static fatigue resistant
- High numerical aperture
- High core-to-clad ratio
- Core sizes from 110 μm to 1000 μm

## HCS® Cables

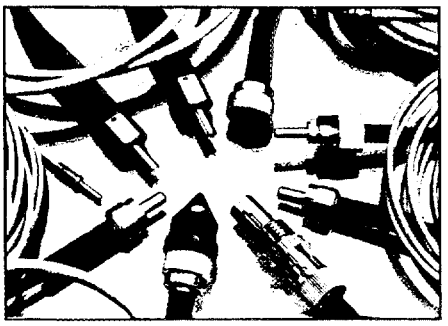


- Cable constructions from simplex to multichannel heavy duty
- Applications from light duty indoor to rugged outdoor in hazardous environments
- 1.8 mm to 3.0 mm sub-channels
- Standard jacket materials: PVC, Polyurethane, Fluoropolymer and Polyethylene
- 1 - 18 channels standard; up to 48 channels available
- Cable constructions with HCS® fibers or standard singlemode and graded index
- UL rated Riser cables available

## HCS® TK-6 Termination Kit

- Quick, easy crimp and cleave terminations, in 3 minutes or less
- SMA and ST® style crimp and cleave connectors
- Kit contains: cable stripper, fiber stripper, crimp tool, Kevlar® scissors and specially designed CT-2 Diamond Cleave Tool
- CT-2 Diamond Cleave Tool scribes the fiber to produce a smooth, even endface, without polishing
- CT-2 Diamond Cleave Tool produces high quality, consistent cleaves on HCS® fibers ranging in core size from 110 μm to 600 μm

## Assemblies

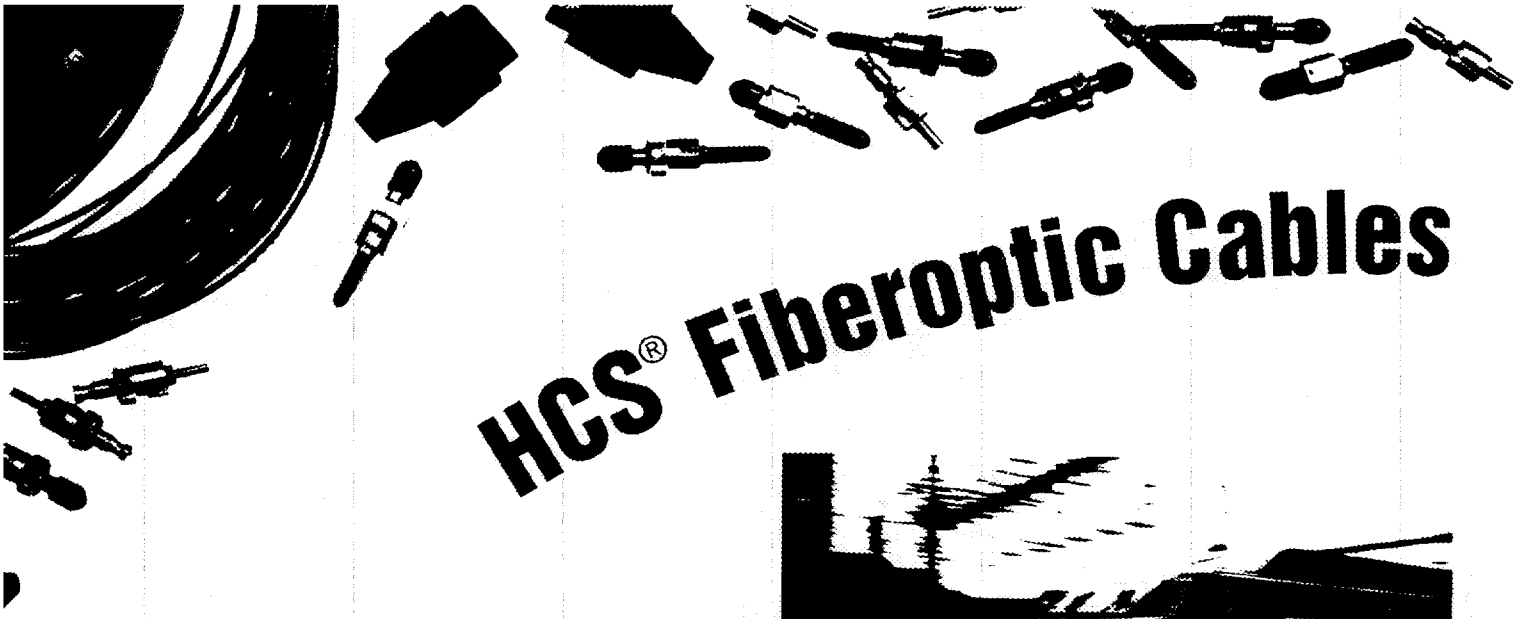


- Automated crimp and cleave assembly capabilities on HCS® fibers up to1000 μm core
- Customized crimp and cleave connections
- Custom designs with a variety of epoxy/polish industry standard connectors
- Custom designed disposable medical probes
- Finished assemblies ranging from pigtails and jumpers to complete tactical cable harnesses

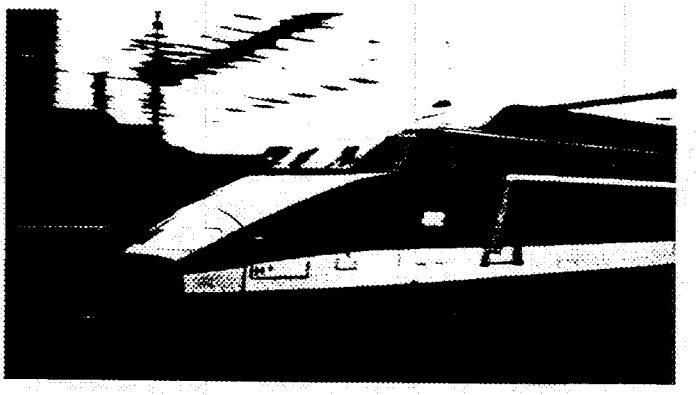
**NOTE**: Additional product information available upon request

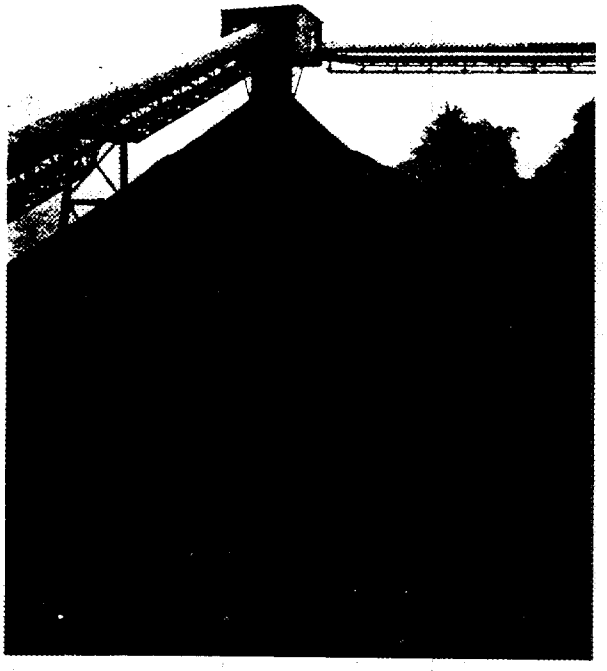
HCS08/91

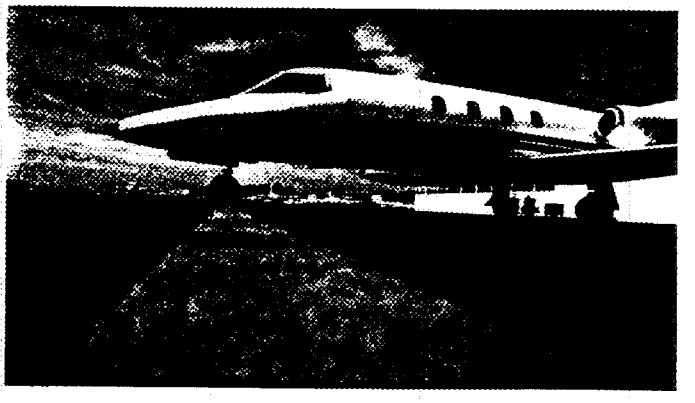
Ensign-Bickford Optics Company, 150 Fisher Drive, Avon, Connecticut 06001 USA Tel 203-678-0371 Fax 203-674-8818



# HCS® Fiberoptic Cables








Ensign-Bickford Optics Company

**The dynamic force in fiber.**

Ensign-Bickford Optics Company, 150 Fisher Drive, Box 1260, Avon, CT 06001-1260 USA
203/678-0371 Fax 203/674-8818

# Quality is the ultimate competitive advantage.

Ensign-Bickford Optics Company's customers in the industrial, data communication, medical, avionics and military areas expect continuous gains in total quality. Our objective is to utilize every employee's personal commitment to customer satisfaction to make that user expectation a reality. Since our customer base is global, we have structured our quality program to comply with future ISO9000 requirements, Good Manufacturing Practices (GMP), regulatory compliance and numerous military standards. The journey to achieving quality is never complete. We continually strive to identify new means of improvement to better serve you, our customer.

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# HCS® Fiberoptic Cables

Ensign-Bickford Optics Company (EBOC) has been serving the industrial, medical, military and aerospace markets with the Hard-Clad Silica (HCS®) fiberoptic family of products for over ten years. Today, the HCS® family is comprised of multimode, step-index fibers ranging in core size from 100 µm to 1000 µm. These fibers are offered in either silica core/hard polymer cladding or silica core/silica cladding/hard coating constructions. The patented polymer of HCS® fibers allows the crimping of a connector directly onto the fiber's cladding. This feature combined with EBOC's innovative cleaving process eliminates the time consuming and expensive process of traditional epoxy/polish connectors.

In this catalog we present EBOC's extensive line of HCS® fiberoptic cables. Since we manufacture both the fiber *and* cable, we can offer the broadest range of cable designs combined with low cost and short delivery lead times. The four series and special cable offerings incorporate large core, multimode, step-index fibers in a tight buffer construction. We emphasize that the products described herein are our standard cable offering and represent but a sampling of our cabling capabilities. EBOC can custom design and manufacture cables utilizing the vast family of HCS® fibers and can build cables up to 48 channels. EBOC's full product offering extends well beyond HCS® fibers and cables to include: singlemode fiber, cable and assemblies; graded-index, datacom cables and assemblies; industrial and medical grade assemblies; and fiberoptic bundles.

EBOC welcomes the opportunity to work with you in engineering solutions to your fiberoptic needs. Our technical team and state-of-the-art facilities and equipment ensure the success of your program.

# Fiberoptic Technology

Ensign-Bickford has been involved in the research and development of fiber optic technology since 1968. Ensign-Bickford Optics Company invented Hard Clad Silica (HCS®) and has pioneered its use in a variety of special and often harsh applications since the inception of the company in 1984. Today, EBOC continues to develop and manufacture optical fibers and, through its global presence, pursues the total quality goal of meeting your evolving fiber optic needs.

## Why use fiber optics?

- Wide Bandwidth
- Low Attenuation
- Electromagnetic Immunity
- Radio Frequency Interference
- Small size
- Light weight
- Security
- Safety in Hazardous Environments

A constant concern in communications is sending ever-increasing amounts of information with greater efficiency over a medium requiring less space and less susceptibility to outside interferences. As speeds and transmission distance increase, the problems caused by electromagnetic interference (EMI), radio frequency interference (RFI), cross talk and signal distortion become more troublesome. In the areas of signal integrity and information-carrying capacity, fiber optics offers many advantages over copper cable. Furthermore, optical fibers emit no radiation and are safe from sparking and shock. These features make fiber the ideal choice for many processing applications where safe operation in hazardous or flammable environments is a requirement.

## Why use HCS® fiberoptic cables?

Large core, multimode, step-index HCS® fiberoptic cables make fiber optic technology user-friendly and help designers to realize substantial cost savings. The coupling efficiency of HCS® fibers allows the use of less expensive transmitters and receivers. Patented HCS® polymer technology permits direct crimping onto the fiber cladding. Field terminations can be performed in 3 minutes or less, with minimal training and no consumables. Our cable factory produces a variety of standard and custom cable designs to meet the requirements of your demanding applications.

# Product Summary

The fiberoptic cables in this catalog incorporate EBOC large core, multimode, step-index HCS® fibers and represent our most popular cable designs. The cable products described herein represent but a sampling of our cabling capabilities. Our flexibility in manufacturing allows for customized cables that may incorporate any of the various HCS® fiber grades (HCN, HCP, HCR, All-Silica) and sizes (100 µm to 1000 µm) in a variety of cable constructions and colors up to 48 channels. Discuss your cable application with us and we will design a cable construction to meet your needs.

HCS® cables are offered in a tight buffer design. Tight buffer cables result in a smaller cable diameter, more flexibility, and greater resistance to crushing forces than loose-tube cables of equivalent fiber count.

Where the high tensile strength of a loose tube cable construction is required for extra long pulls, a heavy-duty version of the A Series cable is offered (see page 16). While a loose-tube cable may offer lower cable attenuation from graded-index fiber at low temperatures, the step-index profile of large core HCS® fibers minimizes such loss even when incorporated in a tight buffer design.

In simplex, duplex and zipcord constructions, the HCS® fiber is concentrically surrounded by a Aramid Yarn layer for added strength and protection and with an extruded outer jacket. These cables are commonly used for short interconnects in conduit, cable trays and for applications where there is no foot traffic. In breakout constructions, HCS® simplex subchannels are stranded around a central, fiberglass epoxy strength member and tape wrapped before an outer jacket is extruded. The rugged, overall jacket allows for ease of handling and installation while the individual subchannels allow for easy separation and termination using the EBOC crimp and cleave system.

## Standard Product Matrix

| | A Series Simplex, Zipcord Duplex, Breakout | A Series Heavy Duty Breakout | A Series Heavy Duty Armored | J Series Simplex, Zipcord, Breakout | C Series Simplex | D Series (Avioptics®) Simplex |
|---|---|---|---|---|---|---|
| **FIBER TYPE** | HCP – Premium, Low Loss HCS® | | | | | HCP & HCR Rad Hard HCS® |
| **FIBER SIZE** | 200 µm | 200 µm | 200 µm | 200 µm | 110 – 1000 µm | 200 µm |
| **NUMBER OF FIBERS** | 1 – 6 | 2 | 2 | 1 – 2 | 1 | 1 |
| **STRENGTH MEMBER** | Aramid Yarn, FRP | Aramid Yarn, FRP | Aramid Yarn, FRP, Steel | Aramid Yarn, FRP | Aramid Yarn | Aramid Yarn |
| **OUTER JACKET MATERIALS** | PVC, PE | PVC, PE | PE | PVC | PU | ETFE |
| **DIELECTRIC/ARMORED** | Dielectric | Dielectric | Armored | Dielectric | Dielectric | Dielectric |
| **TERMINATION** | All HCS® cables, up to 600 µm, can be terminated on-site utilizing our TK-6 Termination Kit and crimp and cleave connectors. | | | | | |
| **FLAMMABILITY RATINGS** | OFNR, MSHA | OFNR, MSHA | NA | OFNP, OFNR, MSHA | NA | NA |
| **PAGES** | 6 – 7 | 8 | 8 | 9 | 10 | 11 |

Cable constructions incorporating up to 48 channels and other core sizes are available.

FRP = Fiberglass Reinforced Plastic
PE = Polyethylene
PVC = Polyvinylchloride
PU = Polyurethane

# HCS® Fiberoptic Cable Selection

## Industrial, Factory Floor, DataCom Fiberoptic Cables

**A SERIES** Simplex — Zipcord — Duplex — Breakout — Heavy-Duty — Armored Pages 6 – 8

**J SERIES** Simplex — Zipcord — Breakout Page 9

- Low Cost
- General purpose. PVC subunit jackets and PVC or PE outer jacket
- Manufactured with Premium HCP 200 μm fiber

## DataCom, Power Delivery Fiberoptic Cables

**C SERIES** Simplex Page 10

- Manufactured with Premium HCP fiber in core sizes from 100 μm to 1000 μm
- Polyurethane jacket is flame, impact and cut-through resistant

## Avionics and Military Fiberoptic Cables

**D SERIES** Simplex Page 11
**Avioptics**

- Manufactured with Premium HCP or Radiation Resistant HCR 200 μm fiber
- Chemical resistant, ETFE outer jacket
- Compact and lightweight
- Operating temperature range from -65°C to + 125°C

## Specialty Fiberoptic Cables

**SPECIALS** Pages 12 – 13

- UL Riser (OFNR), UL Plenum (OFNP), M.S.H.A.
- Low Halogen, Medical Grade
- Loose Tube Heavy Duty

# Part Numbering

**CABLE PART NUMBER** HCX – MXXXXT – X XX X X XX

**Fiber Type**

P = Premium (HCP)
R = Radiation Resistant (HCR)

**Fiber Core Size**

| | |
|---|---|
| 100 µm | 400 µm |
| 125 µm | 600 µm |
| 200 µm | 1000 µm |
| 300 µm | |

**Cable Sub-Channels**

A = 2.5 mm diameter
J = 2.2 mm diameter
C = 3.0 mm diameter
D = 1.8 mm diameter

**Number of Sub-Channels**

01 to 48

**Final Jacket Material**

E = Polyethylene
F = ETFE
M = MSHA
P = Plenum
R = Riser
U = Polyurethane
V = Polyvinylchloride (PVC)
Z = Zero Halogen

**Cable Construction**

S = Simplex
Z = Zipcord
D = Duplex
B = Breakout

**Special Construction**

HD = Heavy Duty
HA = Heavy Duty, Armored

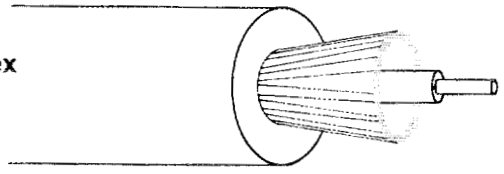
**Example:** HCP-M0200T-A02EB is a 2 Channel Breakout Cable incorporating two 200 µm, 2.5 PVC jacketed subunits and Polyethylene outer jacket.

# A Series

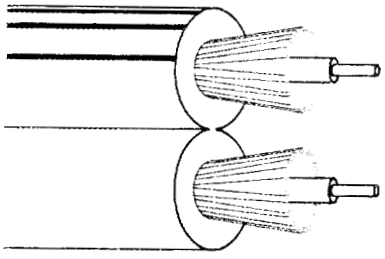
## Product Features

- Optical fibers in Simplex, Duplex and Zipcord constructions are surrounded by Aramid Yarn strength members and a flame retardant PVC jacket.
- In multi-fiber breakout cables, sub-channels are stranded around a central, non-rigid tensile strength member. UV resistant, rugged polyethylene outer jacket provides environmental protection.
- Subunits are color coded for easy identification.
- Up to 18 fiber cable constructions are possible.

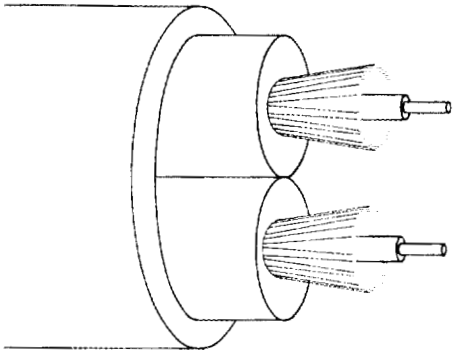
**Simplex**
**A01VS**



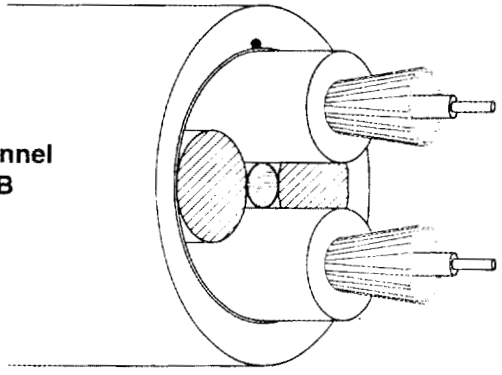
**Zipcord**
**A02VZ**



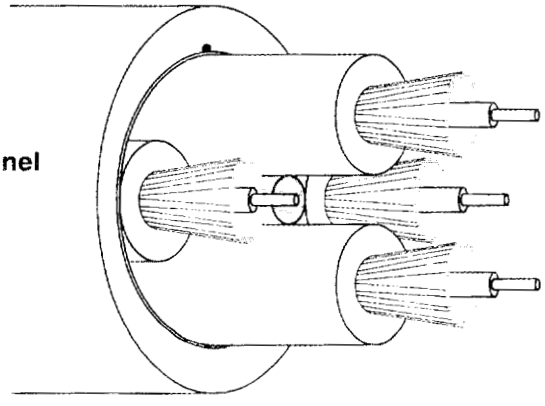
**Duplex**
**A02VD**



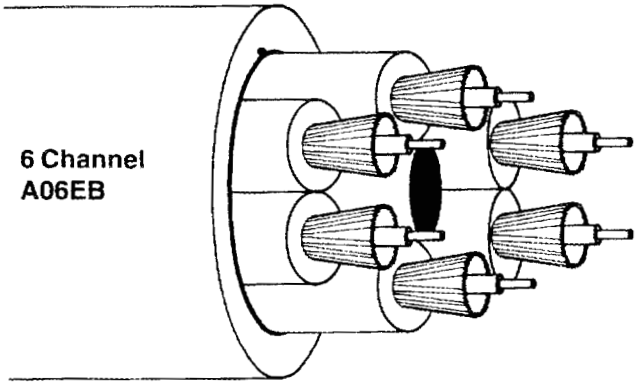
**2 Channel**
**A02EB**



**4 Channel**
**A04EB**

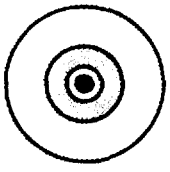


**6 Channel**
**A06EB**

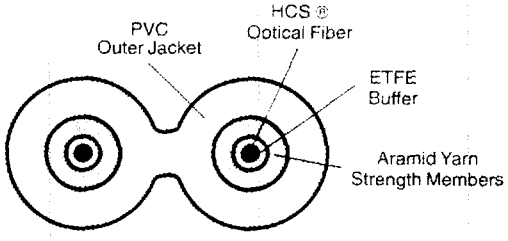


# A Series

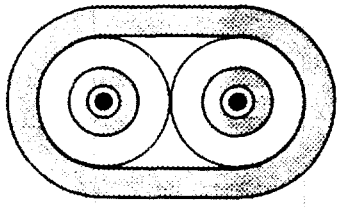
**Simplex**
**HCP-M0200T-A01VS**



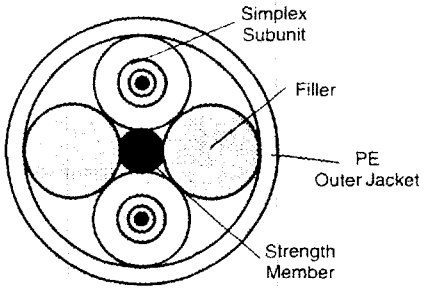
**Zipcord**
**HCP-M0200T-A02VZ**



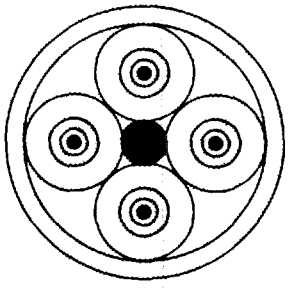

**Duplex**
**HCP-M0200T-A02VD**



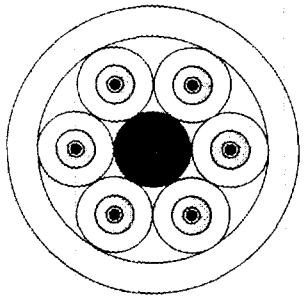
**2 Channel**
**HCP-M0200T-A02EB**




**4 Channel**
**HCP-M0200T-A04EB**



**6 Channel**
**HCP-M0200T-A06EB**



| | SIMPLEX | ZIPCORD | DUPLEX | 2 CHANNEL | 4 CHANNEL | 6 CHANNEL |
|---|---|---|---|---|---|---|
| Cable Diameter (mm) | 2.5 | 2.5 x 5.4 | 3.5 x 6.0 | 8.0 | 8.0 | 10.0 |
| Cable Weight (kg/km) | 6.5 | 11.0 | 20 | 45 | 45 | 61 |
| Jacket Type | PVC | PVC | PVC | Polyethylene | Polyethylene | Polyethylene |
| Standard Jacket Color | Orange | Orange | Orange | Black | Black | Black |
| Maximum Pull Tension | 75 lb. (335N) | 110 lb. (490N) | 150 lb. (670N) | 210 lb. (940N) | 360 lb. (1,600N) | 870 lb. (3,880N) |
| Maximum Long-term Tension | 55 lb. (245N) | 85 lb. (370N) | 110 lb. (490N) | 155 lb. (690N) | 265 lb. (1,175N) | 630 lb. (2,800N) |
| Break Strength | 200 lb. (890N) | 300 lb. (1,340N) | 400 lb. (1,780N) | 530 lb. (2,370N) | 900 lb. (4,000N) | 2,500 lb. (11,000N) |
| Impact Strength at 1.6 N-m | 100 | 100 | 150 | 200 | 200 | 200 |
| Cyclic Flexing (cycles) | >5,000 | >5,000 | >5,000 | >2,000 | >2,000 | >2,000 |
| Minimum Bend Radius (mm) | 25 | 25 | 25 | 50 | 50 | 75 |
| Operating Temperature: | -20° C to +80° C | -20° C to +80° C | -20° C to +80° C | -40° C to +80° C | -40° C to +80° C | -40° C to +80° C |
| Storage Temperature: | -40° C to +80° C | -40° C to +80° C | -40° C to +80° C | -40° C to +80° C | -40° C to +80° C | -40° C to +80° C |
| Cable Attenuation: 06 dB/km @ 820 nm | | | | | | |

# A Series Heavy Duty

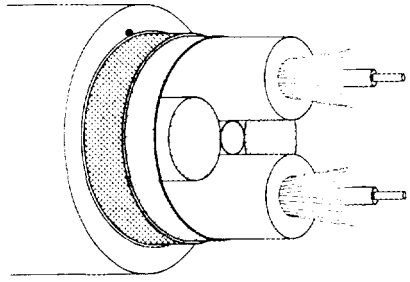
## Product Features

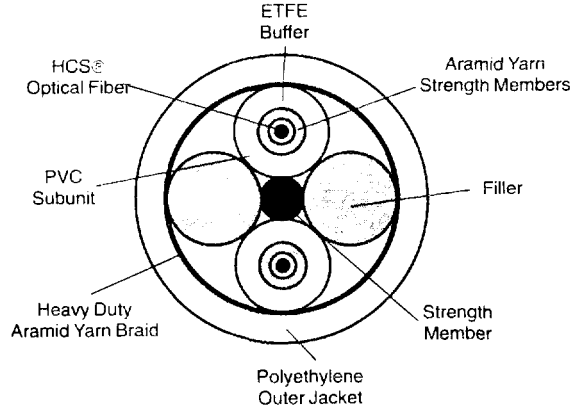
- Heavy-Duty Aramid Yarn braid under polyethylene outer jacket to provide additional pull tension and break strength.
- Standard 2 channel; 4 and 6 channel available.

| | 2 CHANNEL HEAVY DUTY |
|---|---|
| Cable Diameter (mm) | 8.4 |
| Cable Weight (kg/km) | 50 |
| Jacket Type | Polyethylene |
| Standard Jacket Color | Black |
| Maximum Pull Tension | 475 lb. (2.100N) |
| Maximum Long-term Tension | 340 lb. (1.500N) |
| Break Strength | 1,350 lb. (6.000N) |
| Impact Strength @ 1.6 N-m | 200 |
| Cyclic Flexing (cycles) | >2,000 |
| Minimum Bend Radius (mm) | 50 |

Cable Attenuation: 06 dB/km @ 820 nm
Operating Temperature: -40° C to +80° C
Storage Temperature: -40° C to +80° C

HCP-M0200T-
A02EB-HD






# A Series Heavy Duty Armored

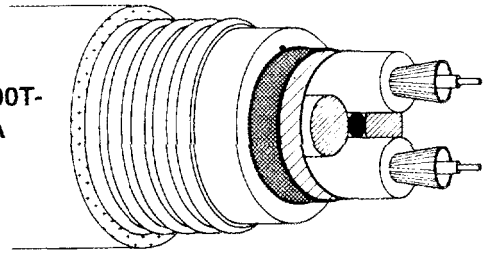
## Product Features

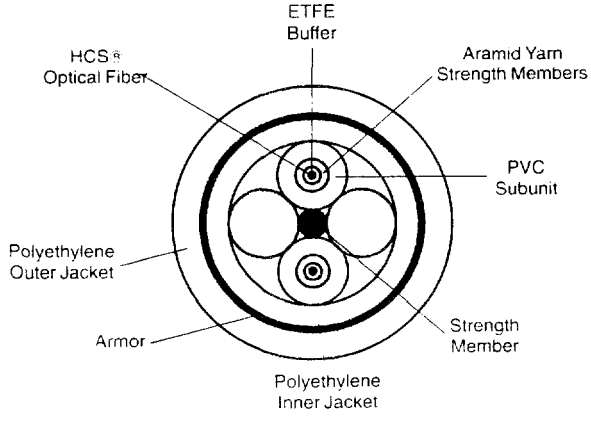
- Corrugated steel tape and outer polyethylene jacket surround an A Series Heavy Duty sub-cable.
- Provides rodent protection. ■ Suitable for direct burial
- Standard 2 channel; 4, 6 and 8 channel available.

| | 2 CHANNEL H.D. ARMORED |
|---|---|
| Cable Diameter (mm) | 13.0 |
| Cable Weight (kg/km) | 135 |
| Jacket Type | Polyethylene |
| Standard Jacket Color | Black |
| Maximum Pull Tension | 600 lb. (2.670N) |
| Maximum Long-term Tension | 200 lb. (890N) |
| Break Strength | 1,500 lb. (6.675N) |
| Impact Strength @ 1.6 N-m | 300 |
| Cyclic Flexing (cycles) | >2,000 |
| Minimum Bend Radius (mm) | 130 |

Cable Attenuation: 06 dB/km @ 820 nm
Operating Temperature: -40° C to +80° C
Storage Temperature: -40° C to +80° C

HCP-M0200T-
A02EB-HA





# J Series

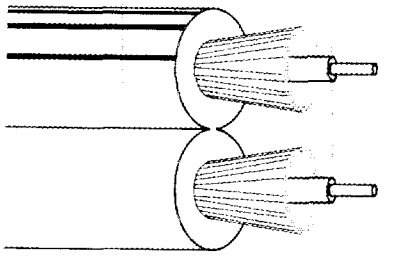
## Japanese Industrial Style

日本工業の方式

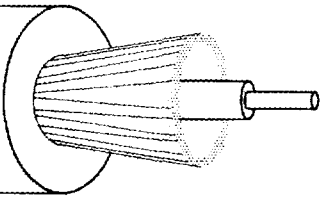
## Product Features

- Optical fibers in Simplex, Duplex and Zipcord constructions are surrounded by Aramid Yarn strength members and a flame retardant PVC jacket.
- Compatible with Japanese Industrial Style connectors.
- Multi-fiber Breakout cables have a UV resistant, rugged polyethylene jacket for environmental protection.
- Subunits are color coded for easy identification.

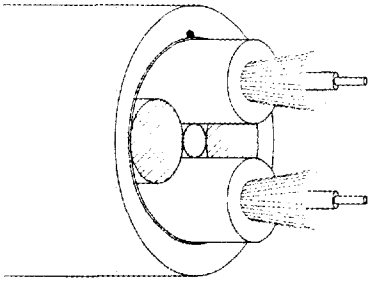
HCP-M0200T-J02VZ

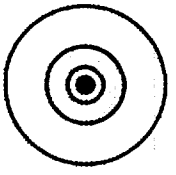


HCP-M0200T-J01VS

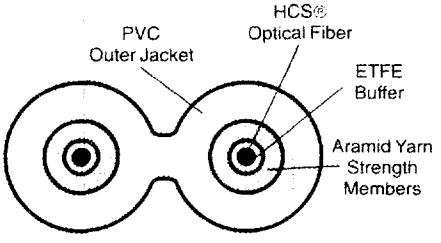


HCP-M0200T-J02VB

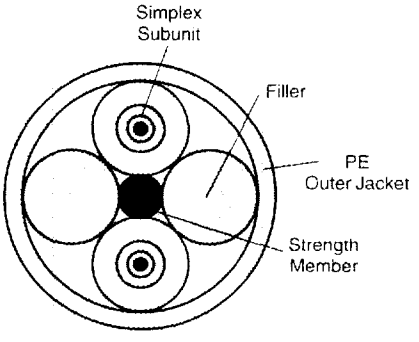




Simplex




Zipcord



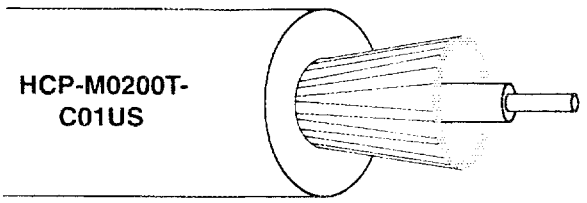

2 Channel

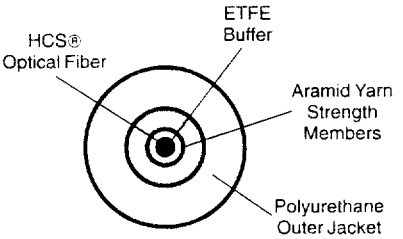
| | SIMPLE | ZIPCORD | 2 CHANNEL |
|---|---|---|---|
| Cable Diameter (mm) | 2.2 | 2.2 x 2.4 | 8.4 |
| Cable Weight (kg/km) | 4.0 | 8.0 | 50 |
| Jacket Type | PVC | PVC | PVC |
| Standard Jacket Color | Orange | Orange | Black |
| Maximum Pull Tension | 35 lb. (155N) | 75 lb. (335N) | 135 lb. (600N) |
| Maximum Long-term Tension | 25 lb. (110N) | 55 lb. (245N) | 100 lb. (445N) |
| Break Strength | 100 lb. (445N) | 200 lb. (890N) | 550 lb. (2,400N) |
| Crush Resistance | 100 lb./in. | 100 lb./in. | 200 lb./in. |
| Impact Strength @ 1.6 N-m | 20 | 20 | 100 |
| Cyclic Flexing (cycles) | >5,000 | >5,000 | >2,000 |
| Minimum Bend Radius (mm) | 25 | 25 | 50 |
| Operating Temperature: | -20° C to +80° C | -20° C to +80° C | -40° C to +80° C |
| Storage Temperature: | -40° C to +80° C | -40° C to +80° C | -40° C to +80° C |
| Cable Attenuation: 05 dB/km @ 820 nm | | | |

# C Series

## Product Features

- Optical fibers in Simplex construction, surrounded by Aramid Yarn strength member and a flame retardant polyurethane jacket.
- Excellent impact and cut-through resistance.
- Jacket is resistant to hydrolysis, oil and chemicals.
- Available in core sizes ranging from 110 µm and 1000 µm.
- Stock available in full range of core sizes, ensuring quick delivery.




**Simplex**

| | SIMPLEX |
|---|---|
| Cable Diameter (mm) | 3.0 |
| Cable Weight (kg/km) | 8.0 |
| Jacket Type | Polyurethane |
| Standard Jacket Color | Orange |
| Maximum Pull Tension | 75lb. (330N) |
| Maximum Long-term Tension | 55 lb. (245N) |
| Break Strength | 200 lb. (890N) |
| Crush Resistance | 570 lb./in. (1,000 N/cm) |
| Impact Strength @ 1.6 N-m | 1,000 |
| Cyclic Flexing (cycles) | >10,000 |
| Operating Temperature: -40° C to +85° C<br>Storage Temperature: -40° C to +85° C | |

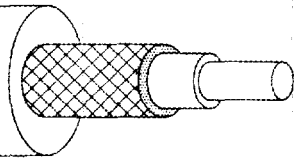
| CABLE PART NUMBER | CABLE ATTENUATION (dB/km @ 820 nm) | MINIMUM BEND RADIUS (mm) |
|---|---|---|
| HCP-M0110T-C01US | 12 | 15 |
| HCP-M0125T-C01US | 12 | 16 |
| HCP-M0200T-C01US | 6 | 25 |
| HCP-M0300T-C01US | 8 | 37 |
| HCP-M0400T-C01US | 8 | 100 |
| HCP-M0600T-C01US | 8 | 150 |
| HCP-M1000T-C01US | 10 | 200 |

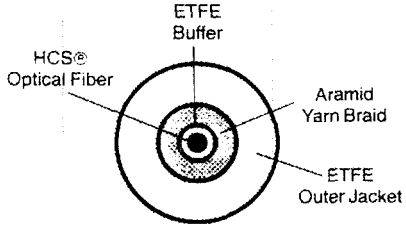
# D Series

## Product Features

- Optical fiber in Simplex construction, surrounded by braided Aramid Yarn strength members and an ETFE outer jacket.
- Available in HCP, Premium Low Loss or HCR, Radiation Resistant type fibers.
- Jacketing offers excellent chemical and oil resistance.
- Lightweight and compact size suitable for airframe applications.

**HCP-M0200T-D01FS**
**or HCR-M0200T-D01FS**






**Simplex**

| | SIMPLEX |
|---|---|
| Cable Diameter (mm) | 1.8 |
| Cable Weight (kg/km) | 3.5 |
| Jacket Type | ETFE |
| Standard Jacket Color | Violet |
| Maximum Pull Tension | 100 lb. (450N) |
| Maximum Long-term Tension | 25 lb. (110N) |
| Break Strength | 200 lb. (890N) |
| Crush Resistance | 285 lb./in. (500N/cm) |
| Impact Strength @ 1.6 N-m | 500 |
| Cyclic Flexing (cycles) | >50,000 |
| Minimum Bend Radius (mm) | 10 |

Cable Attenuation: 08 dB/km @ 820 nm
Operating Temperature: -65° C to +125° C
Storage Temperature: -65° C to +125° C

# Special Cables

## Riser

UL Listed Type OFNR cables meet requirements of UL 1666 Vertical Flame Test and may be used in vertical passages connecting one floor to another. HCS® Riser cables are available in A and J Series constructions.

## Plenum

UL Listed Type OFNP cables pass Steiner Tunnel Test, UL 910. These cables may be installed in ducts, plenums, and air handling spaces without the use of conduit. HCS® Plenum cables are available in A and J Series constructions.

## M.S.H.A.

HCS® M.S.H.A. cables meet Mine Safety and Health Administration 30 CFR Part 18 and MSHA signaling cable acceptance criteria. One to 48 channel cables are possible.

## ZKC (Zero Kevlar® Cable)

The inherent strength of HCS® fiber allows for an innovative cable construction where the fiber itself acts as the strength member. ZKC Simplex construction is comprised of 200 or 400 μm HCP fiber and a 2.2 mm UL rated Plenum outer jacket.

# Special Cables

## Low-Halogen

Flame retardant, zero-halogen jacketing material is used in a range of constructions to replace the standard PVC or polyethylene jacket. Low-Halogen cables have low smoke properties and are used in areas where public safety is of great concern.

## Medical

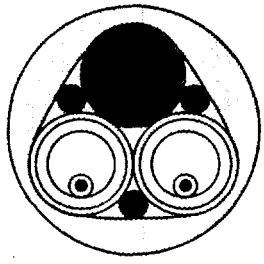
HCS® A Series cables are available with a medical grade PVC jacket for those applications where the cable will require sterilization for use in a clean environment.

## Hybrids

HCS® hybrid cables may incorporate a combination of copper pairs and/or communication grade multimode/singlemode fibers, along with HCS® fiber to provide telephone voice signals and high speed data transmission within the same cable.

## Heavy Duty Loose Tube

For environmental conditions requiring the ruggedness of a loose-tube design, Ensign-Bickford Optics offers a B Series cable in the following construction:

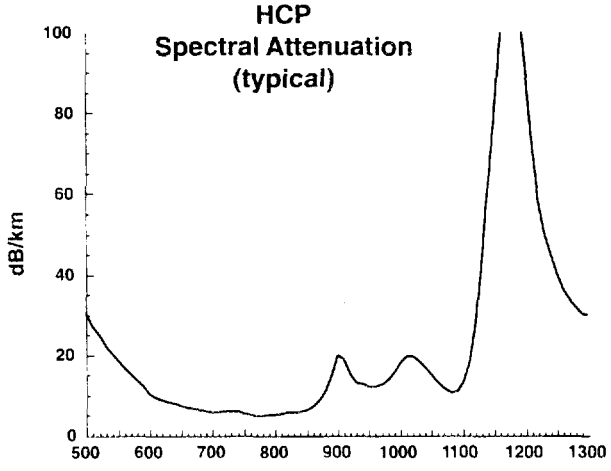


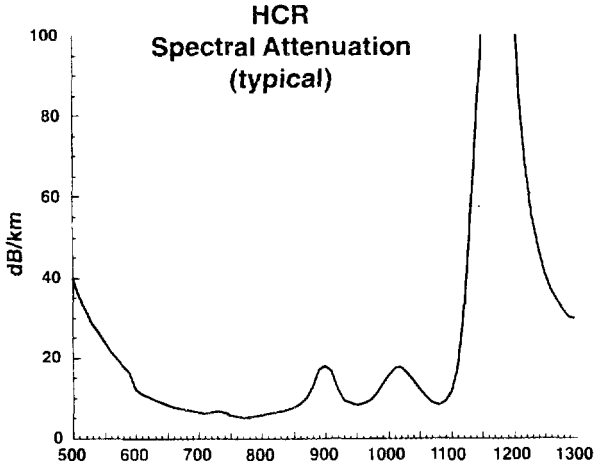
# HCP and HCR Fiber Specifications

## Product Features

- High Tensile Strength (>720 kpsi)
- Static Fatigue Resistant (n = 24)
- High Core-to-Clad Ratio
- High Numerical Aperture (0.37 ± 0.02)
- ETFE Buffer

| | HCP M0110T | HCP M0125F | HCP M0200T | HCP M0300T | HCP M0400T | HCP M0600T | HCP M1000T | HCR M0200T |
|---|---|---|---|---|---|---|---|---|
| Core φ (μm) | 110±5 | 125±5 | 200±4 | 300±6 | 400±8 | 600±10 | 1000±15 | 200±5 |
| Cladding φ (μm) | 125+1/-5 | 140+2/-5 | 230+0/-10 | 330+5/-10 | 430+5/-10 | 630+5/-10 | 1035±15 | 230+0/-10 |
| Buffer φ (μm) | 250-0/+50 | 250-0/+50 | 500±30 | 650±30 | 730±30 | 1040±30 | 1400±50 | 500±30 |
| Max Core-to-Clad Offset (μm) | 5 | 5 | 5 | 6 | 8 | 8 | 10 | 5 |
| Nominal Bandwidth (MHz-km) | 25 | 25 | 20 | 15 | 13 | 9 | – | 20 |
| Proof Test (kpsi) (100% tensile proof tested) | 100 | 100 | 150 | 150 | 100 | 75 | – | 200 |



# Fiberoptic Cable Installation Guidelines*

## Safety First

Train personnel on the equipment that EBOC fiber optic cable placement requires. This equipment may include hand-held tools, tension meters, optical power meters and various cleaners and adhesives. Observe all local practices and regulations. These may include such things as personal safety equipment and guidelines for their use. Always dispose of fiber waste. This practice will help to avoid glass fragments getting into clothes, fingers or eyes.

## Review Cable Specs

Before installation, review the cable parameters and EBOC cable specifications such as cable construction, outer jacket material, strength member material, maximum pulling tension and minimum bend radius under load.

## Observe Maximum Pulling Tension

The cable should never be pulled at a force greater than the maximum allowable pulling tension. Excessive loads produced by bending or pulling may cause fiber damage. A running line tension meter should be utilized to determine the pulling tension applied to the cable during the entire cable placement.

## Never Exceed Minimum Bend Radius

The cable should not be pulled around any bends smaller than 20 times the cable diameter when under load and 10 times the cable diameter at no load.

Entrance in and out of metal pull boxes must be smooth so as not to damage the cable sheath.

# Installation Methods

## Conduit and Duct Installation

Conduit and duct installation of fiber optic cables are similar to those of electrical wires. Avoid janking, flipping or wrapping cable which could result in unnecessary tightening. Small cables should not be subjected to foot traffic or crushing forces.

## Direct Burial Installation

Heavy Duty and Armored cables may be buried directly in the ground. This method may prevent environmental hazards such as freezing water, crushing forces, ground disruption from construction and rodents. Double jacketing or armoring may also be used for further protection.

## Aerial Installation

Most round, tight buffer and loose-tube cables are compatible with helical lashing, clamping or tied mounting. Aerial installation is possible utilizing methods similar to electrical cables.

*For more extensive explanation of cable installation procedures, please request our "Fiberoptic Cable Installation Guide."

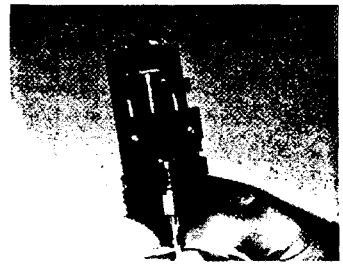
# Crimp and Cleave Connectorization

## Product Features

- Quick, easy crimp and cleave field terminations in 3 minutes or less, using no consumables.
- TK-6 for use with U.S. standard cables.
- JK-6 for use with Japanese Industrial Style (JIS) cables.
- ZK-6 for use with Hewlett Packard Versatile Link devices.
- Kit contains subunit jacket stripper, fiber stripper, crimp tool, scissors and Diamond Cleave Tool.
- Specially designed Diamond Cleave Tool produces high quality, consistent cleaves on HCS fiber core sizes from 200 μm to 600 μm.

**HCS® TK-6 Termination Kit**

Crimping an SMA Connector directly onto HCS® fiber cladding.



Activating the trigger on the CT-2 performs three actions – fiber clamps hold the fiber in place; a spring places tension on the fiber; the diamond blade scribes the fiber, thus initiating the cleave.

## Crimp and Cleave Connectors

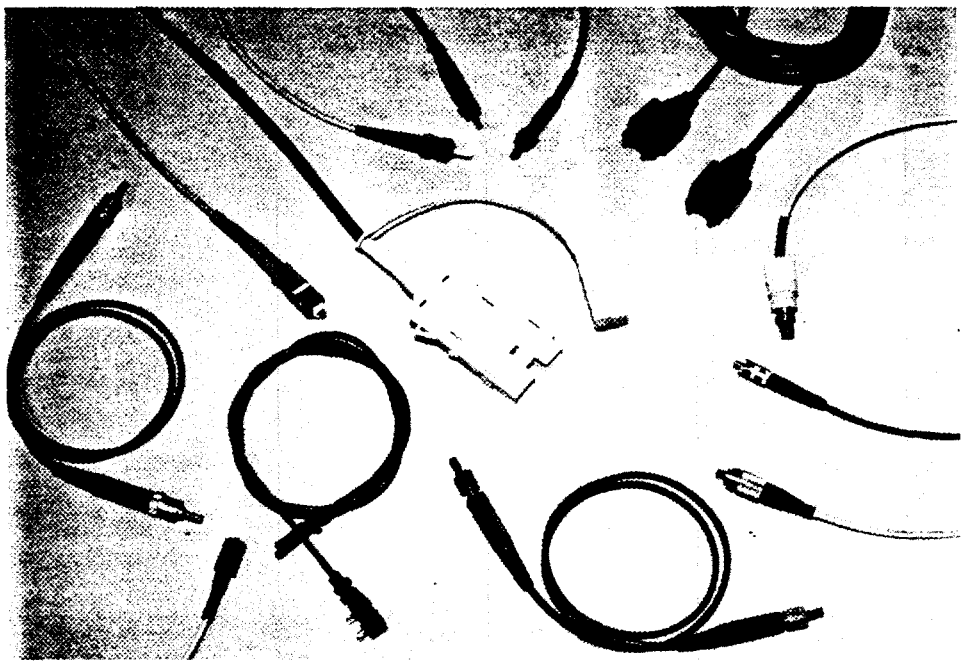
| | |
|---|---|
| SMA 905 Commercial | Compatible with all systems using SMA 905 device mounts or splice bushings. |
| SMA 905 Military | Designed to meet the MIL-C-83522B specification |
| ST® | Compatible with all systems using ST® device mounts or splice bushings |
| Japanese Industrial Style | Designed for industrial process control data communication networks such as Toslink® and Sumilink® systems |
| Z-Pin | Designed for low cost data links utilizing Versatile Link devices and Plenum rated ZKC (Zero Kevlar Cable) |

We have the engineering capabilities to design crimp and cleave connectors for your particular applications. Contact our Inside Technical Sales staff (203/687-0371) with your specifications.

HCS and Avioptics are registered trademarks of Ensign-Bickford Optics Company
Kevlar is a registered trademarks of Dupont
ST is a registered trademark of AT&T
Sumilink is a registered trademark of Sumitomo
Toslink is a registered trademark of Toshiba

# Fiberoptic Cable Assemblies

Ensign-Bickford Optics Company offers you the best value in fiberoptic cable assemblies because of the breadth of our manufacturing resources. We have control of all relevant fiberoptic technologies in our own facilities : these include the manufacture of optical glass preforms, optical fiber, cable and connectors. This fully integrated capability allows us to produce 100% tested fiberoptic cable assemblies at attractive prices with very short delivery leadtimes. Contact us regarding both our standard, off-the-shelf product offering, as well as for products adapted to meet your special needs.



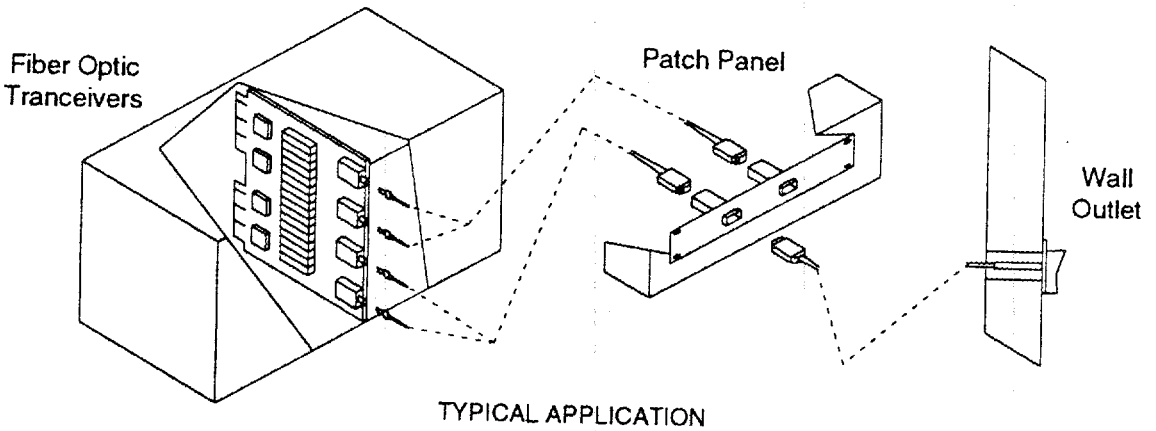
Ensign-Bickford
Optics Company

150 Fisher Drive, P. O. Box 1260, Avon, Connecticut USA
Tel: 203-678-0371; Fax: 203-674-8818

# APPLICATIONS and CAPABILITIES

| APPLICATIONS | CAPABILITIES |
| --- | --- |
| **Interconnects for:**<br>• **Telecommunication panels**<br>• **Local area networks**<br>• **Industrial process control**<br>• **Office buildings** | • **All popular connector types**<br>• **Step-index fibers**<br>• **Graded-index fibers**<br>• **Singlemode fibers**<br>• **Hybrid assemblies**<br>• **Pigtail assemblies**<br>• **Multifiber breakout assemblies**<br>• **Custom assemblies** |

Ensign-Bickford Optics Company provides standard and special fiberoptic cable assemblies for a wide variety of applications. Assemblies are available with telecommunications grade singlemode, multimode graded-index and HCS® (Hard Clad Silica) fibers to meet your most demanding application needs. All standard connector types are available for jumper, pigtail and hybrid assemblies. Special custom connector types are available upon request.



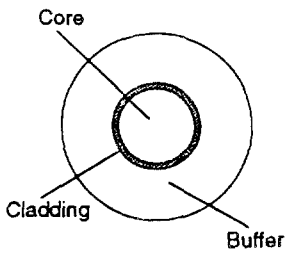

TYPICAL APPLICATION

Ensign-Bickford
Optics Company

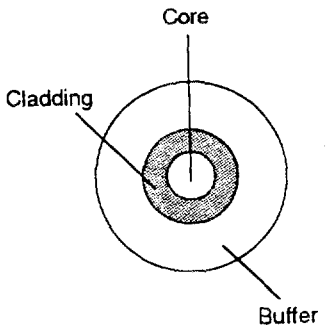
HCS is a registered trademark of Ensign-Bickford Optics Company

# FIBER SPECIFICATIONS

| Multimode Step-Index HCS® | HCP M0110T | HCP M0125T | HCP M0200T | HCP M0400T |
|---|---|---|---|---|
| Core Ø (μm) | 110±5 | 125±5 | 200±5 | 400±10 |
| Cladding Ø (μm) | 125+1/-5 | 140+2/-5 | 230+0/-10 | 430+5/-10 |
| Buffer Ø (μm) | 250-0/+50 | 250-0/+50 | 500±50 | 730±50 |
| Max. Core-to-Clad Offset (μm) | 5 | 5 | 5 | 9 |
| Attenuation @ 820 nm (dB/km) | 12 | 12 | 6 | 8 |
| Nominal Bandwidth @ 820 nm (MHz-km) | 17 | 17 | 17 | 13 |
| Proof Test (kpsi) (100% tensile proof tested) | 100 | 100 | 100 | 50 |

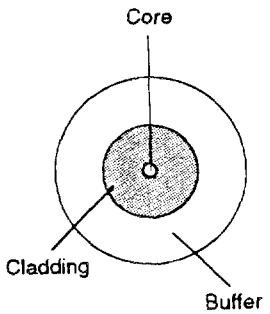



| Multimode Graded-Index | GI 50/125 | GI 62.5/125 | GI 62.5/125 FDDI | GI 100/140 |
|---|---|---|---|---|
| Core Diameter (*microns*) | 50 ± 3.0 | 62.5 ± 3.0 | 62.5 ± 3.0 | 100 ± 4.0 |
| Clad Diameter (*microns*) | 125 ± 3.0 | 125 ± 3.0 | 125 ± 3.0 | 140 ± 6.0 |
| Buffer Diameter | 500± 25 | 500 ± 25 | 500 ± 25 | 500 ± 25 |
| Max. Attenuation 850 nm/1300 nm | 4.0/2.0 | 5.0/3.0 | 4.0/2.0 | 5.0/4.0 |
| Typical Attenuation 850 nm/1300 nm | 3.5/1.0 | 4.0/2.0 | 3.5/1.0 | 4.5/3.5 |
| Min. Bandwidth 850 nm/1300 nm | 400/400 | 100/300 | 160/500 | 100/100 |
| Numerical Aperture | .200 ± .015 | .275 ± .015 | .275 ± .015 | .290 ± .015 |
| Proof Test (kpsi) | 100 | 100 | 100 | 100 |




## Singlemode Telecommunications Grade

| | |
|---|---|
| Mode Field Diameter | 9.5 μm ± 8% |
| Cladding Diameter | 125.0 μm ± 2 μm |
| Core/Cladding Concentricity Error | 1 μm max. |
| Cladding Noncircularity | less than 2% |
| Coating Diameter - Standard | 250 ± 15 μm |
| Coating Diameter - Optional | 500 ± 20 μm |
| Coating Concentricity | 70% min. |
| Cuttoff Wavelength | 1260 ± 70 nm |
| Attenuation @ 1310 nm | <0.40 dB/km |
| @ 1550 nm | <0.30 dB/km |
| Proof Test, Entire Length | 50 kpsi (0.35 GN/m²) |



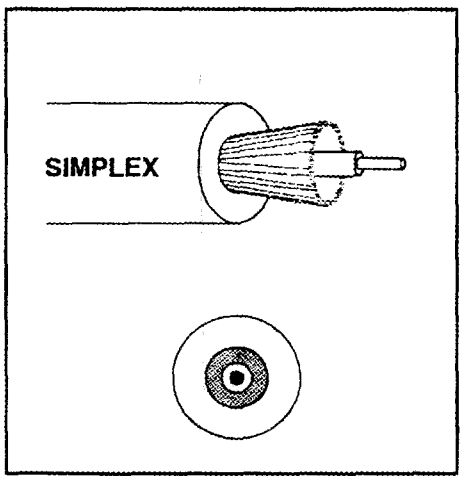

Ensign-Bickford Optics Company

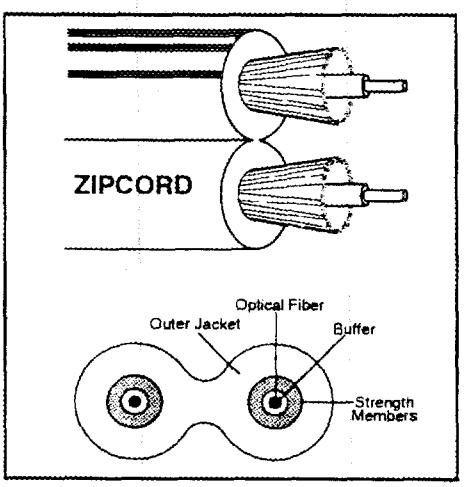
# CABLE SPECIFICATIONS

Ensign-Bickford Optics Company's fiberoptic assemblies are available in a variety of cable series, depending on the type of fiber utilized and the application environment. Assemblies requiring HCS® optical fibers incorporate A, C and J Series cables. Graded-index fiberoptic assemblies utilize E Series type cables. C and E Series cables are used in singlemode fiberoptic assemblies.

The A, E and J Series cables have PVC jackets to provide superior flame resistance characteristics for such applications as riser and plenum installations. When superior crush, impact, abrasion, cut-through or low temperature flexibility performance is required, polyurethane (PU) jacketed C Series cables offer the best choice.

| | A Series Simplex | A Series Zipcord | C Series Simplex | E Series Simplex | E Series Zipcord | J Series Simplex | J Series Zipcord |
|---|---|---|---|---|---|---|---|
| Cable Diameter (mm) | 2.5 | 2.5 x 5.4 | 3.0 | 3.0 | 3.0 x 6.3 | 2.2 | 2.2 x 5.4 |
| Cable Weight (kg/km) | 6.5 | 11.0 | 8.0 | 9.0 | 18.0 | 4.0 | 8.0 |
| Jacket Type | PVC | PVC | Polyurethane | PVC | PVC | PVC | PVC |
| Standard Jacket Color | Orange | Orange | Orange | Orange | Orange | Orange | Orange |
| Max. Pull Tension | 75 lb. (330N) | 110 lb. (490N) | 75 lb. (330N) | 75 lb. (330N) | 150 lb. (660N) | 30 lb. (130N) | 60 lb. (270N) |
| Max. Long-term Tension | 45 lb. (200N) | 70 lb. (310N) | 25 lb. (110N) | 25 lb. (110N) | 50 lb. (220N) | 10 lb. (45N) | 20 lb. (90N) |
| Break Strength | 200 lb. (890N) | 300 lb. (1,340N) | 200 lb. (890N) | 200 lb. (890N) | 400 lb. (1,780N) | 100 lb. (445N) | 200 lb. (890N) |
| Impact Strength @ 1.6 N-m | 100 | 100 | 1,000 | 500 | 500 | 20 | 20 |
| Cyclic Flexing (cycles) | >5,000 | >5,000 | >10,000 | >5,000 | >5,000 | >5,000 | >5,000 |
| Operating Temperature C | -40° to +85° | -40° to +85° | -20° to +85° | -20° to +85° | -20° to +85° | -40° to +85° | -40° to +85° |
| Storage Temperature C | -40° to +85° | -40° to +85° | -40° to +85° | -40° to +85° | -40° to +85° | -40° to +85° | -40° to +85° |




Ensign-Bickford Optics Company

# CONNECTOR SPECIFICATIONS

**A**

**SMA 906**

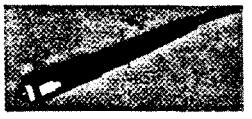
| | |
|---|---|
| Multimode loss: | <1.0 dB* |

**B**

**BICONIC**

| | |
|---|---|
| Multimode loss: | <0.6 dB* |
| Singlemode loss: | <0.6 dB* |
| Singlemode return loss: | >30 dB* |

**C**



**SC/PC**

| | |
|---|---|
| Multimode loss: | <0.6 dB* |
| Singlemode loss: | <0.3 dB* |
| Singlemode return loss: | >38 dB* |

**D**

**NEC-D4**

| | |
|---|---|
| Multimode loss: | <0.6 dB* |
| Singlemode loss: | <0.3 dB* |
| Singlemode return loss: | >40 dB* |

**E**

**SMA 905**

| | |
|---|---|
| Multimode loss: | <1.0 dB* |

**F**

**FC/PC**

| | |
|---|---|
| Multimode loss: | <0.6 dB* |
| Singlemode loss: | <0.3 dB* |
| Singlemode return loss: | >35 dB* |

Connector ferrules are availabe in stainless steel, ceramic and plastic materials. Other connector types can be supplied upon request.

**I**

**C & C SMA 905**

| | |
|---|---|
| Multimode loss: | <1.1 dB* |

**S**

**C & C ST®**

| | |
|---|---|
| Multimode loss: | <1.1 dB* |

**J**

**TOCP-201**

| | |
|---|---|
| Multimode loss: | <2.5 dB* |

**M**

**FDDI - MIC**

| | |
|---|---|
| Multimode loss: | <0.6 dB* |

**N**

**Mini BNC**

| | |
|---|---|
| Multimode loss: | <1.0 dB* |

**T**

**ST®/PC**

| | |
|---|---|
| Multimode loss: | <0.6 dB* |
| Singlemode loss: | <0.3 dB* |
| Singlemode return loss: | >40 dB* |

**V**

**Versatile Link**

| | |
|---|---|
| Multimode loss: | <2.5 dB* |

**X** Letter designation used in specifying connector type for assembly part number.

* Typical



Ensign-Bickford Optics Company

## STANDARD ASSEMBLIES

| CORE/ CLADDING | CONNECTOR TYPE | CABLE TYPE | CABLE DIAMETER | JACKET MATERIAL | PART NUMBER |
|---|---|---|---|---|---|
| **FIBER TYPE: MULTIMODE, STEP-INDEX HCS®** | | | | | |
| 200/230 µm | C&C SMA | Simplex | 2.5 mm | PVC | HCP-0200.0-A01VS-II |
| 200/230 µm | C&C SMA | Zipcord | 2.5 mm | PVC | HCP-0200.0-A02VZ-II |
| 200/230 µm | C&C SMA | Simplex | 3.0 mm | PU | HCP-0200.0-C01US-II |
| 200/230 µm | C&C ST | Simplex | 2.5 mm | Riser | HCP-0200.0-A02RS-SS |
| 200/230 µm | C&C ST | Zipcord | 2.5 mm | Riser | HCP-0200.0-A02RZ-SS |
| 200/230 µm | TOCP 201 | Zipcord | 2.2 mm | PVC | HCP-0200.0-J02VZ-JJ |
| 400/430 µm | Versatile Link | Simplex | 2.2 mm | Plenum | HCP-0400.0-J01PX-VV |
| **FIBER TYPE: MULTIMODE, GRADED-INDEX** | | | | | |
| 50/125 µm | SMA 906 | Simplex | 3.0 mm | Riser | GI3-0050.0-E01RS-AA |
| 50/125 µm | SMA 906 | Zipcord | 3.0 mm | Riser | GI3-0050.0-E02RZ-AA |
| 50/125 µm | ST/PC | Simplex | 3.0 mm | Riser | GI3-0050.0-E01RS-TT |
| 50/125 µm | ST/PC | Zipcord | 3.0 mm | Riser | GI3-0050.0-E02RZ-TT |
| 50/125 µm | SC/PC | Simplex | 3.0 mm | Riser | GI3-0050.0-E01RS-CC |
| 50/125 µm | SC/PC | Zipcord | 3.0 mm | Riser | GI3-0050.0-E02RZ-CC |
| 50/125 µm | BICONIC | Simplex | 3.0 mm | Riser | GI3-0050.0-E01RS-BB |
| 62.5/125 µm | SMA 906 | Simplex | 3.0 mm | Riser | GI5-0062.5-E01RS-AA |
| 62.5/125 µm | SMA 906 | Zipcord | 3.0 mm | Riser | GI5-0062.5-E02RZ-AA |
| 62.5/125 µm | ST/PC | Simplex | 3.0 mm | Riser | GI5-0062.5-E01RS-TT |
| 62.5/125 µm | ST/PC | Zipcord | 3.0 mm | Riser | GI5-0062.5-E02RZ-TT |
| 62.5/125 µm | SC/PC | Simplex | 3.0 mm | Riser | GI5-0062.5-E01RS-CC |
| 62.5/125 µm | SC/PC | Zipcord | 3.0 mm | Riser | GI5-0062.5-E02RZ-CC |
| 62.5/125 µm | BICONIC | Simplex | 3.0 mm | Riser | GI5-0062.5-E01RS-BB |
| 62.5/125 µm | ST/PC to FDDI | Zipcord | 3.0 mm | Riser | GI5-0062.5-E02RZ-TM |
| 62.5/125 µm | FDDI | Zipcord | 3.0 mm | Riser | GI5-0062.5-E02RZ-MM |
| 100/140 µm | SMA 905 | Simplex | 3.0 mm | Riser | GI1-0100.0-E01RS-EE |
| 100/140 µm | SMA 905 | Zipcord | 3.0 mm | Riser | GI1-0100.0-E02RZ-EE |
| 100/140 µm | ST/PC | Simplex | 3.0 mm | Riser | GI1-0100.0-E01RS-TT |
| 100/140 µm | ST/PC | Zipcord | 3.0 mm | Riser | GI1-0100.0-E02RZ-TT |
| 100/140 µm | BICONIC | Zipcord | 3.0 mm | Riser | GI1-0100.0-E02RZ-BB |
| 100/140 µm | ST/PC to BICONIC | Zipcord | 3.0 mm | Riser | GI1-0100.0-E02RZ-TB |
| 100/140 µm | Mini BNC to BICONIC | Zipcord | 3.0 mm | Riser | GI1-0100.0-E02RZ-NB |
| **FIBER TYPE: SINGLEMODE, TELECOMMUNICATIONS** | | | | | |
| 9.5/125 µm | ST/PC | Simplex | 3.0 mm | Riser | SMT-0009.5-E01RS-TT |
| 9/5/125 µm | ST/PC | Simplex | 3.0 mm | PU | SMT-0009.5-C01US-TT |
| 9.5/125 µm | SC/PC | Simplex | 3.0 mm | Riser | SMT-0009.5-E01RS-CC |
| 9/5/125 µm | SC/PC | Simplex | 3.0 mm | PU | SMT-0009.5-C01US-CC |
| 9.5/125 µm | BICONIC | Simplex | 3.0 mm | Riser | SMT-0009.5-E01RS-BB |
| 9/5/125 µm | BICONIC | Simplex | 3.0 mm | PU | SMT-0009.5-C01US-BB |
| 9.5/125 µm | FC/PC | Simplex | 3.0 mm | Riser | SMT-0009.5-E01RS-FF |
| 9/5/125 µm | FC/PC | Simplex | 3.0 mm | PU | SMT-0009.5-C01US-FF |
| 9.5/125 µm | FC/PC to SC/PC | Simplex | 3.0 mm | Riser | SMT-0009.5-E01RS-CF |
| 9/5/125 µm | NEC-D4 | Simplex | 3.0 mm | Riser | SMT-0009.5-E01RS-DD |
| 9/5/125 µm | NEC-D4 | Simplex | 3.0 mm | PU | SMT-0009.5-C01US-DD |

# PART NUMBERING

It's easy to determine the correct part number for your cable assembly requirements. Simply specify the correct fiber type; choose the cable construction and connectors; and specify assembly length.

**ASSEMBLY PART NUMBER** XXX - XXXXX.X - X XX X X - XX - XXX

**Fiber Type**

HCP = Multimode, Step-Index HCS®
GI1 = Multimode, Graded-Index (100 Mhz-km)
GI3 = Multimode, Graded-Index (300 Mhz-km)
GI5 = Multimode, Graded-Index (500 Mhz-km)
SMT = Singlemode, Telecommunications

**Fiber Core Size (µm)**

| STEP-INDEX | | GRADED-INDEX | SINGLEMODE |
|---|---|---|---|
| 0110.0 | 0400.0 | 0050.0 | 0006.5 |
| 0125.0 | 0600.0 | 0062.5 | 0009.5 |
| 0200.0 | 1000.0 | 0100.0 | |
| 0300.0 | | | |

**Cable Sub-Channels**

A = 2.5 mm diameter
J = 2.2 mm diameter
C = 3.0 mm diameter
E = 3.0 mm diameter

**Number of Sub-Channels**

01 to 48

**Final Jacket Material**

C = C.S.A.
E = Polyethylene
F = Tefzel®
M = MSHA
P = OFNP Plenum
R = OFNR Riser
U = Polyurethane
V = Polyvinylchloride (PVC)
Z = Zero Halogen

**Cable Construction**

S = Simplex
Z = Zipcord
D = Duplex
B = Breakout
X = No Kevlar®

**Connector Type (each end)**

A = SMA 906
B = BICONIC
C = SC/PC
D = NEC D4
E = SMA 905
F = FC/PC
G = C&C SMA Military
I = C&C SMA 905
J = TOCP 201
K = Bare Fiber, cleaved
M = FDDI - MIC
N = Mini BNC
S = C&C ST®
T = ST®/PC
V = Versatile Link
Z = Bare Fiber, cut

**Assembly Length**

Indicate required length (001 = 1 meter)

**Example:** GI5-0062.5-E02RZ-TM-050 is a 50 meter, 3.0 mm Riser Zipcord Cable assembly, incorporating 500 Mhz-km bandwidth 62.5 µm fiber connectorized with ST®/PC to FDDI-MIC connectors.

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# GRADED-INDEX, MULTIMODE, FIBER OPTIC CABLES
# 2.5 mm TIGHT BUFFER

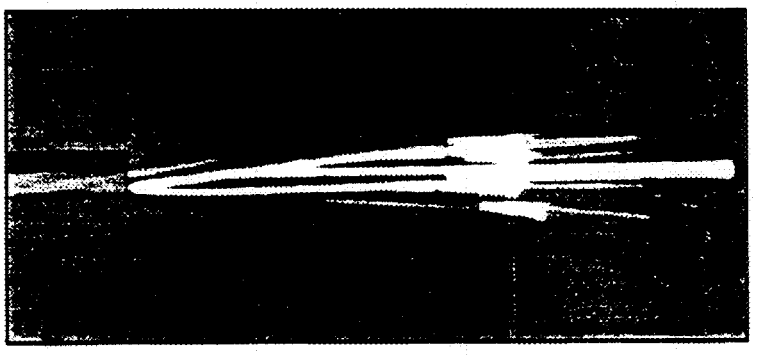
Ensign-Bickford Optics Company 2.5 mm Tight Buffer Cables consist of 900 µm buffered, graded-index, multimode optical fibers surrounded by Kevlar® strength members and a flame retardant PVC jacket. Available with communication grade fibers.

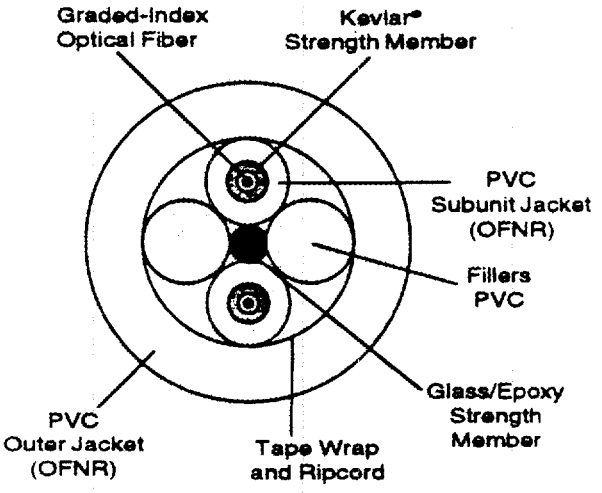
## *APPLICATIONS*

- Industrial Communications Links
- Pulls Through Conduit
- Environmental Protection
- Local Area Networks
- Signal Distribution
- FDDI Networks
- Patch Cord (simplex) Cables
- Duplex (zipcord) Cables
- Equipment Interconnection

## *FEATURES AND BENEFITS*

- Available in 50/125 µm, 62.5/125 µm and 100/140 µm fibers
- Up to 18 fibers per cable
- Flame resistant PVC subunit jackets, color coded for easy identification
- Riser (OFNR) rated
- Continuous lengths up to 2200 meters
- Rugged breakout construction for reliable installation and ease of connector installation
- Wide temperature range (-20° to +80°C)
- Available in heavy duty constructions

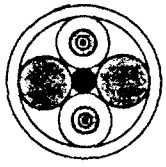
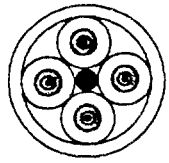
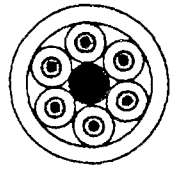





For more information call (203-678-0371), FAX (203-674-8818), or write (150 Fisher Drive, Avon, CT 06001) our Technical Sales Department.

* Subject to change without notice

# SPECIFICATIONS:
## Graded-Index, Multimode Fiber Optic Cables
## 2.5 mm Tight Buffer

| Cable Code | 2-CHANNEL  | 4-CHANNEL  | 6-CHANNEL  |
|---|---|---|---|
| Cable Diameter | 8.0 mm | 8.0 mm | 10.0 mm |
| Cable Weight | 47 kg/km | 47 kg/km | 64 kg/km |
| Jacket Type | PVC FR Riser | PVC FR Riser | PVC FR Riser |
| Standard Jacket Color | Orange | Orange | Orange |
| Maximum Pull Tension | 200 lbs. ( 890N) | 340 lbs. (1,510N) | 480 lbs. (2,130N) |
| Max. Long-term Tension | 60 lbs. ( 265N) | 100 lbs. ( 445N) | 160 lbs. ( 710N) |
| Break Strength | 530 lbs. (2,370N) | 900 lbs. (4,000N) | 2,500 lbs. (7,120N) |
| Impact Strength @ 1.6 N-m | 200 cycles | 200 cycles | 200 cycles |
| Cyclic Flexing | >2,000 cycles | >2,000 cycles | >2,000 cycles |
| Flammability Rating | UL 1666 Pass<br>UL OFNR Rating | UL 1666 Pass<br>UL OFNR Riser | UL 1666 Pass<br>UL OFNR Riser |
| Operating Temperature C | -20° to +80° C | -20° to +80° C | -20° to +80° C |
| Storage Temperature C | -40° to +80° C | -40° to +80° C | -40° to +80° C |

**SPECIFICATIONS:**

| Multimode Fiber | Max. Attenuation 850 nm/1300 nm | Typical Attenuation 850 nm/1300 nm | Min. Bandwidth 850 nm/1300 nm | Core Dia. (microns) | Clad Dia. (microns) | N.A. | Prooftest (kpsi) |
|---|---|---|---|---|---|---|---|
| 50/125 | 4.0/2.0 | 3.5/1.0 | 400/400 | 50 ± 3.0 | 125 ± 3.0 | .200 ± .015 | 100 |
| 62.5/125 | 5.0/3.0 | 4.0/2.0 | 100/300 | 62.5 ± 3.0 | 125 ± 3.0 | .275 ± .015 | 100 |
| 62.5/125 (FDDI) | 4.0/2.0 | 3.5/1.0 | 160/500 | 62.5 ± 3.0 | 125 ± 3.0 | .275 ± .015 | 100 |
| 100/140 | 5.0/4.0 | 4.5/3.5 | 100/100 | 100 ± 4.0 | 140 ± 6.0 | .290 ± .015 | 100 |

Coat Diameter: 500 µm ± 25
Buffer Diameter: 900 µm ± 100

### Part Numbering

**GI - 62.5 - A 0 1 R B - 500**

- **GI** - Graded Index
- **62.5** - Core Diameter in microns
- **A** - Cable Series Designation
- **02** - Number of Sub-channels
- **R** - Final Jacket Material
- **B** - Breakout Cable Construction
- **500** - Cabled Fiber Bandwidth @ 1300 nm

Kevlar is a registered trademark of Dupont

Ensign-Bickford Optics Company, 150 Fisher Drive, Avon, Connecticut 06001 USA TEL 203-678-0371; FAX 203-674-8818

Ensign-Bickford Optics Company

04/92

# GRADED-INDEX, MULTIMODE, FIBER OPTIC CABLES
# 3.0 mm TIGHT BUFFER

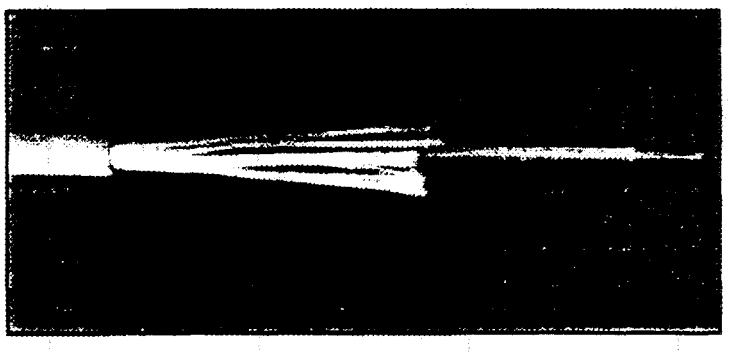
Ensign-Bickford Optics Company Simplex, Duplex and Zipcord Cables consist of 900 µm buffered, graded-index, multimode optical fibers surrounded by Kevlar® strength members and a flame retardant PVC jacket.

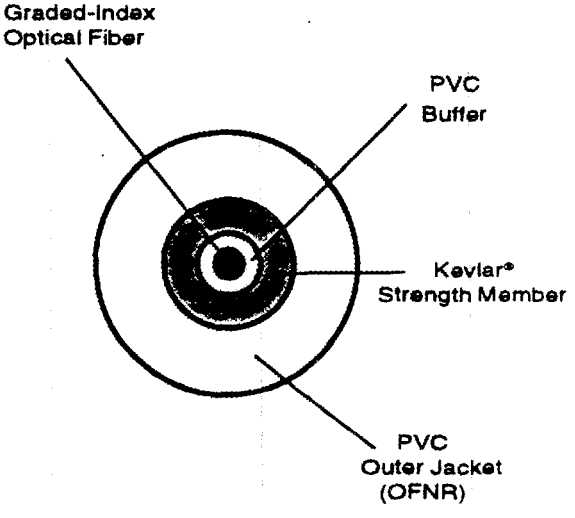
## *APPLICATIONS*

- Short Distance Intrabuilding Cabling
- Patch Panels and Distribution Boxes
- Interconnections
- Local Area Networks
- Plenum Installations
- Equipment Interconnection
- Chemical and Industrial Plants
- Factory or Laboratory Data Acquisition Systems
- FDDI Networks

## *FEATURES AND BENEFITS*

- Suitable for indoor or light-duty outdoor applications
- Available in 50/125 µm, 62.5/125 µm and 100/140 µm fibers
- PVC; flame retardant; low temperature flexibility; excellent impact and cut-through resistance; and, hydrolysis, oil and chemical resistance
- PVC jacket for easy stripping
- Continuous lengths up to 2200 meters
- Wide temperature range (-20° to +80°C)
- 900 µm buffered fiber
- FDDI grade fiber
- Multimode fibers for 850 nm and 1300 nm
- Riser (OFNR) rated






For more information call (203-678-0371), FAX (203-674-8818), or write (150 Fisher Drive, Avon, CT 06001) our Technical Sales Department.

* Subject to change without notice

# SPECIFICATIONS:
## Graded-Index, Multimode Fiber Optic Cables
## 3.0 mm Tight Buffer

| Cable Code | SIMPLEX | DUPLEX | ZIPCORD |
|---|---|---|---|
| Cable Diameter | 3.0 mm | 4.0 x 7.0 mm | 3.0 x 6.3 mm |
| Cable Weight | 8 kg/km | 32 kg/km | 16 kg/km |
| Jacket Type | PVC - FR | PVC - FR | PVC - FR |
| Standard Jacket Color | Orange | Orange | Orange |
| Max. Pull Tension | 330 N ( 75 lbs.) | 660 N (150 lbs.) | 660 N (150 lbs.) |
| Max. Long-term Tension | 110 N ( 25 lbs.) | 220 N ( 50 lbs.) | 220 N ( 50 lbs.) |
| Break Strength | 890 N (200 lbs. ) | 1,780 N (400 lbs.) | 1,780 N (400 lbs.) |
| Crush Resistance | 400 N/cm (340 lbs/in) | 800 N/cm (455 lbs/in) | 400 N/cm (340 lbs/in) |
| Impact Strength @ 1.6 N-m | 100 cycles | 100 cycles | 100 cycles |
| Cyclic Flexing | > 1,000 cycles | > 1,000 cycles | > 1,000 cycles |
| Flammability Rating | OFNR | OFNR | OFNR |
| Operating Temperature | -20° to +80°C | -20° to +80°C | -20° to +80°C |
| Storage Temperature | -40° to +80°C | -40° to +80°C | -40° to +80°C |

**SPECIFICATIONS:**

| Multimode Fiber | Max. Attenuation 850 nm/1300 nm | Typical Attenuation 850 nm/1300 nm | Min. Bandwidth 850 nm/1300 nm | Core Dia. (microns) | Clad Dia. (microns) | N.A. | Prooftest (kpsi) |
|---|---|---|---|---|---|---|---|
| 50/125 | 4.0/2.0 | 3.5/1.0 | 400/400 | 50 ± 3.0 | 125 ± 3.0 | .200 ± .015 | 100 |
| 62.5/125 | 5.0/3.0 | 4.0/2.0 | 100/300 | 62.5 ± 3.0 | 125 ± 3.0 | .275 ± .015 | 100 |
| 62.5/125 (FDDI) | 4.0/2.0 | 3.5/1.0 | 160/500 | 62.5 ± 3.0 | 125 ± 3.0 | .275 ± .015 | 100 |
| 100/140 | 5.0/4.0 | 4.5/3.5 | 100/100 | 100 ± 4.0 | 140 ± 6.0 | .290 ± .015 | 100 |

Coat Diameter: 500 µm ± 25
Buffer Diameter: 900 µm ± 100

### Part Numbering

**GI - 62.5 - E 0 1 R S - 500**

- **GI** - Graded Index
- **62.5** - Core Diameter in microns
- **E** - Cable Series Designation
- **01** - Number of Sub-channels
- **R** - Final Jacket Material
- **S** - Cable Construction
- **500** - Cabled Fiber Bandwidth @ 1300 nm

Kevlar is a registered trademark of Dupont

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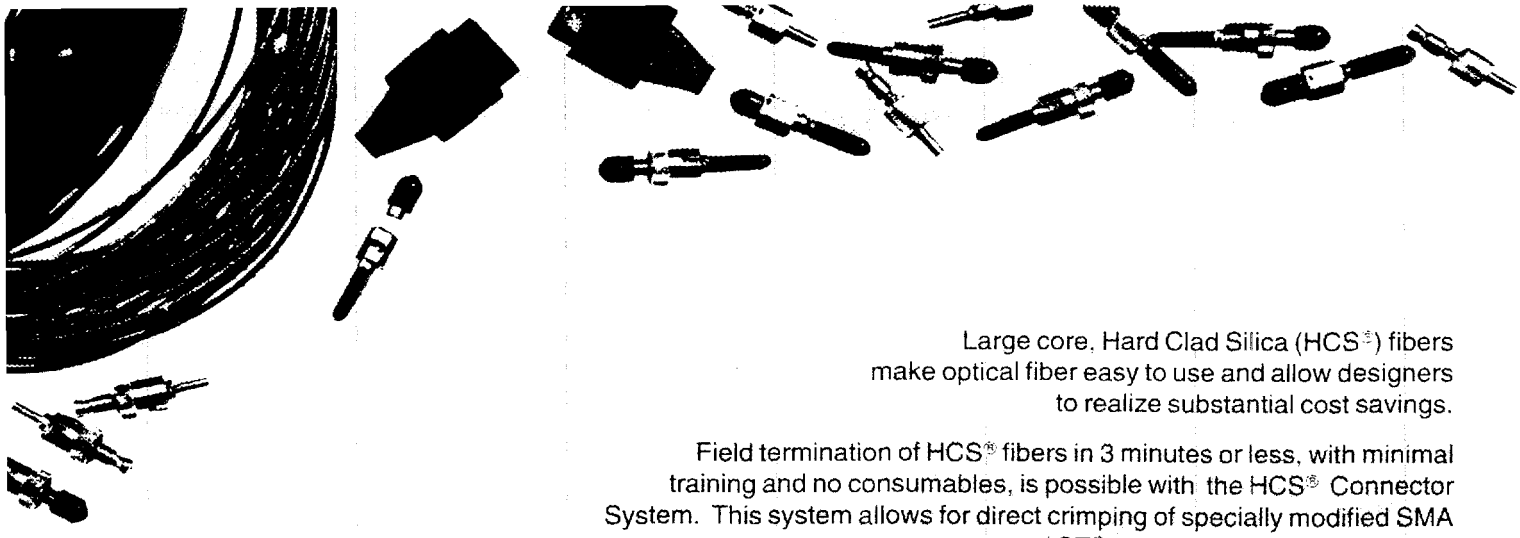
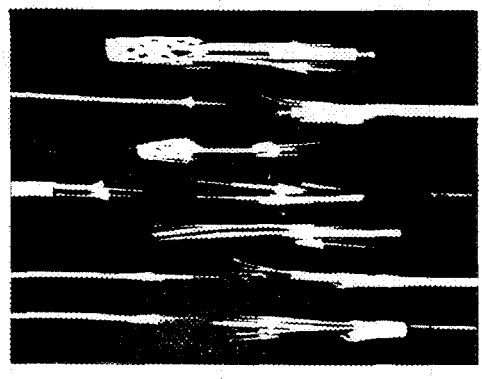


Large core, Hard Clad Silica (HCS®) fibers make optical fiber easy to use and allow designers to realize substantial cost savings.

Field termination of HCS® fibers in 3 minutes or less, with minimal training and no consumables, is possible with the HCS® Connector System. This system allows for direct crimping of specially modified SMA and ST® connectors onto the cladding.

Less expensive transmitters and receivers can be used because large core HCS® 200 µm fibers couple much more power from a typical LED than smaller core fibers.

The HCS® Connector System provides the large core fiber, cable and connector solution economically and reliably.



*A variety of HCS® Fiberoptic Cables*

# Features and Benefits

## Reliable, Easy Field Installation of Connectors.

Patented HCS® polymer technology permits direct crimping onto the cladding, utilizing the HCS® TK-6 Termination Kit and crimp and cleave SMA or ST® connectors.

## Enhanced Optical Budget.

HCS® fibers offer large 200 µm core and a high numerical aperture (NA) of .37 which allow greater coupling efficiency. *A typical surface emitting LED will couple approximately 10 times more power into HCS® 200 µm fiber than into 62.5 µm fiber (about 5 times more than 100 µm fiber).*

## Real Cost Savings.

The coupling efficiency of large core HCS® fibers allow for the use of less expensive transmitters and receivers. Field terminations are performed in 3 minutes or less, with minimal training and require no consumables.

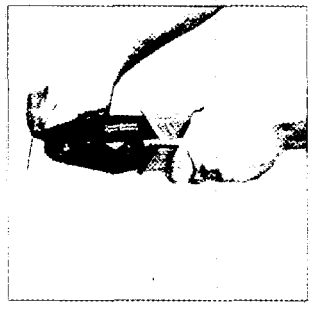
## Tight Bend Radius.

Proof testing 200 µm fiber to levels far exceeding industry standards (up to 600 kpsi) ensures the survivability of HCS® fibers in extreme conditions.

## Wide Selection of Cable Styles.

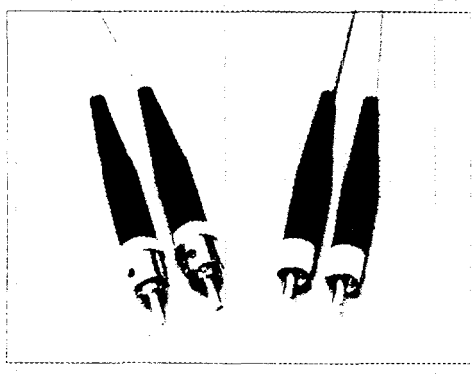
Fully dedicated cable department produces a variety of custom and standard cable designs. Assembly group provides design engineering and automated assembly capabilities.

*Ensign-Bickford Optics Company products covered by one or more of the following US patents: 4,511,209, 4,599,098, 4,707,076, 5,028,246, 5,108,021, 5,175,785.



*Crimping a SMA Connector directly onto HCS® fiber eliminating epoxy.*

*Using the Diamond Cleave Tool to cleave fiber, eliminating polish.*



*Finished assemblies, completed in 3 minutes or less, using the HCS® Connector System*

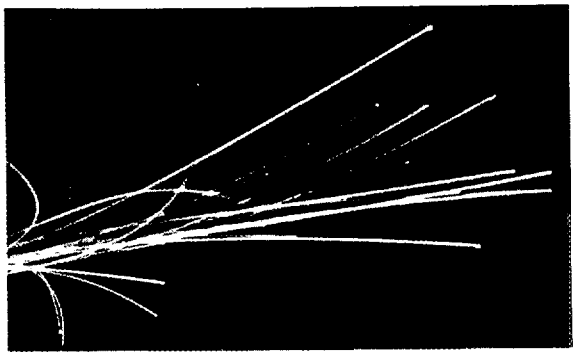
**Ensign-Bickford Optics Company** **The dynamic force in fiber.**

Ensign-Bickford Optics Company, 150 Fisher Drive, Box 1260, Avon, CT 06001-1260 USA
203/678-0371 Fax 203/674-8818

# Other Ensign-Bickford Optics Company Capabilities

## HCS® Fibers - HCN, HCP or HCR

- High tensile strength
- Static fatigue resistant
- High numerical aperture
- High core-to-clad ratio
- Core sizes from 110 µm to 1000 µm

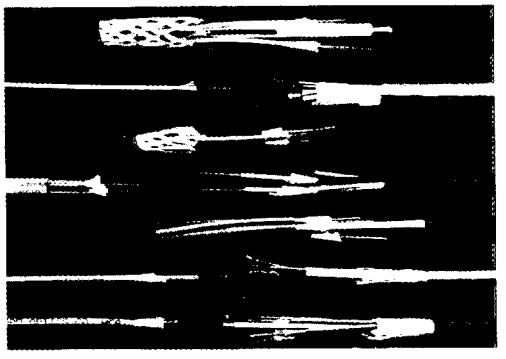


## Specialty Singlemode Fibers

- Selected cut-off
- Bend insensitive
- Custom coils & delay lines

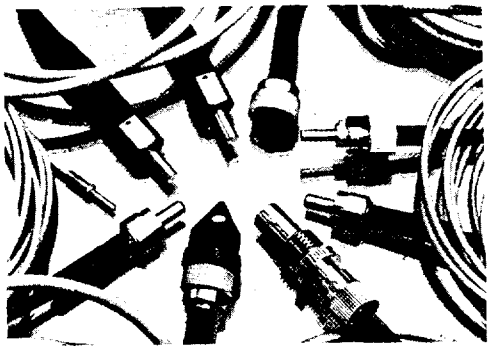
## Cables

- Fully dedicated cable department
- Variety of custom and standard cable designs in tight buffer constructions. Up to 48 channels available, incorporating:
  - HCS® fibers
  - Specialty Singlemode fibers
  - Graded-Index type fibers



## Assemblies

- Automated crimp and cleave assembly capabilities on HCS® fibers up to 1000 µm core size
- Customized crimp and cleave connectors
- Standard datacom graded-index (62.5/125, 50/125, 100/140) assemblies utilizing industry standard epoxy/polish connectors
- Custom designed disposable medical probes
- Finished assemblies ranging from pigtails and jumpers to complete tactical cable harnesses
- Passive linear optical TAP systems



## Bundles

- Special bundle designs for:
  - Remote fiberoptic sensing
  - Illumination
  - Radiation detection/particle counting
  - Inspection/scanning systems

## HCS® Termination Kits

- ZK-6 For field-installable, crimp & cleave Z-Pin connectors (compatible with Hewlett Packard Versatile Link devices) on ZKC (Zero Kevlar® Cable).
- JK-6 For field-installable, crimp & cleave Japanese Industrial Standard (JIS) connectors on HCS® J-Series Cable.

**Ensign-Bickford Optics Company**

All specifications and tolerances are subject to change. Manufactured in the U.S.A. by Ensign-Bickford Optics Company.
Kevlar and Tefzel are registered trademarks of DuPont. ST is a registered trademark of AT&T.
HCS is a registered trademark of Ensign-Bickford Optics Company.

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203/678-0371 Fax 203/674-8818

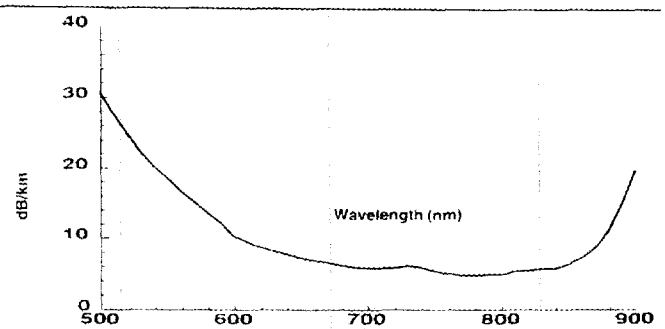
03/93

# HCS® Fiber

## HCP, Low Loss HCS

For medium haul (100 meter to 3 kilometers) data transmission

**Spectral Attenuation (typical)**




| | HCP M0200T |
|---|---|
| Core O (µm) | 200 ± 4 |
| Cladding (µm) | 230 +0/−10 |
| Buffer O (µm) | 500 ± 30 |
| Max Core-to-Clad Offset (µm) | 5 |
| Nominal Bandwidth (MHz-km) | 20 |
| Proof Test (kpsi) (100% tensile proof tested) | 150 |

## Performance Comparisons
(at 850 nm)

| | Multimode Fiber Core Size | | |
|---|---|---|---|
| | HCS® 200 µm (HCP) | 100 µm | 62.5 µm |
| Typical Attenuation (dB/km) | 6.0 | 5.0 | 4.0 |
| Bandwidth (Mhz-km) | 20 | 100 | 160 |
| Numerical Aperture | .37 | .29 | .275 |
| Connector Type (Epoxy Polish = E/P; HCS® crimp & cleave = C/C) | C/C | E/P | E/P |
| Field Installation time (incl. cable prep.) | 3 min | 30 min | 30 min |
| Typical Connector Loss (SMA 905) per mated pair (dB) | 1.1 | 1.5 | 1.5 |
| **Sample Power Budget Comparison** (assumes surface emitting LED transmitter) | | | |
| Coupled Power (dBm) | -6 | -13 | -16 |
| Less: | | | |
| Connector Loss - 2 mated pairs (dB) | 2 | 3 | 3 |
| Net (dBm) | -8 | -16 | -19 |
| Detector power required (dBm) | -24 | -24 | -24 |
| Available Power (dBm) | -16 | -8 | -5 |
| Fiber Attenuation (dB/km) | 6 | 5 | 4 |
| Distance Possible (km) | 2.7 | 1.6 | 1.25 |

**TYPICAL COUPLED POWER INTO HCS® 200 µm FIBER**

| Vendor/Device | Typical Coupled Power (µW) |
|---|---|
| **Honeywell** | |
| HFE4000-015 | 955 |
| HFE4003-024 | 631 |
| HFE4020-013 | 331 |
| HFE4023-013 | 331 |
| HFE4070-013 | 320 |
| **Hewlett Packard** | |
| HFBR-1604 | 12 |
| HFBR-14X4 | 794 |
| HFBR-14X2 | 355 |
| **ABB Hafo** | |
| IA192 | 1000 |
| IA191 | 1100 |
| IA208 & IA228 | 1300 |
| IA272 | 2000 |

This chart represents a limited selection of available devices. For complete device offerings and specifications, please contact manufacturers directly.

**HCP — M0200T — X XX X X — 06**

**Fiber Type**

P = Low Loss (HCP)

**Fiber Core Size and Construction**

200 Micron is standard fiber size for HCS® Connector System, other sizes are available.

**Cable Sub-Channels**

A = 2.5mm Ø PVC Tight Buffer sub-channels
B = 3.0mm Ø Polyurethane Loose Tube sub-channels

**Number of Sub-channels**

01, 02, 04, and 06 are standard. Up to 48 possible.

**Final Jacket Material**

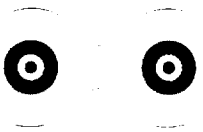
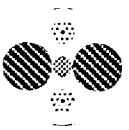
V = PVC
E = Polyethylene

**Cable Construction**

B = Breakout Z = Zipcord
S = Simplex D = Duplex

**Cabled Fiber Attenuation** (dB/km @ 820 nm)

# HCS® Cable

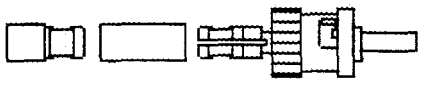
| | | |
|---|---|---|
| **HCS® 200 Simplex** | | ■ light duty indoor applications<br>■ cable trays<br>■ short conduits<br>■ loose tie wrapping<br>■ sub-channels for breakout cables |
| **HCS® 200 Zipcord** | | |
| **HCS® 200 Duplex** |  | |
| **HCS® 200 Breakout** |  | ■ *outdoor environments*<br>■ multifiber runs where each channel is *connectorized and routed separately*<br>■ aerial runs<br>■ long conduit pulls<br>■ 2, 4 and 6 channels standard |
| **HCS® 200 Heavy Duty Duplex** | | ■ rugged<br>■ *wide temperature range*<br>■ direct burial<br>■ loose tube sub-channel design<br>■ high tensile stress applications |

Some installations require special designs — very wide temperature ranges; very high tensile requirements due to long pulls or small bend radii; Flame Resistant Cables such as UL Riser, UL Plenum, MSHA, and CSA; and armored designs for crush resistance or rodent protection. We routinely design and manufacture cables for a wide variety of difficult environments. Please contact us for more details.

| | | Simplex | Zipcord | Duplex | 2-Channel | 4-Channel | 6-Channel | Heavy Duty Duplex |
|---|---|---|---|---|---|---|---|---|
| **Product Code:** | | | | | | | | |
| | HCP-M0200T | -A01VS | -A02VZ | -A02VD | -A02EB | -A04EB | -A06EB | -B02EB |
| **Diameter** | (mm) | 2.5 | 2.5 x 5.4 | 3.5 x 6.0 | 8.0 | 8.0 | 10.0 | 8.6 |
| | (inches) | .10 | .10 x 2.1 | .14 x .24 | .31 | .31 | .39 | .34 |
| **Weight** | (kg/km) | 6.5 | 11.0 | 20 | 45.0 | 45.0 | 61.0 | 55.0 |
| **Installation:** | | | | | | | | |
| **Max. Tension** | | | | | | | | |
| | (Newtons) | 335 | 490 | 670 | 890 | 1510 | 2490 | 1645 |
| | (Pounds) | 75 | 110 | 150 | 200 | 340 | 560 | 370 |
| **Min. Bend Radius:** | | | | | | | | |
| | (mm) | 38 | 38 | 25 | 50 | 50 | 50 | 50 |
| | (inches) | 1.5 | 1.5 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| ***Operating:*** | | | | | | | | |
| **Max. Tension** | | | | | | | | |
| | (Newtons) | 200 | 310 | 400 | 535 | 870 | 1425 | 935 |
| | (Pounds) | 45 | 70 | 90 | 120 | 195 | 320 | 210 |
| **Min. Bend Radius:** | | | | | | | | |
| | (mm) | 10 | 10 | 38 | 38 | 50 | 50 | 50 |
| | (inches) | .40 | .40 | 1.5 | 1.5 | 2.0 | 2.0 | 2.0 |
| **Maximum Shipping Lengths** | (meters) | 2200 | 2200 | 2200 | 2200 | 1600 | 1600 | 1300 |
| **Temperature Range** | | | | | | | | |
| **Storage** | | -40°C to +85° C | | | | | | |
| ***Operating*** | | -20°C to +85°C | | | -40°C to +85°C | | | |

**Flex Life** <0.04 dB increase, 2000 cycles
**Twist Life** <0.03 dB increase, 1000 cycles

# HCS® Crimp and Cleave Connectors

| | | |
|---|---|---|
| **HCS® SMA Commercial 905** | | ■ Field installable in 3 minutes or less<br>■ Cost-effective, substantially less than installed epoxy/polish<br>■ High tensile strength — HCS® fiber permits crimping directly onto the hard cladding<br>■ Static fatigue resistant<br>■ Easy to assemble — no epoxy or other consumables required<br>■ Reduced labor cost — no grinding or polishing<br>■ Automated factory assembly also available |
| **HCS® CCST®** |  | |

One of the biggest drawbacks of fiber in industrial applications is cable termination. HCS® Crimp and Cleave Connectors and TK-6 Termination Kit have eliminated this problem. The HCS® Connector System is easy to use; requires no consumables, glue, water or polishing techniques; can be performed even in close quarters; and over a wide range of environmental conditions.

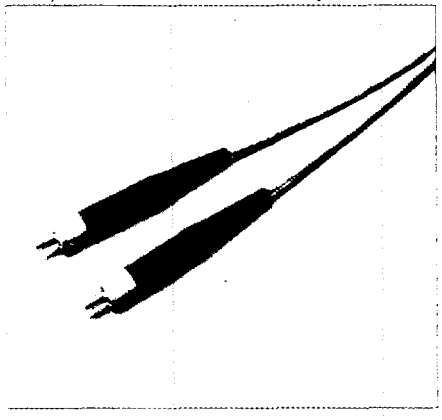
Both SMA and ST® connectors have been modified for 200 µm HCS® fiber cables and crimp and cleave assembly. Nearly all U.S. manufactured interfaces, modules and systems can be accommodated using either of these two crimp and cleave connectors. Ensign-Bickford Optics Company also offers crimp and cleave cable systems compatible with Japanese Industrial Standards (JIS) and Hewlett Packard Versatile Link devices. Contact us for more details.

## HCS® Crimp and Cleave Connector Specifications

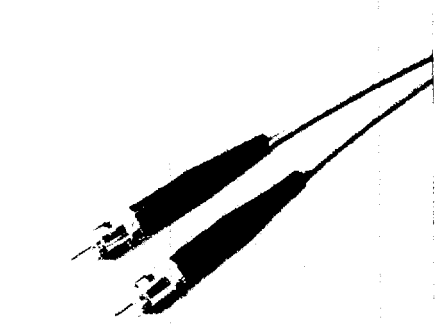
| | CC-SMA-230-X.X† | CC-ST-230-X.X† |
|---|---|---|
| **Optical Performance** | | |
| Insertion Loss (Specification) | 2.0 dB | 2.0 dB |
| Insertion Loss (Typical) | 1.1 dB | 1.1 dB |
| **Mechanical Performance** | | |
| Mating Durability | < 0.03 dB increase, 250 cycles* | |
| Cable Crimp Retention | > 50 lbs | |
| **Environmental Performance** | | |
| TEMPERATURE RANGE | | |
| Operational | -40° C to +85° C* | |
| Thermal Cycling | <0.5 dB increase, -40° C to +85° C | |
| **Dimensions (nominal)** | | |
| Overall | 2.50" (63.5 mm) | 2.75" (69.9 mm) |
| Ferrule Length | 0.3860" (9.8 mm) | 0.3105" (7.9 mm) |
| Ferrule Ø | 0.1248" (3.2 mm) | 0.0984" (2.5 mm) |
| Through Hole | 231 µm | |

† Cable anchor diameter
* Tests performed using HCN-M0200T-A01VS-12

*Crimp and Cleave SMA Assembly*



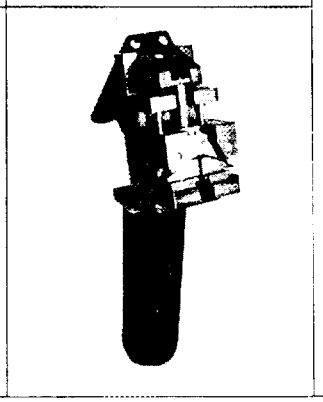
*Crimp and Cleave ST® Assembly*



# HCS® Termination Kit

**TK-6**
**Termination Kit**

**CT-2**
**Diamond Cleave Tool**



- Quick, easy crimp and cleave terminations in 3 minutes or less
- Field installable SMA and ST® connectors with minimal training
- TK-6 Termination Kit contains:
  - Cable stripper
  - Fiber stripper
  - Crimp tool
  - Kevlar® scissors
  - CT-2 Diamond Cleave Tool
  - Set of tension springs
  - SMA and ST® adaptor plates
  - Instruction booklet
- CT-2 Diamond Cleave Tool produces high quality, consistent cleaves on HCS® fibers ranging in core size from 110 μm to 600 μm
- CT-2 Diamond Cleave Tool scribes the fiber to produce a smooth, even endface, without polishing

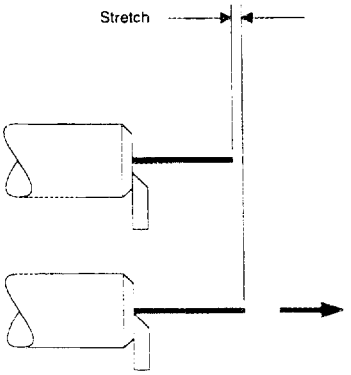
## The Crimp and Cleave Process

The crimp and cleave process was developed with two goals – to make fiber optic terminations easier and to eliminate the human factor from the process. In the traditional epoxy/polish method of connectoring, operator experience is crucial in achieving perfect end finish.

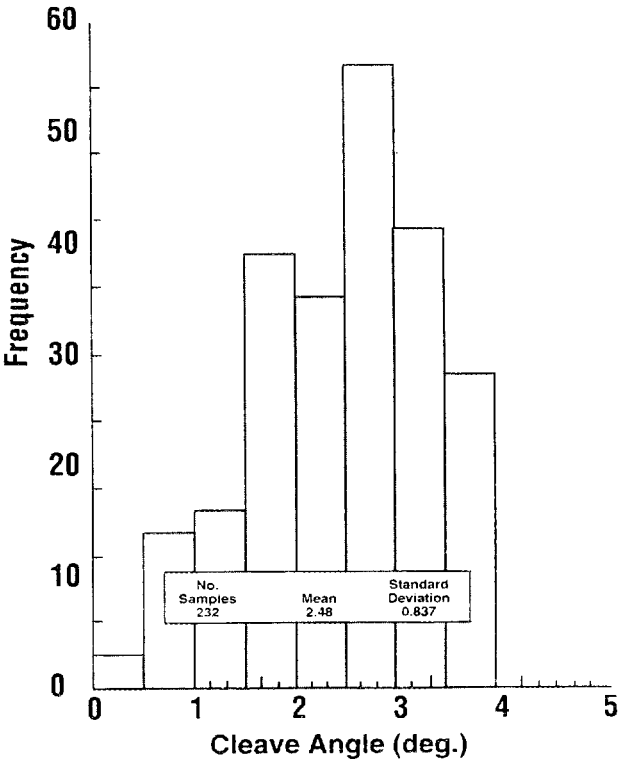
The crimp tool is utilized to secure the connector onto the fiber cladding thereby eliminating the need for epoxy.

The CT-2 Diamond Cleave Tool eliminates the guesswork of polishing. Preparation of the fiber end face is now mechanized. Actioning the trigger on the CT-2 performs three actions simultaneously – fiber clamps move in to hold the stripped fiber in place; a carefully calibrated spring places tension on the fiber; the diamond blade then scribes the fiber, thus initiating the cleave.

The cleave releases the spring tension causing the fiber to recess into the ferrule. Recessed ends prevent fiber endface damage and resultng power loss during connector matings.




*Cleaving Process*



# APPENDIX B
# LASER DIODES

**PRELIMINARY DATA REPORT**
**HIGH POWER LASER DIODE ON-LINE RADIATION TEST**

Table I presents a summary of the test results for the first three IR laser diodes (Mitsubishi) and the first two visible laser diodes (Toshiba) that were tested. The IR laser diodes (nominal wavelength of 785 nm) had a maximum power output of 60 mW, and the visible laser diodes (nominal wavelength of 690 nm) had a maximum power output of 35 mW. The laser diodes were irradiated while operating at maximum power. The change in photodiode current at the maximum power output recorded in the last column of Table I is between measurements made before and after irradiation in the Ohio State University Nuclear Reactor Laboratory's $Co_{60}$ Gamma Irradiator.

**Table I. Summary of Preliminary Results**

| Manufacturer | Serial Number | Total Tissue Equivalent Dose (Mrad) | Change in photodiode current at max power (%) |
|---|---|---|---|
| Mitsubishi | 549062 | Control | -0.50 |
| | 549064 | 0.62 | -0.25 |
| | 549073 | 1.20 | -0.26 |
| | 549074 | 1.20 | -0.25 |
| Toshiba | 0201 | Control | 0.00 |
| | 0202 | 1.00 | -0.19 |
| | 0203 | 0.99 | -0.18 |

Figures 1 and 2 on the following pages display the photodiode current before and after irradiation at all power levels for the Mitsubishi and Toshiba laser diodes, respectively. In addition, Figures 3 through 7 show the farfield beam images at the beginning and end of radiation, and at the beginning and end of the recovery period as recorded by a CCD camera. The radiation period was approximately two hours, and the recovery period approximately one hour. No noticeable changes in beam shape occurred during radiation and recovery. The observed changes in intensity are believed to be caused by the darkening of the collimating lens in the radiation environment. The double images present in some of the data are due to the neutral density filter between the laser beam and the CCD camera.

The preliminary data indicate that the high power laser diodes are not adversely affected by the radiation dose.

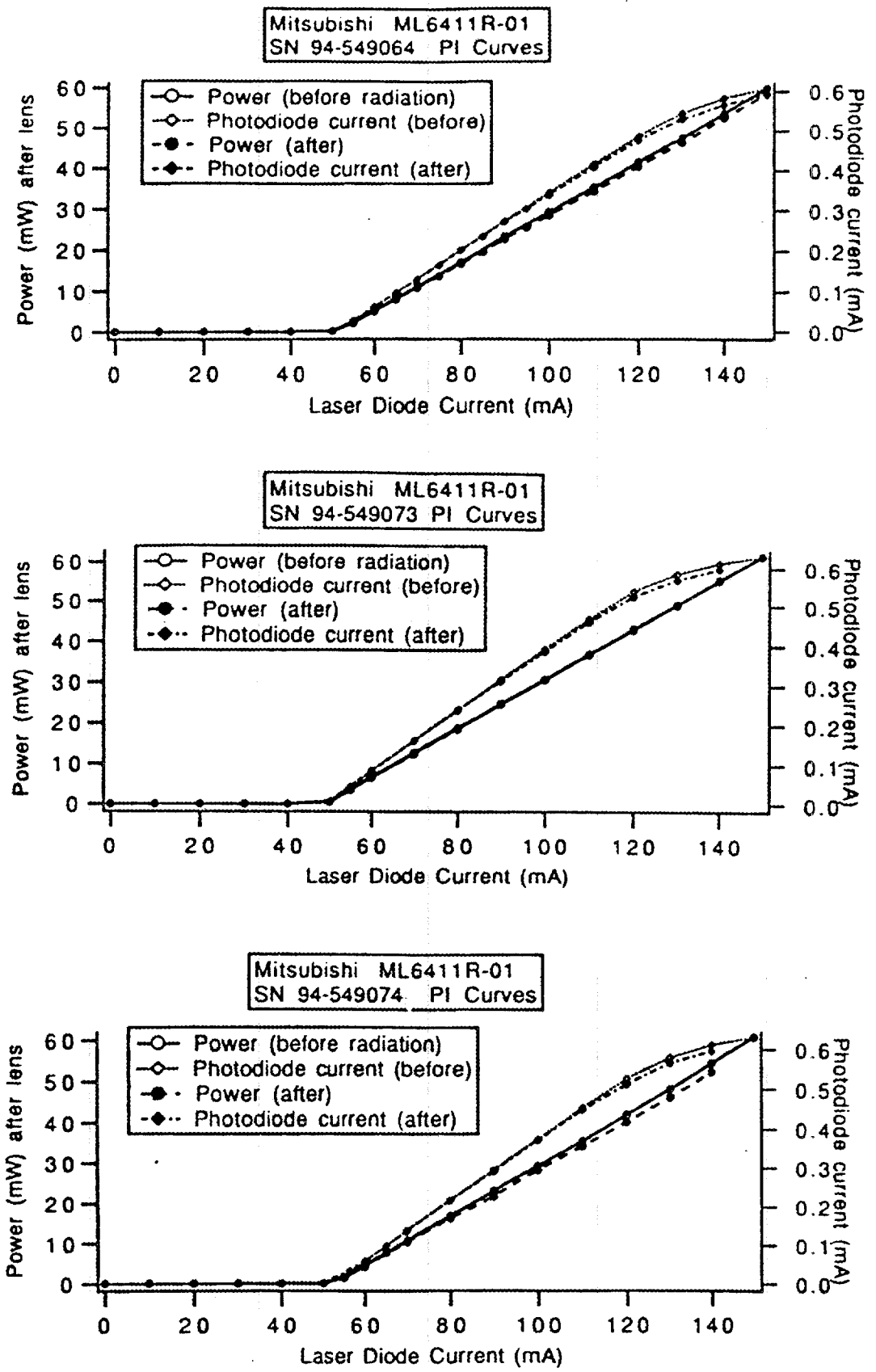
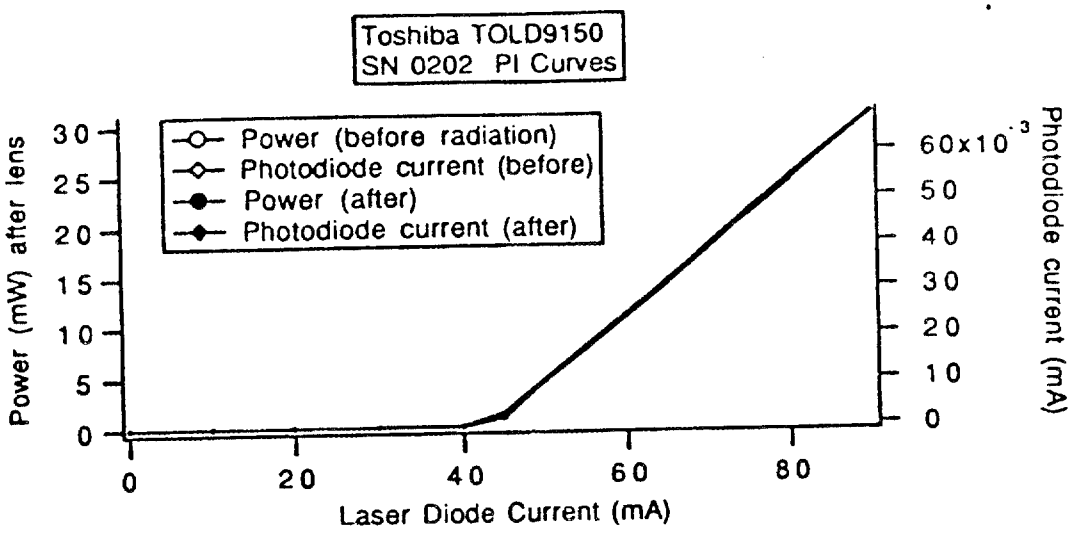



Figure 1. Effect of irradiation on optical power-current relationship for 785 nm laser diodes.



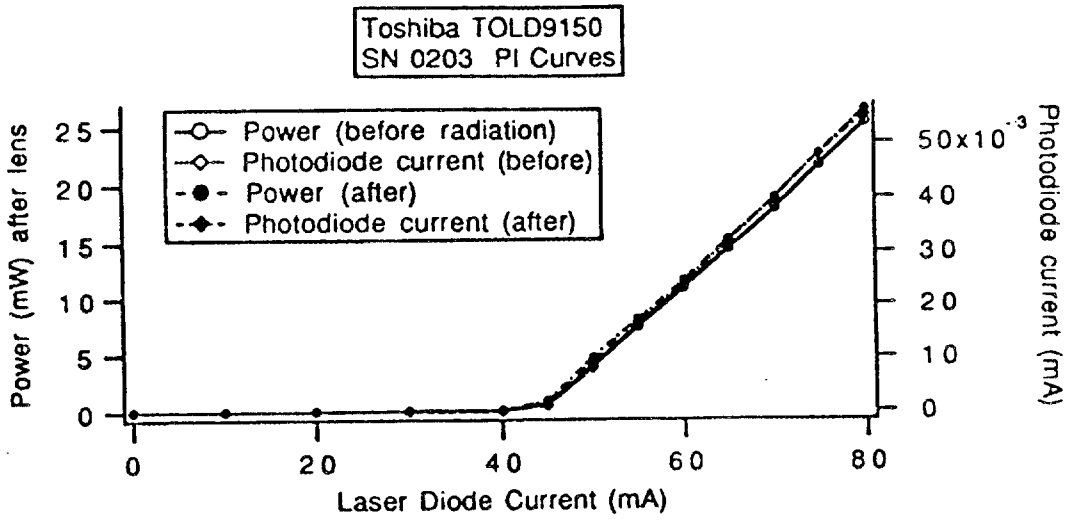




Figure 2. Effect of irradiation on optical power-current relationship for 690 nm laser diodes.

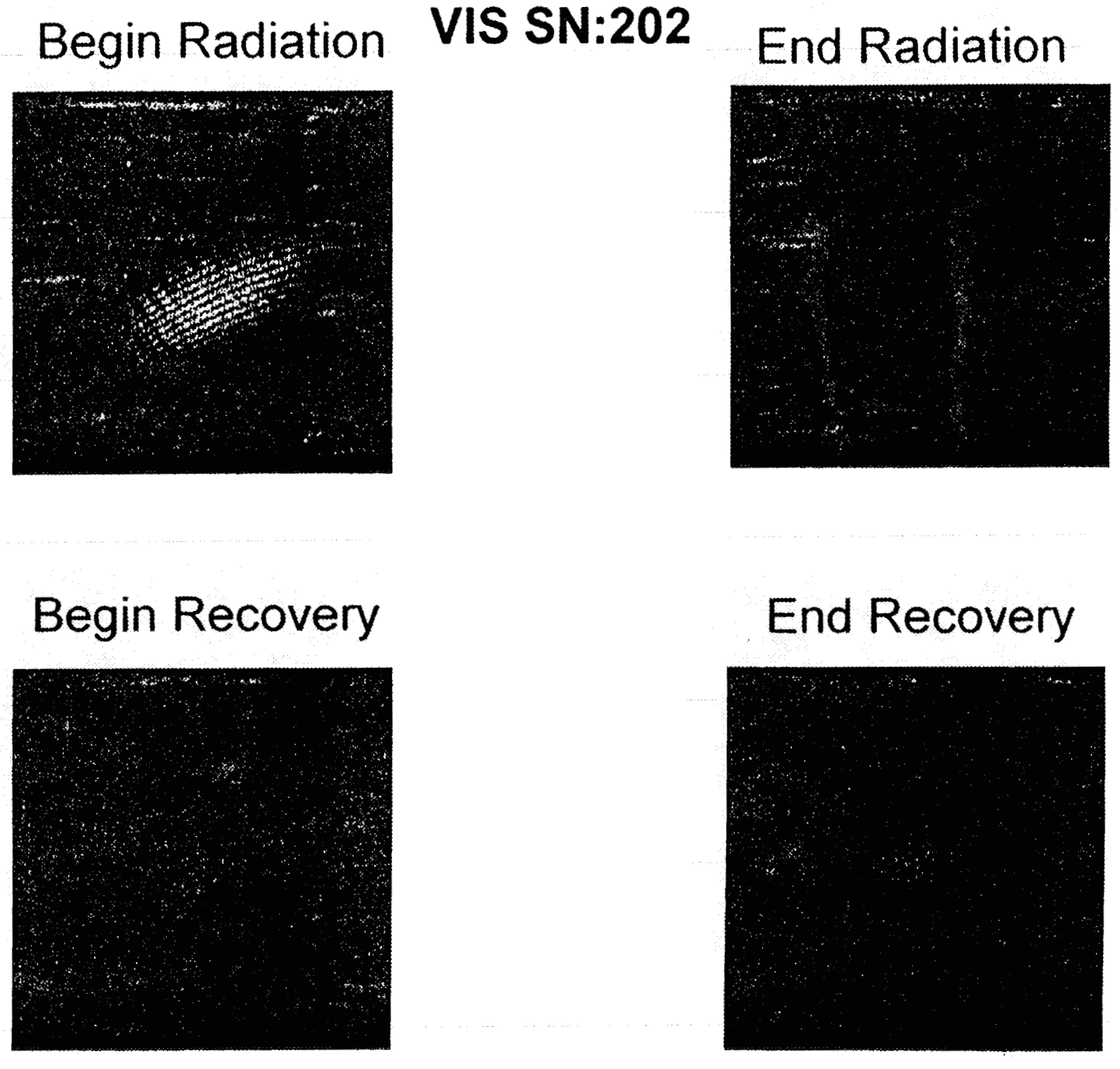



Figure 3. Change in beam image during irradiation and during recovery (690 nm).

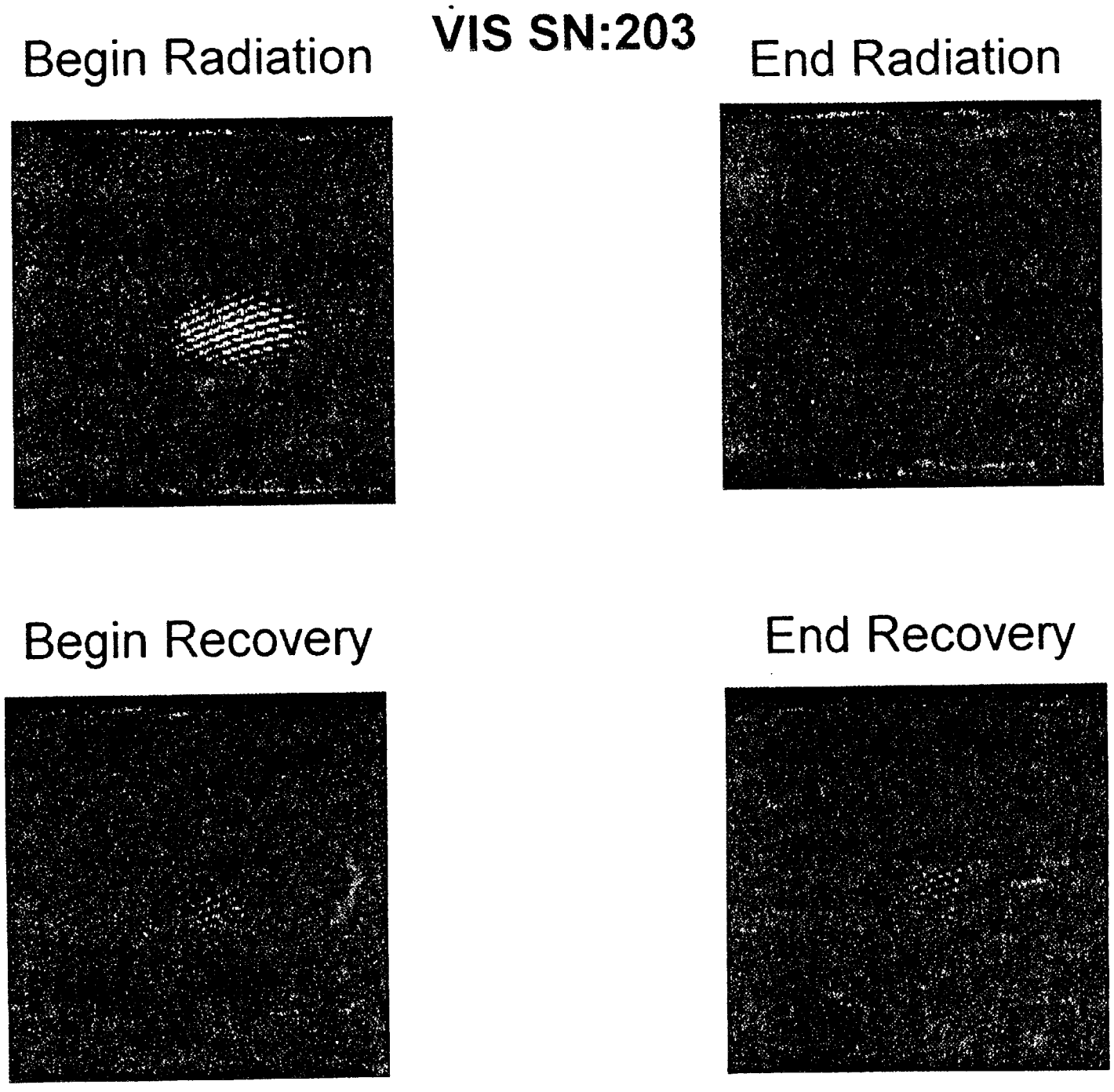



Figure 4. Change in beam image during irradiation and during recovery (690 nm).

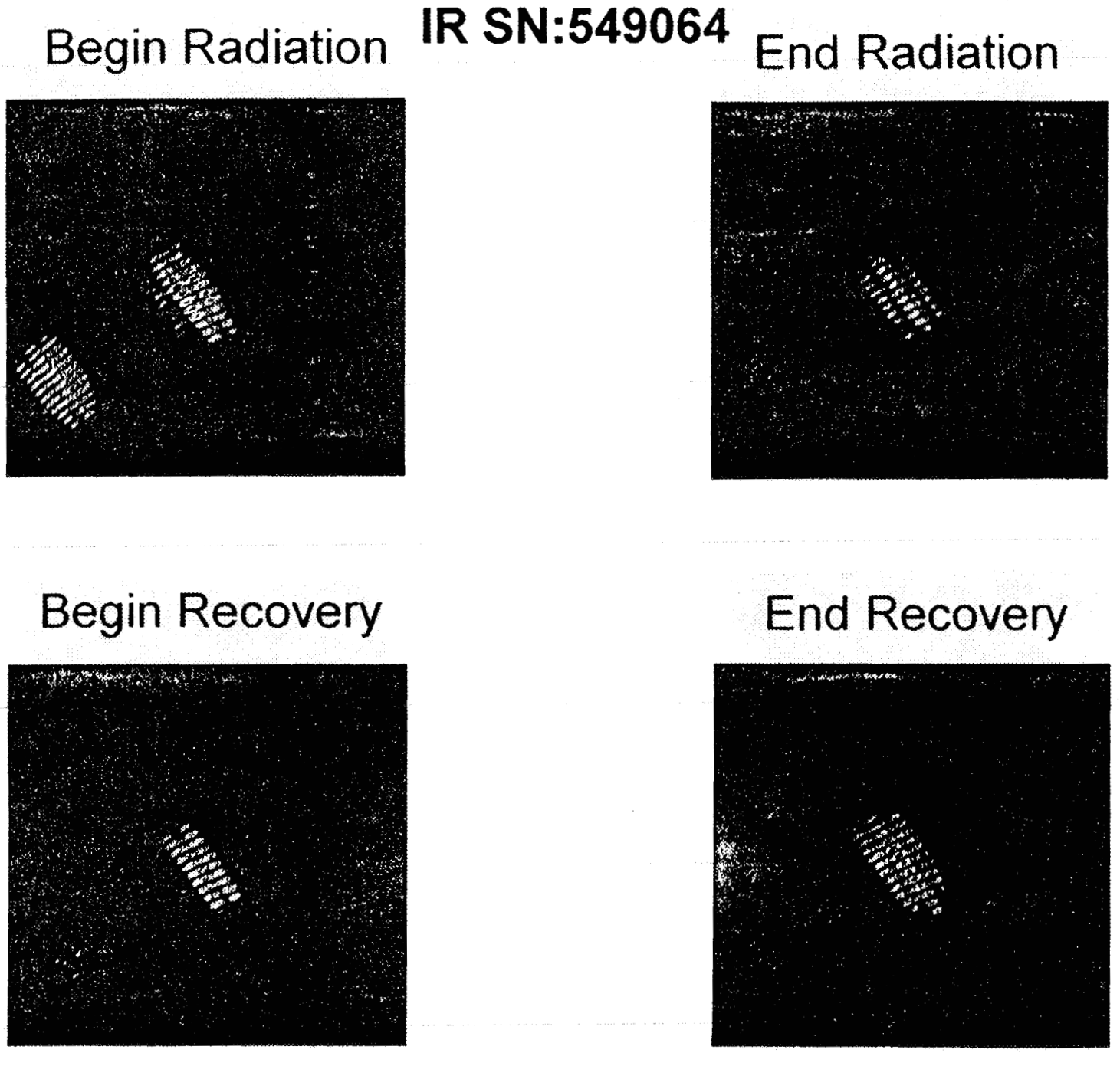



Figure 5. Change in beam image during irradiation and during recovery (785 nm).

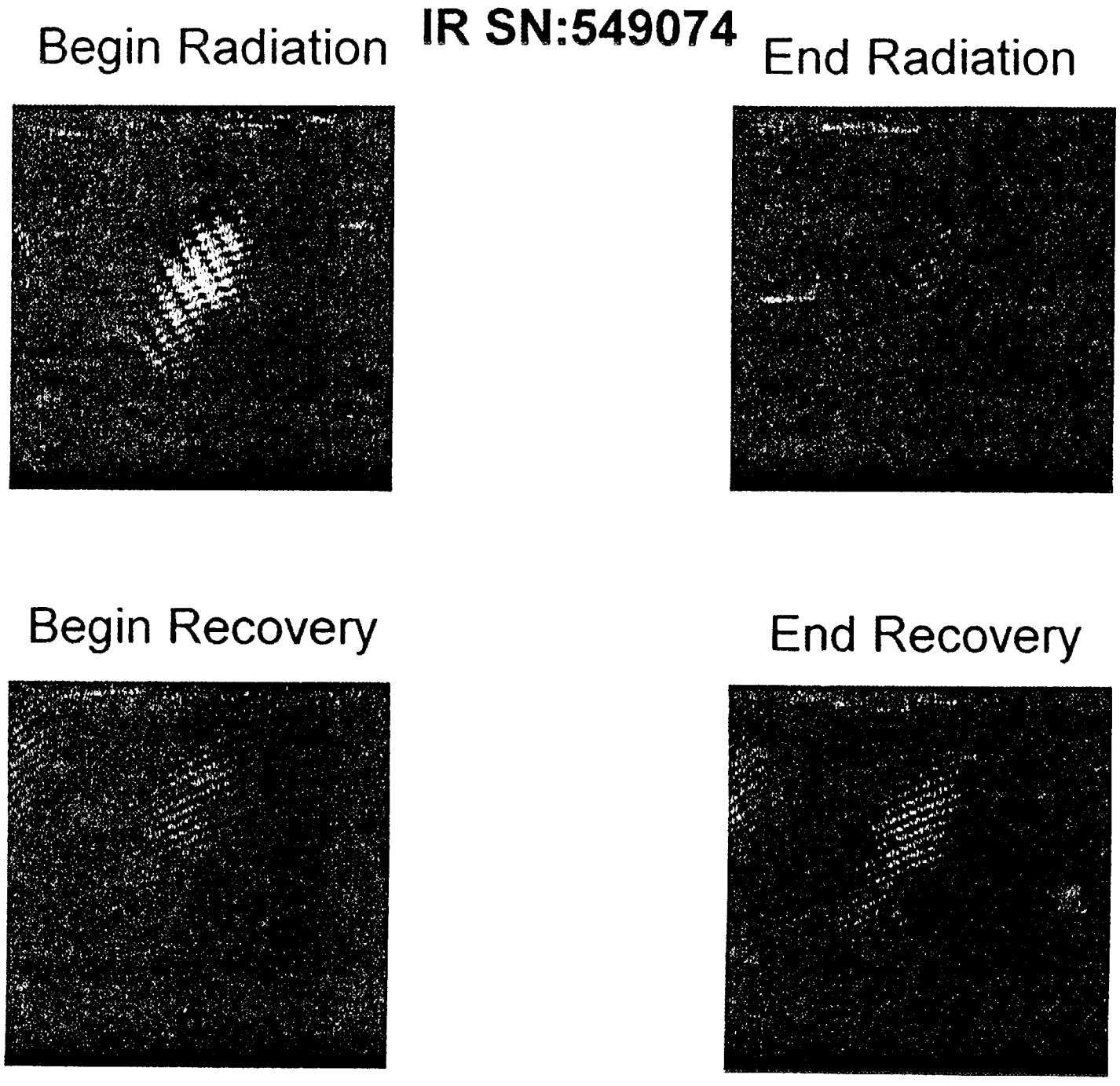



Figure 6. Change in beam image during irradiation and during recovery (785 nm).

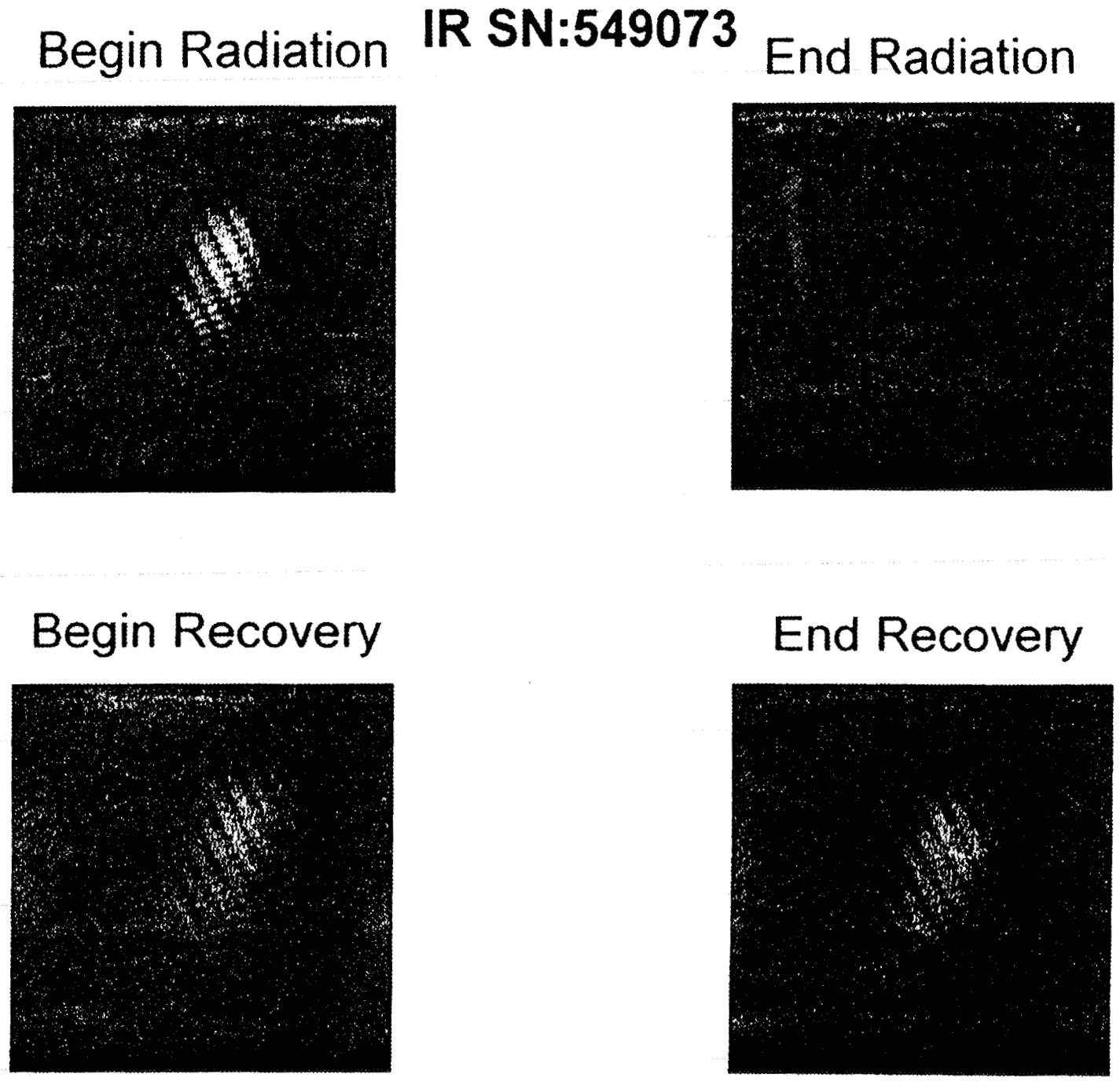



Figure 7. Change in beam image during irradiation and during recovery (785 nm).

# APPENDIX C
# CAMERAS

CIDTEC®

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Liverpool, New York 13088
(315) 451-9410 FAX (315) 451-9421

December 10, 1993

David Holcomb
Oakridge National Lab
Instrument and Controls Development
Oakridge, TN 37831-6010

Dear David:

Thanks for your recent inquiry. Enclosed please find technical information describing our complete line of solid-state cameras and the CID technology that makes them unique. Also included are specifications for the ICM7000 Easy Integrator, our powerful new interface control module offering "plug and play" coordination of vision system components for orchestrated system integration.

CIDTEC traces its roots to General Electric where the CID concept originated. The first CID camera was produced in 1972 and ongoing development since then has generated some 30 patents. With advances in electronic imaging calling for progressively higher levels of system accuracy and operational flexibility, CID technology has increasingly become the preferred alternative to Charge Coupled Devices (CCD's) for demanding imaging applications.

CID cameras provide:

- Anti-blooming even under severe light overloads for distortion-free images
- Contiguous pixel structures with high fill factors for complete, accurate dimensional data and precise edge detection
- Progressively scanned square pixel formats for variable scan mode pixel-lock digitizing
- UV response to 185 nm for extended imaging range, and near-IR response to 1100 nm without blooming, fringing, or loss of data resolution
- Asynchronous full-frame capture of high-speed or short-duration events
- Higher frame rates for faster capture and processing
- On-chip "area of interest" readout for faster data acquisition
- Extended integration for multiple-frame exposure enhancement of static low-light scenes

We back our products with comprehensive technical assistance, applications support, and product development programs. Talk with us about custom camera modifications, application-specific calibration procedures, new imager development, and process hardening to operate cameras in radiation environments.

If a review of the enclosed material suggests a fit for CID cameras in your application, give us a call. We'd be happy to discuss your imaging needs and demonstrate the difference CID technology can make for you.

Sincerely,

Tony Chapman
Technical Sales

Encls: Product Literature

# CID Cameras: An Overview

## Principle of Operation

Charge Injection Device (CID) structure, principle of operation, and readout techniques are fundamentally different from Charge-Coupled Devices (CCD's), providing useful performance advantages. Each pixel in the CID array is individually addressed during readout. Scanning routines are implemented via electronic switching of row and column electrodes which are fabricated in a thin, clear polysilicon matrix over the surface of the array. While CCD's transfer collected charge out of the pixels during readout (hence erasing the image stored on the sensor), CID's do not transfer charge from site to site in the array.

Instead, readout is accomplished by transferring or "shifting" the collected "charge packet" within an individually addressed pixel, and sensing displacement values across the electrodes at the site. Readout is *non-destructive* because charge remains intact in the pixel after the signal level has been determined. To empty the pixel for new frame integration, row and column electrodes are biased to "inject" the charge packet into the substrate collector.

## Suspending Readout: The Inject Inhibit Function

Nondestructive readout techniques enhance user control of light integration and image readout, useful for low-light, stop-motion and pulsed-capture applications. The Inject Inhibit (I/I) function suspends imager readout and injection without interrupting normal scanning or image integration. In other words, on-chip scanning and image acquisition proceed, but pixel signal levels are not read and erased.

I/I can be applied to initiate an extended integration mode for multiple-frame, time-lapse exposure enhancement of static low-light scenes. Or it can be used to suspend readout within a single frame time to capture asynchronous high-speed or short-duration events. Images can be captured and "stored" on the imager during a "readout suspended" frame scan, then read out when new frame scanning begins, ensuring full-frame readout of the captured image. Inject Inhibit can also be employed to manage "snapshot" readout from several cameras into a single frame grabber. Camera readout is suspended until each unit is released in sequence for image down-loading.

## Non-destructive Readout (NDRO)

In standard CID cameras, a single frame is read out after an extended period of integration, representing the accumulated image. Integration may proceed for milliseconds or up to hours with the addition of sensor cooling, applied to retard accumulation of thermally-generated Dark Current. Implementing Non-Destructive Readout (NDRO) modifications in CID

cameras provides a higher level of user control. Camera readout may continue at video rates, but charge injection is inhibited, so the developing image can be viewed on a TV monitor as integration proceeds. This real-time exposure control is especially useful for resolving faint details in low-light scientific applications, significantly expanding dynamic range.

## Anti-blooming Performance

At bright intensities, "blooming" describes the distortion in an image that can occur when solid-state video cameras are exposed to concentrated light intensities (Figure 1). Charge can spill from over-saturated elements to adjoining pixels, or the charge transfer mechanisms during readout, eradicating portions of the image. By contrast, CID imagers are more tolerant to intense light because optical overloads are confined to illuminated pixels. Charge is not exported from the pixel collectors, so the structure offers no paths along which overloads can propagate; and radial spreading of charge is minimized as the excess is drawn into the underlying charge collector.

This inherent anti-blooming performance ensures accurate image detail even under extreme lighting conditions, making CID cameras particularly effective for testing and measurement (especially laser analysis), missile tracking, semiconductor pattern recognition, and a wide variety of other applications where reflections and the appearance of specular light intensities give rise to over-saturated regions within a properly exposed image.

## Contiguous Pixel Structure, Wide Spectral Response, Radiation Tolerance

The contiguous pixel structure of CID arrays further contributes to accurate imaging, because there are virtually no opaque areas between pixels where image detail can be lost. This attribute is important for applications where precise dimensional data is critical; for instance the determination of object edges for inspection, measurement, positioning, and tracking. It is also essential for applications where complete data is crucial, as in particle analysis where illuminated particles may "disappear" if they "fall into a crack" (opaque region) on the sensor. Employing interpixel processing techniques to achieve sub-pixel resolution, CID cameras are currently utilized in precision gauging equipment performing measurements accurately to half a micron.

The uniform topological structure of the CID imager provides homogeneous pixel-to-pixel response to coherent illumination for more accurate reproduction of laser profiles, ideal for beam analysis and alignment. Camera output is impressively linear, and can be radiometrically calibrated to provide maximum linearity for a given application wavelength. CID imagers offer wide spectral response, from 185 to 1100 nanometers, extending imaging range into the UV and providing near-IR response without blooming, fringing, or loss of data resolution.

Furthermore, the PMOS semiconductor structure of CID imagers reduces radiation effects on imager operation, making CID's less vulnerable to disruption in radiation environments

than NMOS devices (structure used in many CCD's). Further hardening can be achieved through special processing.

## Camera Scanning Formats

Since each pixel in the CID array is addressed individually, flexible readout and processing options are possible. It is important to note, though, that standard CID imagers utilize sequential addressing circuitry, so standard camera models always scan from top to bottom, left to right (as viewed on a monitor). However, some advanced development CID cameras offer selective image data acquisition utilizing innovative scanning techniques. For maximum flexibility, Random Access CID's (RACID's, currently under development) incorporate address decoders instead of sequential shift registers to provide programmable access to individual pixels in any sequence for readout and special charge manipulation routines. RACID imager functions are computer-directed, providing state-of-the-art acquisition management and control.

Several standard CID camera models feature "Progressive Scan" readout, also referred to as "Sequential Scan" readout, to speed processing by eliminating the delay introduced by 2:1 interlace scanning. Interlaced cameras read out every other row of pixels, meaning there are always gaps in the output. In general, odd and even fields must both be acquired before vision systems can proceed with image processing. Progressive scan cameras, by contrast, read rows of pixels one after another (lines 1, 2, 3, 4, etc.) so the data stream from camera to frame grabber is sequential and comprehensive.

Some CID camera models feature progressive scan, 60 frame per second output for high-speed operation that is nonetheless compatible with RS-170 frame grabbers, TV monitors, and VCR's. Escaping the limitations imposed by RS-170 (TV broadcast) standards, high resolution progressive scan CID cameras provide variable scan mode interfacing, described below, for maximum accuracy, speed and control.

## Frame Grabber Interfacing Options

Sequential scan, square pixel format CID cameras simplify computational algorithms and increase processing speed. Interfaced with variable input frame grabbers in the Variable Scan mode (VSC), they provide optimal digitizing stability and repeatability in applications calling for accurate pixel-to-pixel measurements In VSC mode, the frame grabber (slave) digitizes video based on timing from the camera (master) pixel clock, blanking interval (composite blanking or H drive), and V drive signal. The camera's element rate clock (ERC) is used to synchronously clock A/D readings into discreet memory locations on a one-to-one basis, creating a pixel-lock between camera and frame grabber memory. Pixels are represented in frame memory with a 1:1 aspect ratio; i.e. pixel (x,y) = memory (x,y). There is no spatial distortion of pixel values stored in memory.

By contrast, 2:1 interlace systems interface in Phase Lock Loop (PLL) or Crystal Control modes. In PLL mode, the frame grabber (slave) digitizes video from the camera (master) using an internal clock locked to the camera's H-drive signal. The frame grabber's digitizing clock is likely to be different from the camera's pixel clock. The frame grabber is not pixel-locked. Board sampling rate and memory format determine spatial distortion of pixel values stored in memory.

In the Crystal Control mode, the frame grabber (master) supplies standard RS-170 sync pulses (either composite sync or discreet H & V sync signals) to the camera (slave). Pixels are digitized based on the frame grabber's internal clock. Again, the frame grabber is not pixel-locked. Board sampling rate and memory format determine spatial distortion of pixel values stored in memory.

Unless the camera and frame grabber clock rates are the same, and the pixel array format matches the memory format, over- or under-sampling will occur. Under-sampling takes place when pixel information from the camera is sampled by the frame grabber at a rate lower than the pixel data is clocked out. Example: 755 pixels sampled 640 times results in 640 memory locations filled with data. Each memory location represents 1.18 pixel. Over-sampling takes place when pixel information from the camera is sampled by the frame grabber at a rate higher than the pixel data is clocked out. Example: 512 pixels sampled 640 times results in 640 memory locations filled with data. Each memory location represents 0.8 pixel.

Even when camera and frame grabber formats and clocks match, digitization in the phase lock loop and crystal control modes is subject to pixel jitter (pixel "registration" errors) due to timing inaccuracies between system components that occur during the 63.5 microsecond interval between horizontal sync pulses. The variable scan mode interface eliminates pixel jitter by locking the system to the camera's pixel clock, bringing superior time resolution to the pixel digitizing process.

## Scanning Reset: the Frame Reset Function

In applications where full frame resolution is not required but faster capture is, "Frame Reset" is used to decrease vertical frame size for higher frame rates. Applying Frame Reset sends scanning back to the top of the array at the completion of the latest row scan. By counting H drive pulses, the user may reset the camera after scanning a predetermined number of rows. With fewer lines to read, "shorter" frames can be read out faster. Of course, faster frame rates mean shorter integration times, so stronger illumination may be required.

## Electronic Windowing: the Rapid Scan Function

For applications where only specific regions in the field of view require attention at any given time, the "Rapid Scan" function is used to isolate areas of interest, establishing "windows" for readout at normal rates while scanning at a very high rate between windows. The selective

data extraction speeds imager readout and reduces system data volume, facilitating high-speed processing.

This capability is especially powerful for target acquisition where objects must be tracked at rates up to several hundred images per second as they move within the field of view. Windowing can also be used for on-line inspection. For example, specific sections of a pharmaceutical bottle can be read out for high-speed processing to check cap placement or verify expiration date and lot code.

It is important to note that the rapid scan function can only be implemented with a few commercially available frame grabbers. Windowing uses two horizontal clocks, and most systems can only follow one H clock. Consult with CIDTEC to discuss system options and application considerations.

## Asynchronous Clear: the Dump Function

The "Dump" function is used to "empty" all pixels in the imager (via charge injection) just prior to image capture. Since accumulated charge remains in the unscanned rows after a frame reset, the dump function is used to clear the array before new frame capture, removing any shading variations brought about by differences in pixel integration times.

## Asynchronous Image Capture

The stop motion or "freeze frame" capability of CID cameras enables them to accurately capture and read *asynchronous* high-speed or short-duration events. An example of this is shown in Figure 2 using a CID camera to capture a fast-moving bottle. CID operation allows image capture to proceed independent of camera timing, so the user times the camera to the event instead of timing the event to the camera's "vertical blanking interval" (period between frames when scanning returns to the top of the array in preparation for new frame readout).

As the bottle travels down the production line, a vision system senses when it has moved into position within the camera's field of view and engages the Inject Inhibit function. Sensor scanning continues, but readout is suspended. However, since the camera optics are stopped down to essentially a black ambient between strobe firings, the system integrates very little background light until the vision system fires the strobe at the appropriate moment, and the image of the bottle is captured by the imager. Scanning continues without readout until the onset of the vertical blanking interval when Inject Inhibit is released, returning the camera to normal operation. Readout of the captured image proceeds at the completion of vertical blanking as new frame scanning begins, providing readout of the complete image. As shown in Figure 2, objects can enter the field of view randomly and the camera will always capture their images in center frame.

The Frame Reset feature, discussed earlier, can be used in this application to increase throughput speed. When the bottle in our example moves into position, the vision system

triggers Frame Reset and Dump, resetting the camera for new frame scanning and clearing the array. The strobe is fired during the vertical blanking interval and the image is captured by the imager. Image readout proceeds at the completion of vertical blanking when new frame scanning begins. The vision system resets the camera asynchronously in response to random events, providing almost immediate readout of the captured images.

The same principles of operation apply to asynchronous capture of pulsed lasers. In anticipation of laser firing, frame reset returns the camera to the vertical blanking interval, and dump clears the array. The laser is fired and the image is captured by the imager. Image readout proceeds at the completion of vertical blanking as new frame scanning begins.

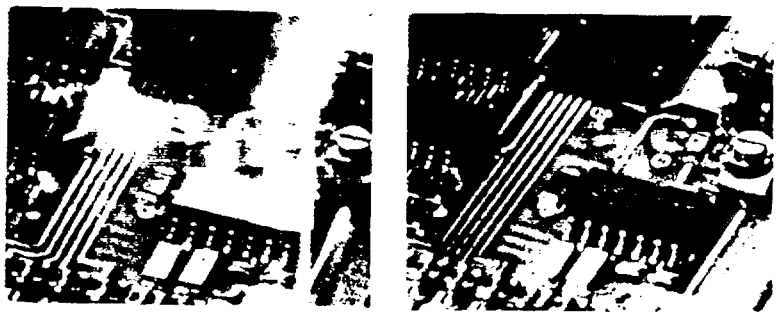


**Figure 1.**
*Unlike many conventional camera images (left), the CIDTEC camera images (right) show virtually no smearing or blooming.*

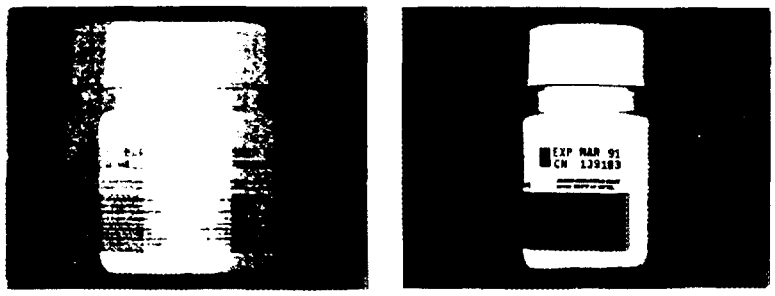
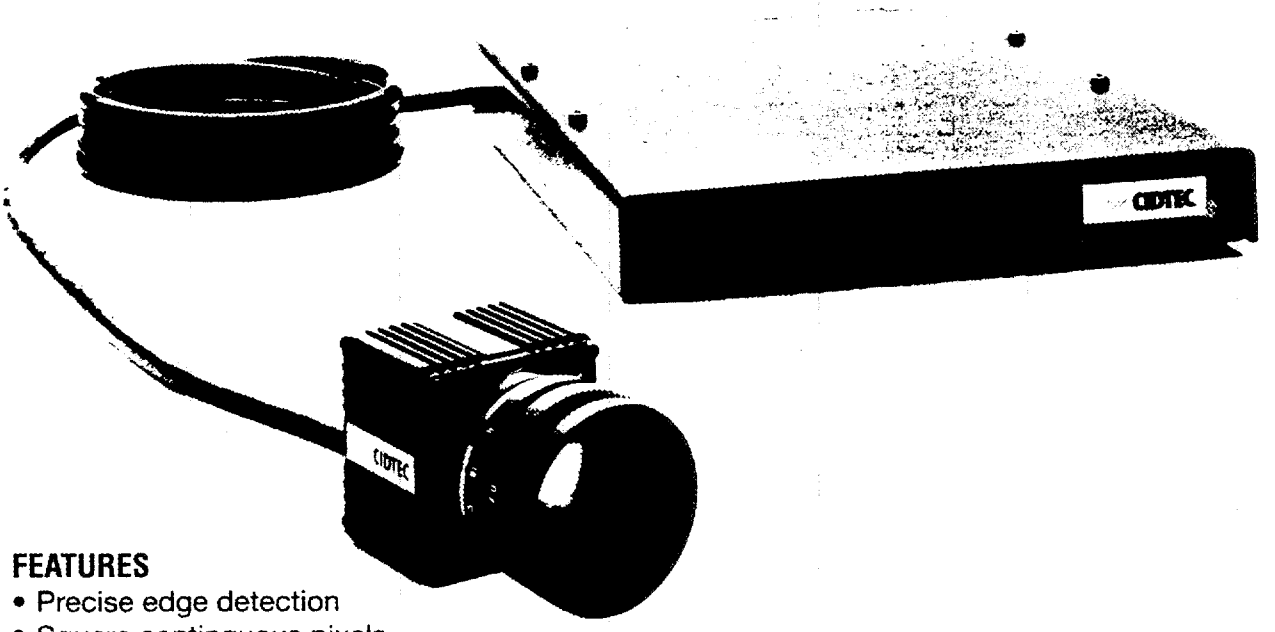


**Figure 2.**
*Typical camera timing does not allow for variations in event timing, leading to positional uncertainty of the captured images as events occur out of sync with the camera (left). Flexible timing and function control of CID cameras provide accurate repeatability for high-speed, asynchronous image capture (right). And CID cameras deliver complete frames for full-frame resolution in stop motion or pulsed applications (not just one field of video as can occur with typical cameras).*

# CID2221D

## 256 X 251
## SOLID-STATE MONOCHROME VIDEO CAMERA




### FEATURES

- Precise edge detection
- Square continguous pixels
- Asynchronous full-frame capture
- High-speed variable frame output
- Superior anti-blooming
- Multiple-frame integration
- UV through near IR spectral response
- On-chip windowing

**The Model CID2221D** solid-state monochrome video camera features a **progressively scanned 256H X 251V CID array** in a compact, remote video head connected to the camera control unit via flexible cable supplied to length.

The **integrated single-board layout** of the camera control unit and the **surface mount technology** of the remote head deliver improved performance at lower cost. A versatile camera head mounting feature simplifies installation in small spaces, and the standard **"C" mount lens** adaptor provides **back-focus adjustment.**

The CID2221D requires an external power source supplying +12 to +17VDC. The camera is also available in an **"E" version** using 115VAC input power for **direct AC operation.** (Note: **CID2221E** CCU case is 1/2" taller)

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# SPECIFICATIONS - CID2221D

## Imager

| | |
|---|---|
| Imager Format | |
| Total Pixels | 270H x 264V |
| Displayed Pixels | 256H X 251V (276 mode) |
| Displayed Pixels | 256H x 242V (262 mode) |
| Pixel Size | 28.0μm x 28.0μm |
| Full Well Capacity | 1,900,000 electrons |
| Active Area | 10.1mm diagonal |
| Optical Format | 2/3" |
| Scanning Format | Sequential |

## Electrical

| | |
|---|---|
| S/N Ratio | 60db (typ.) - Measured Peak Signal/Total RMS Noise 10KHz-4.2MHz |
| Sensitivity | Full Output at 1.5fc Faceplate Illumination (T=2850°K) |
| Composite Video | 1V p-p terminated into 75 ohms |
| Black Level | +50mV avg. (Auto Black Clamp) |
| White Level | +700mV (min.) |
| Sync Level | -300mV |
| Geometric Distortion | 0% |
| Input Power | 8 Watts (max.) |
| Input Voltage | |
| Camera | +15VDC nominal (+12.0 to +17.0) |
| Line Adaptor | 115VAC ± 10%, 50/60 Hz |
| Input Current | |
| Camera (@ 15V) | <550mA avg.; 1000mA peak turn on |
| Spectral Response | See Response Curve |
| Gamma | 1 |

## Environmental

| | |
|---|---|
| Temp. Range | |
| Operating | 0°C to 50°C |
| Storage | -25°C to 85°C |
| Humidity | 0-95% Non-Condensing |
| Shock | 50G (1/2 Sinewave at 10ms Duration) |

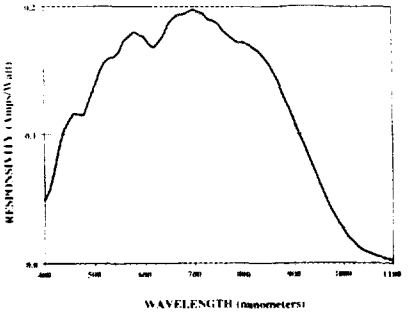
## Interface Signals

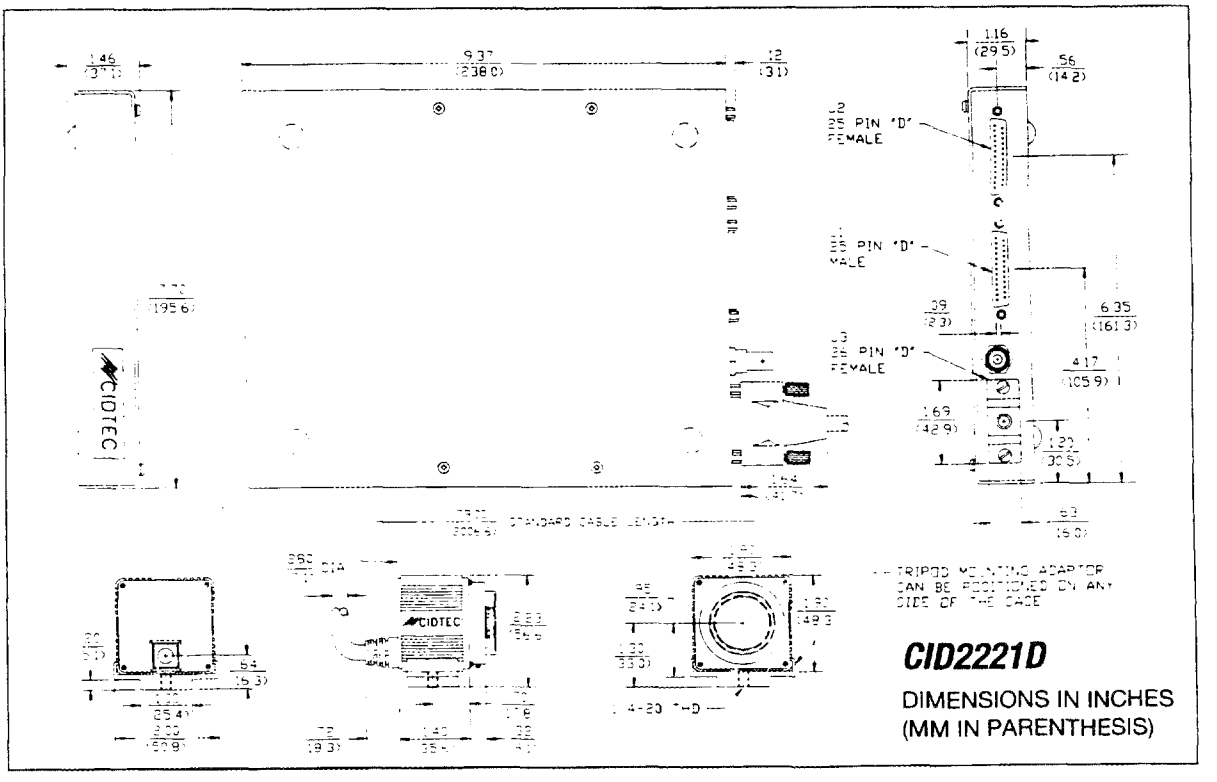
| | | |
|---|---|---|
| Outputs | (J1) | Video, End of Frame, End of Line, H&V Drive, Composite Sync and Blanking |
| | (J2) | Video, ALC, 5 MHz ER Clock, Rapid Scan Clock |
| | BNC | Composite Video |
| Inputs | (J1) | +15VDC, Composite Sync (D3), H Drive (D4), Host +5VDC |
| | (J2) | V Drive (D4), Dump, Inject Inhibit, Frame Reset, Rapid Scan, 262/276 Format Select (D2 & D3 only) |

## Mechanical

| | | |
|---|---|---|
| Weight | | CCU - 0.79 kg. (28 oz.)<br>CH (less cable) - 0.16 kg. (5.6 oz.) |
| Dimensions | | See Outline Drawing |
| Cable Length | | 2 meters (other lengths optional) |
| Lens Mount | | Standard C Mount (1.0" - 32 Thread) |
| Camera Mount | | 1/4" - 20 Thread |
| Connectors | (J1) | 25 Pin D (male) |
| | (J2) | 25 Pin D (female) |
| | (J3) | 26 Pin D (female) |
| | | Standard BNC |

## SPECTRAL RESPONSE

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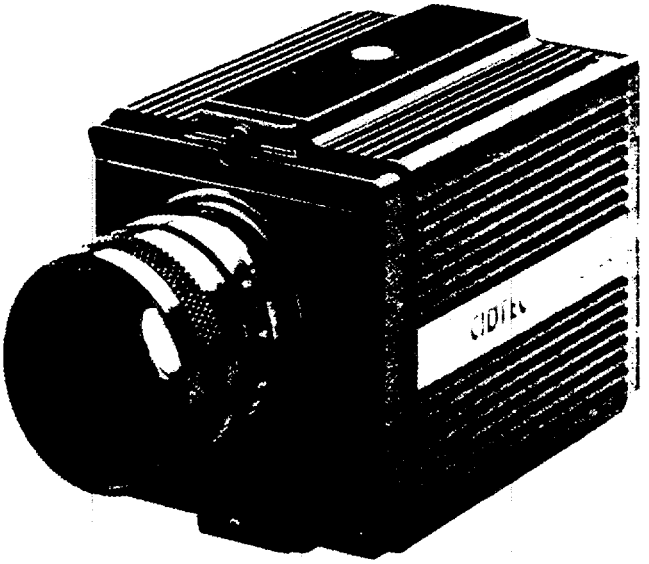
FORM NO. 2221I

# CID2220

## 270 X 264
## SOLID-STATE MONOCHROME VIDEO CAMERA
## HIGH-SPEED 60 FPS, SQUARE PIXELS, RS-170 COMPATIBLE



The **Model CID2220** is designed to address the needs of an expanding image processing market. The camera features a **270 x 264 CID array** that matches standard memories for efficient computer interfacing. **Wide spectral response,** from 200–1100 nanometers, allows the camera to capture images produced by light sources ranging from UV to the near IR. The **large full-well capacity** of the imager provides expansive dynamic range. And **superior anti-blooming performance,** inherent to CID's, ensures accurate image detail even under extreme lighting conditions.

The **contiguous pixel structure** provides for accurate edge detection since there are virtually no opaque areas between pixels where incident light can fail to register on the sensor. **Square pixels** make computational algorithms simpler for more efficient image processing.

The camera's **Progressive Scan** readout enables real-time processing by eliminating the delay other cameras require to interlace odd and even fields, but the standard **60 FPS** full frame output is **RS-170 compatible** for easy interfacing to existing frame-buffers, TV monitors, and VCR's. For high-speed applications, **Frame Reset** initiates vertical blanking on demand, allowing the user to read out smaller frames, faster. In addition, the **CID2220** features **command stop motion** to capture and read asynchronous high-speed events in center frame, **multiple-frame integration** for time-lapse exposures, and **multiple sync options** to facilitate system integration. The switch-selectable (fixed) **Manual Gain Control** has Normal, 2X, and 4X settings for user-controlled signal amplification.

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## SPECIFICATIONS—CID2220

### Electrical

| | |
|---|---|
| Sensor Format | |
| Pixel Elements | 270H × 264V |
| Active Elements | 268H × 242V (Sequential mode)<br>268H × 243V (RS-170 mode) |
| Pixel Size | 28μm × 28μm |
| Full Well Capacity | 1,900,000 electrons |
| Imager Size | |
| Active Area | 10.1mm diagonal |
| Optical Format | 11mm (2/3") |
| Scanning Format | Sequential & RS-170 compatible |
| Resolution | >200TVL (Horizontal) |
| SNR | 50db (typ)—Measured Peak Signal/Total RMS Noise (10KHz – 3.8MHz) |
| Sensitivity | Full output at 1.2fc faceplate normal gain. Useable video at .01fc faceplate (× 4 gain) |
| Composite Video | 1V p-p terminated in 75 ohms |
| Black Level | 50 mV |
| White Level | 700 mV |
| Sync Level | – 300 mV |
| Geometric Distortion | 0% |
| Input Power | 3.5 Watts |
| Input Voltage | |
| Camera | + 12 to + 35 VDC ± 4% |
| Line Adapter | 120 VAC ± 10%, 60 Hz |
| Input Current | |
| Camera (@ 15V) | <235mA, <400 peak turn on |
| Spectral Response | See Curve |
| Gamma | 1 |

### Interface Signals

| | |
|---|---|
| Outputs | |
| I/O | Clock (6.14 MHz), H&V Drive, Blanking |
| Video | Composite, 1 Volt p-p |
| Inputs | |
| I/O | 2 × Clock (12.27 MHz), x2 & x4 Gain, Inject Inhibit, Frame Reset |

### Environmental

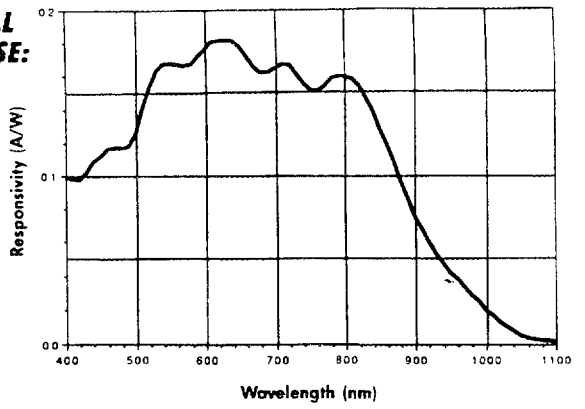
| | |
|---|---|
| Temp Range | |
| Operating | 0°C to + 50°C |
| Storage | – 30°C to + 70°C |
| Humidity | 0–95% Non-Condensing |
| Shock | 50G (½ sinewave at 10 ms duration) |

### Mechanical

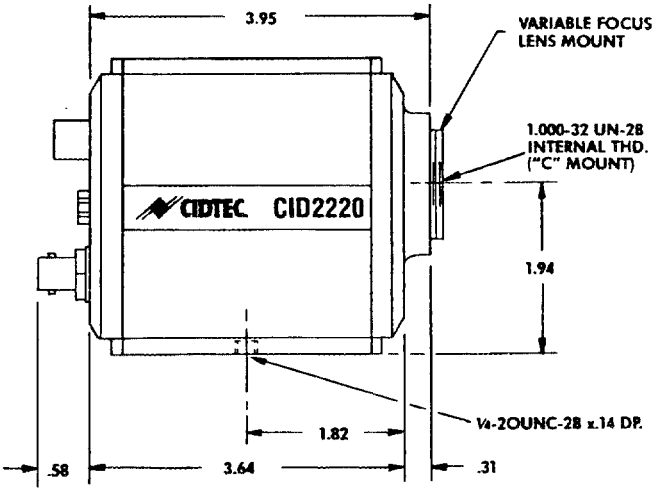
| | |
|---|---|
| Weight | 23 oz. |
| Dimensions | See Outline Drawing |
| Variable Focus Lens Mount | Standard C Mount (1.00" – 32 Thread) |
| Camera Mount | ¼" – 20 Thread |
| Connectors | |
| Video | BNC |
| Power | 7 Pin Viking |
| I/O | 15 pin "D" |

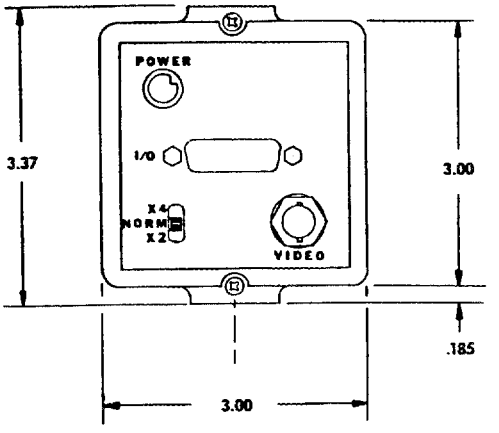
Camera specifications subject to change without notice.

## SPECTRAL RESPONSE:




## CID2220 DIMENSIONS (inches)





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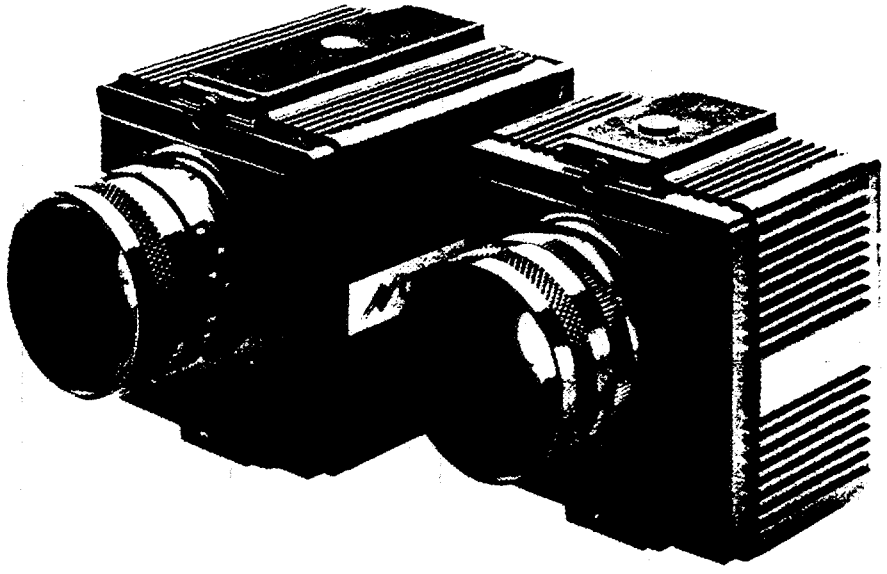
FORM NO. 222

# CID2705 CID2505

## 388 X 248
## SOLID-STATE MONOCHROME VIDEO CAMERAS
## HIGH-SPEED 60 FPS OPERATION, RS-170 COMPATIBLE



The **Model CID2505** is designed to address the needs of an expanding image processing world. The camera features an X,Y addressable **388H X 248V CID array** with **wide spectral response,** from 200–1100 nanometers, allowing the camera to capture images produced by light sources ranging from UV to the near IR. **Superior antiblooming performance,** inherent to CID's, ensures accurate image detail even under extreme lighting conditions. And the **contiguous pixel structure** provides for accurate edge detection since there are virtually no opaque areas between pixels where incident light can fail to register on the sensor.

The camera's **Progressive Scan** readout enables real-time processing by eliminating the delay other cameras require to interlace odd and even fields, but the standard **60 FPS** full frame output is **RS-170 compatible** for easy interfacing to existing frame-buffers, TV monitors, and VCR's. In addition, the **CID2505** features **command stop motion** to capture and read asynchronous high-speed events in center frame, **multiple-frame integration** for time-lapse exposures, and **multiple sync options** to facilitate system integration. The **Gain Option** is jumper-selectable at two levels for increased sensitivity.

The **Model CID2705** features all of the above, ***plus* Video Enhancement Circuitry** for improved signal-to-noise performance, selectable **8:1 Automatic Gain Control (AGC),** and switch-selectable (fixed) ***Manual Gain Control*** with Normal, 2X, and 4X settings for user-controlled signal amplification.

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# SPECIFICATIONS—CID2705/CID2505

## Electrical

| | |
|---|---|
| Sensor Format | |
| Pixel Elements | 388H × 248V |
| Active Elements | 377H × 237V |
| Pixel Size | 23.3μm × 27.2μm |
| Full Well Capacity | 900,000 electrons |
| Imager Size | |
| Active Area | 11mm diagonal |
| Optical Format | 11mm (2/3") |
| Scanning Format | Sequential & RS-170 compatible |
| Resolution | >250TVL (Horizontal) |
| SNR | |
| CID2705 | 54db (typ) |
| CID2505 | 45db (typ) |
| | Measured Peak Signal/Total RMS Noise (10KHz–4.2MHz) |
| Sensitivity | Full output at 0.6fc faceplate 0db gain, Useable video at .01fc faceplate (× 4 gain) |
| Composite Video | 1V p-p terminated in 75 ohms |
| Black Level | 50 mV |
| White Level | 700 mV |
| Sync Level | −300 mV |
| Geometric Distortion | 0% |
| Input Power | |
| CID2705 | 8 Watts |
| CID2505 | 2.1 Watts |
| Input Voltage | |
| CID2705 | +12 to +18 VDC |
| CID2505 | +12 to +35 VDC |
| Line Adapters | 120 VAC ± 10%, 60 Hz |
| Input Current | |
| CID2705 (@ 12V) | <700mA avg; <1.2A peak turn on |
| CID2505 (@ 12V) | <175mA avg; <300mA peak turn on |
| Spectral Response | See Curve |
| Gamma | |
| CID2705 | 1.0 (internally continuously adjustable 0.4 to 1.0) |
| CID2505 | 1.0 |
| Automatic Gain Control (CID2705 only) | Selectable in/out-8:1 continuous gain range |

## Interface Signals

| | |
|---|---|
| Outputs | |
| I/O | |
| CID2705 | Clock (14.3MHz), H&V Drive, Video |
| CID2505 | Clock (14.3MHz), H&V Drive, (Non-buffered) |
| Iris | |
| CID2705 | Gnd, Video + 12VDC |
| CID2505 | Gnd, Video + 10VDC |
| Video | Composite, 1 Volt p-p, RS-170 |
| Inputs | |
| I/O | |
| CID2705 | × 2 & × 4 Gain, Sync, Inject Inhibit, AGC Inhibit, Power, V-Drive |
| CID2505 | × 2 & × 4 Gain, Sync, Inject Inhibit |

## Environmental

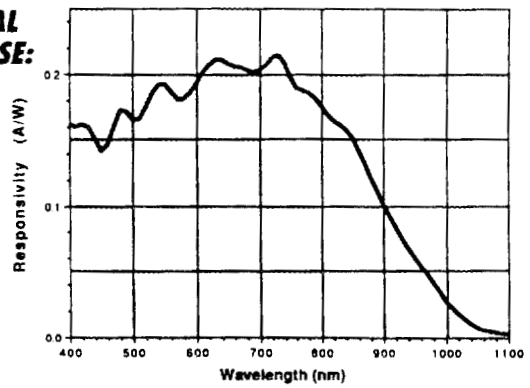
| | |
|---|---|
| Temp Range | |
| Operating | −20°C to +50°C |
| Storage | −30°C to +70°C |
| Humidity | 0–95% Non-Condensing |
| Shock | 50G (1/2 sinewave at 10ms duration) |

Camera specifications subject to change without notice.

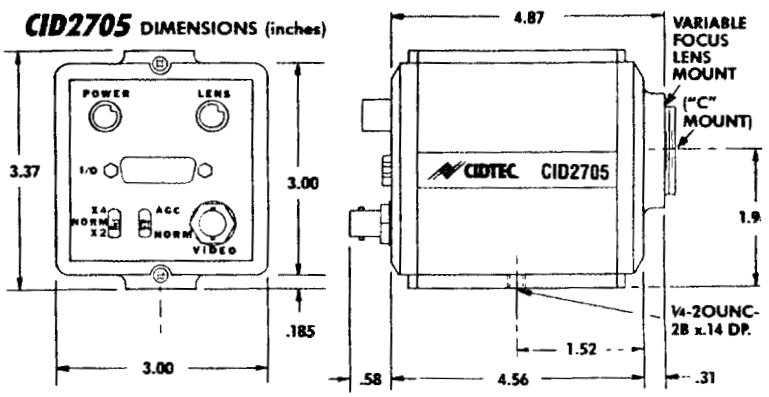
## Mechanical

| | |
|---|---|
| Weight | |
| CID2705 | 23 oz. |
| CID2505 | 13.5 oz. |
| Dimensions | See Outline Drawing |
| Variable Focus Lens Mount | Standard C Mount (1.00" – 32 Thread) |
| Camera Mount | 1/4" – 20 Thread |
| Connectors | |
| Video | BNC |
| Lens | 7 Pin Viking |
| Power | 7 Pin Viking |
| I/O | |
| CID2705 | 15 pin "D" |
| CID2505 | 12 pin Viking |

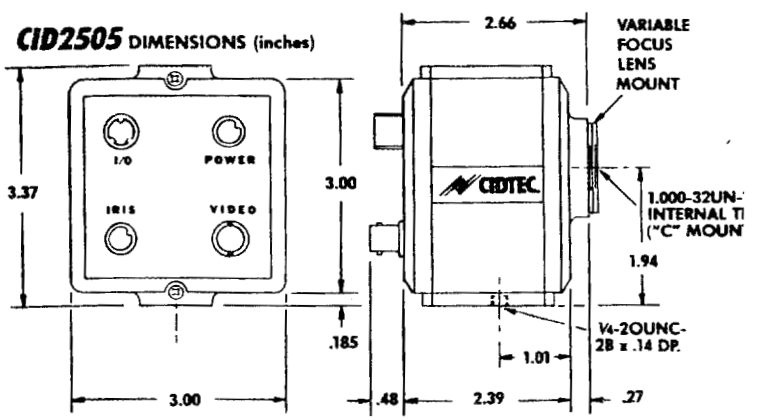
**SPECTRAL RESPONSE:**




**CID2705 DIMENSIONS (inches)**




**CID2505 DIMENSIONS (inches)**





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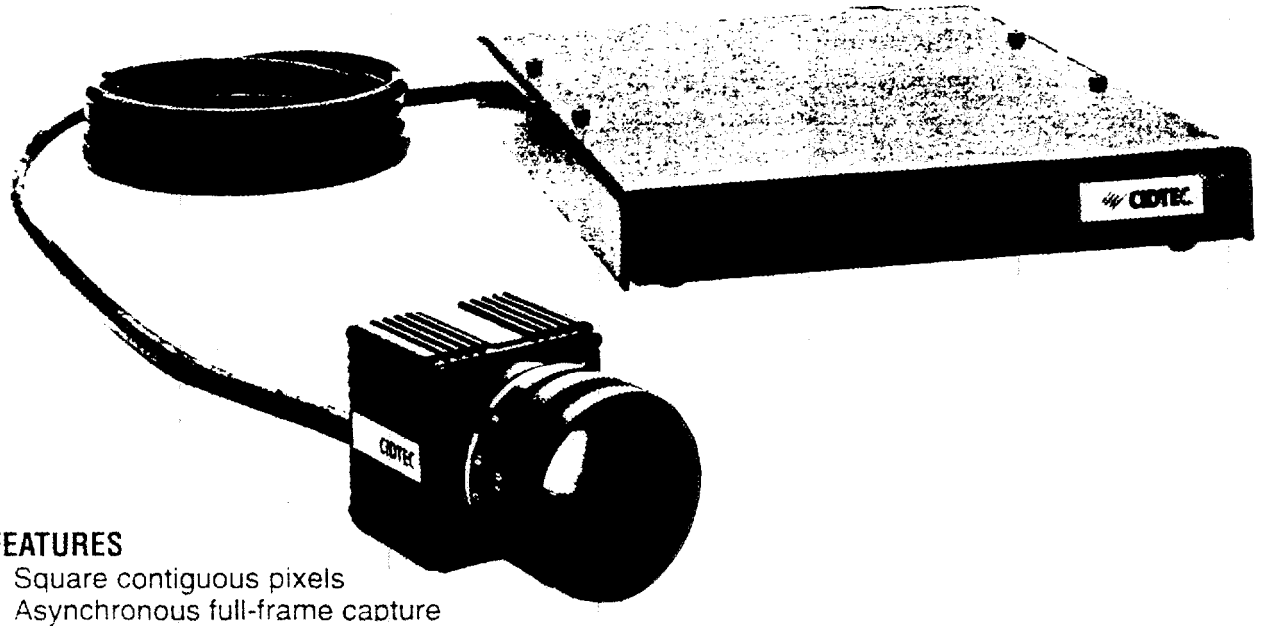
FORM NO. 2705/2

# CID2250D

## 512 X 512
## SOLID-STATE MONOCHROME VIDEO CAMERA




### FEATURES

- Square contiguous pixels
- Asynchronous full-frame capture
- High-speed variable frame output
- Superior anti-blooming
- Multiple-frame integration
- Wide spectral response
- On-chip windowing

The **Model CID2250D** solid-state monochrome video camera features a **progressively scanned 512H X 512V CID array** in a compact, remote video head connected to the camera control unit via flexible cable supplied to length.

The **integrated single-board layout** of the camera control unit and the **surface mount technology** of the remote head deliver improved performance at lower cost. A versatile camera head mounting feature simplifies installation in small spaces, and the standard **"C" mount lens** adaptor provides **back-focus adjustment**.

The CID2250D requires an external power source supplying +11 to +17VDC. The camera is also available in an **"E" version** using 115VAC input power for **direct AC operation**.
(Note: **CID2250E** CCU case is 1/2" taller)

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# SPECIFICATIONS - CID2250D

## Imager

| | |
|---|---|
| Imager Format | |
| Total Pixels | 522H x 528V |
| Displayed Pixels | 512H x 512V (532 mode) |
| Displayed Pixels | 512H x 505V (525 mode) |
| Pixel Size | 15.0µm x 15.0µm |
| Full Well Capacity | 450,000 electrons |
| Optical Format | Nominal 11.0mm (2/3") diagonal |
| Scanning Format | Progressive/Sequential |

## Electrical

| | |
|---|---|
| S/N Ratio | 52db (typ.) - Measured Peak Signal/Total RMS Noise |
| Sensitivity | Full Output at 0.7fc Faceplate Illumination (T=2850°K) |
| Composite Video | 1V p-p terminated into 75 ohms |
| Black Level | +50mV avg. (Auto Black Clamp) |
| White Level | +700mV (min.) |
| Sync Level | -300mV |
| Geometric Distortion | 0% |
| Input Power | 8 Watts (max.) |
| Input Voltage | |
| Camera | +15VDC nominal (+11.0 to +17.0) |
| Line Adaptor | 115VAC ± 10%, 50/60 Hz |
| Input Current | |
| Camera (@ 15V) | <550mA avg.; 1000mA peak turn on |
| Spectral Response | See Response Curve |
| Gamma | 1 |

## Environmental

| | |
|---|---|
| Temp. Range | |
| Operating | 0°C to 50°C |
| Storage | -25°C to 85°C |
| Humidity | 0-95% Non-Condensing |
| Shock | 50G (1/2 Sinewave at 10ms Duration) |

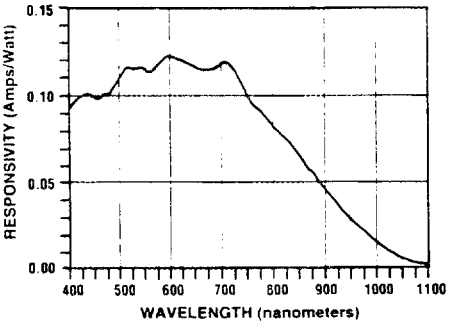
## Interface Signals

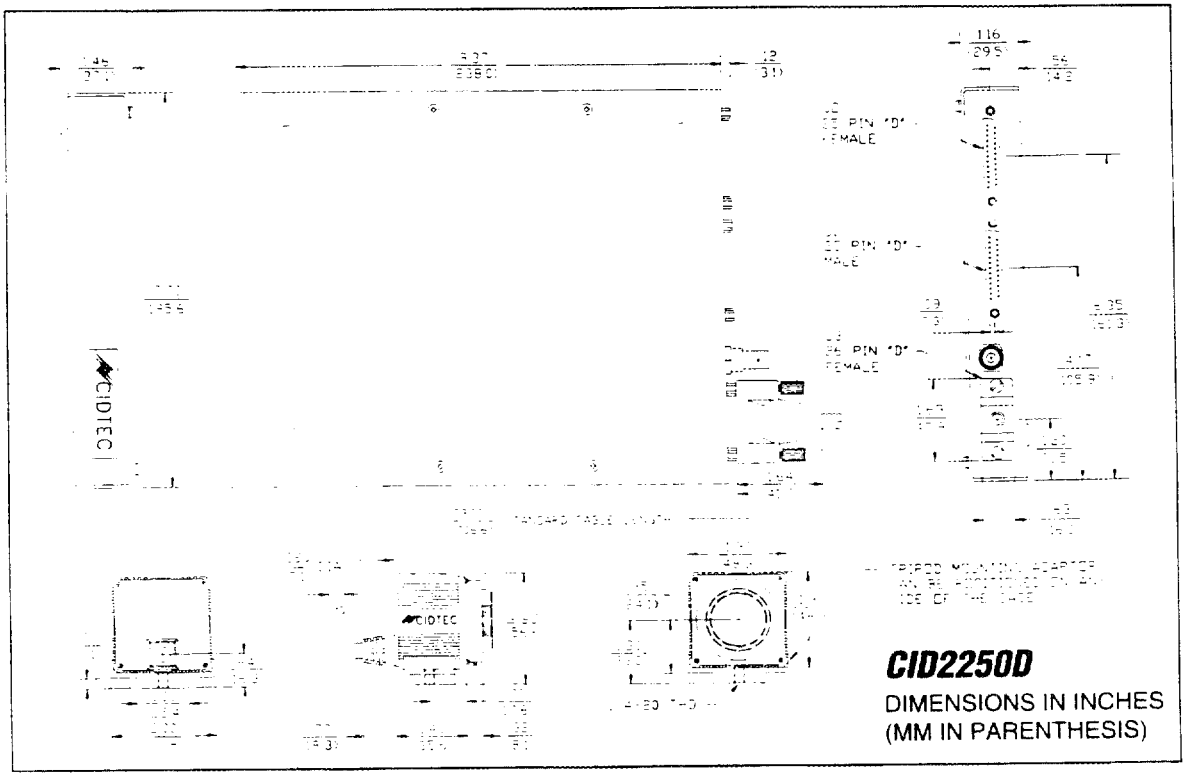
| | | |
|---|---|---|
| Outputs | (J1) | Video, End of Frame, End of Line, H&V Drive, Composite Sync and Blanking |
| | (J2) | Video, ALC, 10 MHz ER Clock, Rapid Scan Clock |
| | BNC | Composite Video |
| Inputs | (J1) | +15VDC, Composite Sync (D3), H Drive (D4), Host +5 VDC |
| | (J2) | V Drive (D4), Dump, Inject Inhibit, Frame Reset, Rapid Scan, 532/525 Format Select (D2 & D3 only) |

## Mechanical

| | | |
|---|---|---|
| Weight | | CCU - 0.79 kg. (28 oz.)<br>CH (less cable) - 0.16 kg. (5.6 oz.) |
| Dimensions | | See Outline Drawing |
| Cable Length | | 2 meters (other lengths optional) |
| Lens Mount | | Standard C Mount (1.00" - 32 Thread) |
| Camera Mount | | 1/4" - 20 Thread |
| Connectors | (J1) | 25 Pin D (male) |
| | (J2) | 25 Pin D (female) |
| | (J3) | 26 Pin D (female) |
| | | Standard BNC |

## SPECTRAL RESPONSE

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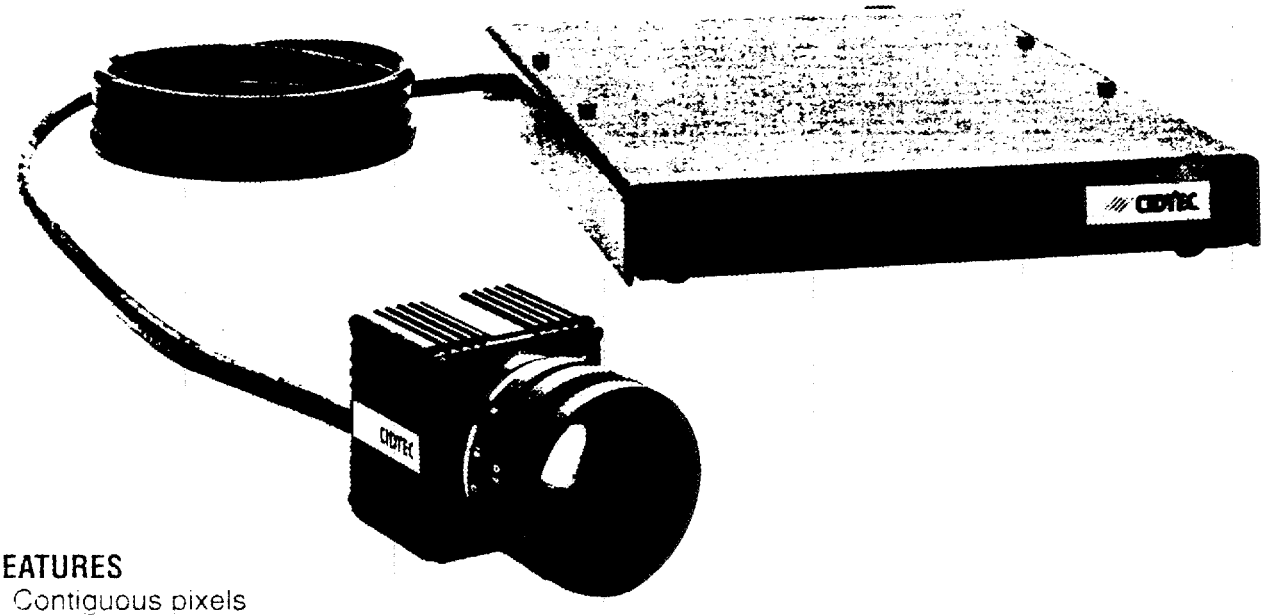
FORM NO. 2250D

# CID3710D

## 776 X 512
## SOLID-STATE MONOCHROME VIDEO CAMERA




### FEATURES

- Contiguous pixels
- Asynchronous full-frame capture
- Superior anti-blooming
- Multiple-frame integration
- Wide spectral response

The **Model CID3710D** solid-state monochrome video camera features a **2:1 interlace scanned 776H X 512V CID array** in a compact, remote video head connected to the camera control unit via flexible cable supplied to length.

The **integrated single-board layout** of the camera control unit and the **surface mount technology** of the remote head deliver improved performance at lower cost. A versatile camera head mounting feature simplifies installation in small spaces, and the standard **"C" mount lens** adaptor provides **back-focus adjustment**.

The CID3710D requires an external power source supplying +11 to +17VDC. The camera is also available in an **"E" version** using 115VAC input power for **direct AC operation**. (Note: **CID3710E** CCU case is 1/2" taller)

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# SPECIFICATIONS - CID3710D

## Imager

| | |
|---|---|
| Imager Format | |
| Total Pixels | 776H x 512V |
| Displayed Pixels | 755H x 484V |
| Pixel Size | 12.0µm x 13.7µm |
| Full Well Capacity | 300,000 electrons |
| Optical Format | Nominal 11.0mm (2/3") diagonal |
| Scanning Format | RS-330, 2:1 Interlace |
| Resolution | >450 TVL (horizontal) |

## Electrical

| | |
|---|---|
| S/N Ratio | 50db (typ.) - Measured Peak Signal/Total RMS Noise |
| Sensitivity | Full Output at 0.3fc Faceplate Illumination (T=2850°K) |
| Composite Video | 1V p-p terminated into 75 ohms |
| Black Level | +50mV avg. (Auto Black Clamp) |
| White Level | +700mV (min.) |
| Sync Level | -300mV |
| Geometric Distortion | 0% |
| Input Power | 8 Watts (max.) |
| Input Voltage | |
| Camera | +15VDC nominal (+11.0 to +17.0) |
| Line Adaptor | 115VAC ± 10%, 50/60 Hz |
| Input Current | |
| Camera (@ 15V) | <550mA avg.; 1000mA peak turn on |
| Spectral Response | See Response Curve |
| Gamma | 1 |

## Environmental

| | |
|---|---|
| Temp. Range | |
| Operating | 0°C to 50°C |
| Storage | -25°C to 85°C |
| Humidity | 0-95% Non-Condensing |
| Shock | 50G (1/2 Sinewave at 10ms Duration) |

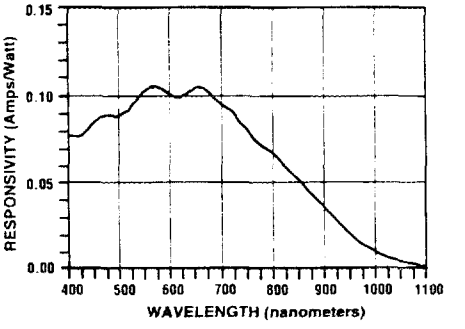
## Interface Signals

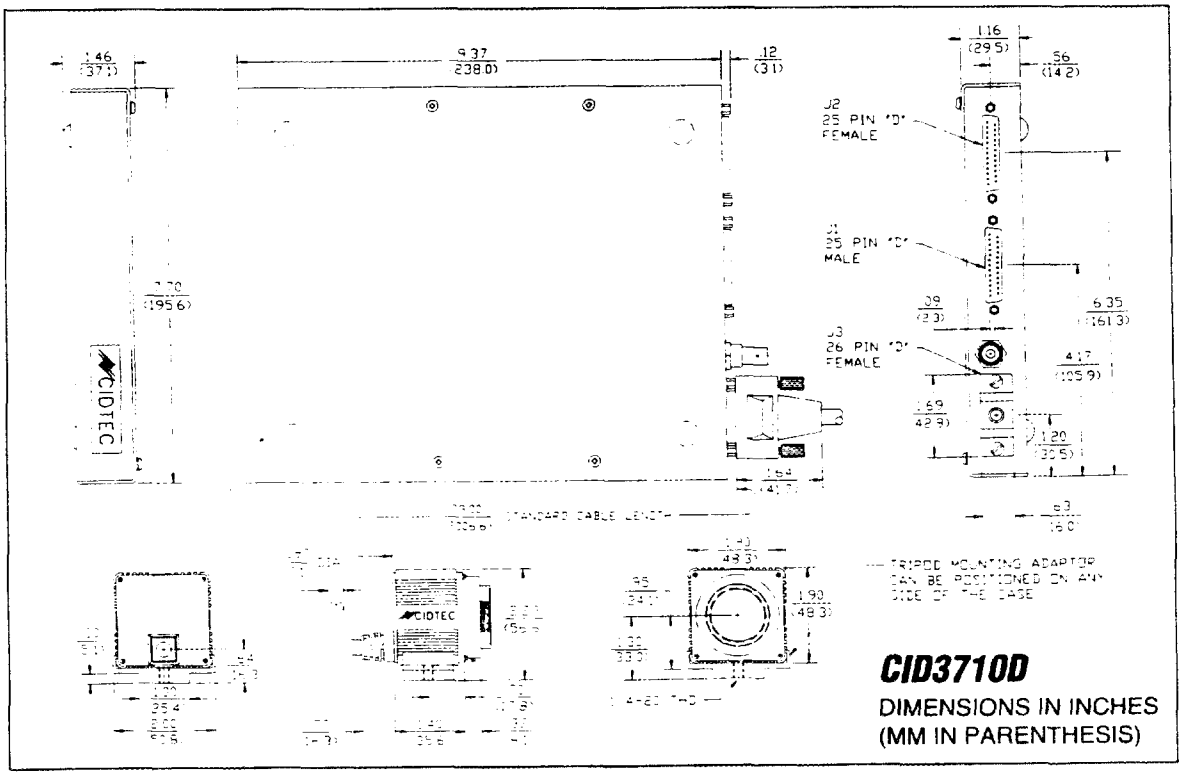
| | | |
|---|---|---|
| Outputs | (J1) | Video, End of Field, End of Line, H&V Drive, Composite Sync and Blanking, Field 1 ID, Strobe Trigger |
| | (J2) | Video, ALC, 14.318 MHz ER Clock |
| | BNC | Composite Video |
| Inputs | (J1) | +15VDC, Composite Sync (D3), H Drive (D4) |
| | (J2) | V Drive (D4), Dump, Inject Inhibit, Frame Reset, External Trigger |

## Mechanical

| | | |
|---|---|---|
| Weight | | CCU - 0.79 kg. (28 oz.)<br>CH (less cable) - 0.16 kg. (5.6 oz.) |
| Dimensions | | See Outline Drawing |
| Cable Length | | 2 meters (other lengths optional) |
| Lens Mount | | Standard C Mount (1.00" - 32 Thread) |
| Camera Mount | | 1/4" - 20 Thread |
| Connectors | (J1) | 25 Pin D (male) |
| | (J2) | 25 Pin D (female) |
| | (J3) | 26 Pin D (female) |
| | | Standard BNC |

## SPECTRAL RESPONSE

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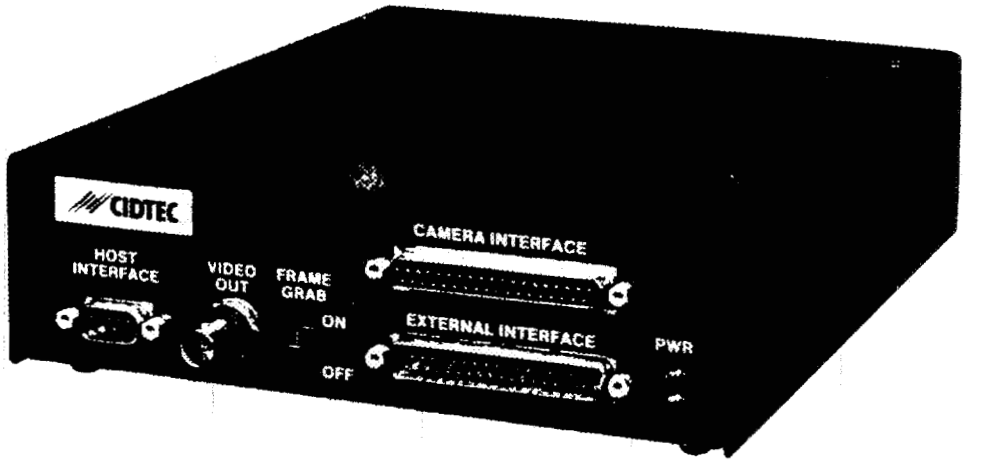
FORM NO. 3710I

# ICM7000

## EASY INTEGRATOR




CIDTEC's new **Easy Integrator** is a powerful interface control module facilitating rapid vision system integration. The ICM7000 provides immediate access to the unique features and functional capabilities of CID cameras. Now, even non-technical users can bring camera region-of-interest readout, asynchronous full-frame capture, and multiple-frame integration capabilities to their imaging systems – in minutes, not months.

System configuration and operating modes are selected and controlled via easy-to-use software that runs on your PC-compatible computer under Windows. An optional hand-held terminal featuring liquid crystal display and membrane keyboard offers a more portable alternative to the PC.

*Optional hand-held terminal with liquid crystal display and membrane keyboard may be used.*

To set up, just connect the ICM7000 to your system components, select your "acquisition recipe" and you're up and running. To modify your setup, simply change your recipe. The ICM7000 programming flexibility lets you integrate a variety of options in minutes to quickly try out iterative system concepts to prove feasibility. No timing and control (T/C) circuit development, no soldering. Virtually all system I/Os are easily accessible via a dozen BNCs, making signal interfacing a real snap.

### Features and Benefits:

- **Quick camera and system component hookup:**
  No circuit design
  No soldering
  No programming
- **Immediate access to:**
  Camera region-of-interest readout
  Asynchronous full-frame capture
  Multiple-frame integration
- **Time and money saving**
  Fast demonstration of system proof-of-principle
  Vastly reduced system development time
  Accelerated time-to-market for enhanced competitiveness
- **Friendly to technical and non-technical users**

For the system developer, optional DOS and Windows libraries are available to allow you to merge acquisition control routines with your processing software. In addition, an internal frame grabber is available to facilitate demonstration and monitor display.

As your proven system moves into production, low cost, application specific T/C circuits can be developed to free up the ICM7000 for your next project. Or you may elect to incorporate the ICM7000 for maximum flexibility.

Any way you choose to use CITEC's **Easy Integrator**, the bottom line is a substantial savings in both time and money.

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# SPECIFICATION : ICM7000F

# Interface Control Module

## Cameras Supported

**Note: ICM7000F may not be compatible with "X" version cameras; consult factory.**

CID2220 ..... A2
CID2250 ..... A/D/E2,3,4
CID3710 ..... D/E2,3,4

## Operating Modes

**Note: F=Frame Reset, D=Dump, I=Inject Inhibit, aPIP=asyncPIP, sPIP=syncPiP**

**Async. Capture:**

CID2220 ..... FI, I
CID2250 (full frame) ..... FDI, FI, DI, I
CID2250 (wndos) ..... FDI, FI, DI, I
CID3710 ..... FDI, FI, DI, I, aPIP, sPIP

**Extended Integration (1 to 255 frames):**

CID2220 ..... FI,I
CID2250 ..... FDI, FI, DI, I
CID3710 ..... FDI, FI, DI, I

**Windows (5 max.):**

CID2250 ..... full frame
CID3710 ..... 1st field only

## Programmable Signal Timing

timing resolution ..... 63nsec. minimum or ERC
sync. signal delay ..... less than 30nsec.
signal inversion ..... ERCout, BLANKout, HDRout, SYNCout, VDRout, HDRin SYNCin, VDRin
function timing ..... timing diagrams for each function available by request
custom timing ..... programmable architecture supports custom applications
watchdog timer ..... hardware reset after 1.2 sec.

**Windows Limitations:**

max. number ..... 5
top line of 1st wndo ..... line 6 min.
window spacing ..... 6 lines min.

## Signal Interface

**Host Interface:**

type ..... EIA-232
connector ..... DB9M
baud rate ..... 9600
start bits ..... 1
stop bits ..... 1
parity ..... none
protocol ..... DTE (DCE)

**Camera Interface:**

connector ..... DB37F
signal levels ..... TTL (except video)

**External Interface:**

connector ..... DB37M
signal levels ..... TTL (24ma. drive)
spare inputs ..... 4
spare outputs ..... 4

**Auxiliary Interface:**

connectors ..... 12 BNC
signal levels ..... TTL (24ma. drive)

**Video Interface:**

connector ..... BNC
video output ..... 1 volt peak to peak into 75ohm
S/N degradation ..... <.5db (measured peak signal to total RMS noise)

## Power

connector ..... standard 3-prong IEC
switch ..... ON/OFF rocker
input voltage ..... 85 to 264vac
input frequency ..... 47 to 440Hz.
aux. outputs ..... +5vdc @ .5a, +12v @ 1.5a (powers up to two cameras)
power input ..... 35W with CID2250
fuse (internal) ..... 5MF 2A 250V
indicators ..... +5vdc, +12vdc (LEDs)

## Mechanical

weight ..... 50 oz. less cables
dimensions ..... approx. 2.3"H x 7.7"W x 10.3"D

## Environmental

temp. operating ..... 0°C to 50°C
temp. storage ..... -25°C to 85°C
humidity ..... 0 - 95% non-condensing

## Optional Equipment

**Hand Held Terminal:**

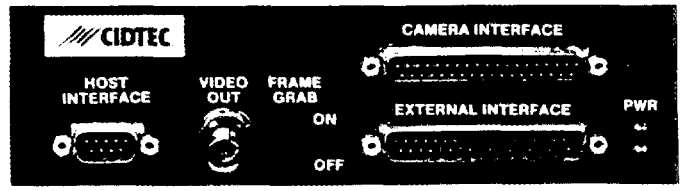
display ..... 20x4 LCD (Liquid Crystal Display)
keyboard ..... 6x4 matrix
connector ..... RJ11
cable ..... coiled, extends up to 2 meters

**PC Interface:**

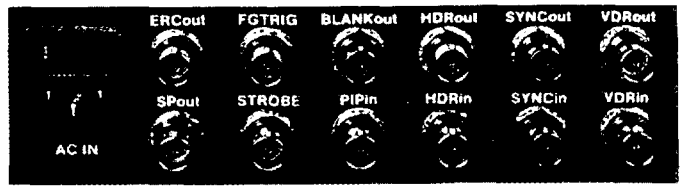
cable ..... DB9M to DB9F - 2m length
Application software ..... Windows 3.1 compatible
DOS library ..... MS "C" V7.0 compatible
Windows DLL ..... MS QuickC for Windows

**Internal Frame Grabber:**

signal input/output ..... RS-170/330, CCIR or non-interlaced
memory size ..... 960H x 612V x 8bits
data readout ..... analog video only
video delay ..... one frame from video input
clock source ..... camera pixel clock




Front view




Rear view

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FORM NO. A9698

# CID TECHNOLOGIES INC.

101 Commerce Blvd.
Liverpool, NY 13088

Phone.....315-451-9410 ext. 229
Fax.....315-451-9421

**Date** : 12/10/93

**To** : Oakridge National Lab **Atten:** David Holcomb
**City / State** : Oakridge , TN
**Fax Phone** : 615-574-4058

**From** : Tony Chapman

**Subject** : **Radiation information for CID cameras**
**Pages** : 14 (Including Cover)

If there are any problems in transmission, please call 315-451-9410 x229.

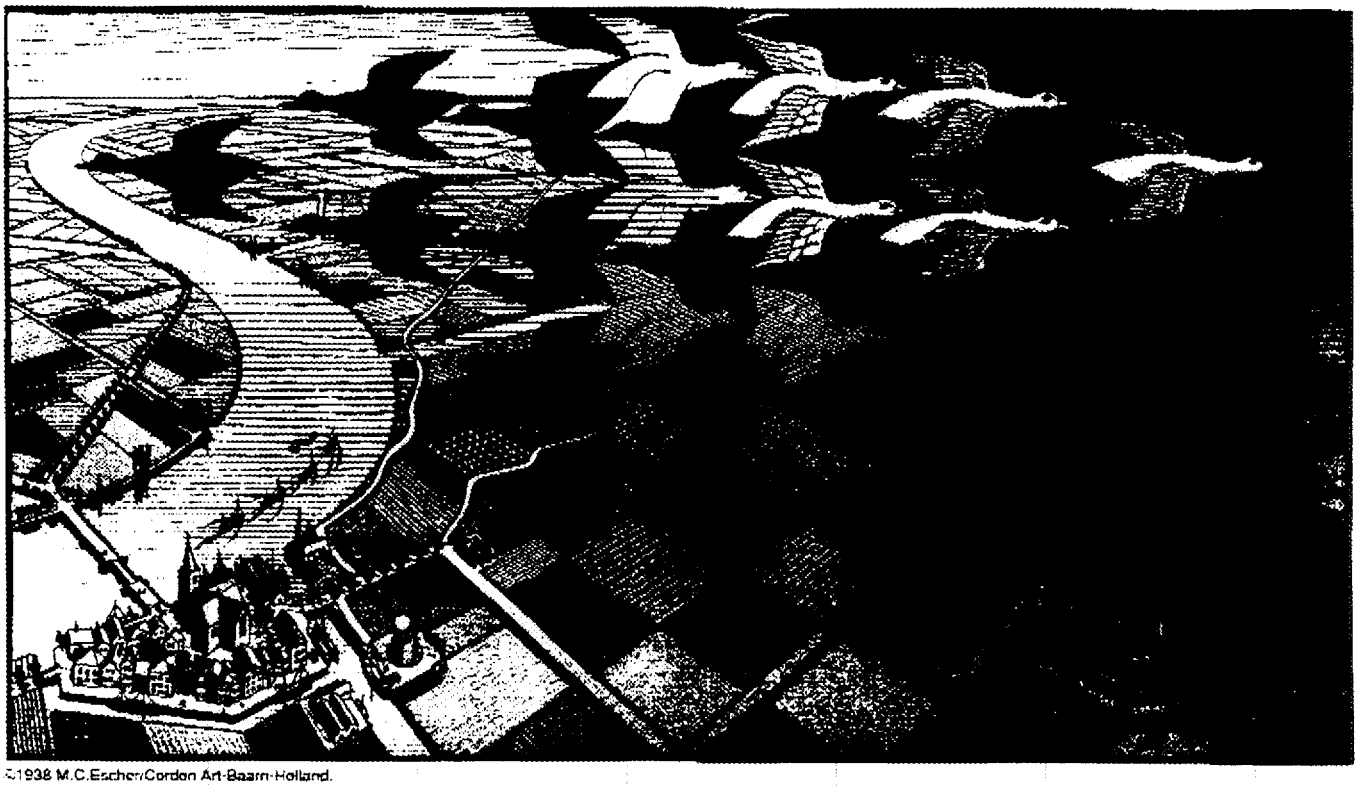
Dear David,

Here is some of the radiation information that you requested.

Feel free to give me a call if you have any questions.

Best Regards,

Tony Chapman



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# Optical disillusion.

## If you're disillusioned by CCD camera performance, consider a different perspective — CID, the alternative solid-state camera technology from CIDTEC.

Ask yourself the following questions:

| YES | NO | |
|---|---|---|
| ☐ | ☐ | Does your CCD camera prevent blooming or streaking under extreme lighting conditions? |
| ☐ | ☐ | Does your CCD camera maintain accurate dimensional detail and give you the edge detection precision you need? |
| ☐ | ☐ | Does your CCD camera capture *full frame* asynchronous images of high speed or short duration events? |
| ☐ | ☐ | Does your CCD camera allow you to read out multiple areas of interest within a given frame at higher rates for faster capture and processing? |
| ☐ | ☐ | Does your CCD camera give you UV response down to 185 nm and near-IR response without blooming, fringing or loss of data resolution? |
| ☐ | ☐ | Does your CCD camera tolerate high radiation environments? |

If you answered "NO" to *even one* of these questions, Charge Injection Device (CID) technology, invented in 1972 at G.E.'s Research and Development Center, could be your imaging solution.

CIDTEC offers a complete line of CID cameras and accessories. Backed by our 18-year history of product quality, responsive service and sound technical knowledge, CIDTEC will assist you with your most demanding imaging applications.

CID cameras may offer your best — or only — imaging solution. Call us at 315-451-9410, fax us at 315-451-9421, or write to CID Technologies Inc., 101 Commerce Blvd., Liverpool, NY 13088.

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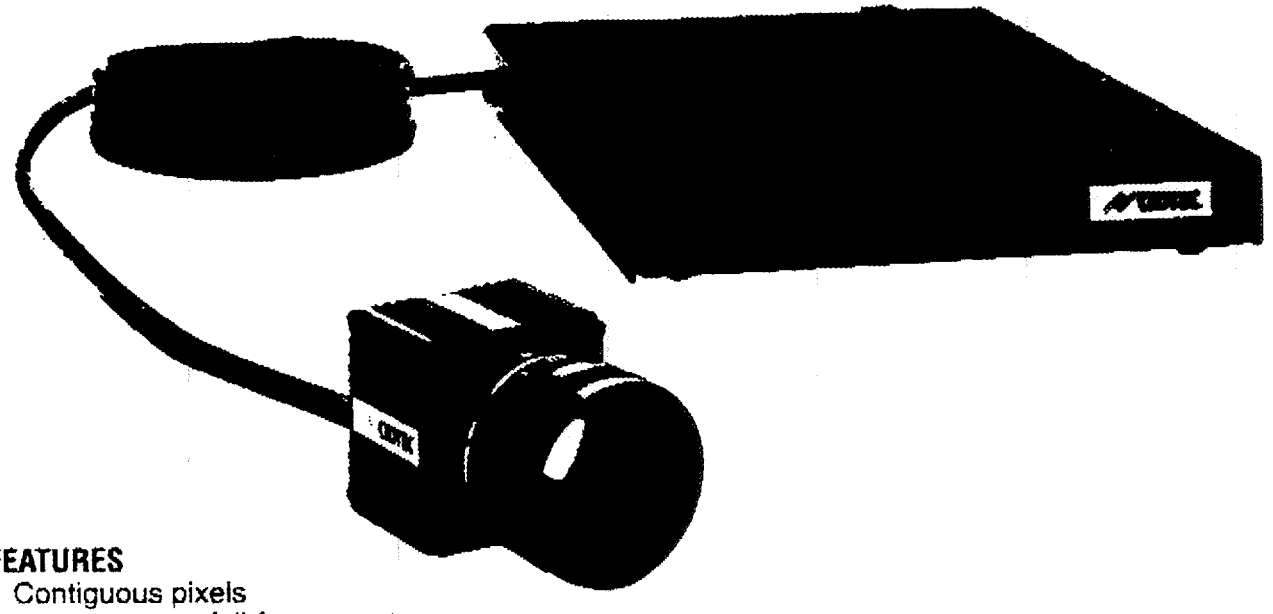
**CID Technology — We'll show you the difference.**

# CID3710D

## 776 X 512
## SOLID-STATE MONOCHROME VIDEO CAMERA



### FEATURES
- Contiguous pixels
- Asynchronous full-frame capture
- Superior anti-blooming
- Multiple-frame integration
- Wide spectral response

The **Model CID3710D** solid-state monochrome video camera features a **2:1 interlace scanned 776H X 512V CID array** in a compact, remote video head connected to the camera control unit via flexible cable supplied to length.

The **integrated single-board layout** of the camera control unit and the **surface mount technology** of the remote head deliver improved performance at lower cost. A versatile camera head mounting feature simplifies installation in small spaces, and the standard **"C" mount lens** adaptor provides **back-focus adjustment**.

The CID3710D requires an external power source supplying +11 to +17VDC. The camera is also available in an **"E" version** using 115VAC input power for **direct AC operation**. (Note: **CID3710E** CCU case is 1/2" taller)

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# SPECIFICATIONS - CID3710D

## Imager

| | |
|---|---|
| Imager Format | |
| Total Pixels | 776H x 512V |
| Displayed Pixels | 755H x 484V |
| Pixel Size | 12.0µm x 13.7µm |
| Full Well Capacity | 300,000 electrons |
| Optical Format | Nominal 11.0mm (2/3") diagonal |
| Scanning Format | RS-330, 2:1 Interlace |
| Resolution | >450 TVL (horizontal) |

## Electrical

| | |
|---|---|
| S/N Ratio | 50db (typ.) - Measured Peak Signal/Total RMS Noise |
| Sensitivity | Full Output at 0.3fc Faceplate Illumination (T=2850°K) |
| Composite Video | 1V p-p terminated into 75 ohms |
| Black Level | +50mV avg. (Auto Black Clamp) |
| White Level | +700mV (min.) |
| Sync Level | -300mV |
| Geometric Distortion | 0% |
| Input Power | 8 Watts (max.) |
| Input Voltage | |
| Camera | +15VDC nominal (+11.0 to +17.0) |
| Line Adaptor | 115VAC ± 10%, 50/60 Hz |
| Input Current | |
| Camera (@ 15V) | <550mA avg.; 1000mA peak turn on |
| Spectral Response | See Response Curve |
| Gamma | 1 |

## Environmental

| | |
|---|---|
| Temp. Range | |
| Operating | 0°C to 50°C |
| Storage | -25°C to 85°C |
| Humidity | 0-95% Non-Condensing |
| Shock | 50G (1/2 Sinewave at 10ms Duration) |

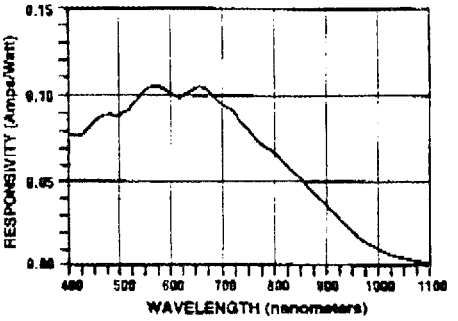
## Interface Signals

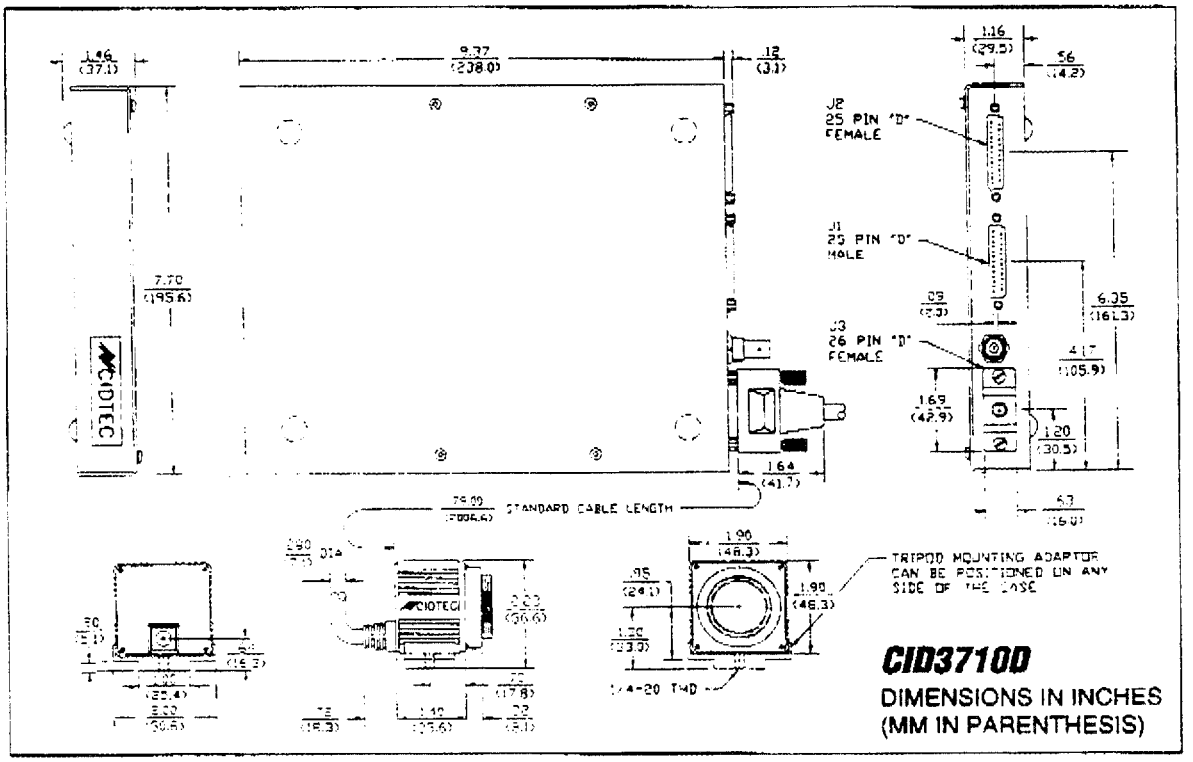
| | | |
|---|---|---|
| Outputs | (J1) | Video, End of Field, End of Line, H&V Drive, Composite Sync and Blanking, Field 1 ID, Strobe Trigger |
| | (J2) | Video, ALC, 14.318 MHz ER Clock |
| | BNC | Composite Video |
| Inputs | (J1) | +15VDC, Composite Sync (D3), H Drive (D4) |
| | (J2) | V Drive (D4), Dump, Inject Inhibit, Frame Reset, External Trigger |

## Mechanical

| | | |
|---|---|---|
| Weight | | CCU - 0.79 kg. (28 oz.)<br>CH (less cable) - 0.16 kg. (5.6 oz.) |
| Dimensions | | See Outline Drawing |
| Cable Length | | 2 meters (other lengths optional) |
| Lens Mount | | Standard C Mount (1.00" - 32 Thread) |
| Camera Mount | | 1/4" - 20 Thread |
| Connectors | (J1) | 25 Pin D (male) |
| | (J2) | 25 Pin D (female) |
| | (J3) | 26 Pin D (female) |
| | | Standard BNC |

## SPECTRAL RESPONSE

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ontario hydro

700 University Avenue, Toronto, Ontario M5G 1X6

## Summary of Test Results

| | |
|---|---|
| Device Tested : | CID3710D2-20 Solid State Camera with 10 meter cable and Class "B" sensor. |
| Manufacturer: | CID Technologies Inc. |
| Date: | August 24, 1993 |
| Location: | McMaster University, Hamilton, Ontario |
| Purpose: | To measure Camera Head performance under radiaion. |

| | |
|---|---|
| Reported by: | Sam Lin, Ontario Hydro |
| Witnessed by: | R. A. Carta, CIDTEC<br>M. Butler, McMaster University |

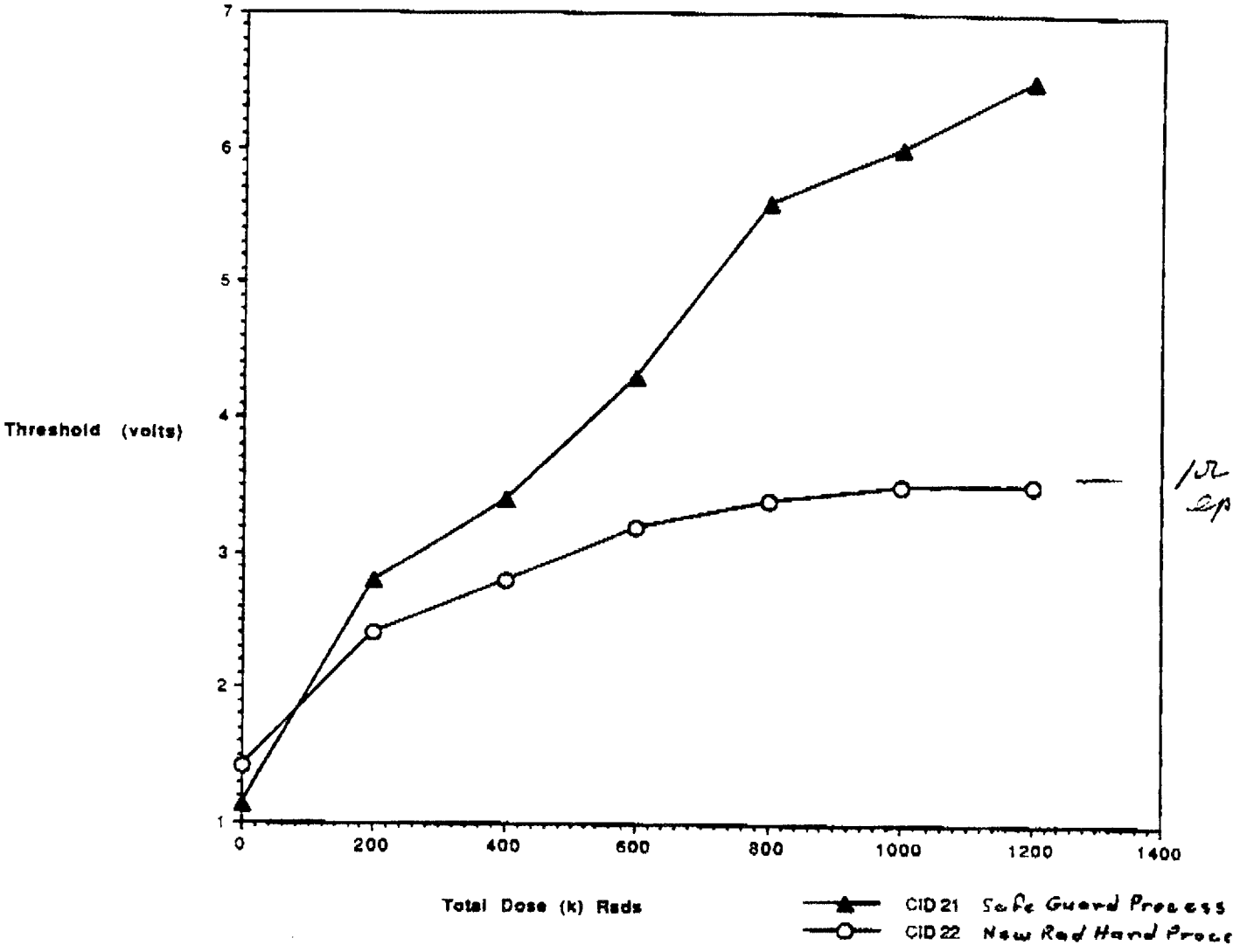
| | |
|---|---|
| Radiation Source: | Cobalt 60, 4000 Currie |
| Dose Rate: | Camera operational at 5.5 Krad/hr to 450 Krad/hr |
| Integrated Dose: | Camera Failed after Receiving 276 Krad. |
| Maximum S/N Ratio: | 43.2 dB at 5.5 Krad<br>40.2 dB at 59 Krad<br>32.8 dB at 450 Krad |

Observations:

- Minimal Annealing was observed after the test.
- The standard head electronics was undamaged by the test. The camera operated normally after the damaged sensor was replaced.
- Was able to improve picture quality by adjusting the EPI and Horizontal Scanner Drive Voltage.

Ontario Hydro Test

Gate Threshold shift of irradiated CID 21's and CID 22's



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101 Commerce Boulevard
Liverpool, New York 13088
(315) 451-9410 FAX (315) 451-9421

# Effects of Ionizing Radiation On CID Sensors

The thicker the silicon oxide/nitride dielectric, the more susceptible the sensor is to ionizing radiation damage.

The present CID process called the "safe guard process", uses two (2) dielectric layers. The first layer is silicon oxide and the second layer is silicon nitride which is more prone to damage by ionizing radiation.

To harden the sensor further, the process would be modified to remove the silicon nitride layer which is more prone to radiation damage and at the same time it would thin the dielectric thereby serving a dual purpose.

The CID is built on a PMOS structure. When irradiated, gate voltage thresholds in the scanners shift in a direction where the on state is not as strong. However, the on/off function of the device is still intact. Readjusting the bias levels of the gates restores the strength of the on state.

CCD's, which are built on NMOS structures, tend to turn on stronger when exposed to ionizing radiation which means they are moving toward a short and can not be restored to normal operation by adjusting the bias. Moreover, they become more difficult to turn off.

In the CID, the signal charge need not be transfered out of the pixel site were it is collected to be sensed. With the CCD, the signal charge has to be transferred across and down to one corner the sensor to the output amplifier to be sensed. Radiation damage degrades the charge transfer efficiency of a CCD making it much more susceptible to radiation environments.

In the CID,well capacity drops when exposed to a radiation environment, but the scanners even though they have wide margins for threshold shift would shut down before the pixel wells would be totally depleted.

R.A.Carta
March 1, 1991

# ELECTRONIC ANALYSIS OF CHARGED PARTICLE AND FISSION FRAGMENT DISTRIBUTIONS: NUCLEAR TRACK TECHNIQUE IN REAL-TIME

R. Gregory Downing
National Institute of Standards and Technology, Center for Analytical Chemistry, Gaithersburg, Maryland, U.S.A. 20899

A real-time electronic position sensitive detection system for analyzing charged particle emission has been developed over the past three years based on the electronic properties of the Charged Injection Device (CID), optical cameras and advances in personal computer technology. This class of charge transfer device has advantages over the charge coupled device (CCD) for studies that historically have required plastic nuclear track detectors or other solid-state charged particle detector media. The CID is inherently more resistant to radiation damage than the CCD, thereby allowing its use with intense neutron fields for the detection of neutron-induced fission fragments or charged particles. Using the appropriate electronics, the electronic state of individual pixels from the array may be queried without altering the contents, and allowing repetitive verification of event-position information if needed. The detector system shows stability over periods of weeks, allowing long-term exposures and yielding good detection limits for spontaneous events with little or no background interference. Events that strike the boundary between pixel elements are not lost, and experiments indicate essentially 100% detection of particles that exceed certain energy thresholds and impinge upon the surface of the CID. The surfaces are reasonably rugged and the system is simple to use. Several different pixel and device sizes are available to suit particular applications. Thus far, the detection system has been operated at TV frame-rates although the system can be read much more rapidly. Software has been developed for a personal computer to allow: 1) real-time viewing of experimental results, 2) cumulative statistics on events at individual pixels without concern for "burn-out" (i.e. loss of information from numerous overlapping track producing events), 3) mapping of the distribution of events including registration to the physical sample source, 4) moderate capabilities for energy discrimination of events, 5) electronic output of track maps in digital and hard-copy formats, and 6) background subtraction. Sample handling, registration of emission source to the tracks and the processing time of the data is significantly enhanced with the system. Examples of low level geological studies and technological applications will be presented as well as a description of the instrumentation.

August 23, 1991

Dear Bob,

This note is in response to our phone conversation of this morning concerning the use of CIDTEC cameras in neutron fields. By way of example the camera models 2710 and 3710 have been used extensively in our collaborative studies at the NIST 20 megawatt research nuclear reactor facilities. Both the full camera with sensor and remote head model camera with sensor have been used in direct neutron beam studies. Although the gamma doses in our beams are very moderate, of the order of 1 rad/hr, the time in beam has extended for over 6 weeks of cumulative irradiation for a couple of the sensor chips. Many other chips have been used for shorter time periods. The remote head electronics has seen even greater total time in beam as have the non-remote camera as we change the sensor chips on occasion to use for other purposes.

The neutron beam fluence rate ranges up to 6 x $10^8$ n/cm$^2$/sec. Usually though the beam strength is of the order of $10^7$ n/cm$^2$/sec. This is a thermalized neutron beam. Total dose to any one sensor could be as high as $10^{13}$ neutrons and to the electronics directly behind the sensor chip. No chip has had to be replaced due to neutron damage. All the camera's functions met or exceeded our needs for live-mode operation in neutron/gamma exposure. Because of the basic design and function of the CID device it was chosen for the studies over the CCD design.

I have some suggestions and observations concerning the proposed use in underground testing. Fast neutrons damage the camera and sensor more severely than thermal neutrons, however the neutrons field coming from the blast are described as being secondary. This means that a significant amount of thermalization will occur, reducing potential damage. Also the damage to the camera is not likely to be fatal to its functioning but only reduce its dynamic range. This is impart due to the design of the chip.

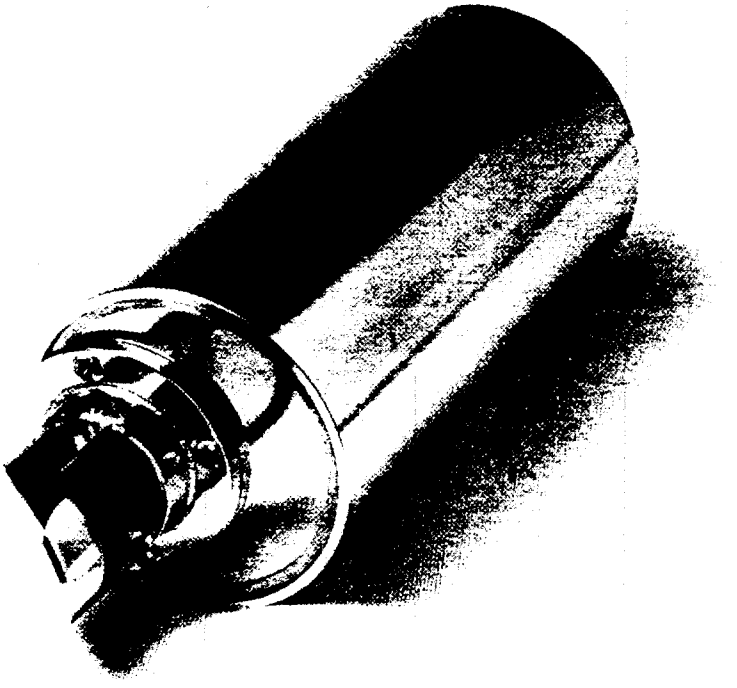
Another point you might consider is that the cover plate to the sensor might discolor during irradiation. This could effect the subsequent use of the camera during and after the blast. This cover plate might be replaced with another material, but perhaps it could be dispensed with completely. This is how we use the camera and have had no difficulties functioning in this fashion. The plates are often off the sensor for months at a time. Also the cover plates contain boron which could affect any measurements made at the time of irradiation.

I realize this is brief but hopefully it will qualitatively answer some of the questions. I will be happy to help further if needed. The project is interesting enough that I would casually offer to consult/collaborate if desired.

Best regards,

R. Gregory Downing, Ph. D.
Nuclear Methods Group,
National Institute of Standards and Technology
(301) 975-6286

# RCS-510
# Radiation Tolerant Zoom Color Television Camera



The model RCS-510 camera uses a miniature high resolution Y-C forma camera, a precision front surface mirror and extensive lead shielding to achieve a high radiation tolerance. A 22-90 mm zoom lens with non-browning optics and a very short near focal distance of 10 inches makes the RCS-510 camera ideal for close-up detail color inspections in a high radiation field.

The stainless steel housing is completely sealed and tested for underwater use to 150 feet.

The RCS-510 camera is designed specifically to operate with the model CU-141( rack mountable controller. This unit provides appropriate power to the camera and incorporates remote controls for the zoom, focus, iris and shutter functions

A stainless steel connector on the back of the housing mates with the intercon necting cable. With the model R12364 polyurethane jacket cable assembly, th camera and controller can be separated by up to 400 feet.

**FEATURES:**

- **Underwater or in-air operation.**
- **High resolution color.**
- **Radiation tolerant to 3.17 x $10^7$ rads accumulated dose (0.5 MeV) $Co^{60}$.**
- **22-90 mm non-browning zoom lens.**
- **10 inch near focus distance.**
- **Remote zoom, focus, iris and shutter controls.**
- **Rugged stainless steel modular construction.**
- **Cable length to 400 feet.**

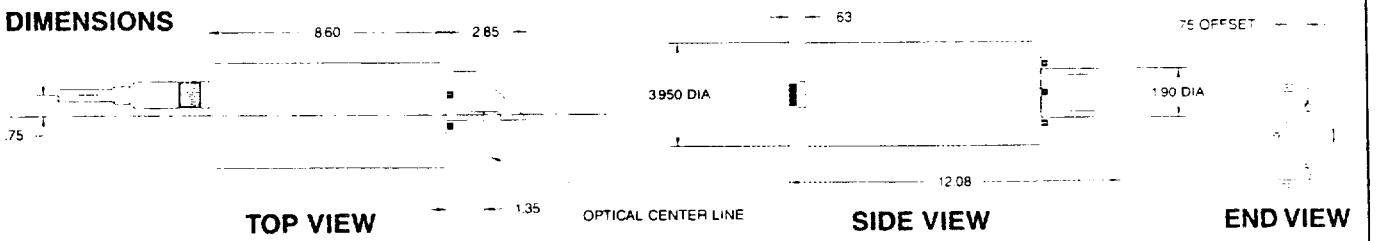
# R.J. Electronics

5504 Val View Drive S.E. • Turner, Oregon 97392

(503) 743-3709 • (503) 743-3706 • Fax (503) 743-3707


| SYSTEM SPECIFICATIONS | MODEL RCS-510 CAMERA |
|---|---|
| POWER: | 12 VDC supplied via Model CU1410 controller. |
| SENSOR: | ½" interline transfer CCD. |
| SCAN AREA: | 6.54 × 4.89 mm. |
| HORIZONTAL RESOLUTION: | 460 TV lines. |
| MINIMUM SCENE ILLUMINATION: | 100 lux at f/3.5. |
| RECOMMENDED SCENE ILLUMINATION: | 1300 lux at f/3.5. |
| S/N RATIO: | 46 dB. |
| OUTPUT IMPEDANCE: | 75 Ohms. |
| LENS: | Special zoom lens with non-browning optics. |
| ZOOM: | 22-90 mm remotely controlled. |
| FOCUS: | 10 inches to infinity remotely controlled. |
| IRIS: | f/3.5 to f/45 remotely controlled. |
| SHUTTER: | 1/60 sec. to 1/10,000 sec. remotely controlled. |
| IN-AIR FIELD OF VIEW: | 16.90 deg. to 4.16 deg. horizontal. |
| UNDERWATER FIELD OF VIEW: | 12.69 deg. to 3.13 deg. horizontal. |
| HOUSING DIAMETER: | 3.95 inches. |
| HOUSING OVERALL LENGTH: | 12.40 inches. |
| IN-AIR WEIGHT: | 28 pounds. |
| IN-WATER WEIGHT: | 12 pounds. |
| HOUSING MATERIAL: | 300 series stainless steel. |
| WINDOW MATERIAL: | Non-browning fused quartz. |
| CONNECTOR: | Model RCS-1501-BC stainless steel. |
| MATING CONNECTOR: | Model RCS-1501-CC. |
| DEPTH RATING: | 150 feet. |
| TEMPERATURE RATING: | −10 to 40 deg. C (14 to 104 deg. F). |
| RADIATION TOLERANCE: | $3.17 \times 10^7$ accumulated dose 0.5 MeV $Co^{60}$.<br>$6.34 \times 10^7$ accumulated dose 0.5 MeV $Ce^{137}$.<br>$1.8 \times 10^5$ accumulated dose 1.0 MeV $Ce^{60}$.<br>$3.6 \times 10^5$ accumulated dose 1.0 MeV $Ce^{137}$. |
| RADIATON DOSE RATE: | Up to $3 \times 10^3$ rads/hr. $Co^{60}$. |
| CABLE LENGTH: | Up to 400 feet. |

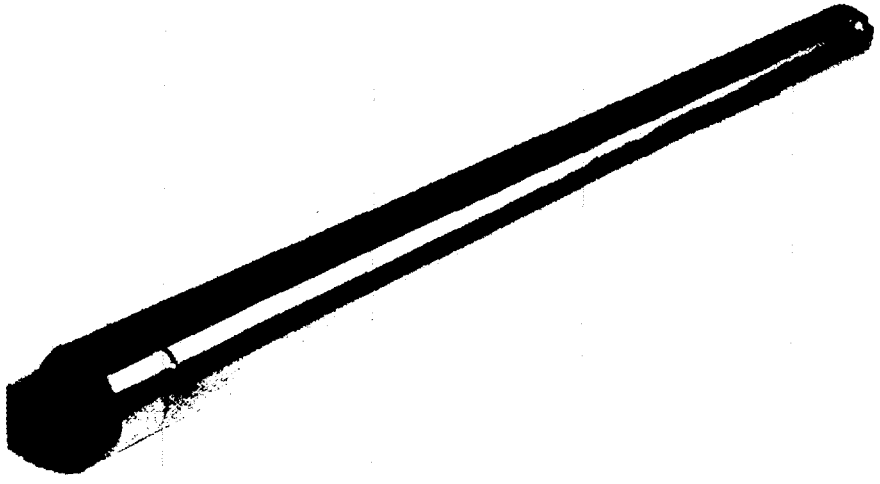
**DIMENSIONS**




**NOTES:**

1. RJ Electronics should be consulted with regard to very critical viewing requirements, or in cases where there are important lighting, resolution, environmental or viewing angle considerations.
2. In applications where there are severe space constraints care should be taken to allow for the size of the camera cable mating connector and if necessary, the bend radius of the connecting camera cable.
3. RJ Electronics reserves the right to change the above information without notice.

# RCS-810 and RCS-800
# Downhole Color Compass Television Camera Systems



The model RCS-810 is a Miniature Color Television Camera for underwater or in-air inspection of 2" and larger boreholes, pipelines and well casings.

On the screen display of inclination, magnetic bearing and bore-view picture top orientation are generated via an integral video compass/inclinometer.

Focus, rotate, dual lighting intensity and electronic shutter are all remotely operated via the control unit's function control panel.

The Bore View Camera utilizes the superior S-Video television standard for maximum resolution and signal to noise.

A range of interchangeable bayonet mount viewing heads with integral lighting provide a choice of axial and radial views. The RCS-803 Scanning Head incorporates a motorized mirror for detailed inspection of the bore walls, with illumination by two independently controlled integral light sources.

The model RCS-800 is a bore view only camera compatible with the RCS-810 viewing heads, cables and controller.

**FEATURES:**

- **Underwater or in-air operation.**
- **High resolution color — S-Video.**
- **Interchangeable viewing heads.**
- **Small size — 1.6 inch diameter housing.**
- **Remote focus, shutter, scan motor, and light controls.**
- **Rugged stainless steel construction.**
- **Cable length to 400 feet.**
- **Precision video compass and inclinometer.**

# R.J. Electronics

3504 Mat View Drive S.E. Turner, Oregon 97392
(503) 745-5709 • (503) 745-5706 • Fax (503) 745-5707

## SYSTEM SPECIFICATIONS — MODEL RCS-800 AND RCS-810 CAMERA

| | |
|---|---|
| SENSOR: | ½" interline CCD. |
| SCAN AREA: | 6.54 × 4.89 mm. |
| HORIZONTAL RESOLUTION: | 460 TV lines. |
| MINIMUM SCENE ILLUMINATION: | 15 lux at f/1.6. |
| RECOMMENDED SCENE ILLUMINATION: | 200 lux at f/1.6. |
| S/N RATIO: | 46 db. |
| LENS: | See Camera Head Specification. |
| FOCUS — MOTORIZED: | 0.5 inch to infinity. |
| ELECTRONIC SHUTTER — REMOTELY CONTROLLED: | 1/60 sec. to 1/10,000 sec. |
| HOUSING DIAMETER: | 1.60 inches. |
| LENGTH WITH RCS-801 AXIAL VIEW HEAD 800/810: | 9.6 inches/24.7 inches. |
| LENGTH WITH RCS-803 SCANNINGHEAD 800/810: | 18.4 inches/33.5 inches. |
| WEIGHT WITHOUT HEAD 800/810: | 2.59/5.48 pounds. |
| HOUSING MATERIAL: | 300 Series Stainless Steel. |
| CONNECTOR MODEL: | Model RCS-1501-BC Stainless Steel. |
| DEPTH RATING: | See View Head Specification. |
| TEMPERATURE RATING: | 14° to 122° F (-10° to 50° C). |
| CABLE LENGTH: | Up to 400 feet. |
| AMBIENT HUMIDITY | 100%. |

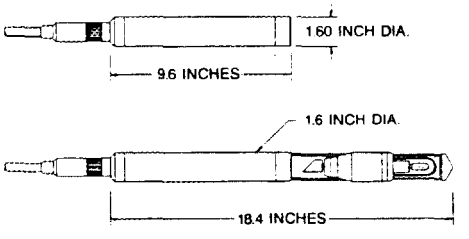
## AXIAL HEAD SPECIFICATION — RCS-801

| | |
|---|---|
| LAMP VOLTAGE: | 0-30 VDC. |
| LAMP POWER: | 10 watts. |
| LENS: | f1.6 7.5 mm. |
| IN-AIR FIELD OF VIEW: | 36.4° × 48.2°. |
| IN-WATER FIELD OF VIEW: | 27.2° × 35.8°. |
| LAMPS: | 8 Focused Bi-Pin Lamps. |
| LAMP LIFE: | 100 hours at Full Power. |
| HOUSING DIAMETER: | 1.6 inches. |
| WEIGHT: | 0.39 pounds. |
| MATERIAL: | 300 Series Stainless Steel |
| WINDOW MATERIAL: | Polished Acrylic. |
| DEPTH RATING: | 300 feet. |

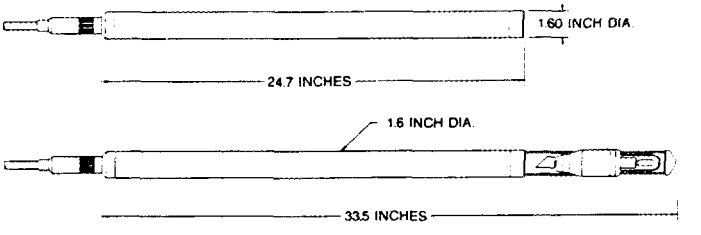
## SCANNING HEAD SPECIFICATION — RCS-803

| | |
|---|---|
| SCANNING LAMP VOLTAGE: | 0 - 30 VDC. |
| SCANNING LAMP POWER | 12 watts. |
| SCANNING LAMP LIFE: | 50 hours at Full Power. |
| FORWARD LAMP VOLTAGE: | 0 - 15 VDC. |
| FORWARD LAMP POWER | 35 watts. |
| FORWARD LAMP LIFE | 100 hours at Full Power. |
| FORWARD LAMP ENCLOSURE: | Fused Quartz Pressure Envelope. |
| LENS: | f1.6 7.5 mm. |
| IN-AIR FIELD OF VIEW: | 36.4° × 48.2°. |
| UNDERWATER FIELD OF VIEW: | 27.2° × 35.8°. |
| MIRROR ROTATION: | Bi-directional — Remote. |
| HOUSING DIAMETER: | 1.6 inches. |
| WEIGHT: | 1.96 pounds. |
| HOUSING MATERIAL: | 300 Series Stainless Steel. |
| DEPTH RATING: | 300 feet. |

## DIMENSIONAL DRAWING RCS-800




## DIMENSIONAL DRAWING RCS-810




**NOTES:**

1. **RJ Electronics should be consulted with regard to very critical viewing requirements, or in cases where there are important lighting, resolution, environmental or viewing angle considerations.**
2. **RJ Electronics reserves the right to change the above information without notice.**

# VIDEO INSPECTION PRODUCTS

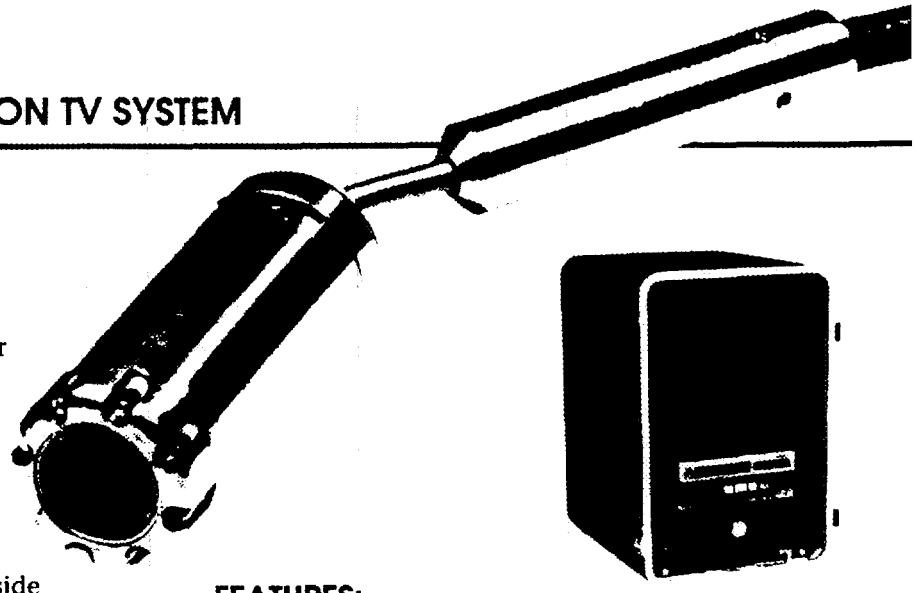
R.J. Electronics, Inc.

Crestone Products, Inc.

# ACE

## MINIATURE PIPELINE INSPECTION TV SYSTEM

MODEL RCS-700



### DESCRIPTION:

The ACE model RCS-700 camera is a miniature high resolution Y-C format color TV camera designed for internal pipeline inspection. It incorporates a ring of eight high-output variable intensity lights for optimized illumination.

The stainless steel housing is completely sealed for underwater use to 100 feet and incorporates a front viewing window of polished acrylic. Modular construction inside allows easy maintenance or replacement of the CCD camera or other components, if necessary.

The RCS-700 camera operates with the model CU-1310 controller, which incorporates remote controls for the camera shutter and lights.

For pipeline inspection applications, the ACE camera is normally supplied with a short flexible cable section near the camera and a longer semi-rigid primary cable. With the model R12364P polyethylene jacketed push cable, the camera and controller can be separated by up to 400 feet.

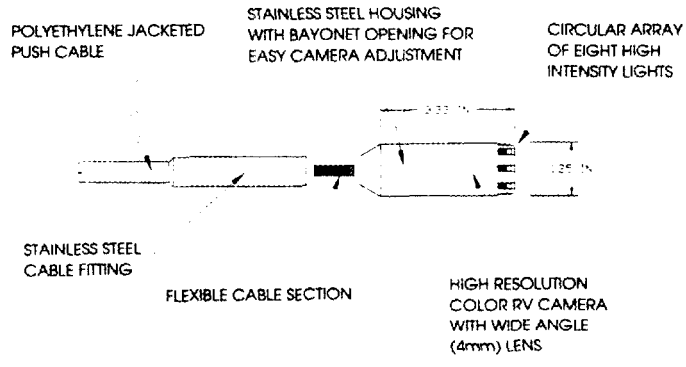
The ACE camera is available with a stainless steel electrical connector and with other cable configurations for special applications. Other versions of the ACE camera are also available for use on longer cables. Special low-friction centering devices are available for push (or pull) applications in pipe diameters up to six inches.

### FEATURES:

- UNDERWATER OR IN-AIR OPERATION
- HIGH RESOLUTION COLOR
- BUILT-IN LIGHTING
- SMALL SIZE — 1.25 INCH DIAMETER HOUSING
- REMOTE SHUTTER SPEED AND LIGHT CONTROL
- WIDE ANGLE 4mm LENS
- RUGGED STAINLESS STEEL CONSTRUCTION
- CABLE LENGTH TO 400 FEET

### SPECIFICATIONS:

| | |
|---|---|
| CAMERA VOLTAGE: | 12 VDC |
| SENSOR: | 1/2 in. interline transfer CCD |
| SCAN AREA: | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION: | 460 TV lines |
| MINIMUM SCENE ILLUMINATION: | 30 lux at f/2 |
| RECOMMENDED SCENE ILLUMINATION: | 400 lux at f/2 |
| S/N RATIO: | 46 dB |
| OUTPUT IMPEDANCE: | 75 Ohms |
| LENS: | 4 mm, f/2.0 |
| FOCUS: | 0.3 inch to infinity manually adjustable |
| IRIS: | f/2.0 manually adjustable |
| SHUTTER: | 1/60 sec. to 1/10,000 sec. remotely controlled |
| IN-AIR FIELD OF VIEW: | 69.1 x92.1 deg. (vertical x horizontal) |
| UNDERWATER FIELD OF VIEW: | 50.5 x 65.5 deg. (vertical x horizontal) |
| LAMPS: | 8 high intensity bi-pin |
| LAMP POWER: | 0-30 VDC, 8.8 watts |
| LAMP LIFETIME: | 30 hours @ full power |
| HOUSING DIAMETER: | 1.25 inches |
| HOUSING LENGTH: | 3.33 inches to rear shoulder |
| HEAD WEIGHT: | 0.87 pounds |
| HOUSING MATERIAL: | 300 series stainless steel |
| WINDOW MATERIAL: | polished acrylic |
| DEPTH RATING: | 100 feet |
| TEMPERATURE RATING: | -10 to 50 deg. C (14 to 122 deg. F) |
| CABLE LENGTH: | Up to 400 feet |



# "LONG ACE"

## MINIATURE PIPELINE INSPECTION TELEVISION SYSTEM
## MODEL RCS-710

DESCRIPTION:

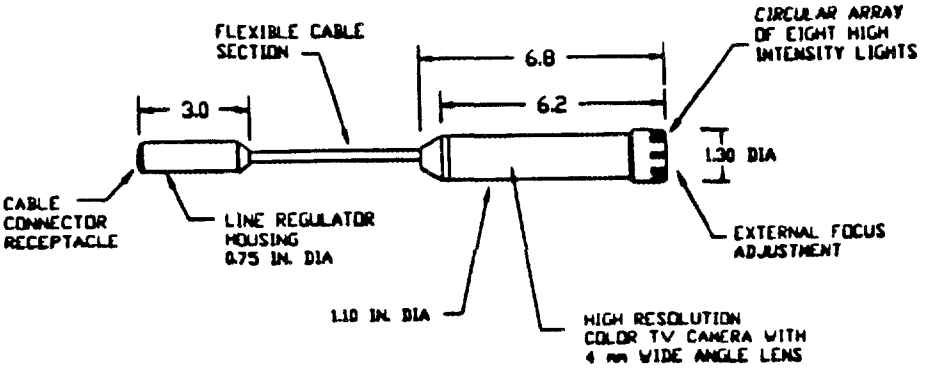
The model RCS-710 is a Miniature Color "Push" Type Camera for the internal inspection of pipelines up to 1,000 ft. in length. It incorporates a ring of eight high output variable intensity lamps for optimum illumination.

The camera features an in-line connector to allow the lightweight camera cable to be detached for ease of handling and storage.

The RCS-720 is an articulated version of the RCS-710 which allows the camera to negotiate 6 inch radius bends in 1.5 inch diameter pipes.

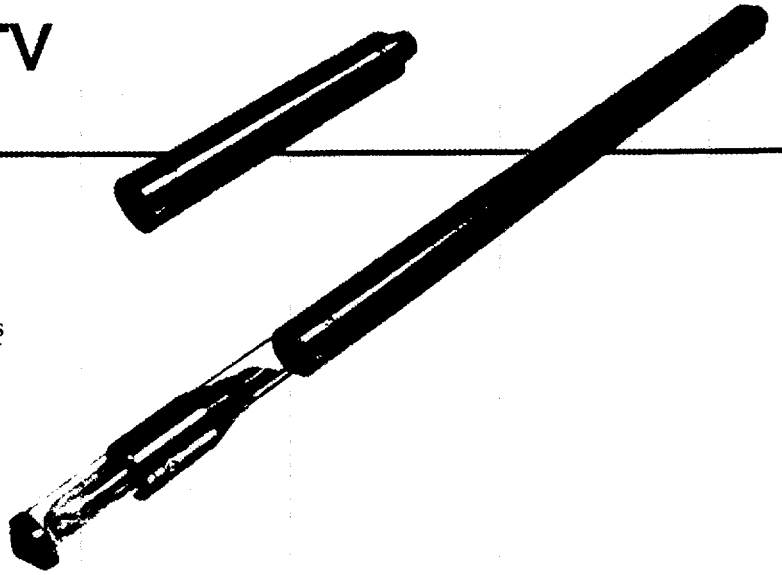
SPECIFICATIONS

| | |
|---|---|
| POWER: | 15 VDC supplied via controller |
| SENSOR: | 1/2 inch interline transfer CCD |
| SCAN AREA: | 6.4 x 4.8 mm. |
| HORIZONTAL RESOLUTION: | 470 TV lines |
| MINIMUM SCENE ILLUMINATION: | 4.5 lux at f/1.2 |
| RECOMMENDED SCENE ILLUMINATION: | 60 lux at f/1.2 |
| S/N RATIO: | 48 dB AGC off |
| OUTPUT IMPEDANCE: | 75 Ohms |
| LENS: | 4 mm., f/2.0 |
| FOCUS: | 0.3 inch to infinity manually adjustable |
| IN-AIR FIELD OF VIEW: | 69.1 x 92.1 deg. (vertical x horizontal) |
| UNDERWATER FIELD OF VIEW: | 50.5 x 65.5 deg. (vertical x horizontal) |
| HOUSING DIAMETER: | 1.30 inches tapering to 1.10 inches |
| HOUSING LENGTH: | 8.5 inches |
| HEAD WEIGHT: | 250 grams |
| HOUSING MATERIAL: | Anodized aluminum |
| WINDOW MATERIAL: | Polished acrylic |
| TEMPERATURE RATING: | -10 to 40 deg.C (14 to 104 deg.F) |
| CABLE LENGTH: | Up to 1,000 feet |
| LIGHTING POWER: | 10 watts. |



# DOWNHOLE COLOR TV CAMERA SYSTEMS

MODELS RCS-800 AND RCS-810



## DESCRIPTION:

The model RCS-800 and RCS-810 downhole cameras are designed for in-air and underwater inspection of boreholes, pipelines and well casings. When equipped with the RCS-801 head, a high resolution color view down the bore is provided. With the RCS-803 head, a motorized scanning mirror provides a radial view of the borehole wall in the center of the screen with a downhole view around this central portion.

The model RCS-810 camera also includes a video compass and inclinometer. When switched on, a compass and inclinometer view is displayed on the video monitor and can be recorded for later analysis. This view provides: (1) the magnetic heading for the picture top of the main viewing camera, (2) the slant angle of the borehole, and (3) the magnetic heading (down the bore) of a slanting borehole.

The axial (forward view) head is equipped with a ring of eight high intensity focused lamps for illumination of the borehole. The scanning head is equipped with a ring of eight wide-angle lamps for illumination of the bore for the right angle view and a single high intensity quartz halogen lamp for axial view illumination.

The camera housing and viewing heads are made of stainless steel and are sealed for underwater use to 300-foot depths. The camera and heads, equipped with a bayonet mounting, can be interchanged without internal adjustments to the camera or controller.

Both cameras operate with the model CU-1210 rack mountable controller. This unit provides appropriate power and control for the cameras, lights, scanning mirror motor, focus motor and camera shutter.

## FEATURES:

- UNDERWATER OR IN-AIR OPERATION
- HIGH RESOLUTION COLOR
- INTERCHANGEABLE VIEWING HEADS
- SMALL SIZE — 1.6 INCH DIAMETER HOUSING
- REMOTE FOCUS, SHUTTER, SCAN MOTOR AND LIGHT CONTROLS
- RUGGED STAINLESS STEEL CONSTRUCTION
- CABLE LENGTH TO 400 FEET
- PRECISION VIDEO COMPASS AND INCLINOMETER (RCS-810 only)

## SPECIFICATIONS:

| | |
|---|---|
| CAMERA VOLTAGE: | 12 VDC supplied via model CU1210 controller |
| SENSOR: | 1/2 in. interline transfer CCD |
| SCAN AREA: | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION: | 460 TV lines |
| MINIMUM SCENE ILLUMINATION: | 15 lux at f/1.6 |
| RECOMMENDED SCENE ILLUMINATION: | 200 lux at f/1.6 |
| S/N RATIO: | 46 dB |
| OUTPUT IMPEDANCE: | 75 Ohms |
| LENS: | See camera head specifications |
| FOCUS: | 0.5 inch to infinity remotely controlled |
| SHUTTER: | 1/60 sec. to 1/10,000 sec. remotely controlled |
| HOUSING DIAMETER: | 1.60 inches |
| LENGTH WITH AXIAL HEAD (800/810): | 9.6 / 24.7 inches |
| LENGTH WITH SCANNING HEAD (800/810): | 18.4 / 33.5 inches |
| WEIGHT WITHOUT HEAD (800/810): | 2.59 / 5.48 pounds |
| HOUSING MATERIAL: | 300 series stainless steel |
| CONNECTOR: | Model RCS-1501-BC stainless steel |
| MATING CONNECTOR: | Model RCS-1501-CC |
| DEPTH RATING: | 300 feet |
| TEMPERATURE RATING: | -10 to 50 deg. C (14 to 122 deg. F) |
| CABLE LENGTH: | Up to 400 feet |

MODEL RCS-801 AXIAL HEAD

| | |
|---|---|
| LAMP POWER: | 0-30 VDC, 10 watts |
| LAMP TYPE: | 8 focused bi-pin lamps |
| LAMP LIFETIME: | 100 hours @ full power |
| LENS: | f/1.6, 7.5 mm focal length (modified) |
| IN-AIR FIELD OF VIEW: | 36.4 deg. x 48.2 deg. |
| UNDERWATER FIELD OF VIEW: | 27.2 deg. x 35.8 deg. |
| HOUSING DIAMETER: | 1.60 inches |
| WEIGHT (head only): | 0.39 pound |
| HOUSING MATERIAL: | 300 series stainless steel |
| WINDOW MATERIAL: | Polished acrylic |
| DEPTH RATING: | 300 feet |

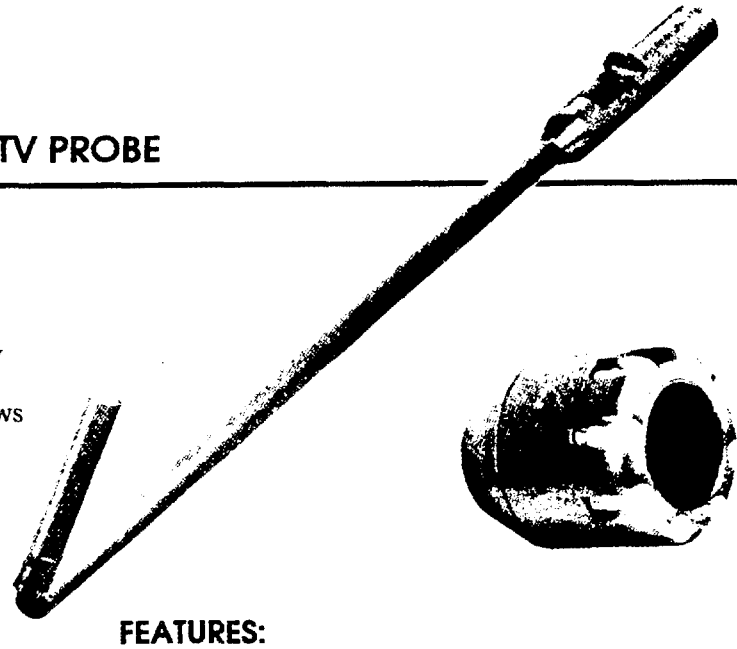
MODEL RCS-803 SCANNING HEAD

| | |
|---|---|
| SCANNING LAMP POWER: | 0-30 VDC, 12 watts |
| SCANNING LAMP LIFETIME: | 50 hours @ full power |
| FORWARD VIEW LAMP POWER: | 0-15 VDC, 50 watts |
| FORWARD LAMP LIFETIME: | 100 hours @ full power |
| LENS: | f/1.6, 7.5 mm focal length (modified) |
| IN-AIR FIELD OF VIEW: | 36.4 deg. x 48.2 deg. |
| UNDERWATER FIELD OF VIEW: | 27.2 deg. x 35.8 deg. |
| SCAN LAMP LIFE: | 50 hours @ full power |
| FORWARD LAMP LIFE: | 100 hours @ full power |
| FORWARD LAMP ENCLOSURE: | Fused quartz pressure envelope |
| HOUSING DIAMETER: | 1.60 inches |
| WEIGHT (head only): | 1.96 pounds |
| HOUSING MATERIAL: | 300 series stainless steel |
| WINDOW MATERIAL: | olished acrylic |
| DEPTH RATING: | 300 feet |

# VIDEO STICK

## MINIATURE ARTICULATING COLOR TV PROBE

MODEL RCS-900



### DESCRIPTION:

The Video Stick is a miniature articulating color TV probe. With a camera head diameter of only 0.8 inches and full articulation in any direction, it allows detailed inspection and observation in places that are difficult to reach. It incorporates a high resolution Y-C format color TV camera in the articulating head, and is controlled by the hand grip on the opposite end of a 3/4 inch diameter anodized aluminum pole. The standard six-foot insertion pole can be extended in six-foot increments.

The head angle is adjusted from straight ahead to straight back along the pole by sliding the angle adjustment knob on the hand grip. By rotating the hand grip, viewing is possible in any direction.

The splashproof camera housing is anodized aluminum for corrosion resistance, and allows manual external focus adjustment before insertion of the probe. Modular construction inside allows easy maintenance or replacement of the CCD camera or other components, if necessary.

The Light Stick (model RCS-1000) and Ring Light (model RL-200) can be used with the Video Stick if additional lighting is needed. The ring light incorporates eight miniature high intensity lights and attaches directly to the Video Stick. It is equipped with a power cord and locking plug for use with the model PS-150 variable intensity power supply.

### FEATURES:

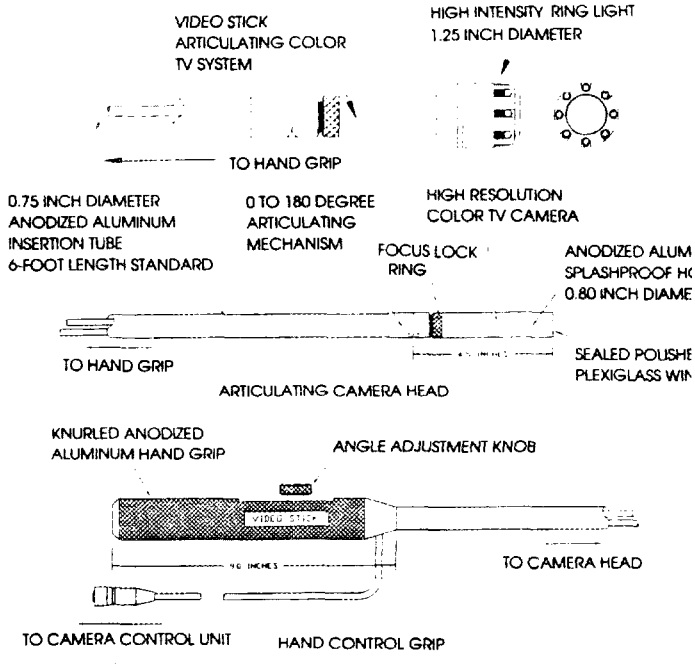
- SMALL SIZE: 0.80 INCH HEAD DIAMETER, 0.75 INCH TUBE DIAMETER
- SPLASHPROOF SEALED HOUSING
- FULL 180 DEGREE ARTICULATION ANGLE
- CORROSION RESISTANT ANODIZED ALUMINUM
- HIGH RESOLUTION Y-C FORMAT COLOR TV CAMERA
- MANUAL EXTERNAL FOCUS ADJUSTMENT
- WIDE ANGLE 4mm LENS
- EASY-TO-USE ANGLE ADJUSTMENT
- REMOTELY CONTROLLED CAMERA SHUTTER
- AUXILIARY HIGH INTENSITY RING LIGHT

### SPECIFICATIONS:

| | |
|---|---|
| CAMERA VOLTAGE: | 12 VDC supplied via camera control unit |
| SENSOR: | 1/2 in. interline transfer CCD |
| SCAN AREA: | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION: | 460 TV lines |
| MINIMUM SCENE ILLUMINATION: | 30 lux at f/2 |
| RECOMMENDED SCENE ILLUMINIATION: | 400 lux at f/2 |
| S/N RATIO: | 46 dB |
| OUTPUT IMPEDANCE: | 75 Ohms |
| LENS: | 4 mm, f/2.0 |
| FOCUS: | 0.2 inch to infinity manually adjustable |
| IRIS: | f/2.0 manually adjustable |
| SHUTTER: | 1/60 sec. to 1/10,000 sec. remotely controlled |
| FIELD OF VIEW: | 69.1 x 92.1 deg. (vertical x horizontal) |
| ARTICULATION ANGLE: | 0 to 180 degrees |
| HOUSING DIAMETER: | 0.80 inch |
| HOUSING LENGTH: | 4.5 inches to pivot |
| INSERTION TUBE DIAMETER: | 0.75 inch |
| INSERTION TUBE LENGTH: | 6.0 feet (standard) |
| WEIGHT: | 2.0 pounds |
| MATERIAL: | Anodized aluminum |
| WINDOW MATERIAL: | Polished acrylic |
| TEMPERATURE RATING: | -10 to 50 deg. C (14 to 122 deg. F) |

RING LIGHT (Model RL-200)

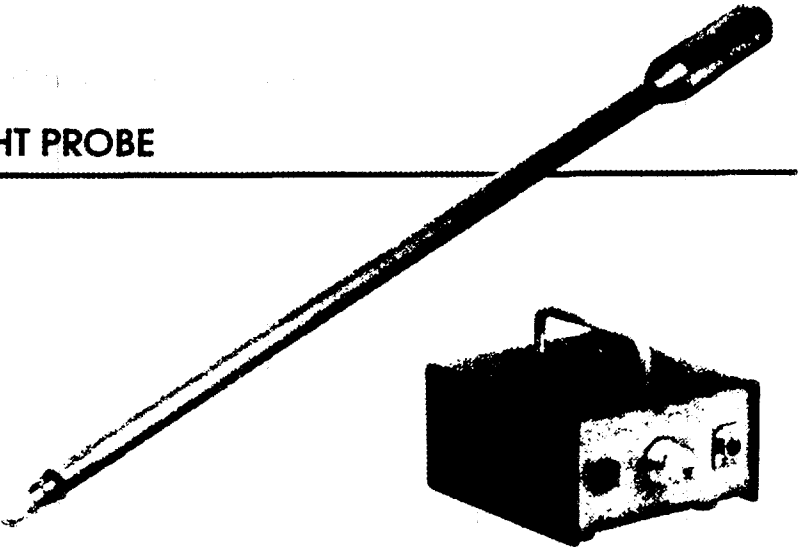
| | |
|---|---|
| VOLTAGE: | 0-15 volts |
| POWER: | 8.8 watts |
| LAMP TYPE: | High intensity bi-pin |
| LAMP LIFETIME: | 30 hours @ full power |
| SIZE: | 1.5 in. long x 1.25 in. dia. |
| WEIGHT: | 0.1 pound |



# LIGHT STICK

## SMALL DIAMETER WATERPROOF LIGHT PROBE

MODEL RCS-1000



### DESCRIPTION:

The Light Stick is a miniature quartz halogen light probe. With a head diameter of only 0.80 inch, and a pole diameter of 3/4 inch, it can be used to provide illumination in areas which are difficult to access. It is the ideal companion to the Video Stick color TV probe, and can also be used for direct viewing applications (tank inspection, etc.) and with other TV and fiber optics inspection probes.

The standard Light Stick incorporates a high intensity quartz halogen bulb which operates on 0-15 volts. It can operate continuously in air and because of the high thermal shock resistance of the protective quartz envelope, can be submerged or splashed with water while operating without damage.

The standard six-foot long insertion pole can be extended in six-foot increments.

The hand grip for the Light Stick has an easy-to-hold knurled surface. It is equipped with a connector socket which mates with the quick disconnect power cord connector. Standard power cord length is ten feet, but other lengths or extension cords can be provided.

The model PS-150 portable power supply provides variable illumination control for the Light Stick, Ring Light and similar low voltage light sources. For safety, the output power is isolated from the 120 volt input power. The front panel contains a locking output receptacle, the on-off switch, a control knob to vary the light output and an indicator light which varies in brightness with the variation in output voltage.

### FEATURES:

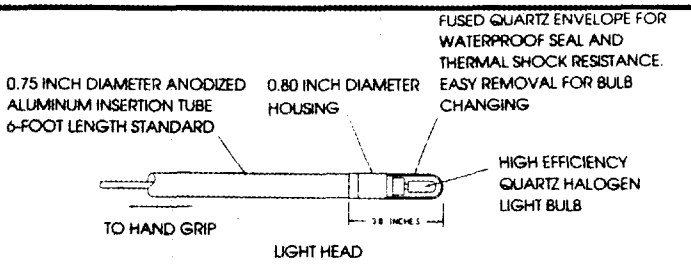
- SMALL SIZE: 0.80 INCH HEAD DIAMETER, 0.75 INCH TUBE DIAMETER
- SEALED WATERPROOF HEAD
- HIGH EFFICIENCY QUARTZ HALOGEN LIGHT BULB
- EASY BULB CHANGING
- LOW VOLTAGE FOR SAFETY
- QUARTZ ENVELOPE FOR WATERPROOF SEAL AND THERMAL SHOCK RESISTANCE
- CORROSION RESISTANT ANODIZED ALUMINUM
- QUICK DISCONNECT POWER CORD
- SIX-FOOT LONG INSERTION TUBE LENGTH STANDARD
- LENGTH EXTENDABLE IN SIX-FOOT INCREMENTS
- VARIABLE INTENSITY CONTROLLER

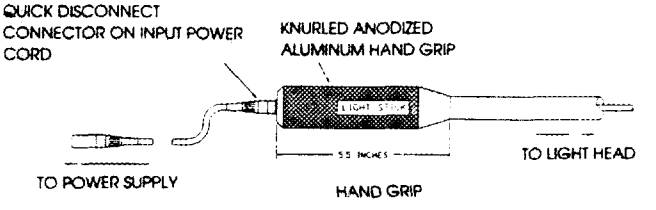
### SPECIFICATIONS:

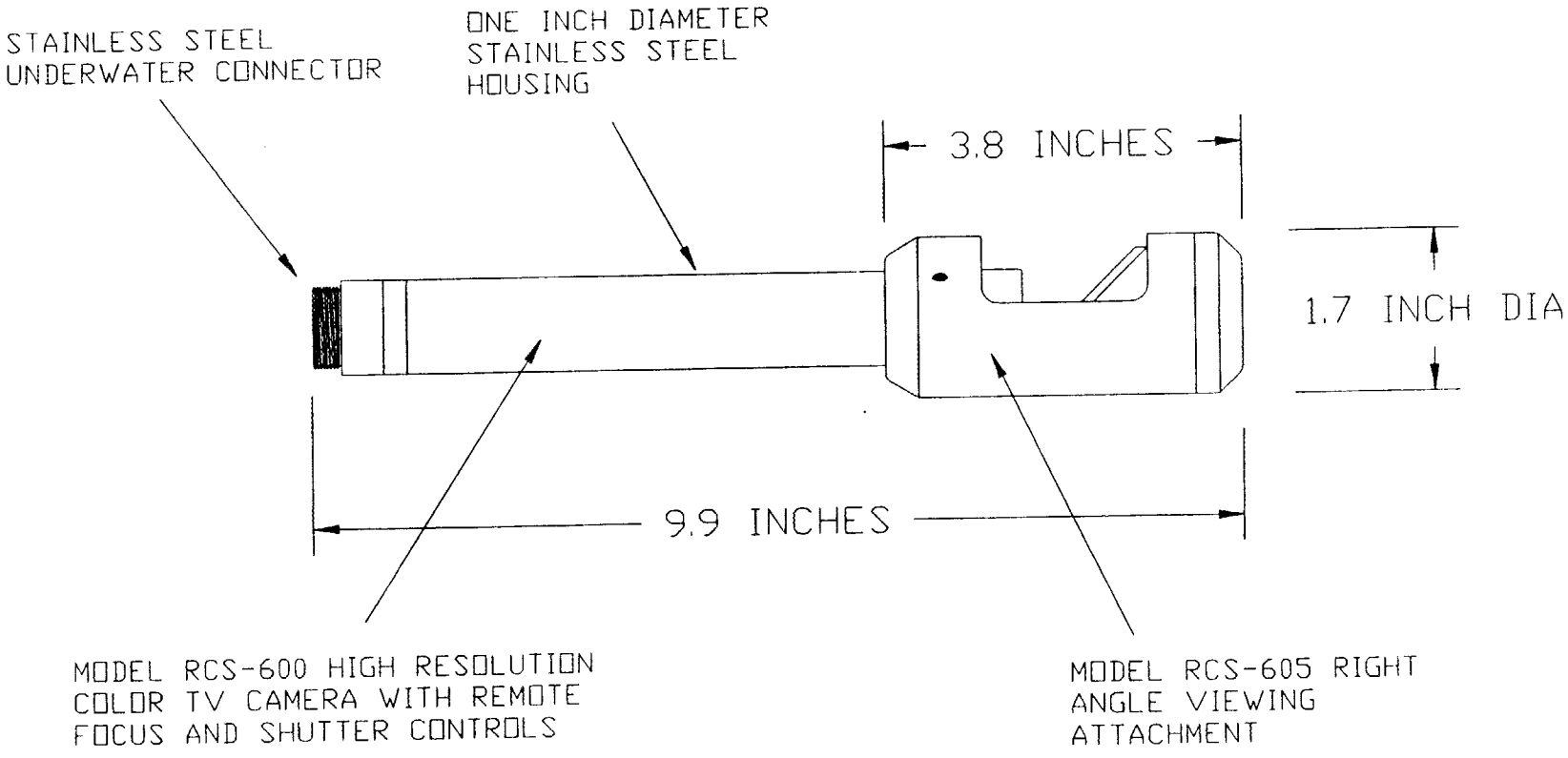
| | |
|---|---|
| VOLTAGE: | 0-15 volts |
| POWER: | 50 watts |
| LAMP TYPE: | Quartz Halogen |
| LAMP LIFETIME: | 100 hours @ full power |
| HOUSING DIAMETER: | 0.80 inch |
| INSERTION TUBE DIAMETER: | 0.75 inch |
| HOUSING LENGTH: | 3.0 inches |
| WEIGHT: | 1.8 pounds |
| MATERIAL: | Anodized aluminum |
| ENVELOPE MATERIAL: | Fused quartz |

POWER SUPPLY (Model PS-150)

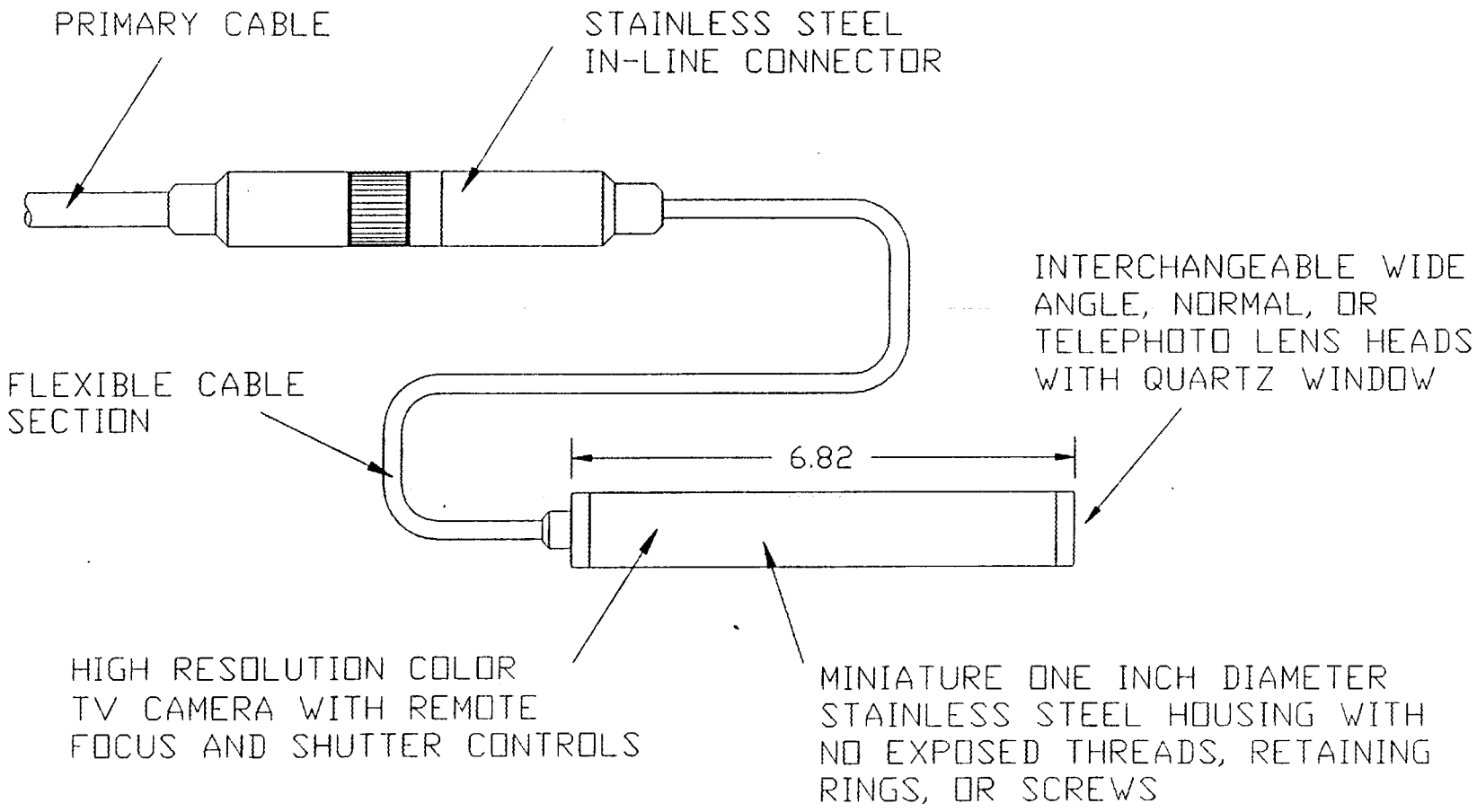
| | |
|---|---|
| INPUT POWER: | 120 VAC |
| POWER RATING: | 56 VA |
| OUTPUT: | 0-15 VAC |
| OUTPUT ISOLATION: | 2500 Volts RMS hipot |
| SIZE: | 3 x 5.25 x 5.88 inches |
| WEIGHT: | 3.0 pounds |
| OUTPUT POWER RECEPTACLE: | TY3F Locking |



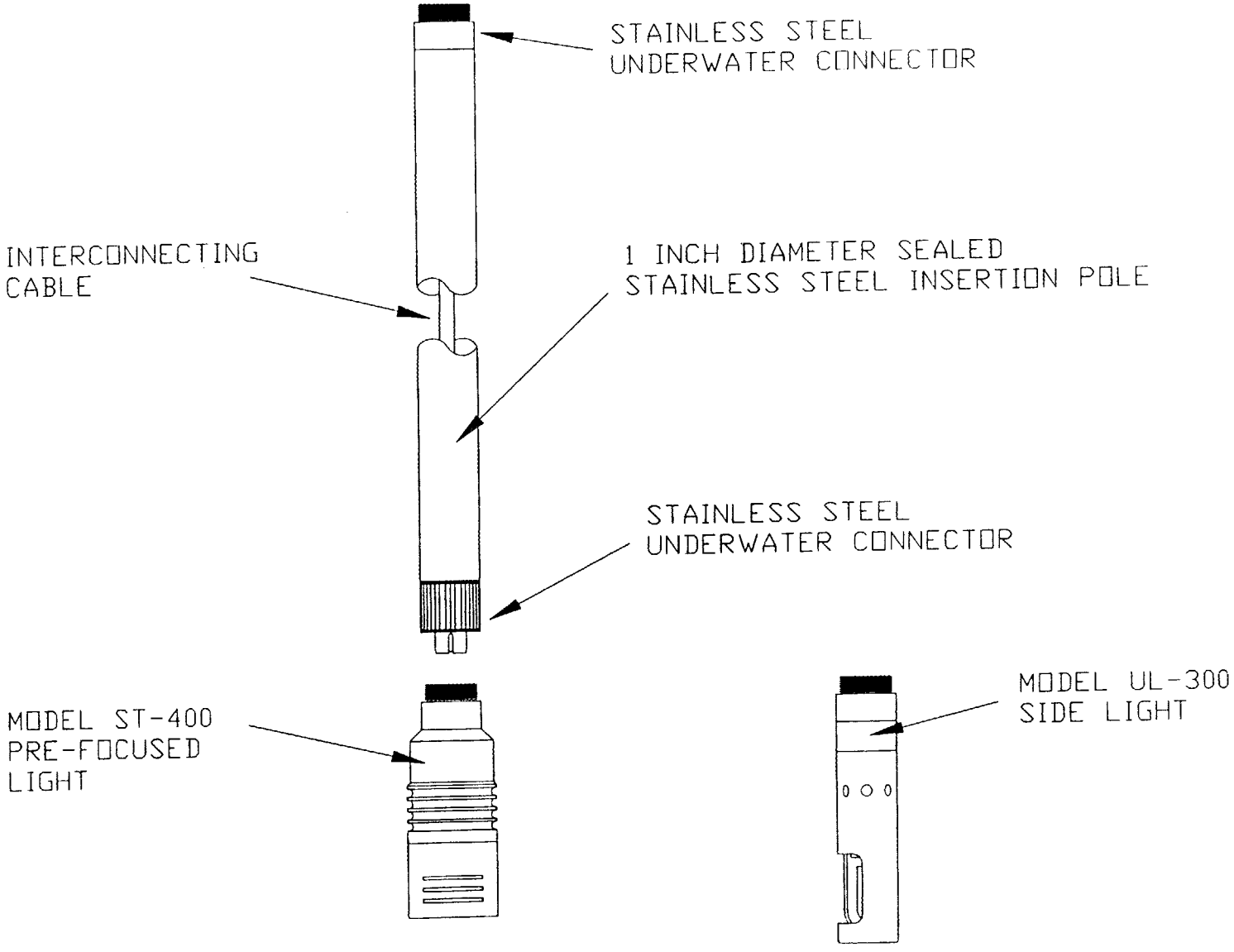






REMOTE FOCUS COLOR TV CAMERA WITH RIGHT ANGLE VIEWING ATTACHMENT




MODEL RCS-620 REMOTE FOCUS TV CAMERA




AUXILIARY LIGHTS AND INSERTION POLE FOR VALVE INSPECTION

# IN AIR SCENE ILLUMINATION

0
1300 Candela

| RANGE (Feet) | ILLUMINATION (Lux) |
|---|---|
| 5 | 559.72 |
| 10 | 139.93 |
| 15 | 62.19 |
| 20 | 34.98 |
| 25 | 22.39 |
| 30 | 15.55 |
| 35 | 11.42 |
| 40 | 8.75 |
| 45 | 6.91 |
| 50 | 5.60 |
| 55 | 4.63 |
| 60 | 3.89 |
| 65 | 3.31 |

0
2750 Candela

| RANGE (Feet) | ILLUMINATION (Lux) |
|---|---|
| 5 | 1184.03 |
| 10 | 296.01 |
| 15 | 131.56 |
| 20 | 74.00 |
| 25 | 47.36 |
| 30 | 32.89 |
| 35 | 24.16 |
| 40 | 18.50 |
| 45 | 14.62 |
| 50 | 11.84 |
| 55 | 9.79 |
| 60 | 8.22 |
| 65 | 7.01 |

0
5850 Candela

| RANGE (Feet) | ILLUMINATION (Lux) |
|---|---|
| 5 | 2518.76 |
| 10 | 629.69 |
| 15 | 279.86 |
| 20 | 157.42 |
| 25 | 100.75 |
| 30 | 69.97 |
| 35 | 51.40 |
| 40 | 39.36 |
| 45 | 31.10 |
| 50 | 25.19 |
| 55 | 20.82 |
| 60 | 17.49 |
| 65 | 14.90 |

# UNDERWATER SCENE ILLUMINATION
## ATTENUATION COEFFICIENT ALPHA = 0.1

0.1
1300 Candela

| RANGE (Feet) | ILLUMINATION (Lux) |
|---|---|
| 5 | 412.67 |
| 10 | 76.06 |
| 15 | 24.92 |
| 20 | 10.34 |
| 25 | 4.88 |
| 30 | 2.50 |
| 35 | 1.35 |
| 40 | 0.76 |
| 45 | 0.44 |
| 50 | 0.27 |
| 55 | 0.16 |
| 60 | 0.10 |
| 65 | 0.06 |

0.1
2750 Candela

| RANGE (Feet) | ILLUMINATION (Lux) |
|---|---|
| 5 | 872.95 |
| 10 | 160.90 |
| 15 | 52.72 |
| 20 | 21.87 |
| 25 | 10.32 |
| 30 | 5.28 |
| 35 | 2.86 |
| 40 | 1.62 |
| 45 | 0.94 |
| 50 | 0.56 |
| 55 | 0.34 |
| 60 | 0.21 |
| 65 | 0.13 |

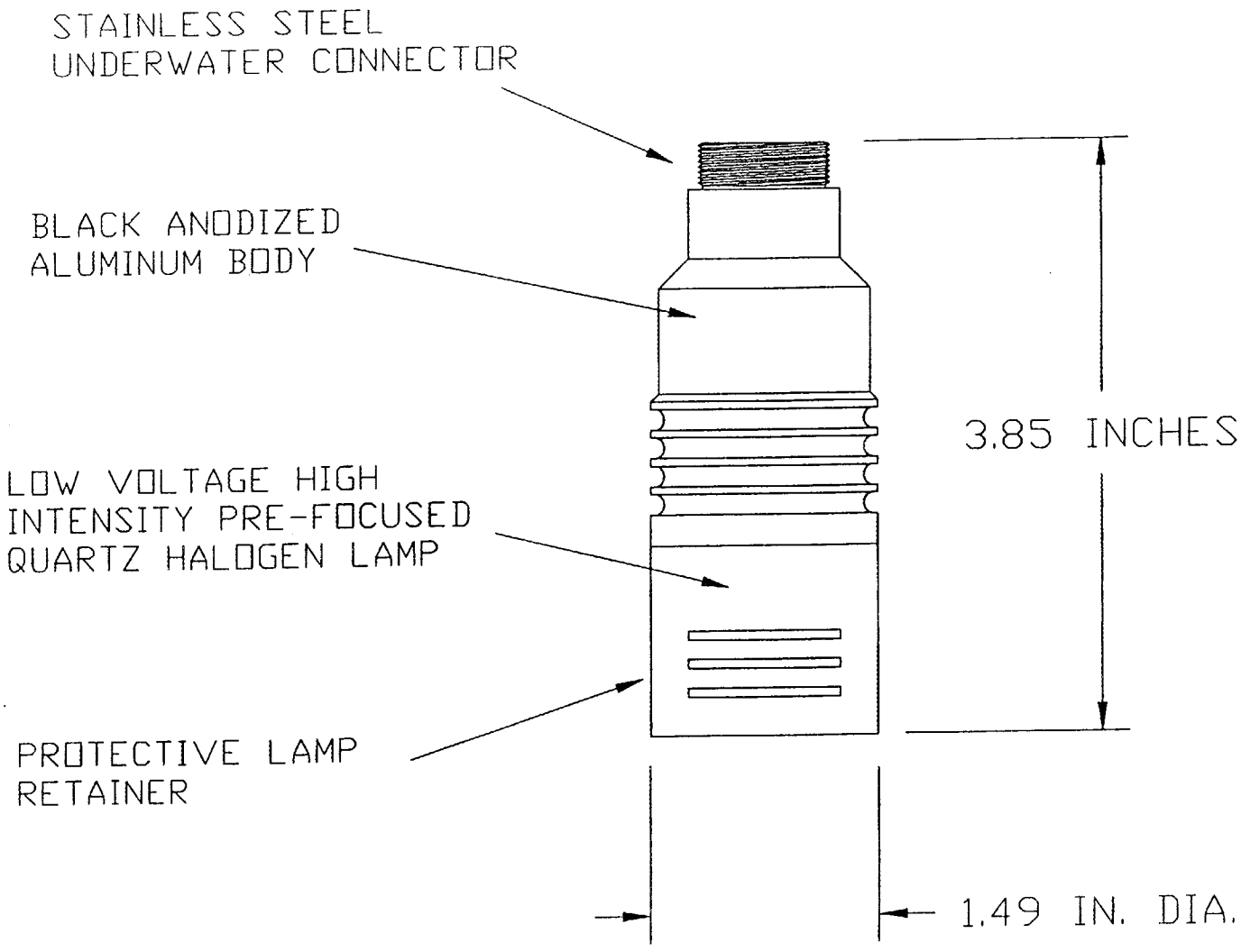
0.1
5850 Candela

| RANGE (Feet) | ILLUMINATION (Lux) |
|---|---|
| 5 | 1857.00 |
| 10 | 342.28 |
| 15 | 112.16 |
| 20 | 46.51 |
| 25 | 21.95 |
| 30 | 11.24 |
| 35 | 6.09 |
| 40 | 3.44 |
| 45 | 2.00 |
| 50 | 1.20 |
| 55 | 0.73 |
| 60 | 0.45 |
| 65 | 0.28 |

# SPECIFICATIONS

**IN-AIR (Model ST-400)**

| | |
|---|---|
| POWER | 0-15 VAC supplied via power supply |
| LAMP TYPE | 35 Watt Quartz Halogen |
| LAMP LIFETIME | 3000 hours @12 volts<br>170 hours @ full power |
| STANDARD BEAM PATTERNS | 30 degrees<br>20 degrees<br>10 degrees |
| RATED INTENSITY (@12 VOLTS) | 1300 candela (30 deg. beam)<br>2750 candela (20 deg. beam)<br>5850 candela (10 deg. beam) |
| HOUSING DIAMETER | 1.49 inches |
| HOUSING LENGTH | 3.85 inches |
| WEIGHT | 0.37 pounds (170 grams) |
| HOUSING MATERIAL | Anodized aluminum |
| CONNECTOR | Model RCS-1501-BC-3 stainless steel |
| MATING CONNECTOR | Model RCS-1501-CC-3 |
| | |

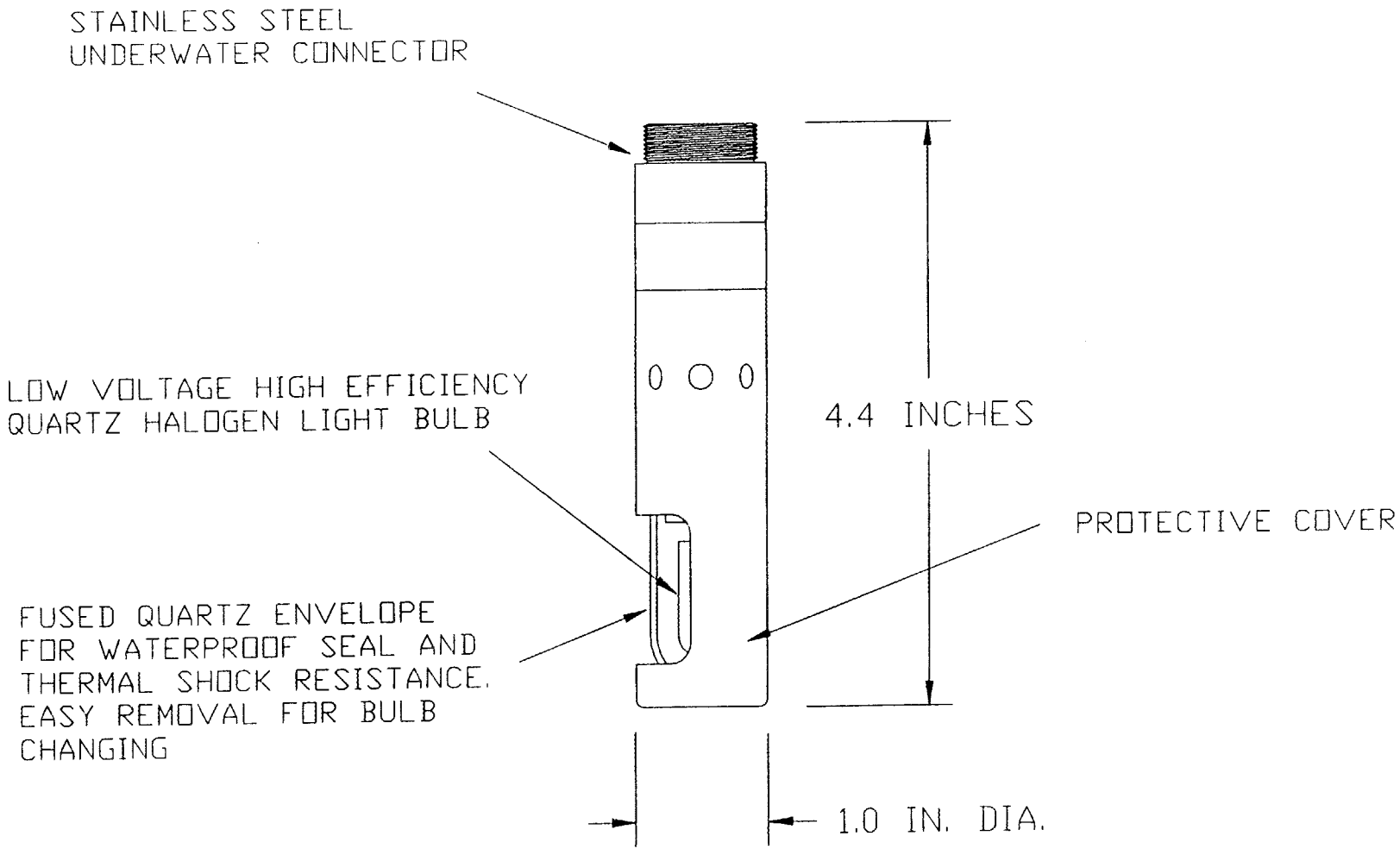



MODEL ST-400 PRE-FOCUSED LIGHT FOR IN-AIR USE

# SPECIFICATIONS

**UNDERWATER LIGHT (Model UL-300)**

| | |
|---|---|
| POWER | 0-15 VAC supplied via power supply |
| LAMP TYPE | 35 Watt Quartz Halogen |
| LAMP LIFETIME | 100 hours @full power |
| HOUSING DIAMETER | 1.00 inches including cover |
| HOUSING LENGTH | 4.4 inches |
| WEIGHT | 0.25 pounds (115 grams) |
| HOUSING MATERIAL | Anodized aluminum |
| ENVELOPE MATERIAL | Fused quartz |
| OPERATING DEPTH | 1000 feet |
| CONNECTOR | Model RCS-1501-BC-3 stainless steel |
| MATING CONNECTOR | Model RCS-1501-CC-3 |

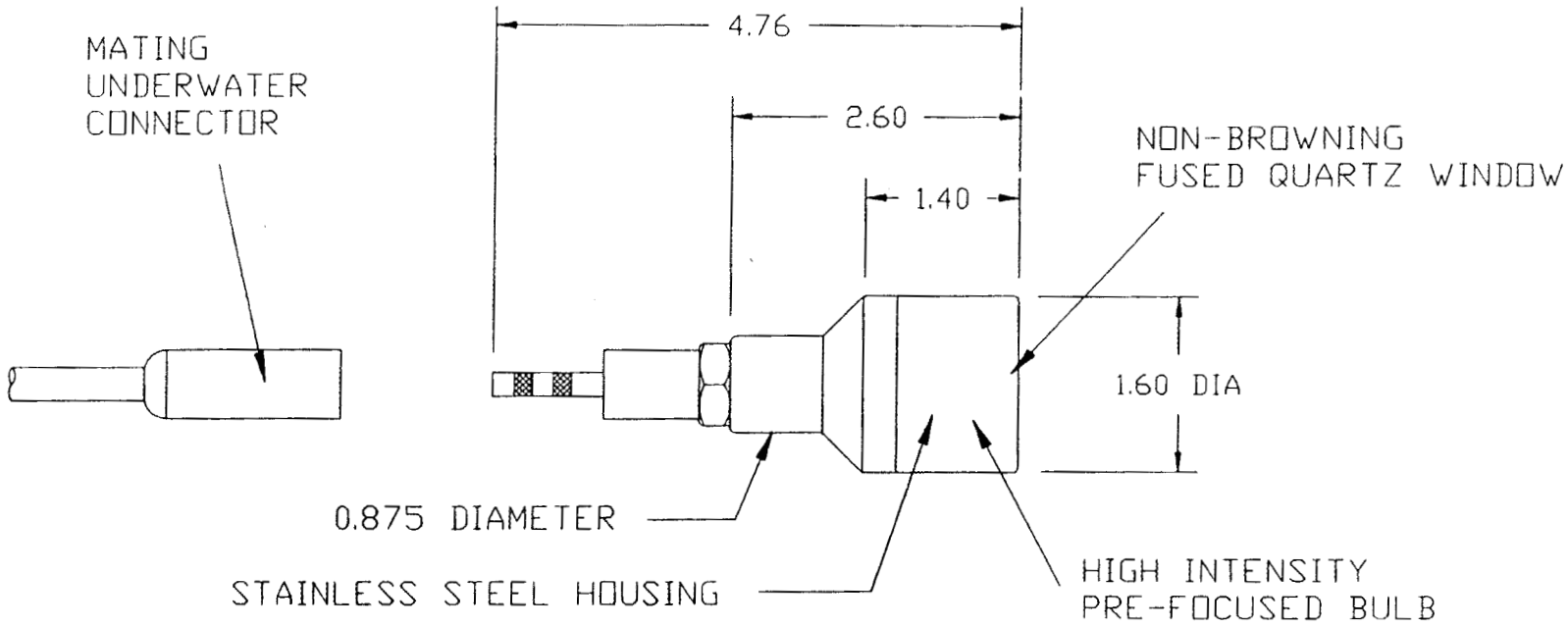



MODEL UL-300 MINIATURE LIGHT FOR UNDERWATER OR IN-AIR USE

# SPECIFICATIONS

**MODEL UL-210 LIGHT**

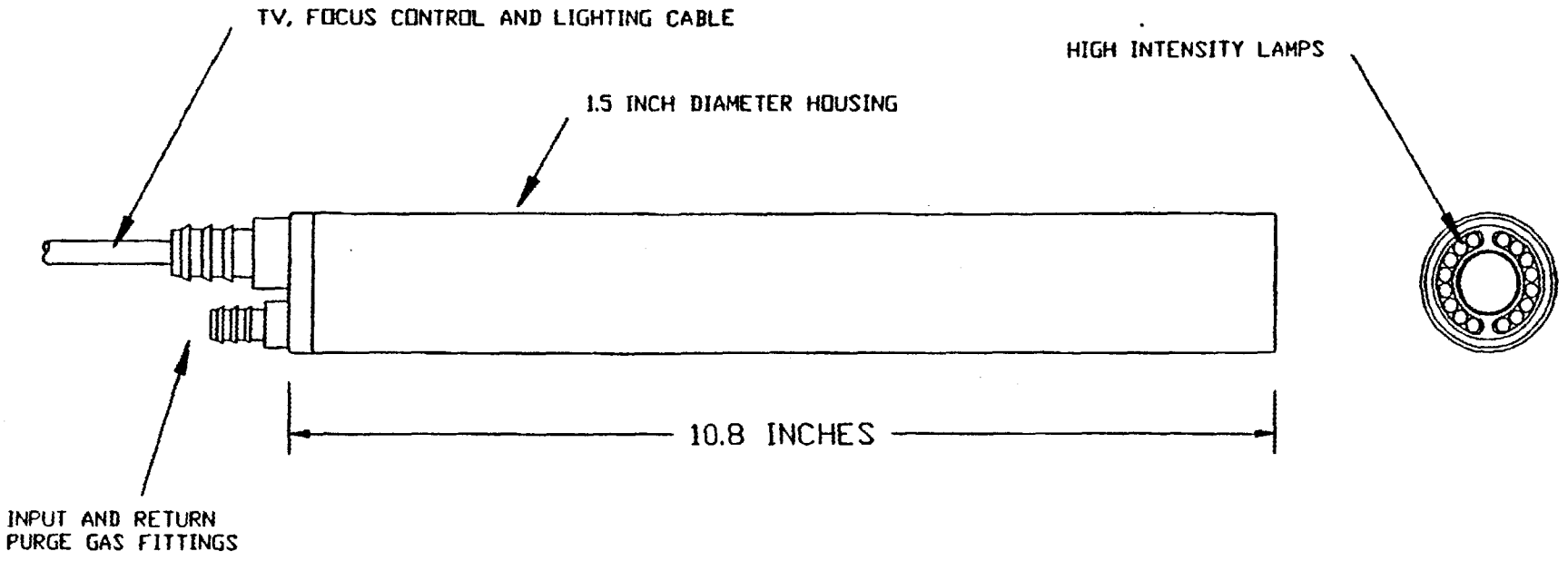
| | |
|---|---|
| VOLTAGE | 12 volts |
| POWER | 35 watts standard |
| OPERATING DEPTH | 500 feet |
| DIAMETER | 1.60 inches |
| HOUSING LENGTH | 2.60 inches |
| OVERALL LENGTH | 4.76 inches |
| WEIGHT IN AIR | 0.59 pounds |
| WEIGHT IN WATER | 0.47 pounds |
| STANDARD BEAM PATTERNS | 30 degrees<br>20 degrees<br>10 degrees |
| RATED INTENSITY | 1300 candela (30 deg. beam)<br>2750 candela (20 deg. beam)<br>5850 candela (10 deg. beam) |
| RATED LAMP LIFE | 3000 hours |
| CONNECTOR | Impulse IE2M-BC |
| MATING CONNECTOR | Impulse IE2F-5/8 |
| WINDOW MATERIAL | Fused Quartz |
| HOUSING MATERIAL | 300 series stainless steel |




FEATURES:

- SMALL SIZE
- STAINLESS STEEL HOUSING
- NON-BROWNING FUSED QUARTZ WINDOW
- HIGH INTENSITY PRE-FOCUSED LAMP
- WIDE RANGE OF LAMP OPTIONS
- EASY LAMP CHANGING
- NO EXPOSED THREADS OR RETAINERS
- SAFE LOW VOLTAGE OPERATION
- DEPTH RATING OF 500 FEET

# MODEL UL-210 MINIATURE UNDERWATER LIGHT



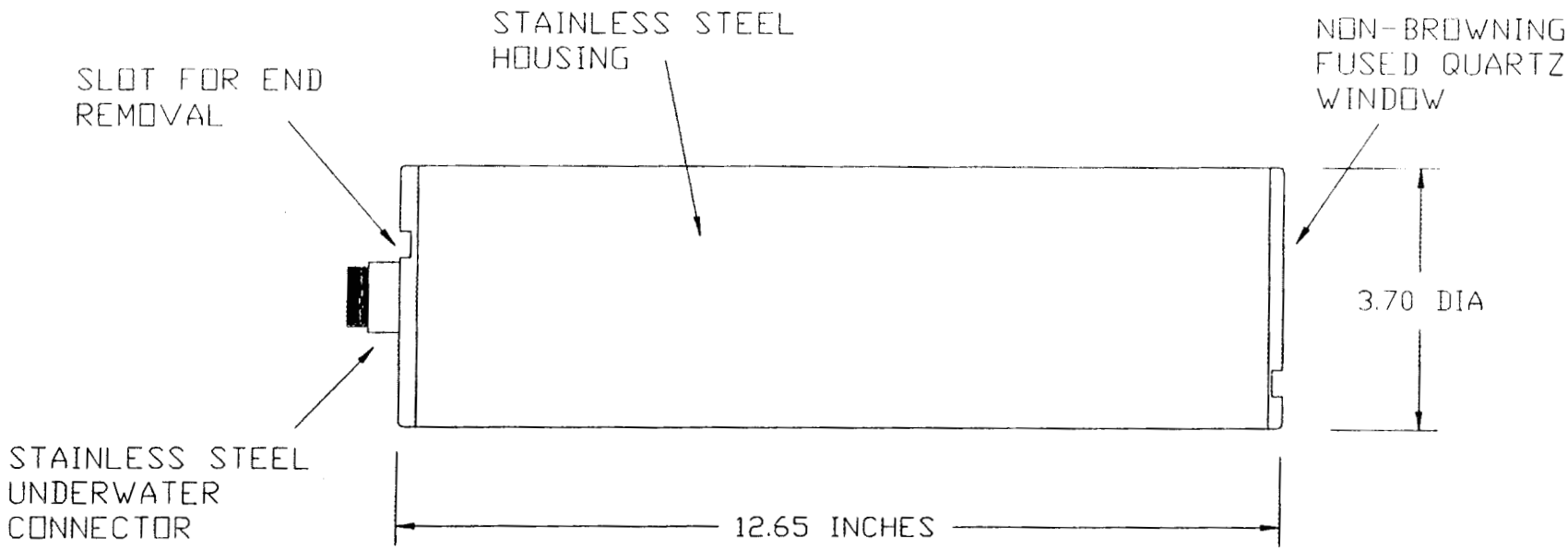

- HIGH RESOLUTION, HIGH SENSIVITY COLOR TV WITH BUILT-IN LINE REGULATOR
- SMALL SIZE FOR USE IN CONFINED AREAS
- CORROSION RESISTANT STAINLESS STEEL HOUSING. COMPLETELY SEALED TO MAINTAIN INTERNAL GAS PRESSURE
- SIXTEEN HIGH INTENSITY FOCUSED LAMPS FOR LONG RANGE UNIFORM LIGHTING
- STANDARD 7.5mm LENS. OPTIONAL WIDE ANGLE AND TELEPHOTO LENSES
- REMOTE FOCUS CONTROL
- FUSED QUARTZ VIEWING WINDOW

GAS PURGED COLOR TV SYSTEM WITH INTEGRAL LIGHTING

# SPECIFICATIONS

**MODEL RCS-1700 CAMERA**

| | |
|---|---|
| POWER | 12 VDC supplied via model CU1410 controller |
| SENSOR | 1/2 in. interline transfer CCD |
| SCAN AREA | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION | 460 TV lines |
| MINIMUM SCENE ILLUMINATION | 5 lux at f/1.4, 10 lux at f/2.8 |
| S/N RATIO | 50 dB |
| OUTPUT IMPEDANCE | 75 Ohms |
| ZOOM | 20-200 mm remotely controlled |
| FOCUS | 1.2 meter to infinity remotely controlled |
| IRIS | f/2.8 to closed remotely controlled |
| IN-AIR FIELD OF VIEW | 18.2 deg to 1.8 deg horizontal |
| UNDERWATER FIELD OF VIEW | 13.6 deg to 1.4 deg horizontal |
| HOUSING DIAMETER | 3.70 inches |
| HOUSING OVERALL LENGTH | 12.65 inches |
| IN-AIR WEIGHT | 10.0 pounds |
| IN-WATER WEIGHT | 6.0 pounds |
| HOUSING MATERIAL | 300 series stainless steel |
| WINDOW MATERIAL | Non-browning fused quartz |
| CONNECTOR | Model RCS-1501-BC-10 stainless steel |
| MATING CONNECTOR | Model RCS-1501-CC-10 |
| DEPTH RATING | 500 feet |
| TEMPERATURE RATING | -10 to 40 deg C (14 to 104 deg F) |




FEATURES:

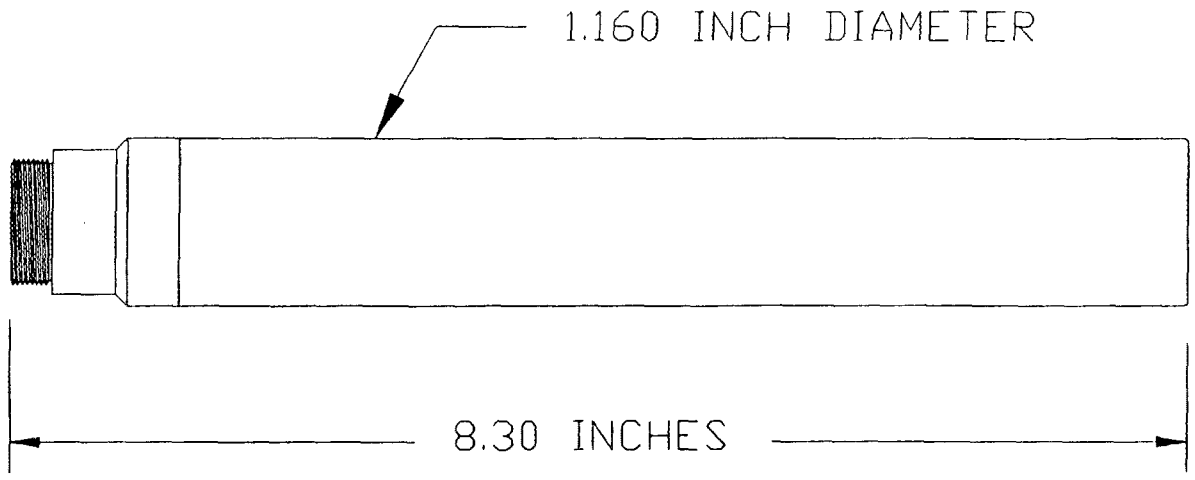
- HIGH RESOLUTION COLOR TV
- 20-200mm 10:1 ZOOM LENS
- REMOTE FOCUS, ZOOM, & IRIS CONTROLS
- STAINLESS STEEL HOUSING
- NON-BROWNING QUARTZ WINDOW
- NO EXPOSED THREADS OR RETAINING RINGS
- STAINLESS STEEL CONNECTOR
- DEPTH RATING OF 500 FEET

RCS-1700 UNDERWATER COLOR ZOOM TV CAMERA

# SPECIFICATIONS

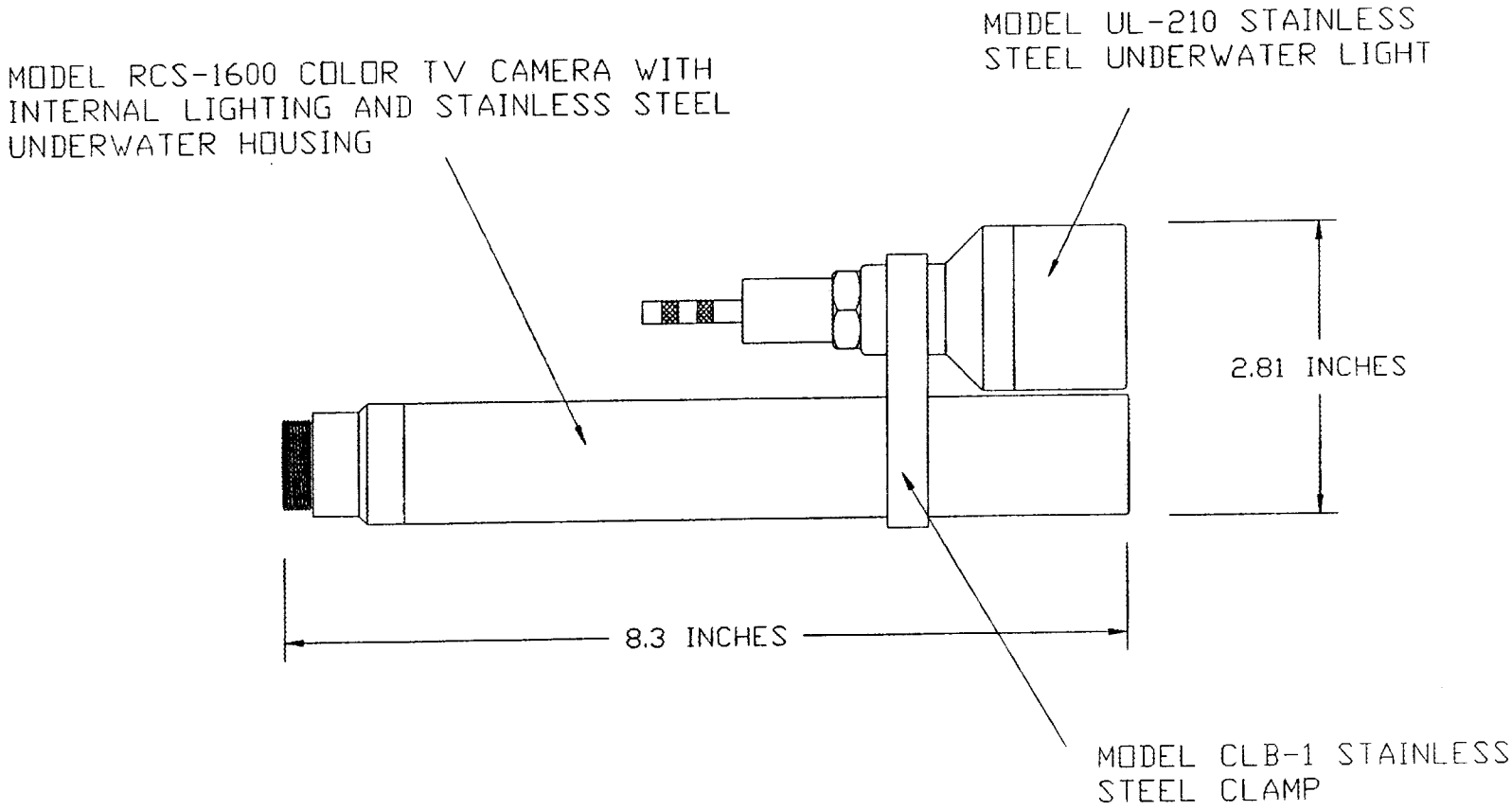
**TV CAMERA MODEL RCS-1610**

| | |
|---|---|
| POWER | 12 VDC supplied via camera control unit |
| SENSOR | 1/2 in. interline transfer CCD |
| SCAN AREA | 6.5 x 4.8 mm |
| HORIZONTAL RESOLUTION | 470 TV lines |
| MINIMUM SCENE ILLUMINATION | 4.5 lux at f/1.2 |
| S/N RATIO | 48 dB |
| OUTPUT IMPEDANCE | 75 Ohms |
| LENS | 7.5 mm, f/1.6 (modified) |
| FOCUS | six inches to infinity manually adjustable |
| IN AIR FIELD OF VIEW | 35.5 x 46.2 deg (vertical x horizontal) |
| UNDERWATER FIELD OF VIEW | 26.5 x 34.3 deg (vertical x horizontal) |
| HOUSING DIAMETER | 1.16 inches |
| HOUSING LENGTH | 8.30 inches |
| WEIGHT | 1.12 pounds |
| MATERIAL | Stainless steel |
| WINDOW MATERIAL | Fused quartz |
| CONNECTOR | Model RCS-1501-BC-10 Stainless steel |
| MATING CONNECTOR | Model RCS-1501-CC-10 |
| TEMPERATURE RATING | -10 to 40 deg C (14 to 104 deg F) |

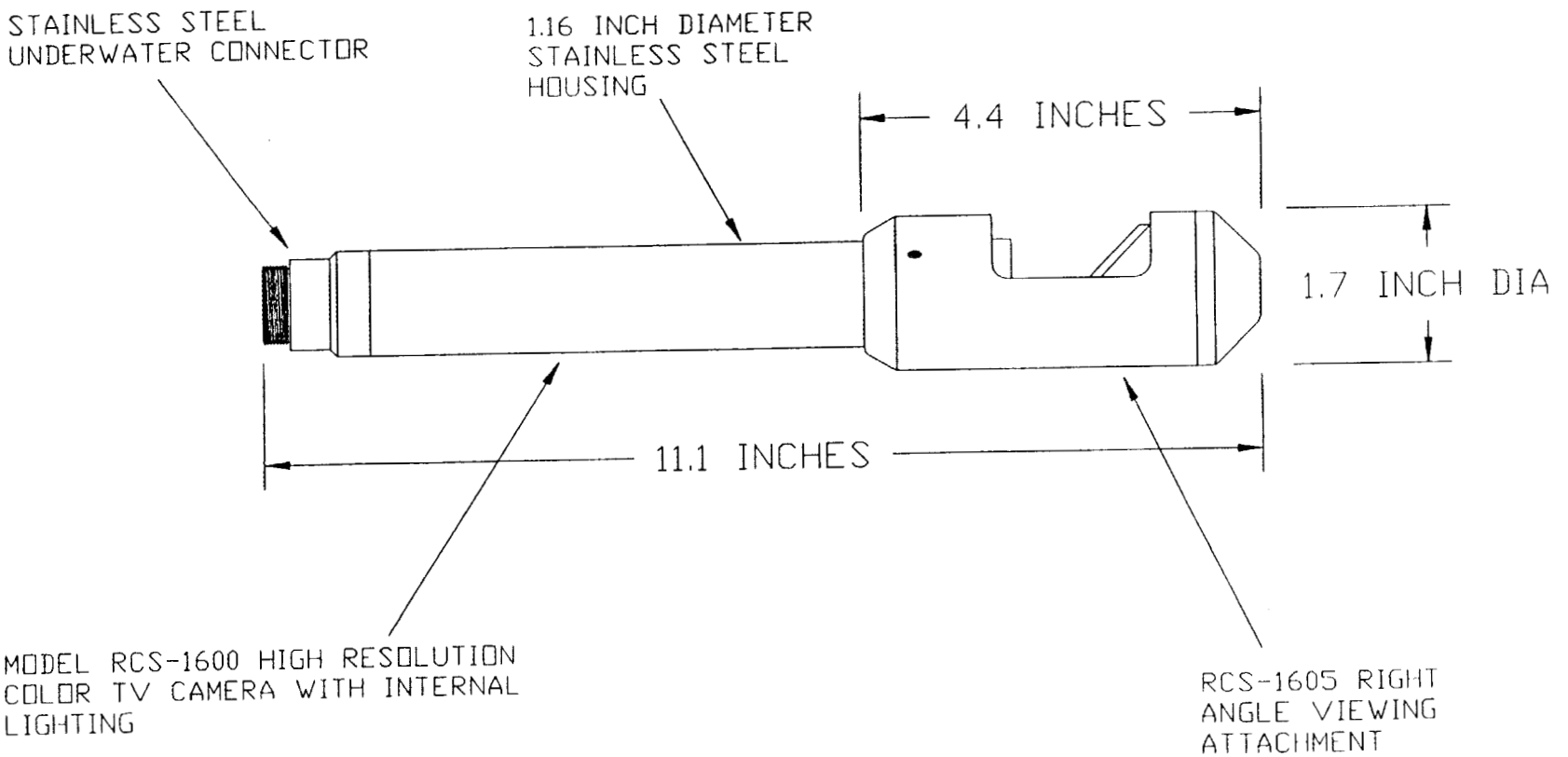



- HIGH RESOLUTION, HIGH SENSIVITY COLOR TV WITH BUILT-IN LINE REGULATOR
- SMALL SIZE FOR USE IN CONFINED AREAS
- CORROSION RESISTANT STAINLESS STEEL HOUSING. COMPLETELY SEALED FOR UNDERWATER USE TO 200 FOOT DEPTHS
- INTERCHANGEABLE WIDE ANGLE, NORMAL OR TELEPHOTO LENSES
- FUSED QUARTZ VIEWING WINDOW
- STAINLESS STEEL UNDERWATER CONNECTOR
- HIGH STRENGTH (.325 INCH DIA) CABLE FOR 1000 FOOT SEPARATION BETWEEN CAMERA AND CONTROLLER

MODEL RCS-1610 UNDERWATER COLOR TV CAMERA




RCS-1600 UNDERWATER COLOR TV CAMERA WITH UL-210 LIGHT

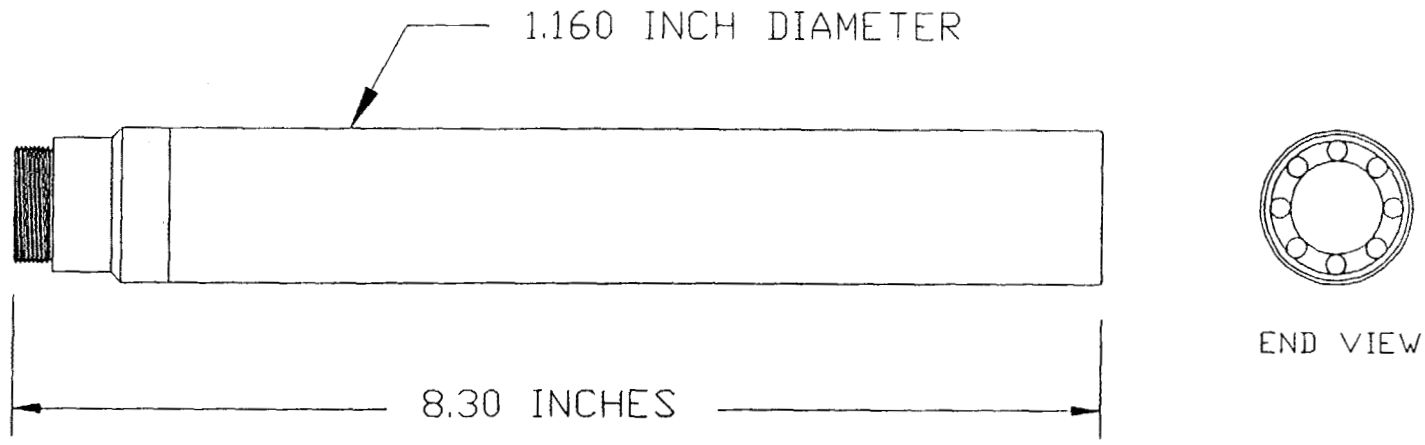



MODEL RCS-1600 COLOR TV CAMERA WITH RIGHT ANGLE ATTACHMENT

# SPECIFICATIONS

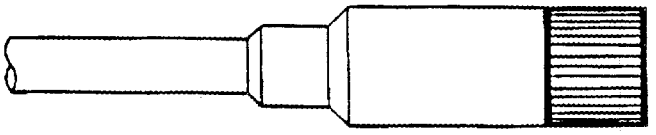
**TV CAMERA MODEL RCS-1600A**

| | |
|---|---|
| POWER | 12 VDC supplied via camera control unit |
| SENSOR | 1/2 in. interline transfer CCD |
| SCAN AREA | 6.5 x 4.8 mm |
| HORIZONTAL RESOLUTION | 470 TV lines |
| MINIMUM SCENE ILLUMINATION | 4.5 lux at f/1.2 |
| S/N RATIO | 48 dB |
| OUTPUT IMPEDANCE | 75 Ohms |
| LENS | 7.5 mm, f/1.6 (modified) |
| FOCUS | 1 foot to infinity manually adjustable |
| IN AIR FIELD OF VIEW | 35.5 x 46.2 deg (vertical x horizontal) |
| UNDERWATER FIELD OF VIEW | 26.5 x 34.3 deg (vertical x horizontal) |
| LIGHTS | 8 ea. high intensity pre-focused |
| LIGHT RING VOLTAGE | 12 volts |
| HOUSING DIAMETER | 1.16 inches |
| HOUSING LENGTH | 8.30 inches |
| WEIGHT | 1.12 pounds |
| MATERIAL | Stainless steel |
| WINDOW MATERIAL | Fused quartz |
| CONNECTOR | Model RCS-1501-BC-10 Stainless steel |
| MATING CONNECTOR | Model RCS-1501-CC-10 |
| TEMPERATURE RATING | -10 to 40 deg C (14 to 104 deg F) |

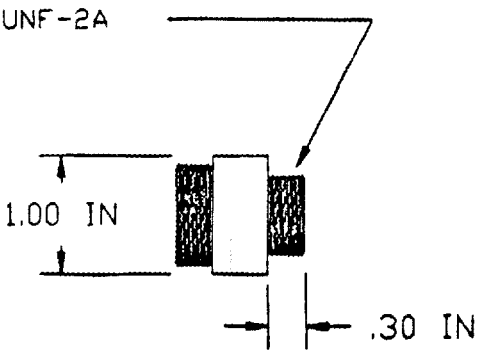



- HIGH RESOLUTION, HIGH SENSIVITY COLOR TV WITH BUILT-IN LINE REGULATOR
- SMALL SIZE FOR USE IN CONFINED AREAS
- CORROSION RESISTANT STAINLESS STEEL HOUSING. COMPLETELY SEALED FOR UNDERWATER USE TO 200 FOOT DEPTHS
- 7.5mm, f/1.6 LENS PROVIDES 34 DEGREE HORIZONTAL UNDERWATER FOV
- EIGHT HIGH INTENSITY FOCUSED LAMPS FOR UNIFORM LIGHTING
- FUSED QUARTZ VIEWING WINDOW
- STAINLESS STEEL UNDERWATER CONNECTOR
- HIGH STRENGTH (.325 INCH DIA) CABLE FOR 1000 FOOT SEPARATION BETWEEN CAMERA AND CONTROLLER

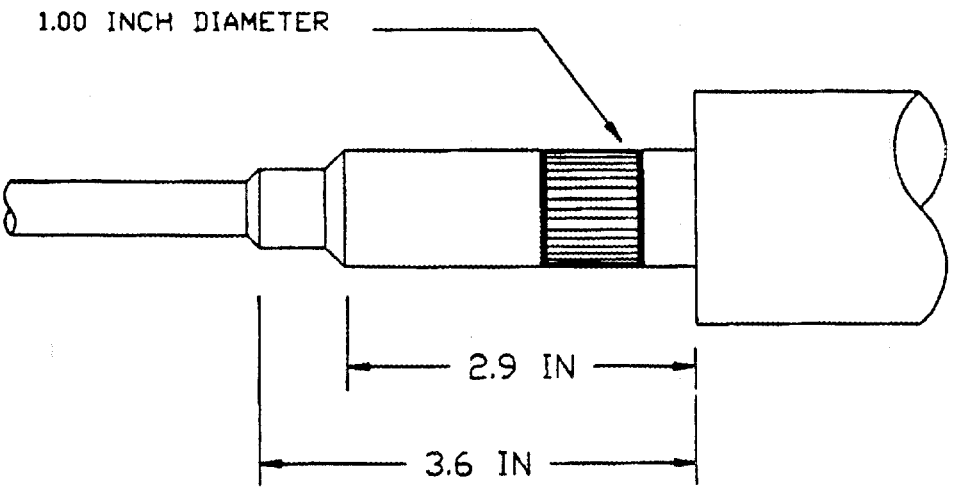
MODEL RCS-1600 UNDERWATER COLOR TV CAMERA WITH INTEGRAL LIGHTING



RCS-1501-CC CABLE CONNECTOR

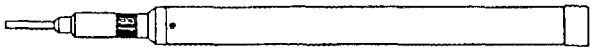



RCS-1501-BC BULKHEAD CONNECTOR

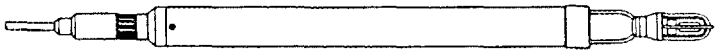



MATED RCS-1501 CONNECTOR ASSEMBLY

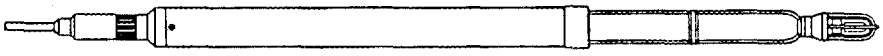
# RCS-1501 UNDERWATER CONNECTOR CONFIGURATION



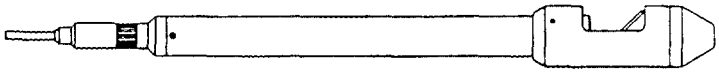
RCS-1400 CAMERA WITH RCS-1401 LIGHT HEAD



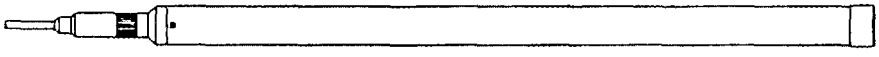
RCS-1400 CAMERA WITH RCS-1402 LIGHT HEAD



RCS-1400 CAMERA WITH RCS-1404 LIGHT HEAD

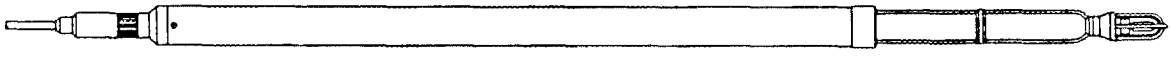


RCS-1400 CAMERA WITH RCS-1401 LIGHT HEAD AND RCS-1405 RIGHT ANGLE ATTACHMENT

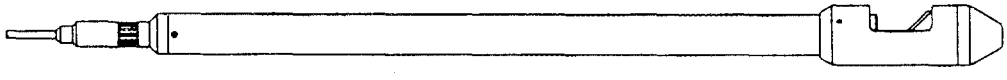


RCS-1410 CAMERA WITH RCS-1401 LIGHT HEAD

RCS-1410 CAMERA WITH RCS-1402 LIGHT HEAD



RCS-1410 CAMERA WITH RCS-1404 LIGHT HEAD



RCS-1410 CAMERA WITH RCS-1401 LIGHT HEAD AND RCS-1405 RIGHT ANGLE ATTACHMENT

# SERIES 1400 BOREHOLE CAMERAS AND VIEWING HEADS

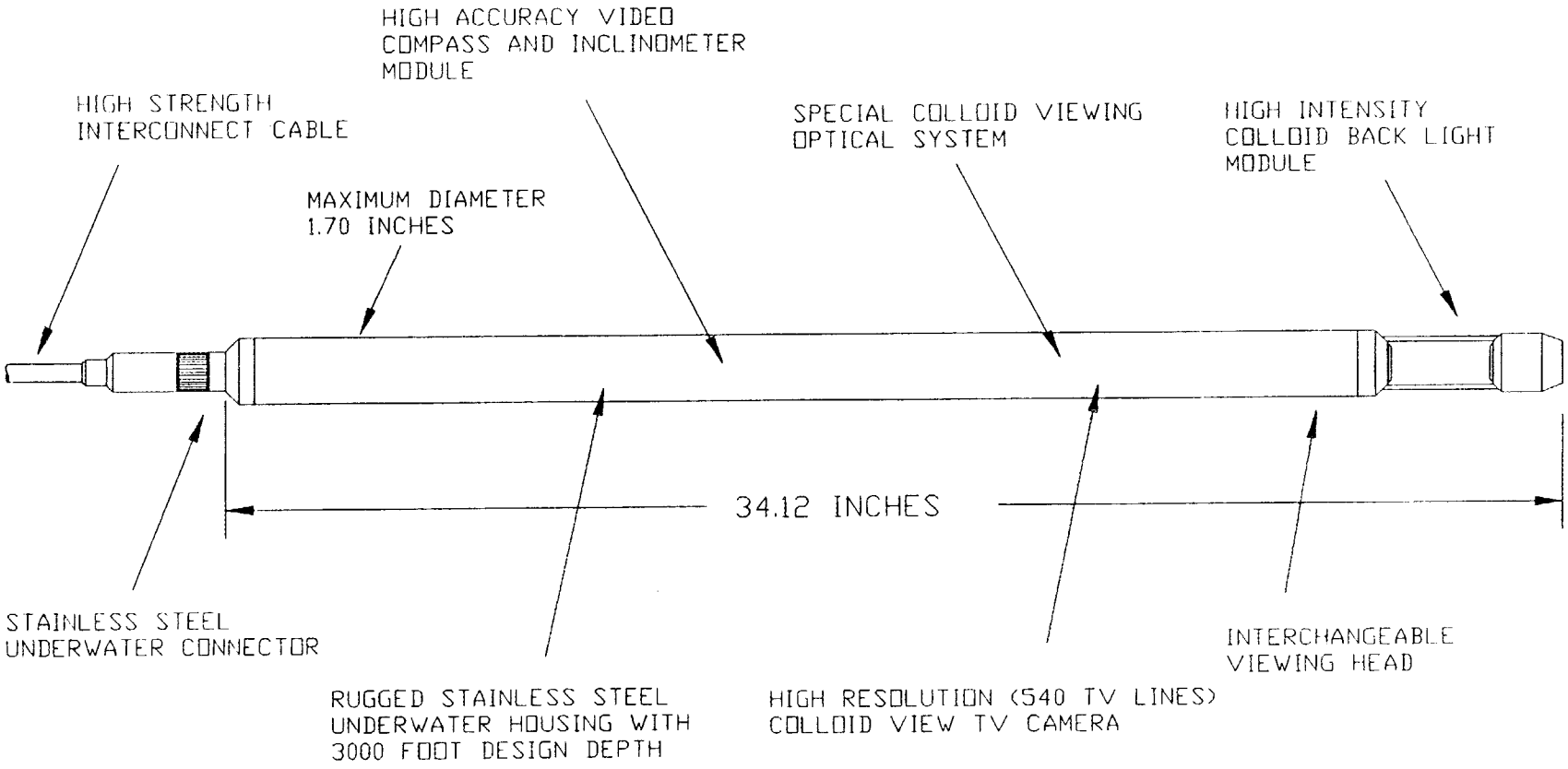
# SPECIFICATIONS

## MODEL RCS-1100A CAMERA

| | |
|---|---|
| POWER | 12 VDC supplied via model CU1210 controller |
| SENSORS (BOTH CAMERAS) | 1/2 in. interline transfer CCD |
| PIXEL | 768 (H) x 494 (V) |
| SCAN AREA | 6.41 x 4.89 mm |
| HORIZONTAL RESOLUTION | 570 (H) x 485 (V) TV lines |
| SCANNING | 525 lines, 1:1 interlace |
| MINIMUM SCENE ILLUMINATION | 1 lux at f/1.4 |
| VIDEO OUTPUT | 1.0 Vp-p composite video |
| S/N RATIO | 50 dB AGC off |
| OUTPUT IMPEDANCE | 75 Ohms |
| OPERATING TEMPERATURE | -10 to +50 deg C |
| COLLOID VIEW LENS | Magnification of 140 with preset iris |
| COLLOID VIEW LIGHTING | Backlight cold light source |
| COMPASS SCALING | 360 deg dial, 5 deg increments |
| INCLINOMETER SCALING | 0-10 deg range, 1 deg increments |
| COMPASS ACCURACY | +/- 30 min (magnetic bearing) |
| INCLINOMETER ACCURACY | +/- 15 min |
| HOUSING DIAMETER | 1.70 inches |
| LENGTH INCLUDING HEAD | 34.12 inches |
| WEIGHT | 9.0 pounds |
| HOUSING MATERIAL | 300 series stainless steel |
| CONNECTOR | Model RCS-1501-BC-10 stainless steel |
| MATING CONNECTOR | Model RCS-1501-CC-10 |
| DEPTH RATING | 3000 feet |
| TEMPERATURE RATING | -10 to 40 deg C (14 to 104 deg F) |
| RECOMMENDED CONTROLLER | R. J. Electronics Model CU-2310 |
| CABLE LENGTH | Up to 1000 feet with CU-2310 controller |

## CAMERA CABLE

| | |
|---|---|
| JACKET MATERIAL | Polyurethane |
| DIAMETER | 0.325 inch |
| WEIGHT | 20 ft. weighs 1 pound |
| STRENGTH MEMBER | Kevlar |
| BREAKING STRENGTH | 426 pounds |
| BEND RADIUS | 3.25 inches |
| MAXIMUM CABLE LENGTH | 3,000 feet |




COLLOID VIDEO BORESCOPE WITH COMPASS AND INCLINOMETER

# R93 Camera Features

| FEATURES | DESCRIPTION | CUSTOMER ADVANTAGE |
|---|---|---|
| ● **Radiation Tolerance** | Radiation tests and widespread use in the world nuclear industry shows the camera is radiation tolerant to the following levels:<br><br>Total absorbed dose 2MGy ($H_2O$) [Co-60] ($2 \times 10^8$ rads)<br>Dose rate >10 $Gys^{-1}$ ($H_2O$) [Co-60]<br>(>$3 \times 10^6$ rads per hour)<br>*Note: Operation at high dose rates may be limited by radiation induced noise, depending on type of tube fitted.* | **Confidence in a well proven design, used throughout the world.** |
| ● **Stainless steel Body** | Camera bodies (and associated viewing heads) are manufactured out of stainless steel.<br><br>In addition a contamination prevention sleeve is available to protect the camera connector. | **Easy to decontaminate.**<br><br>**Allows the electronics module to be removed and be recovered free from contamination.** |
| ● **Wide Range of Viewing Heads** | A wide range of 'viewing heads' are available for the R93 camera. These provide self contained on board lighting, forward and right angle viewing with 360° rotation. | **Allows camera to operate in totally dark areas.**<br><br>**Can complement external lighting.**<br><br>**Camera may be used underwater.**<br><br>**Camera can view inaccessible and difficult scenes.** |
| ● **Range of Sensor Tubes** | Rees cameras can incorporate a wide range of $^2/_3$ inch format tubes which include:<br><br>Vidicon, Newvicon, Non Browning Vidicon, Non Browning Newvicon, Chalnicon and Pasecon.<br><br>The type of tube which is fitted depends on the application and environment (ie. radiation dose rate and total absorbed dose, lighting level and type, temperature, resolution required etc). | **Flexibility - the optimum performance is achieved no matter where the location or conditions.**<br><br>**High resolution pictures available >800 TV lines (center zone 1).**<br>**High sensitivity.**<br>**High temperature operation.** |
| ● **Compact Size** | Rees camera is only 1.6" (40.5mm) diameter | **Access into small & restricted areas.** |
| ● **Remote Control** | The R93 offers remote control of iris and rack focus with an additional drive motor to power ancillary functions ie, rotate and zoom. The light intensity can also be controlled remotely (auto iris is selectable via the CCU). | **Camera can monitor very close o distant objects (from 0.2" (5mm) to infinity). Camera can be adjust ed to suit varying light levels.** |

| FEATURES | DESCRIPTION | CUSTOMER ADVANTAGE |
|---|---|---|
| **Choice of Lenses** | A very wide range of special radiation tolerant lenses are available to the R93 user (including 6mm, 9mm, 25mm, 12-72 zoom, 22-90 zoom, 24-144 zoom, 30-150 zoom, C and D mount). | **Radiation tolerant lenses fitted as standard.**<br><br>**Viewing angle flexibility ensures the desired scene is viewed.** |
| **Rugged Design** | The R93 camera is designed to survive hostile environments.<br><br>A series of environmental tests have been carried out to establish various parameters ie, temperature, vibration, humidity, etc.<br><br>Special cooling systems are also available. | **Cameras can be used in high temperature environments (160°F, 70°C) without cooling (Chalnicon type tube).**<br><br>**Continuous operation up to 130°F (55°C) with other tubes.** |
| **Waterproof** | Rees cameras are designed to work underwater and withstand intense water pressure. | **Can be used in ponds.**<br><br>**Camera will withstand high pressure wash-down.** |
| **Cable** | A range of radiation tolerant camera cables can be specified for the system.<br><br>Special cables have been developed including small diameter and festoon types. | **Cable breaking strain is up to 2200 lbs (1000 kg). Can be used on festoon arrangement (depending on type).** |
| **Camera Control Unit** | A range of CCUs are available. The CCU houses the majority of the electronics including video board, scan board, power supply module and is built using a modular approach.<br><br>The free standing, rack mounting, wall mounting or plug end units all include full control of camera lens, lighting and pan and tilt functions. A version for multicamera systems that incorporates telemetry remote control is also available. | **Allows easy maintenance.**<br><br>**Modular construction means quick replacement.** |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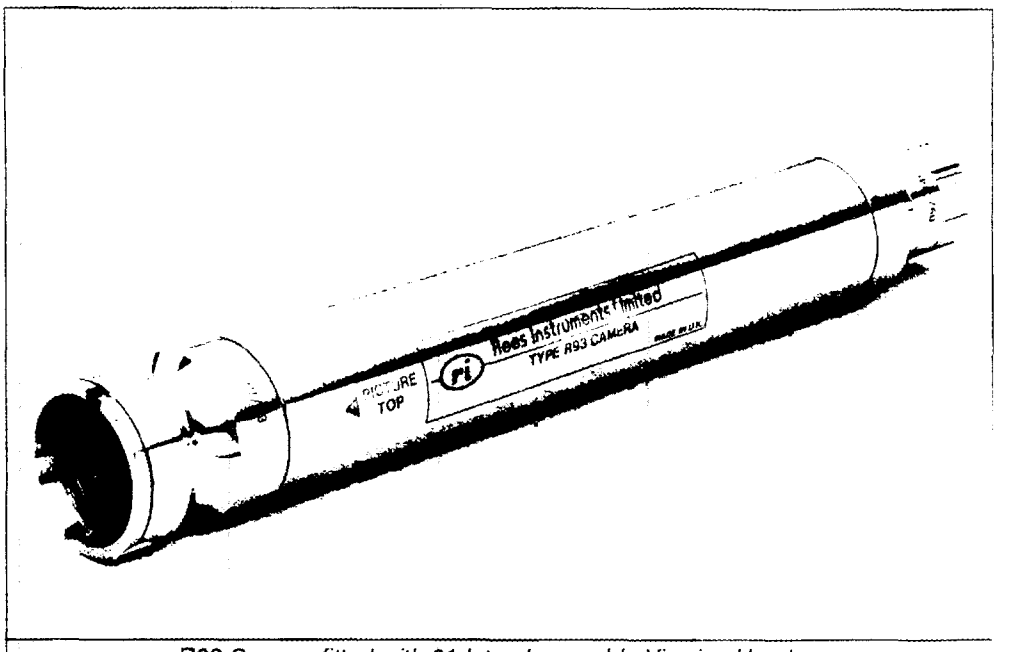
# Rees R93 Mk3 General Purpose Nuclear Camera

## FEATURES

- Compact, rubust construction
- High resolution (>800 TV lines with appropriate lens & tube)
- Independently accredited radiation tolerance exceeding 2 x $10^8$ rads (2 MGy)
- Dose rates >3 x $10^6$ rads per hour (>8 $Gys^{-1}$)
- Wide range temperature operation
- Diverse application using interchangeable lenses, lens bodies, and viewing heads
- Remotely controlled
- Surface mount technology

**The Rees R93 Camera is an extremely versatile unit combining high performance with wide-ranging viewing capabilities and high radiation tolerance.**




*R93 Camera fitted with 01 Interchangeable Viewing Head*

The R93 Mk 3 Camera is based on the industry proven R93 Mk 2, the new design incorporates many new features to enhance performance and extend working life.

The camera is housed in a rigid stainless steel casing that protects the sensor tube, drive circuits and remote function motors. High resolution optical performance is derived from the use of purpose designed 6mm, 9mm and 25mm D mount non-browning lenses with remotely driven motorized focus and auto iris functions. Improved reliability and easier maintenance is achieved using surface mount electronics and precision mechanics for all remote function controls. All materials are carefully selected to maintain long life in radioactive environments.

When fitted with an appropriate Inter-changeable Viewing Head or Lens Body the R93 is fully waterproof for underwater applications to a depth of 660' (200m). A contamination prevention sleeve can also be fitted to allow retrieval of the uncontaminated camera capsule and connector.

The camera can be linked to its Camera Control Unit (CCU) via a range of multicore cables, with matching connectors, to suit various applications.

The R93 camera is designed to be used in conjunction with Rees R90 Series Mk 3 Camera Control Units. Fully compatible with international video standards, R90 Mk 3 Control Units can be integrated or locked to external sources, image processors or machine vision systems. A range of portable or rack mounted versions are available with local control panel or remote control over twisted pair or video coaxial cables.

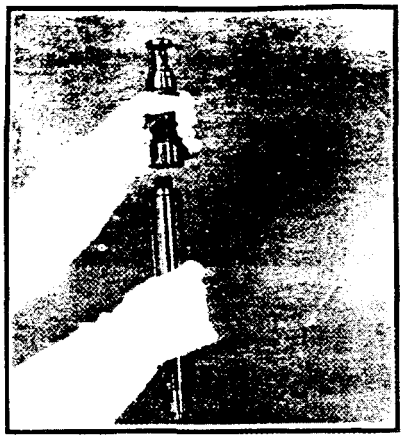
All Rees Camera Control Units are compatible with the R930VEU Video Enhancement Unit which provides an increase in camera sensitivity of 128:1.

For integrated system applications remote function control and picture viewing can be via a central switching and control system from a master control room, or from either of two special Operator Control Units - one designed to be mounted directly on the cave or cell face wall and the other based on a movable trolley. Both include a 12" picture monitor display.

*The R93 Mk 3 has been developed for optimum performance with the range of R90 Mk 3 Camera Control Units, compatibility with earlier generation equipment may require simple modification.*

***Rees Instruments is fully approved for the design and manufacture of CCTV equipment to the following international quality standards:***

***ANSI/ASQC Q91-1987***
***ISO 9001-1987***
***BS 5750: Part 1: 1987***
***EN 29001-1987***



Maximum application flexibility is achieved using interchangeable Viewing Heads or Lens Bodies enabling the R93 Mk 3 to provide:

- underwater applications to a depth of 660' (200m)
- lighting power from 0.7W to 100W
- non-browning 12-72mm f1.8 zoom capability
- radial viewing with full 360° scan facility
- complete hemispherical viewing ability
- wide angle viewing

All the Interchangeable Viewing Heads and Lens Bodies can be matched to the radiation tolerance of the R93 Mk 3 and are very easily fitted to the camera.
*For additional specifications refer to the following data sheets*

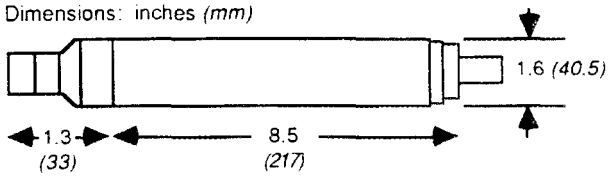
Rees R93 Interchangeable Viewing Heads
Rees R93 Interchangeable Lens Bodies
Rees R90 Mk 3 Camera Control Units
Rees R90 Series Cables and Connectors

## Performance and Specifications

Mechanical: Stainless Steel, non-browning optics
Weight: 2.8 pounds (1.25kg) without Head or Lens Body

Electrical (excluding View Heads or Lens Bodies)
Max power: 3 watts

Dimensions: inches *(mm)*




Environmental:

| | | | |
|---|---|---|---|
| Operating temperature: | -13° to 130°F | (-25 to 55°C) | |
| Storage temperature: | -13° to 140°F | (-25 to 60°C) | |
| Humidity (non-condensing): | 95% | | |

(The R93 Camera is fully waterproof when fitted with an appropriate Viewing Head or Lens Body.)

| | | | |
|---|---|---|---|
| Radiation tolerance: | $2 \times 10^6$ rads | (2 MGy (Si)[Co60]) | total dose |
| | $>3 \times 10^6$ rads per hour | ($>8$ Gys$^{-1}$) | Vidicon |
| | $1 \times 10^5$ rads per hour | (300m Gys$^{-1}$) | Newvicon/Chalnicon |

Performance using R90 MK3 series CCU
Resolution (in air):

| R93 Camera Head/Lens Body | HorizontalResolution Center - Zone 1 (tv lines per picture height) |
|---|---|
| R93/00, 01, 02, 05, 65, 65L | 650 |
| R93/03 | 500 |
| R93/04 | 650 |
| R93/09 (Dome or Cylinder) | 500 |
| R93 Camera with appropriate high resolution tube and lens (to special order) | 800 |

Signal to noise ratio
>43dB (CCU standard gain)
>36dB (CCU high gain)
Typical sensitivity
1 lux scene illumination (usable picture)
7 lux scene illumination (good picture)

Notes...
1. Signal to noise ratio measurements refer to weighted reading over 10 MHz bandwidth using Rhode & Schwarz UPSF video noise meter.
2. Sensitivity using extending red Newvicon tube and F2.0 non-browning lens.
3. A *"good"* picture is defined as one where the illumination available is sufficient for the camera to produce a 1 volt composite video signal with a fully open aperture.
4. A *"usable"* picture can usually be obtained, dependent on the scene viewed and environmental factors etc., when the illumination available is only one third that required to achieve a 1 volt composite video signal at full aperture.

Optics: Non-browning 9mm D mount auto iris lens fitted as standard. Optional non-browning 6mm and 25mm D mount lenses and C mount lenses available.

| Viewing angles in air (typical) | Horizontal | Vertical | Diagonal | Focus Range |
|---|---|---|---|---|
| Standard 9mm lens | 50° | 39° | 61° | 1" to infinity |
| Optional 6mm lens | 73° | 58° | 85° | .2" to infinity |
| Optional 25mm lens | 20° | 15° | 25° | 6.7" to infinity |
| Cable length: | Minikevlar | 660 ft max *(200m)* | TV36 | 660 ft max *(200m)* |

***Notes:***
1. ***Rees should be consulted with regard to very critical viewing requirements, or in cases where there are important lighting, resolution, environmental or viewing angle considerations.***
2. ***In applications where there are severe space constraints care should be taken to allow for the size of the camera cable mating connector and if necessary, the bend radius of the connecting camera cable. Please refer to the Rees R90 series cables and connectors data sheet.***
3. ***Rees Instruments Ltd reserves the right to change the above information without notice.***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# Rees RC93-S
# High Performance Color Camera

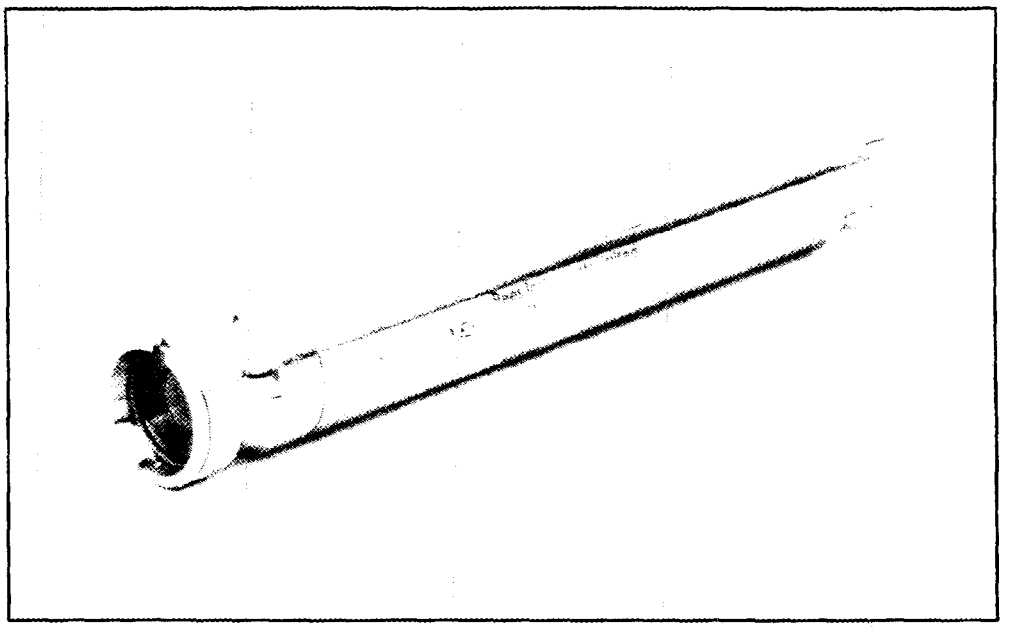
## FEATURES

- **Compact, robust construction**
- **Y/C Output (S-VHS compatible)**
- **Single unit operation option**
- **Full remote control**
- **Diverse application using interchangeable viewing heads**
- **Underwater applications to 660 feet (200m)**

***Rees Instruments is fully approved for the design and manufacture of CCTV equipment to the following international quality standards:***

***ANSI/ASQC Q91-1987***
***ISO 9001-1987***
***BS 5750: Part 1: 1987***
***EN 29001-1987***

**The Rees RC93-S camera combines the latest CCD sensor technology with field proven mechanics to give an outstanding performance for a diverse range of industrial applications.**



Based on ruggedized components the Rees RC93-S incorporates an advanced CCD image sensor which outputs a Y/C chrominance-luminance (separate color/brightness)video signal. To optimize the performance of the sensor, a purpose designed 7.7mm F1.2 D mount lens is fitted as standard, with 25mm F2.5 D mount or other C mount lenses available as options. When used with Y/C (S-VHS) monitors, the combined action of sensor and lens produces high resolution pictures, with enhanced color reproduction and much reduced color patterning on fine detail.

The RC93-S can also be used in composite video (non Y/C) mode for use with standard VHS television equipment. In this mode the picture quality is significantly better than earlier generation camera performance.

The camera outer body is a compact stainless steel casing which houses the image sensor and remote drive motors for the Rees range of interchangeable viewing heads. Viewing heads can be selected for particular tasks and are simply secured to the forward end of the camera. Use of viewing heads can provide axial or radial viewing and on-board lighting. Additionally fitting the appropriate viewing head seals the forward end of the camera which can allow underwater use to a depth of 660 feet (200m).

The camera is linked to its control unit by a tough multicore cable. This contains the video and functional drive conductors, and a strength member to allow direct camera deployment. As an option the cable could be used with a cable drum or reeling system.

Local control of the RC93-S is achieved via the Rees range of control units including the R970 Multi-purpose Control Unit (MCU). This unit features all the necessary function controls to enable the user to drive the cameras motorized functions (focus, iris and, where applicable, rotate for radial viewing). Additionally lighting on/off and intensity controls allow full use of an internally fitted 20W lighting supply or the external 200W or 300W R905 lighting power supply.

The R970 MCU has a 2U nineteen inch chassis suitable for rack mounting. For portable system applications the MCU can be fitted in a durable transit case which can also accommodate the R905 Lighting Power Supply if required.

Where the RC93-S Camera is integrated into a large system, control can be achieved via the Rees R970 Remote Control Unit. This unit is designed for rack mounting and is fitted with suitable telemetry to interface with a remotely situated control system.

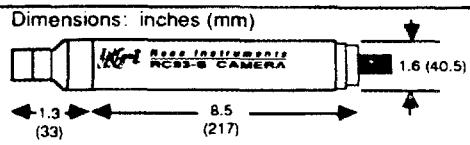
Alternatively the RC93-S can be used as a single unit device connected directly to a monitor and requiring only a simple dc power in, video out type cable. Please consult Rees Instruments for details of this and other options.

## CAMERA SPECIFICATION

**Camera General**

Material ..... stainless steel
Weight ..... 2.7 pounds (1.2 kg) without head or lens body
Operating Temp .. 14° to 104°F (10° to 40°C)

Dimensions: inches (mm)




**Standard Lens**

Focal length ..... 7.7 mm
Aperture ..... F1.2
Focus ..... 1.0" (25mm) to infinity
Type ..... D Mount, standard glass
Geometrical distortion .. < 5% in format corners

| | |
|---|---|
| Outputs ..... Y/C (S-VHS) and composite video | Format ..... NTSC (PAL versions available) |
| Maximum cable length ..... 660 feet (200m) | Sensor ..... Interline transfer hyper HAD CCD |
| Power input range ..... 10 to 15 volts dc | Sync ..... Internal/External |
| Iris ..... CCD electronic auto iris | Horizontal resolution ..... 470 tv lines F1.2 |
| Picture elements ..... 768 horizontal, 493 vertical | Minimum sensitivity ..... 4.5 lux F1.2(AGC on) |
| Operation ..... Remote control via R970 MCU or RCU | S/N ratio ..... >48dB(AGC off) |
| Depth rating (max) ..... 660 ft with appropriate viewing head | Shutter speed ..... 1 millisecond |

***Notes...***

1. ***For full details of the interchangeable viewing heads please refer to the appropriate datasheet.***
2. ***Full performance is achieved using Y/C and S-VHS ancillary equipment (monitors, video cassette recorders, etc). Using standard ancillary equipment resolution and color reproduction is better than earlier VHS cameras.***
3. ***Remote function control requires a multicore cable to drive the motorized drives for the Rees range of interchangeable viewing heads. Suitable control units include the R970 Multi-purpose Control Unit (MCU) and R970 Remote Control Unit (RCU). The R970 MCU is ideal for mobile applications and can be supplied in an industrial transit case. The R970 RCU is designed for rack mounted use in larger integrated systems and is fitted with a suitable telemetry interface for remote control.***
4. ***For applications requiring a zoom function the RC977 Zoom Camera combines a color CCD sensor with a zoom lens.***
5. ***For applications with special requirements Rees provides a custom design service.***

**APPLICABLE VIEWING HEADS**

| Viewing Head | Description | Dimensions |
|---|---|---|
| RC93-S 00 | The R93/00 viewing head protects the lens and enables the R93 Camera to be used underwater. | Length with camera .... 12" (294mm)<br>Diameter ..... 1.6" (40.5mm)<br>Depth rating ..... 660 feet (200m)<br>Weight with camera ... 2.7 lbs (1.4kg) |
| RC93-S 01 | The R93/01 head is designed for use in restricted spaces. It has a low power internal lighting system of 1.8 watts provided by a ring of 8 tungsten lamps and can be used continuously in air or water. | Length with camera .... 12" (294mm)<br>Diameter ..... 1.6" (40.5mm)<br>Depth Rating ..... 660 feet (200m)<br>Weight with camera ... 2.7 lbs (1.4kg) |
| RC93-S 02 | The R93/02 heads have either 20 watt or 100 watt forward mounted halogen lamps. The 20 watt version is designed for continuous operation in air or water, and can be powered by the R90 Mk 3 Lighting Module. The 100 watt version is designed for continuous operation in water, and can be used in air for short periods. | Length with camera .... (20W) 17" (440mm)<br>(100W) 18" (457mm)<br>Diameter ..... 1.6" (42mm)<br>Depth rating ..... 660 feet (200m)<br>Weight with camera ... 3.2 lbs (1.7kg) |
| RC93-S 03 | The radial viewing R93/03 views at right angles to the camera by using a stainless steel mirror which can scan through 360°. The head is fitted with either a 20W or 100W forward lamp and two 0.7W lamps one mounted at each side of the mirror. Light from the forward lamp is back reflected to provide shadow modelling, the 0.7W lamps produce a diffuse light ideal for close-up viewing. The 20W versions can be used continuously in air or water. The 100W version is designed for operation in water, and can be used in air for short periods. | Length with camera .... (20W) 15" (383mm)<br>(100W) 16" (415mm)<br>Diameter ..... 1.65" (42mm)<br>Depth rating ..... 660 feet (200m)<br>Weight with camera ... 3.7 lbs (1.7kg |
| RC93-S 05 | The R93/05 provides good illumination for general purpose viewing from 2 x 10 watt tungsten halogen lamps. It is designed for continuous use underwater and can also be used in air for short periods. After fitting, the head can be rotated manually by up to 180° (without breaking the center waterproof seal), to obtain the optimum lighting alignment, or to fit into specific spaces. | Length with camera .... 11.8" (300mm)<br>Depth rating ..... 660 feet (200m)<br>Weight with camera ... 5.3 lbs (2.4kg) |
| RC93-S 07 | The RC93-S 07 is designed for use underwater, but can be used in air for short periods (approximately 1.5 hours at 68°F ambient). Lighting is provided from 16 x 1.2 watt lamps with a total output of about 20 watts. The lighting design provides wide angle lighting to match the performance of the standard lens. Plain and water corrected windows are available. | Length with camera .... 11.6" (295mm)<br>Diameter ..... 2.56" (65mm)<br>Depth rating ..... 100 feet (30m)<br>Weight with camera ... 3.8 lbs (1.75kg) |
| RC93-S 0C | The RC93-S uses a standard D mount lens, due to the small size of the camera. Fitting a 'C' mount body enables the RC93 camera to be used with any 'C' mount lens. As standard the RC93-0C is provided without environmental protection, but protective or underwater heads can be provided to special order. | Length with camera .... 10.1" (257mm)<br>(w/out lens)<br>Diameter ..... 1.6" (40.5mm) |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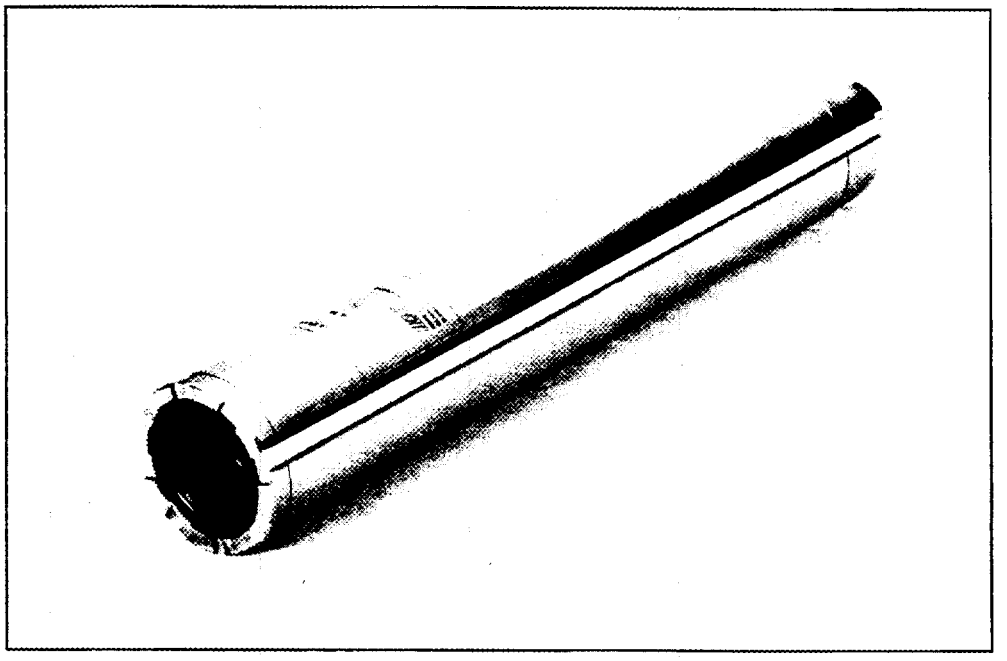
# Rees R940 Compact
# Nuclear Zoom Camera

## FEATURES

- Compact casing
- Radiation tolerant
- Non-browning zoom lens
- Remotely controlled
- Auto Iris with manual override
- 80W Lighting (R940LHA)

**The Rees R940 compact zoom camera has been developed to provide a radiation tolerant zoom facility in a compact 2.2" (55mm) diameter case. The zoom facility comprises a non-browning 22 to 90mm, F3.5 to F45 zoom lens with all the optical functions (ie focus, zoom, iris and where applicable, macro) fully motorized to allow complete remote control via the R90 MK 3 Camera Control Unit.**



Housed in a stainless steel case the R940 cameras incorporate a zoom lens that can focus and track from 10" (250mm) to infinity. This allows the R940CMA version without macro focus motor to suit most applications, but for applications requiring very close focusing (less than 10" (250mm)) the R940CMB version with macro focus motor, can be supplied.

The R940 camera is designed to be used in conjunction with Rees R90 Series Mk 3 Camera Control Units. Fully compatible with international video standards, R90 MK 3 Control Units can be integrated or locked to external sources, image processors or machine vision systems. A range of portable or rack mounted versions are available with local control, or remote control over twisted pair or video coaxial cables. The R940LHA lighting accessory also requires the rack mounting R900LPS Lighting Power Supply.

Remote function control and picture viewing can be via a central switching and control system from a master control room, or from either of two special Operator Control Units - one designed to be mounted directly on the cave or cell face wall and the other based on a movable trolley. Both include a 12" picture monitor display.

All Rees Camera Control Units are compatible with the R930VEU Video Enhancement Unit which provides an increase in camera sensitivity of 128:1.

The R940LHA lighting accessory provides both versions with 80W lighting power via four forward mounted 20W lights.

***Rees Instruments is fully approved for the design and manufacture of CCTV equipment to the following international quality standards:***

***ANSI/ASQC Q91-1987***
***ISO 9001-1987***
***BS 5750: Part 1: 1987***
***EN 29001-1987***

## Specifications

### General

| | R940CMA | R940CMB |
|---|---|---|
| Length | 12.9" (327mm) | 14.5" (367mm) |
| Diameter | 2.2" (55mm) | 2.2" (55mm) |
| Weight (approximate) | 4.4 pounds (2kg) | 5.1 pounds (2.3kg) |
| Lighting Power | Optional 4 x 20W | Optional 4 x 20W |

**Note...**
***The optional R940LHA 80W lighting accessory increases the camera diameter by 69mm (2.7") and weight by 1.75kg (3.8 pounds).***

### Environmental

| | | | |
|---|---|---|---|
| Operating temperature: | -13° to 130°F | (-25° to 55° C) | |
| Storage: | -13° to 140°F | (-25° to 60° C) | |
| Depth rating: | 165' | (50 metres) | |
| Radiation tolerance: | 2 x $10^8$ rads | (2 MGy (Si) [Co60]) | Total dose |
| | >3 x$10^6$ rads per hour | (>8 $Gys^{-1}$) | Vidicon |
| | 1 x $10^5$ rads per hour | (300m $Gys^{-1}$) | Newvicon/Chalnicon |

### System Performance

Resolution: 650 TV lines per picture height (center zone)

Sensitivity: 20 lux scene illumination
(1 volt composite video signal, extended red newvicon, 80% average scene reflectivity, tungsten illumination 2856K)

Lighting range in air using R940LHA03A lighting accessory:

| | |
|---|---|
| Good picture | 6.5' (2m) |
| Usable picture | 13' (4m) |

### Optics

Viewing angles in Air

| | Zoom Out | Zoom In |
|---|---|---|
| Horizontal | 23° | 6° |
| Vertical | 17° | 4° |

Focus range: 10" (250mm) to infinity (R940CMA without macro focus motor)
0.8" (20mm) to infinity (R940CMB with macro focus motor)

Cable Length: 660' (200 metres)

***Specification Notes***

1. *The information provided regarding lighting ranges is approximate only based on tests made in a dark-room viewing scenes with reflectivity of 60% using an R940 camera fitted with a newvicon tube.*
2. *A "good" picture is defined as one where the illumination available is sufficient for the camera to produce a 1 volt composite video signal with a fully open aperture.*
3. *A "usable" picture can usually be obtained, dependent on the scene viewed and environmental factors etc., when the illumination available is only one third that required to achieve a 1 volt composite video signal at full aperture.*
4. *For scenes where lighting is critical Rees can offer simulation facilities. Use of the R930VEU Video Enhancement Unit system can be of great benefit in areas where lighting is difficult. Please refer to the Rees R930VEU data sheet.*
5. *Rees should be consulted to very critical viewing requirements, or in cases where there are important lighting, resolution, environmental or viewing angle considerations.*
6. *In applications where there are severe space constraints care should be taken to allow for the size of the camera cable mating connector and if necessary, the bend radius of the connecting camera cable. Please refer to the Rees R90 series cables and connectors data sheets.*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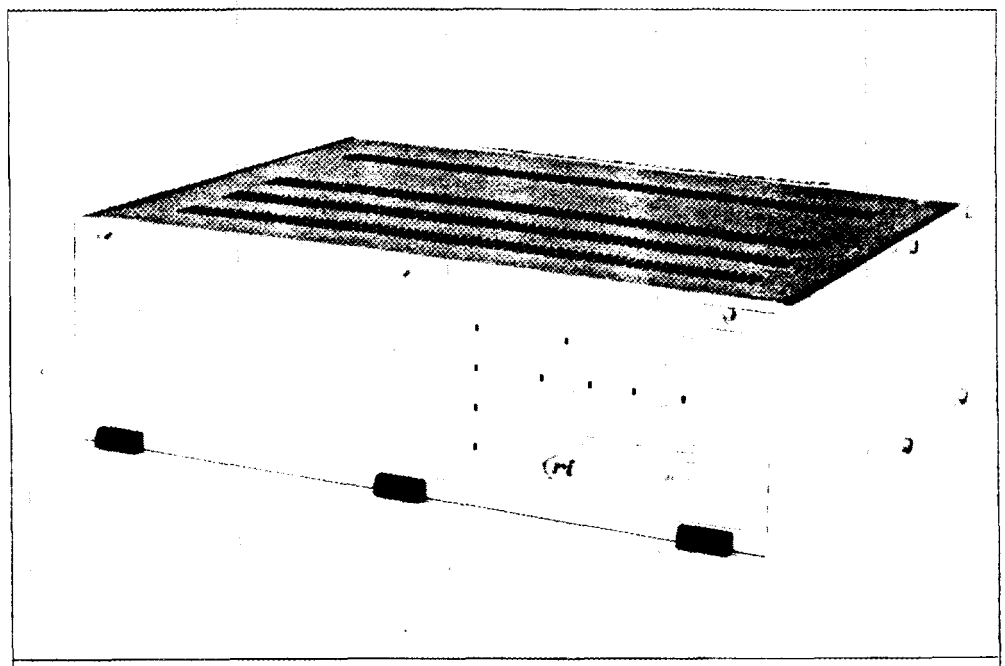
# Rees R90 Mark 3 Local Control
# Camera Control Unit

## FEATURES

- Membrane keypad for controlling camera functions
- 19 inch 3U rack mounting chassis
- Compatible with all Rees Cameras
- Lighting power supply, and pan & tilt supply options
- Optional remote control panel
- Camera type selector switch
- High power external lighting control option

**The Rees R930CUH Local Control CCU is designed to provide full remote control of single channel systems using any Rees Camera. The unit allows operator remote control via a tactile membrane keypad.**



*R930CUH Local Control CCU*

The R930CUH is housed in a nineteen inch rack-mounting chassis with the control keypad mounted on the front panel. An optional remote keypad can provide camera control away from the CCU rack.

The CCU is fully compatible with international video standards and can be integrated or locked to external sources, image processors or machine vision systems. Full compatibility with the R930VEU Video Enhancement Unit which increases camera sensitivity by 128:1. Versions are available in 525 or 625 line standards 100-120V, 200-240V, 50/60Hz.

To maintain high resolution pictures innovative new circuits have been incorporated into the CCU to significantly reduce the effects of radiation damage to the camera and induced noise, dark current temperature instability and tube-ageing.

The Video Card includes an auto-black circuit that detects the darkest area of the viewed scene and uses this as a reference to set the grey scale for the rest of the picture. This optimizes the picture contrast independently of tube dark current variations caused by radiation effects or temperature change. When used with the auto iris or auto target gain circuitry it also greatly improves the picture from scenes of low contrast.

The Scan Card beam current stabilization circuit counters the effects of tube-ageing by sensing the limiter current and controlling the grid voltage to maintain a constant beam current under varying conditions. This automatically stabilizes the beam current producing an improved electron beam spot shape and high resolution.

The combined action of these circuits enables any Rees Mk 3 series camera to provide high resolution pictures for longer periods of time, to higher total absorbed radiation doses (2 x $10^8$ Rads (Si)[Co60]) and at higher temperatures.

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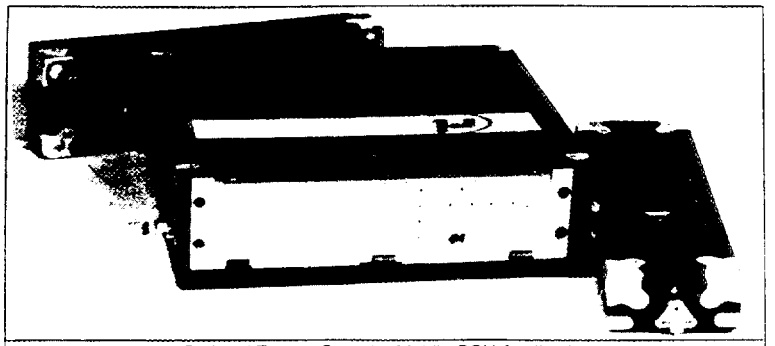
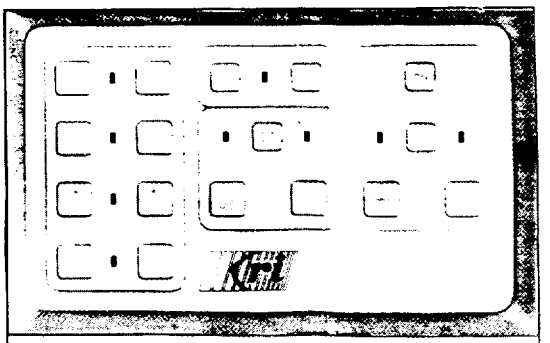
***EN 29001-1987***



*Optional Transit Case for Mobile CCU Applications*



*Membrane Keypad allowing full remote control of camera*

## Performance and Specifications

### R930CUH Local Camera Control Unit

**Dimensions**

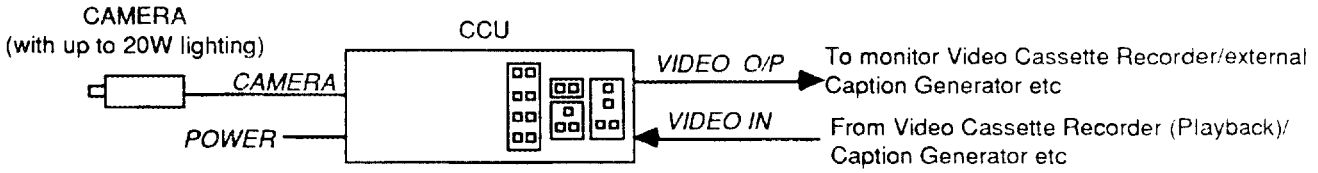
| | | |
|---|---|---|
| Length: | 15" | (380mm) |
| Width: | 19" | (484mm) |
| Height: | 5.2" | (133mm) |
| Weight: | 18.3 pounds | (8.3kg) |

**Environmental**

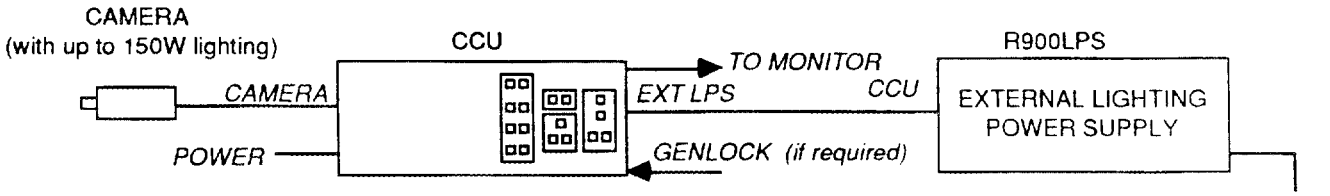
| | | |
|---|---|---|
| Operating temperature: | 32° to 122°F | (0 to 50°C) |
| Storage temperature: | -13° to 140°F | (-25° to 60°C) |
| Humidity: | 95% non condensing | |

**Case Material:** ..... Aluminum

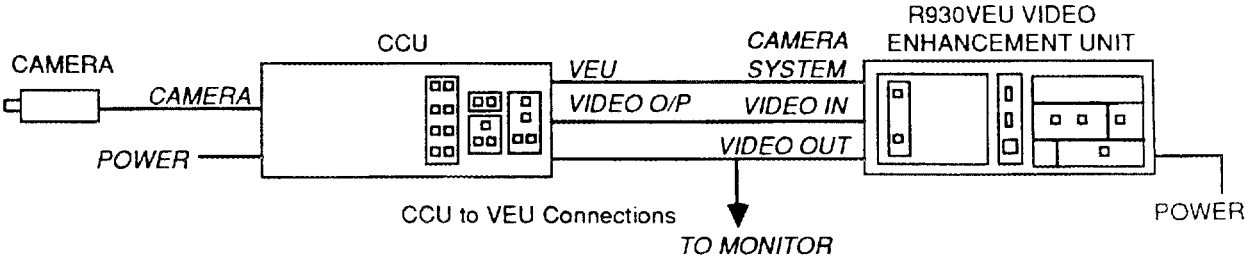
| | |
|---|---|
| Inputs | VEU<br>Mains Supply<br>Camera<br>Genlock<br>Video In<br>Video Out |
| Line standards | 525/625 |
| Supplies (Ac) | 110/120V<br>220/240V<br>50/60Hz |
| Options | Lighting Intensity Card<br>Pan & Tilt Supply<br>Lighting Power Supply<br>Remote Control Panel |




CCU to other Video Equipment




CCU to R900LPS Connections




CCU to VEU Connections

**Typical System configurations**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Fax: 0228 626300


01-08/92


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# Rees R93 Interchangeable Lens Bodies

## FEATURES

- Radiation tolerant
- Wide angle option
- Zoom option
- Prismatic option
- Lighting facilities
- C-Mount lens option
- Interchangeable on R93 capsule
- Underwater use via water corrected windows

**In addition to the interchangeable viewing heads, Rees R93 cameras can be fitted with a range of interchangeable lens bodies which include zoom, prismatic and wide angle types.**

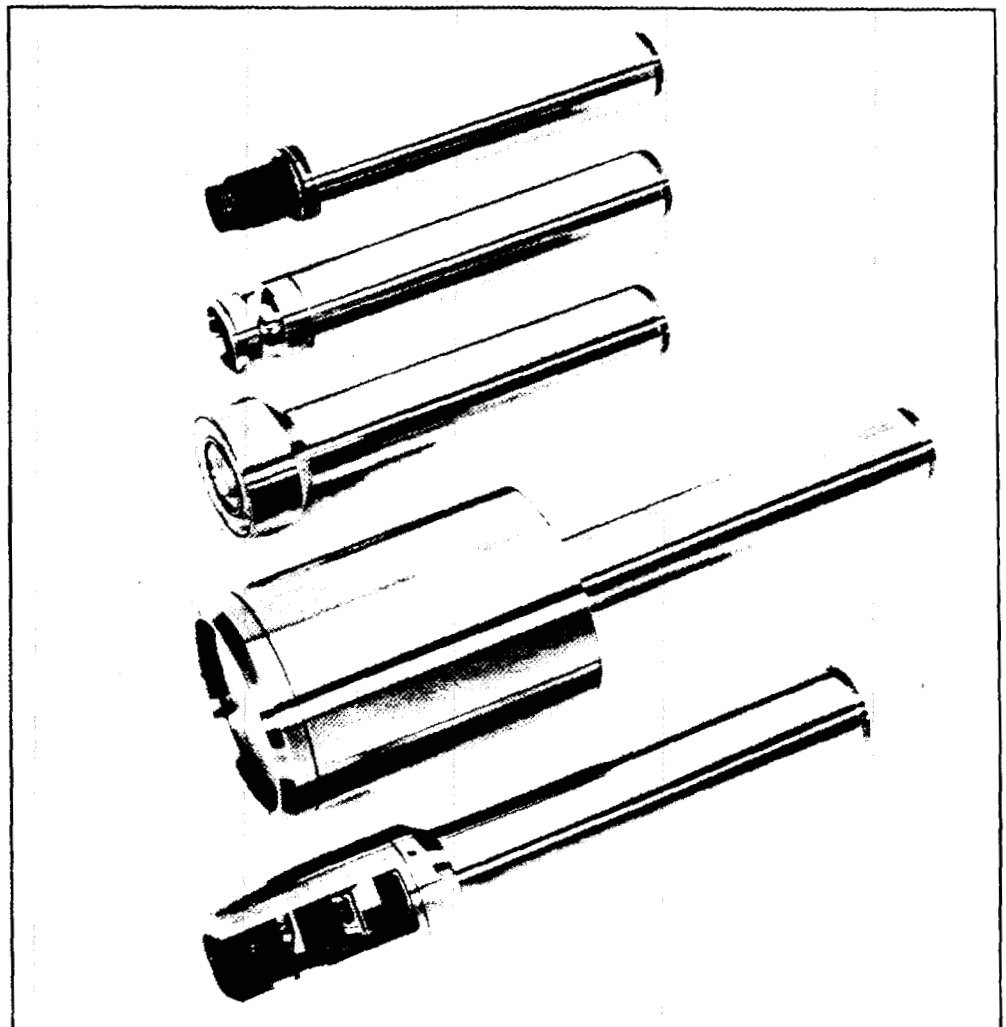
The Interchangeable lens bodies provide different lens facilities to that of the standard R93 Cameras'. This allows the standard R93 Capsule to be used in many varied applications. All the control and power supplies for an interchangeable lens body are fed to the camera by the appropriate composite camera cable.

Fitting an interchangeable lens body is very simple. Unscrewing the camera rear locking ring allows the existing body to be removed and the new body can then be fitted over the camera capsule and dual 'O' rings. Once the locking ring is tightened the camera is waterproof and ready to use.

Plain or water corrected windows are supplied depending upon the application. Plain windows used underwater narrow the viewing angle. When a water corrected window is used in water, the angle of view is the same as a plain window used in air.

Remote control of the various drive functions and light intensity level, up to 20 Watts, is available from the R90 Mk 3 Camera Control Unit (CCU). For lighting power - up to 300 watts, use the Rees R905LPS Lighting Power Supply.

The R93/09 and the R93/65L bodies are provided with lighting systems as standard. High power lighting requires the heat generated by the lights to be dissipated quickly. Underwater environments dissipate heat more rapidly, but in air lower power may have to be used as some lighting systems are not rated for continuous operation in air.



*Range of Interchangeable Lens Bodies*

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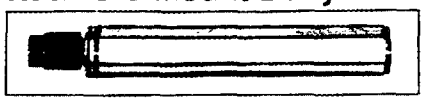
***ISO 9001-1987***
***BS 5750: Part 1: 1987***
***EN 29001-1987***

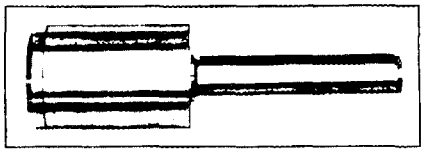
## R93/0C C Mount Body



Rees' range of radiation resistant non-browning lenses use 'D' mounts, due to the small size of the camera. Fitting a 'C' mount body enables the R93 camera to be used with any 'C' mount lens. As standard the R93/0C is provided without environmental protection, but protective or underwater heads can be provided to special order.

Length with camera ..... 10.1" (257mm)
Diameter ..... 1.6" (40.5mm)

## R93/04 Zoom Lens Body

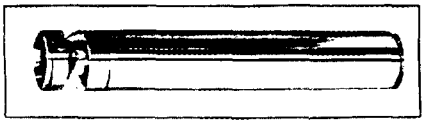


The R93/04 can be fitted with either standard glass 12.5-75mm or non-browning glass 12-72mm, f1.8, 6:1 zoom lenses. Lighting systems are not fitted as standard, but Rees Brightstream or STIQ lights can be fitted externally - please refer to "R90 Series Ancillaries" Data Sheet. Remotely controlled auto/manual iris, focus, macro focus, and zoom functions are provided, with a focus range of 2" to infinity, and a zoom tracking capability from approx 3 feet to infinity in air and from 4.3 feet in water.

| Viewing Angles | Air | | Water | |
|---|---|---|---|---|
| | Wide | Tele | Wide | Tele |
| Horizontal | 39° | 6.7° | 29° | 5.0° |
| Diagonal | 48° | 8.4° | 35° | 6.3° |
| Vertical | 31° | 5.2° | 23° | 3.9° |

Length with camera ..... 15.5" (395mm)
Diameter ..... 4" (104mm)
Depth rating ..... 197 ft (50m)
Weight with camera ..... 6.7 lbs (3.04kg)

## R93/65 6mm Wide Angle Lens Body

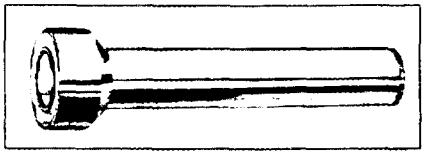


The R93 wide angle head is fitted with a Rees 6mm f2.0 non-browning glass lens and is designed for use in air or underwater. Plain and water corrected windows are available.

| Viewing Angles | Air | Water (Plain Window) |
|---|---|---|
| Horizontal | 72° | 53° |
| Diagonal | 85° | 61° |
| Vertical | 58° | 43° |

Length with camera ..... 11.4" (290mm)
Diameter ..... 1.6" (40.5mm)
Depth rating ..... 330 ft (100m)
Weight with camera ..... 3 lbs (1.41kg)

## R93/65L Wide Angle Lens Body with Lights

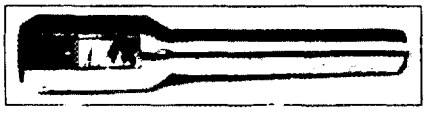


The R93/65L is fitted with the same lens as the R93/65 and is designed for use underwater, but can be used in air for short periods (approximately 1.5 hours at 20°C ambient). Lighting is provided from 16 x 1.2 watt lamps with a total output of about 20 watts. The lighting design has paid particular attention to the need for wide angle lighting to match the performance of the lens. Plain and water corrected windows are available.

| Typical Lighting Range (m) | Air | Water |
|---|---|---|
| For good picture | 1.2 | 0.9 |
| For usable picture | 3.5 | 1.8 |

Length with camera ..... 11" (290mm)
Diameter ..... 2.56" (65mm)
Depth rating ..... 100 ft (30m)
Weight with camera ..... 3.8 lbs (1.75kg)

## R93/09 Prismatic Viewing Lens Body



The R93/09 prismatic viewing lens body is extremely versatile, enabling the user to view any point within a complete hemisphere. This is achieved by using a 25mm f2.5 non-browning lens to view through a tilting and rotating prism, allowing it to look ahead, or, by tilting the prism, to view at any angle up to 90° from the camera axis. In addition the viewing head can continuously in either direction, the combination of the functions providing a complete hemisphere of view.

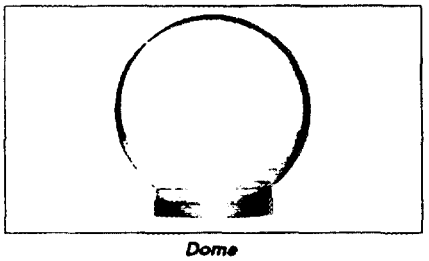
The R93/09 is provided with a 20 watt lamp which is fitted underneath the prism and tracks with the prism tilt movement. The lighting system has been designed for use in air only.

**Typical Lighting Range in air**

| View | Forward | Side |
|---|---|---|
| For good picture | 4.3 ft | 4.3 ft |
| For usable picture | 11 ft | 11 ft |

| Viewing Angles | Air only |
|---|---|
| Horizontal | 20° |
| Vertical | 15° |
| Diagonal | 25° |

Length with camera (less dome) ..... 15" (383mm)
Diameter ..... 2.48" (63mm)
Weight with camera ..... 4.6 lbs (2.1kg)



*Dome*

The R93/09 acrylic viewing dome has been developed to enable the R93/09 head to view underwater.

Dome diameter ..... 5" (127mm)
Length with camera ..... 14.5" (370mm)
Depth rating ..... 165ft (50m)

The acrylic material used for the R93/09 viewing dome has a total radiation tolerance of $10^8$ rads ($10^4$ Gy (Si)), after which it should be replaced due to embrittlement. The R93/09 lens and prism optics are manufactured from non-browning glass.

***Note: Viewing at right angles with a rotating prism causes the picture to become vertically inverted during a 360° scan, ie top becomes bottom and vice versa.***

*Specification Notes...*

1. *The information provided on lighting ranges is approximate only and is based on tests made in a dark-room viewing scenes with reflectivity of 60% using an R93 camera fitted with a Newvicon tube.*
2. *Lighting ranges in water have been calculated from the figures obtained in air.*
3. *A "good" picture is defined as one where the illumination available is sufficient for the camera to produce a 1 volt composite video signal with a fully open aperture.*
4. *A "usable" picture can usually be obtained, dependent on the scene viewed and environmental factors etc, when the illumination available is only one third that required to achieve a 1 volt composite video signal at full aperture.*
5. *The "length with camera" dimensions are defined as the length from the tip of the lens body to the end of the camera connector.*
6. *For scenes where lighting is critical Rees can offer simulation facilities. Use of the R930VEU Video Enhancement Unit system can be of great benefit in areas where lighting is difficult. Please refer to the R930VEU data sheet.*
7. *In applications where there are severe space constraints care should be taken to allow for the size of the camera cable mating connector and if necessary, the bend radius of the connecting camera cable. Please refer to the Rees R90 series cables and connector data sheet.*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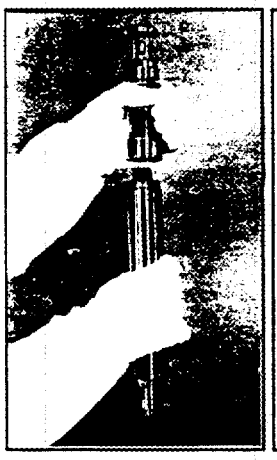
# Rees R93 Interchangeable Viewing Heads

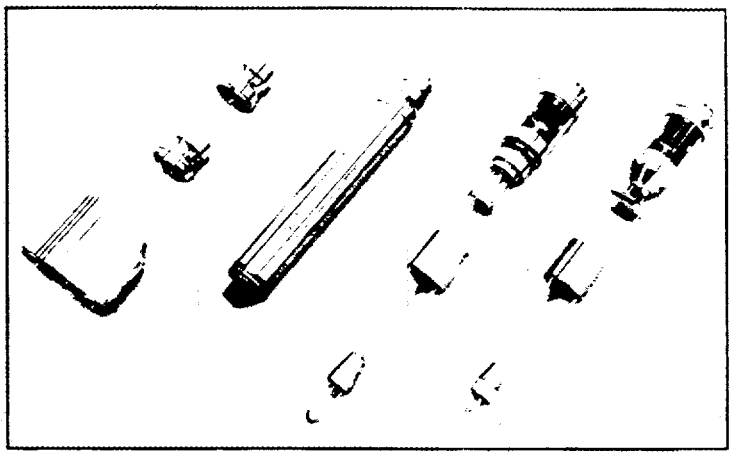
## FEATURES

- **Wide range**
- **Easy to fit**
- **Depths to 660 ft (200m)**
- **Lighting up to 100W**
- **Axial and Radial Viewing**

**Designed to enhance the versatility of the Rees R93 Camera, the range of interchangeable viewing heads simply screw on to the forward end of the camera body and provide rugged protection for the high performance optics.**

Fitting the appropriate viewing head enables the camera to be used underwater and gives the user additional facilities including remotely controlled lighting. The radial viewing R93-03 head also features a rotating mirror remotely driven via a motor in the standard R93 camera. All lighting supplies up to 100 watts are routed through the camera cable to spring loaded contacts adjacent to the camera lens. These connect to gold plated rings at the rear of the viewing head when the head is installed on the camera body.





Plain or water corrected windows are supplied depending upon the application. When a plain window is used underwater it narrows the viewing angle as follows:

| Plane | Air | Water |
|---|---|---|
| Horizontal | 50° | 37° |
| Vertical | 39° | 29° |
| Diagonal | 61° | 45° |

When a water corrected window is used the angle of view in water is the same as the angle of view in air.

The lens focusing range is from 1.2" to infinity - but closer focusing can be provided if required, subject to individual application.

The amount of light that can be provided is governed by a number of factors, the most important being whether the camera is to be used in water or air. In water the heat generated by the lights is dissipated quickly allowing high power to be used. In air lower power may have to be used as heat is dissipated more slowly. In some instances a head may not be rated for continuous operation in air.

Remote control of the various viewing heads including rotation, Hi and Lo light levels, and light intensity is available from the R90 Mk 3 Camera Control Unit (CCU). Lighting power of up to 20 watts is also provided by the R90 Mk 3 CCU Lighting Module. Heads requiring higher power outputs, up to 300 watts, use the Rees R905LPS Lighting Power Supply. This unit is enclosed in a separate 1U high 19 inch rack, interconnecting leads to the R90 Mk 3 CCU enable the lighting power to be routed via the camera cable.

***Note...***
***Rees should be consulted with regard to very critical viewing requirements, or in cases where there are important lighting, resolution, environmental or viewing angle considerations. In addition to the standard range of viewing heads a design service is available to provide customized or purpose-made viewing heads for special applications.***

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***ISO 9001-1987***
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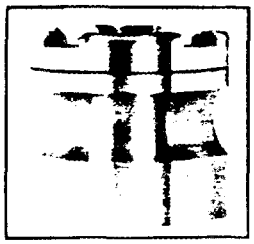


## R93/00

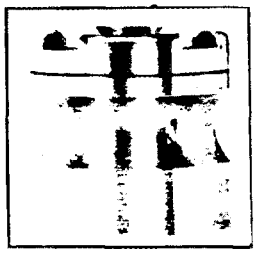
The R93/00 viewing head protects the lens and enables the R93 camera to be used underwater. A water corrected front window is available.
Length with camera: 12" (294mm)
Diameter: 1.6" (40.5mm)
Depth rating: 660 ft (200 metres)
Weight with camera: 3.8 pounds (1.4 kg)

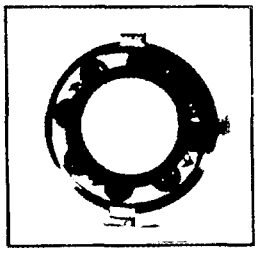
**Specification Notes**

1. The information provided on lighting ranges is approximate only based on tests made in a dark-room viewing scenes with reflectivity of 60% using an R93 camera fitted with a newvicon tube.
2. A "good" picture is defined as one where the illumination available is sufficient for the camera to produce a 1 volt composite video signal with a fully open iris.
3. A "usable" picture can usually be obtained dependent on the scene viewed and environmental factors etc, when the illumination available is only $^1/_3$ that required to achieve a 1 volt composite video signal with a fully open iris.
4. The "*length with camera*" dimensions given relate to the length from the tip of viewing head to the end of the camera connector.
5. Some viewing heads can be used at greater depths than those indicated. Please consult Rees for further information.

***For scenes where lighting is critical Rees can offer simulation facilities. Use of the R930VEU Video Enhancement Unit system can be of great benefit in areas where lighting is difficult. Please refer to the Rees R930VEU data sheet.***

***In applications where there are severe space constraints care should be taken to allow for the size of the camera cable mating connector and if necessary, the bend radius of the connecting camera cable. Please refer to the Rees R90 series cables and connectors data sheets.***



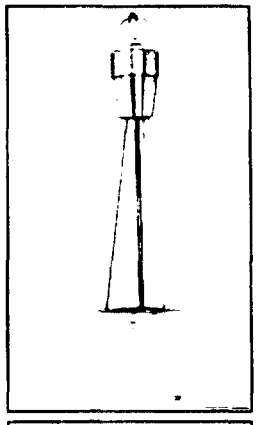


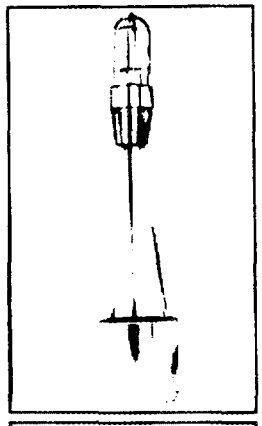
## R93/01

The R93/01 head is designed for use in restricted spaces. It has a low power internal lighting system of 1.8 watts provided by a ring of 8 tungsten lamps and can be used continuously in air or water.

| Lighting Range | In Air | In Water |
|---|---|---|
| For good picture | 51" | 12" |
| For usable picture | 267" | 28" |

Length with camera .... 12" (294mm)
Diameter ..... 1.6" (40.5mm)
Depth Rating ..... 660 ft (200 metres)
Weight with camera ... 2.7 pounds (1.2kg)





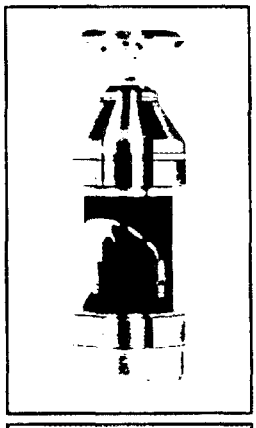
## R93/02

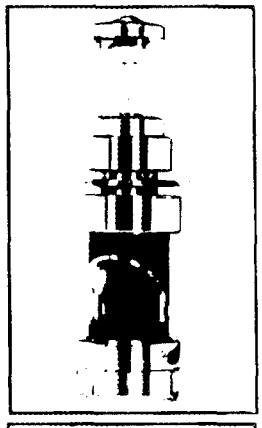
The R93/02 heads have either 20 watt or 100 watt tungsten halogen lamps. The 20 watt version is designed for continuous operation in air or water, and can be powered by the R90 Mk 3 Lighting Module. The 100 watt version is designed for continuous operation in water, and can be used in air for short periods depending upon the prevailing environmental conditions.

Forward viewing is slightly obscured by the lamp housing but this tends to be insignificant for the inspection of tubes and pipes where the extra lighting power available within the same diameter as the R93/01 head is of particular benefit. A water corrected window is fitted as standard.

| Lighting Range | In Air | In Water |
|---|---|---|
| For good pictures (20 watts) | 51" | 30" |
| For usable pictures (20 watts) | 106" | 69" |
| For good pictures (100 watts) | 67" | 39" |
| For usable pictures (100 watts) | 236" | 71" |

Length with camera .... (20W) 17" ( 440mm)
..... (100W) 18" (457mm)
Diameter ..... 1.6" (40.5mm)
Depth rating ..... 660 ft (200 metres)
Weight with camera ... 3.2 pounds (1.4kg)



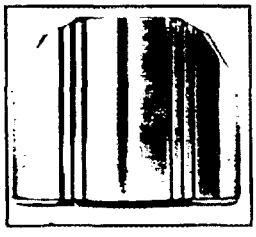


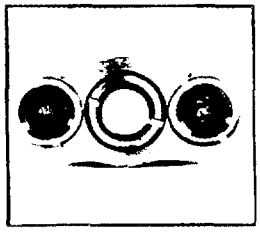
## R93/03

The radial viewing R93/03 views at right angles to the camera by using a stainless steel mirror which can scan through 360°. The head is fitted with either a 20W or 100W forward lamp and two 0.7 W lamps one mounted at each side of the mirror. Light from the forward lamp is back reflected to provide shadow modelling, the 0.7W lamps produce a diffuse light ideal for close-up viewing. The 20W versions can be used continuously in air or water. The 100W version is designed for operation in water, and can be used in air for short periods depending on the prevailing environmental conditions.
***Note: During a 360° scan the picture becomes inverted.***

| Lighting Range | In Air | In Water |
|---|---|---|
| Lo position for good picture (1.4W) | 12" | - |
| Lo position for usable picture (1.4W) | 16" | - |
| Hi position for good picture (20W) | 51" | 14" |
| Hi position for usable picture (20W) | 130" | 37" |
| Hi position for good picture (100W) | 59" | 26" |
| Hi position for usable picture (100W) | 157" | 43" |

Length with camera ... (20W) 15" (383mm)
(100W) 16" (415mm)
Diameter ..... 1.65" (42mm)
Depth rating ..... 660 ft (200 metres)
Weight with camera ... 3.7 pounds (1.7kg)





## R93/05

The R93/05 provides good illumination for general purpose viewing from 2 x 10 watt tungsten halogen lamps. It is designed for continuous use underwater and can also be used in air for short periods. After fitting, the head can be rotated manually by up to 180° (without breaking the center waterproof seal), to obtain the optimum lighting alignment, or to fit into specific spaces.

| Lighting Range | In Air | In Water |
|---|---|---|
| For good picture | 118" | 78" |
| For usable picture | 276" | 181" |

Length with camera .... 12" (300mm)
Depth rating ..... 660 ft (200 metres)
Weight with camera ... 5.3 pounds (2.4kg)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***Rees Instruments reserves the right to amend or change the information on this sheet without prior notice.***

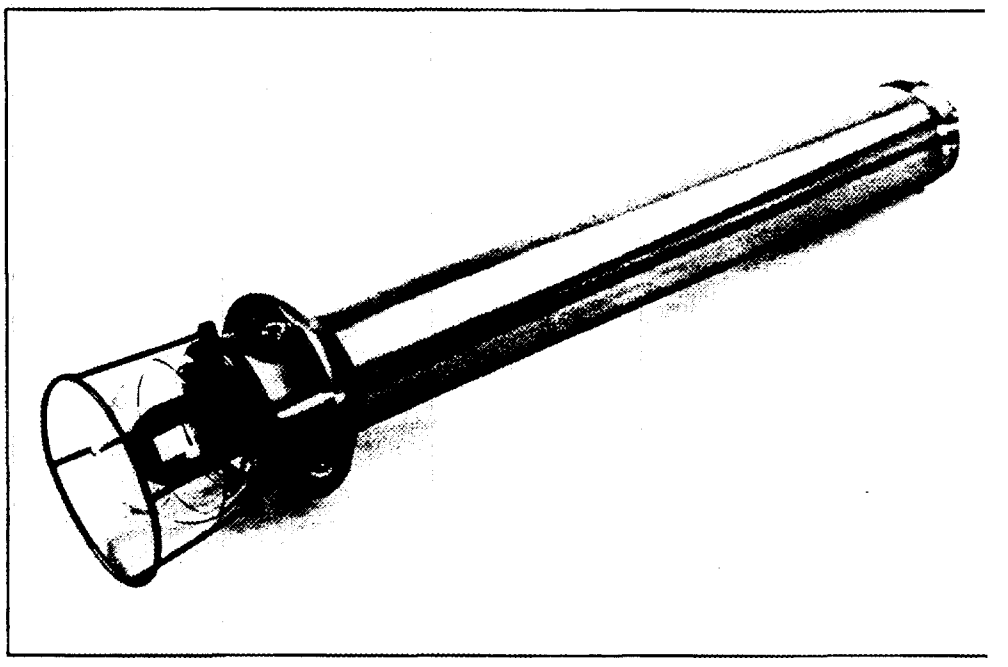
*Rees R936*

# Prismatic Camera

## FEATURES

- Radiation tolerant
- Prismatic optics
- Integral lighting for underwater use
- Remotely controlled
- Auto iris with override

**The Rees R936 Prismatic Camera offers the versatility of a full par and tilt function camera combined into a single compact unit foı deployment underwater in nuclear environments. The R936 cam· era is provided with a tilting prism which is mounted in front of the camera lens and a unique motor mechanism which rotates the prism and the main camera components within a special watertighı stainless steel casing. This arrangement makes it possible to view any point within a hemisphere.**



The R936 camera is designed to be used in conjunction with Rees R90 Series MK3 Camera Control Units. Fully compatible with international video standards, R90 MK3 Control Units can be integrated or locked to external sources, image processors or machine vision systems. A range of portable or rack mounted versions are available with local control panel, or remote control over twisted pair or video coaxial cables. All Rees Camera Control Units are compatible with the R930VEU Video Enhancement Unit which provides an increase in camera sensitivity of 128:1.

Remote function control and picture view ing can be via a central switching anc control system from a master control room or from either of two special Operato Control Units - one designed to be mounted directly on the cave or cell face wall and the other based on a movable trolley. Both include a 12" picture monito display.

***Note...***
***Rees should be consulted with regan to very critical viewing requirements or in cases where there are importan lighting, resolution, environmental o viewing angle considerations.***

*Rees Instruments is fully approved for the design and manufacture of CCTV equipment to the following international quality standards:*

*ANSI/ASQC Q91-1987*
*ISO 9001-1987*
*BS 5750: Part 1: 1987*
*EN 29001-1987*

*Additional information is provided in the following data sheets:*
**'Rees R936 System Configuration'**
**'Rees R90 Series MK3 Camera control Units'**
**'Rees R90 Series Cables and Connectors'**
**'Rees R930VEU Video Enhancement Unit'**
**'Rees Operator Control Units'**

## Performance and Specifications

### Mechanical

| | | |
|---|---|---|
| Case Material: | Stainless steel | |
| Dome Material: | Acrylic | |
| Weight: | 5.5 pounds | (7kg) |

### Dimensions

| | | |
|---|---|---|
| Length: | 24.2 ins | (615 mm) |
| Diameter (max): | 4.4 ins | (112 mm) |

### Environmental

| | | |
|---|---|---|
| Operating temperature: | -13° to 130°F | (-25 to 55°C) |
| Storage temperature: | -13° to 140°F | (-25 to 60°C) |
| Depth rating: | 160 feet | (50 metres) |
| Radiation tolerance: (total) | $2 \times 10^8$ rad | ($2 \times 10^6$ Gy (Si) [Co - 60]) |
| Acrylic dome (total) | $1 \times 10^6$ rad | ($1 \times 10^4$ Gy (Si) [Co - 60]) |
| | Single piece acrylic dome should be replaced after $1 \times 10^6$ rad due to embrittlement | |
| Radiation tolerance: (dose rate) | $3 \times 10^6$ rad per hour | (>8 $Gys^{-1}$ with vidicon tube) |
| | $1 \times 10^5$ rad per hour | (300m$Gys^{-1}$ with Newvicon tube) |

### System Performance

| | | | |
|---|---|---|---|
| Resolution: | 500 TV lines per picture height (centre) | Signal to noise ratio: | >36dB (CCU high gain) |
| Sensitivity: | 16 lux scene illumination (good picture) | | >43dB (CCU standard gain) |
| | 6 lux scene illumination (usable picture) | | |

***Notes...***

1. ***Signal to noise ratio measurements refer to weighted readings over 10MHz bandwidth using Rhode & Schwarz UPSF video noise meter.***
2. ***Sensitivity using extending red Newvicon tube and F2.5 non-browning lens.***
3. ***A 'good' picture is defined as one where the illumination available is sufficient for the camera to produce a 1 volt composite video signal with a fully open aperture.***
4. ***A 'usable' picture can usually be obtained, dependent on the scene viewed and environmental factors etc., when the illumination available is only one third that required to achieve a 1 volt composite video signal at full aperture.***
5. ***The information provided regarding lighting ranges is approximate only based on tests made in a dark-room viewing scenes with reflectivity of 60% using an R936 camera fitted with a Newvicon tube.***
6. ***For scenes where lighting is critical Rees can offer simulation facilities. Use of the R930VEU Video Enhancement Unit system can be of great benefit in areas where lighting is difficult.***

### Optics

25mm f2.5 non browning glass lens

Viewing angles

| | Air | Water |
|---|---|---|
| Horizontal | 19° | 22° |
| Vertical | 14° | 17° |
| Diagonal | 23° | 27° |

| | | |
|---|---|---|
| Focus range: (from dome surface) | 3.9" (100mm) to infinity | 9.8" (250mm) to infinity |
| Lighting range: | not applicable | 5' - 6' 6" (1.5 - 2m) |
| Functions: | Rotate ± 180°<br>Tilt axial to side, 90°<br>Lights on/off, intensity<br>Iris f2.5 to f16<br>Focus | |
| Cable length: | 330 or 660 feet maximum, dependent on cable choice | |

The R936 lighting system has been designed to provide local illumination underwater and is not suitable for use in air. If the camera is to be used for general viewing of large pool or pond areas, then additional lighting should be provided. Power for the R936 lighting system is provided on external Rees Lighting Power Supply.

In applications where there are severe space constraints care should be taken to allow for the size of the camera cable mating connector and if necessary, the bend radius of the connecting camera cable. Please refer to the Rees R90 series cables and connectors data sheet.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# Rees R937
# General Purpose Prismatic Zoom Camera

## FEATURES

- **Radiation tolerant**
  Tested to an accumulated dose of 2 MGy (2 x $10^8$) rads (Si) [Co60] using a spent fuel source.

- **High reliability**
  The camera's motor drive and mechanical systems including the prism shutter have all passed a 30 year accelerated life test.

- **Proven performance**
  The electronics of the R937 have been developed from the R93 camera used in nuclear power plants throughout the world.

- **Spot filter**
  A neutral density spot filter can be fitted to the zoom lens to enable the camera to be used with modern sensor tubes over a wide range of lighting levels.

- **Focus range**
  The R937 will focus from infinity down to 2" (50mm) from the camera dome using macro focus; zoom lens re-tracks automatically after macro use.

- **Automatic iris with override**
  The auto iris automatically changes the iris setting as the light level varies between different scenes.

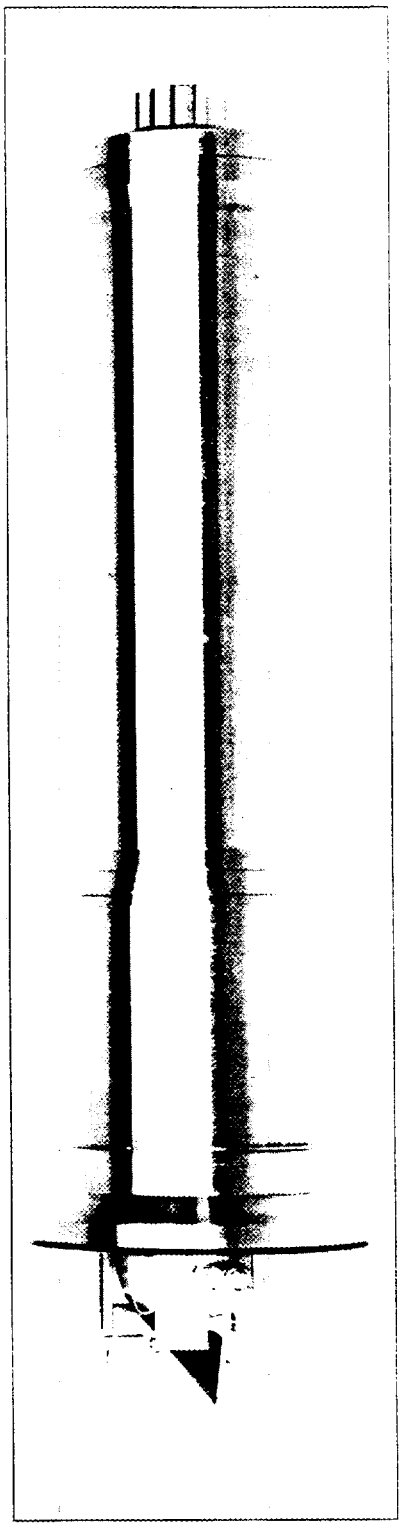
- **Choice of Sensor Tubes**
  The camera can be fitted with a range of $^2/_3$" (18mm) sensor tubes depending on sensitivity, temperature, radiation tolerance and resolution requirements.

- **Shutter mechanism**
  A prism following shutter mechanism is fitted which shields the unused surfaces of the prism to reduce spurious reflections

- **Zoom Lens**
  The R937 is provided with a radiation tolerant motorized zoom lens to give the operator remotely variable magnification over a range of 5.4 to 1.

***Rees Instruments is fully approved for the design and manufacture of CCTV equipment to the following international quality standards:***

***ANSI/ASQC Q91-1987***
***ISO 9001-1987***
***BS 5750: Part 1: 1987***
***EN 29001-1987***



**The Rees R937CMB General Purpose camera combines the versatility of a pan, tilt and zoom camera system into one compact unit for deployment in air.**

The R937CMB camera is designed to be used inside nuclear cells and is encased in a waterproof stainless steel housing and views through a non browning glass dome. Its powerful optical system utilizes a rotating, tilting prism and a zoom lens to view in excess of a hemisphere. The R937CMB camera is easy to decontaminate and is an ideal solution to applications requiring television surveillance on or from spent fuel handling and processing machines.

The R937CMB camera is designed to be used in conjunction with Rees R90 Series Mk 3 Camera Control Units. Fully compatible with international video standards R90 Mk 3 Control Units can be integrated or locked to external sources, image processors or machine vision systems. A range of rack mounted versions is available with local or remote control facilities. Options available include a local control panel, telemetry receiver cards for remote control over twisted pair or video coaxial cables, and a motor position card with tell-back information for all monitor functions - enabling the R937 viewing system to be automatically linked to the movements of an in-cell machine or manipulator. All Rees Camera Control Units are compatible with the R930VEU Video Enhancement Unit which provides an increase in camera sensitivity of 128:1.

Remote function control and picture viewing can be via a central switching and control system from a master control room, or from either of two special Operator Control Units - one designed to be mounted directly on the cell wall and the other based on a movable trolley. Both include a 12" picture monitor display.

Additional information is provided in the following data sheets:
**'Rees R937 Underwater Camera'**
**'Rees R937 System Configurations'**
**'Rees R90 Series Mk3 Camera Control Units'**
**'Rees R90 Series Cables and Connectors'**
**'Rees R930 VEU Video Enhancement Unit'**

## PERFORMANCE AND SPECIFICATIONS

### Mechanical (R937CMB)

| | |
|---|---|
| Dimensions: | 6" (156mm) maximum diameter (including dome) x 25" (627mm) including camera connector. |
| Material: | Stainless steel |
| Weight: | 33 pounds (15 kg) |

### Environmental

| | | |
|---|---|---|
| Operating temperature: | -13° to 130°F | (-25 to 55°C) |
| Storage temperature: | -13° to 140°F | (-25 to 60°C) |
| Radiation tolerance | $2 \times 10^8$ rads | ($2 \times 10^6$ Gy (Si) [Co60]) total dose) |
| | $3 \times 10^6$ rads per hour | (>8Gys$^{-1}$) vidicon) |
| Radiation tolerance (dose rate) | $1 \times 10^5$ rads per hour | (300 mGys$^{-1}$) Newvicon/Chalnicon) |

### System Performance

| | |
|---|---|
| Resolution: | >550 TV lines (central zone) |
| Sensitivity: | 50 lux (F3.6) 4,000 lux (F32). |
| | >18,000 lux with ND spot filter. |
| Signal to noise ratio: | >43 dB (CCU standard gain) |
| | >36 dB (CCU high gain) |

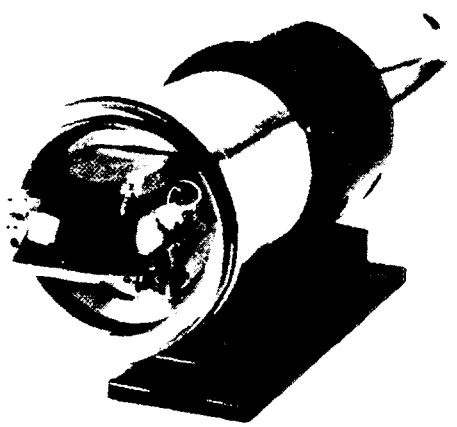
***Notes...***

1. ***Signal to noise ratio measurements refer to weighted reading over 10 MHz bandwidth using Rhode & Schwarz UPSF video noise meter.***
2. ***Sensitivity using extending red Newvicon tube tungsten illumination 2856K, 80% average scene reflectivity.***

### Optics

| Viewing angles (in air) | Zoom Out | Zoom In |
|---|---|---|
| Horizontal | 21° | 3° 30' |
| Vertical | 16° | 2° 40' |
| Diagonal | 26° | 4° 20' |

| | |
|---|---|
| Focus range: | 2" (50mm) (from glass dome) to infinity. |
| Function: | Rotate ± 180° Tilt axial to side, 90° |
| | Zoom 25mm - 135mm Iris F3.6: F32 |
| | (T180 with ND spot) |



### Cable Length

Camera to CCU separation 660 feet (200 metres) (TV36).

### Sensor Tubes

$^2/_3$" (18mm) format Vidicon, Newvicon, Chalnicon and Pasecon tube types are all suitable, dependent on application.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## Rees R937

# Thru-Wall/Thru-Roof Viewing System

## FEATURES

- **Viewing capability**
  Exceeds a full hemisphere through a single piece dome by using rotate and prism tilt to effect pan and tilt operations.

- **Radiation tolerant**
  Tested to an accumulated dose of 2 MGy ($2 \times 10^8$) rads (Si) [Co60] using a spent fuel source.

- **High reliability**
  The camera's motor drive and mechanical systems including the prism shutter have all passed a 30 year accelerated life test.

- **Proven performance**
  The electronics of the R937 have been developed from the R93 camera used in nuclear power plants throughout the world.

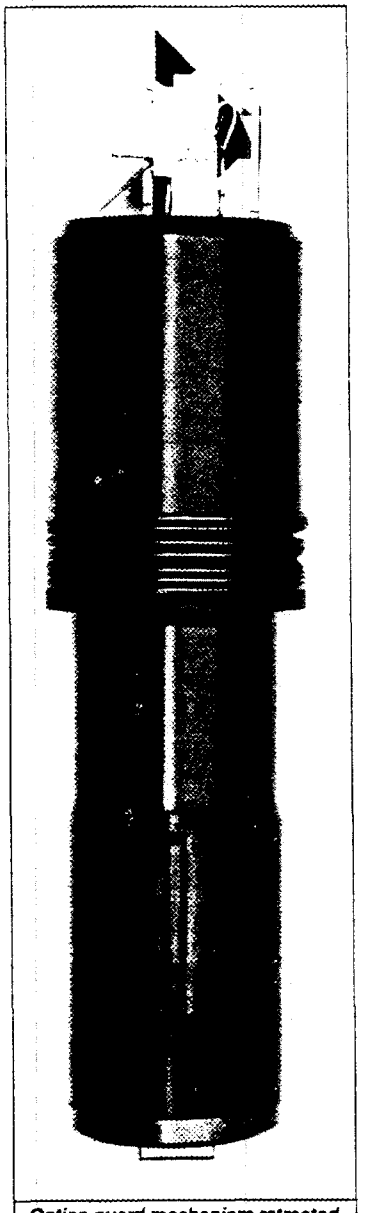
- **Zoom Lens**
  The R937 is provided with a radiation tolerant motorized zoom lens to give the operator a remotely variable magnification ratio of 5.4:1.

- **Focus range**
  The R937 will focus from infinity down to 2" (50mm) from the camera dome using macro focus; zoom lens re-tracks automatically after macro use.

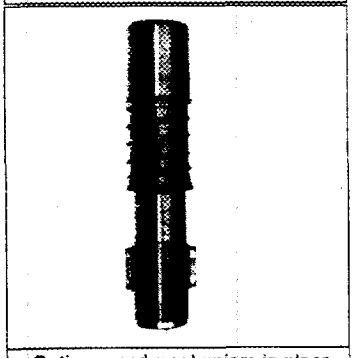
- **Automatic iris with override**
  The auto iris automatically changes the iris setting as the light level varies between different scenes.

- **Choice of Sensor Tubes**
  The camera can be fitted with a range of (7/3") 18mm sensor tubes depending on sensitivity, radiation tolerance, temperature and resolution requirements.

- **Shutter mechanism**
  A prism following shutter mechanism shields the rear surfaces of the prism to reduce spurious reflections.



*Optics guard mechanism retracted*



*Optics guard mechanism in place*

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***EN 29001-1987***

**The Rees R937 thru-wall and thru-roof viewing system provides an ideal solution to the problems of television monitoring and surveillance of nuclear processing cell interiors.**

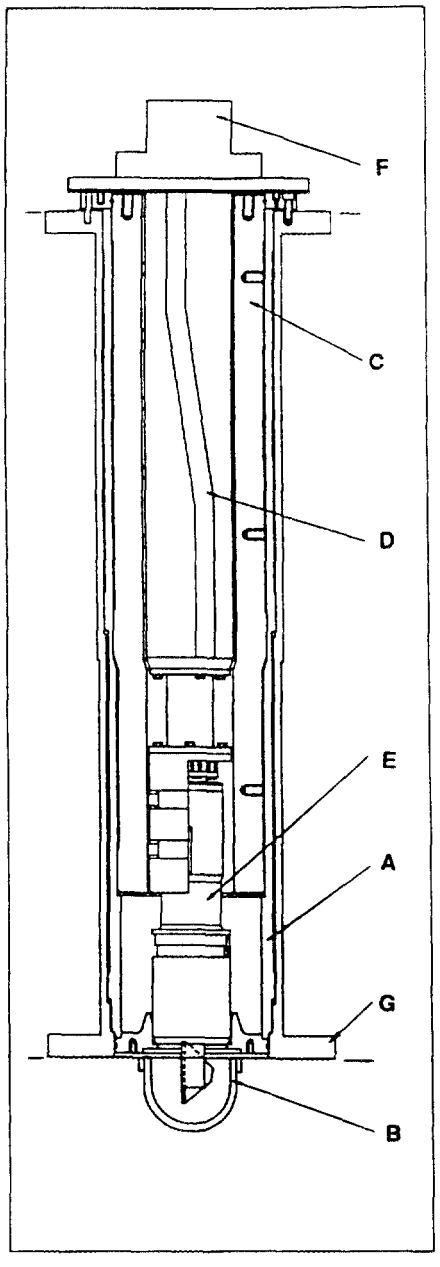
The R937 thru-wall and roof viewing system uses a Rees R937CME camera fitted in a plug-unit installed in the shield wall (or roof). The camera views the inside of the cell through a special viewing dome which acts as a biological shield allowing the camera to be "posted" in and out of the cell wall within a shielded liner assembly. All camera components are therefore accessible for maintenance from the exterior of the cell. Man-entry for maintenance or replacement is unnecessary, and because the camera has been protected from the risk of contamination it can be maintained and repaired in an ordinary electronic instrument workshop. Use of the R937 thru-wall and roof viewing system is, therefore, fully in keeping with the latest ALARA (As Low As Reasonably Achievable) precepts concerning radiation dose uptake for nuclear operators.

The R937 shielded liner system requires a much smaller aperture in the shield wall than a viewing window, making it easier and more cost effective to accommodate within seismic design constraints. Window viewing requires very high ambient light to be provided, which in turn produces heat. The R937CME camera will operate in relatively low light levels and, therefore, its use may reduce cell temperatures, and ease heat control and venting problems.

### CAMERA CONTROL

The R937CME camera is designed to be used in conjunction with Rees R90 Series Mk3 Camera Control Units. Fully compatible with international video standards R90 Mk3 Control Units can be integrated or locked to external sources, image processors or machine vision systems. A range of plug unit, wall or rack mounted versions is available with local or remote control facilities. Options available include a local control panel, telemetry receiver cards for remote control over twisted pair or video coaxial cables, and a motor position card with tell-back information for all motor functions - enabling the R937 viewing system to be automatically linked to the movements of an in-cell machine or manipulator. All Rees Camera Control units are compatible with the R930VEU Video Enhancement Unit which provides an increase in camera sensitivity of 128:1.

Remote function control and picture viewing can be via a central switching and control system from a master control room, or from either of two special Operator Control Units - one designed to be mounted directly on the cave face wall and the other based on a mobile trolley. Both include a 12" picture monitor display.




**A** The intermediate liner which is designed and manufactured to fit within a 10.6" (270mm) site encast liner G (the system can also be accommodated within 6" (150mm) liners if required).

**B** Camera viewing dome is constructed from a single piece in non-browning glass and is fitted to the cell-side of the intermediate liner to act as a biological shield. It allows viewing in excess of a full hemisphere.

**C** The filler liner is used to reduce the size of the intermediate liner and to provide radiation shielding. Use of a filler liner also reduces the weight of the shield plug.

**D** The shield plug assembly can be inserted and removed from the filler liner without breaking the biological seal. It is provided with a shielded cable conduit and a camera carrying cradle. A special spring loaded push/pull connector system is incorporated which acts as a positional register ensuring that the camera's optical system is positioned exactly in the center of the viewing dome.

**E** The Rees R937CME thru-wall/roof viewing camera. When the camera is inserted into the liner system on the shield plug its optics are protected by a spring loaded guard mechanism which retracts on contact with the front of the liner system to reveal the prism optics.

**F** A plug unit mounted R90 Mk3 Camera Control Unit in stainless steel can be fixed directly onto the rear of the shield plug assembly, all of the electrical connections to the camera are achieved via a push-pull connector arrangement. Video and control cable connectors are provided as part of the unit.

Designs exist for thru-wall liner systems which can accommodate a wall thickness from approximately 28" (700mm) to 10 feet (3m) and beyond. Shield plugs are available in lead shot concrete of varying densities and solid lead. Rees are able to offer full advice on the appropriate shielding material and density given the full specification of the irradiating source.

| **Shielded Liner System (subject to application)** | | | |
|---|---|---|---|
| Dimensions: | Diameter: 6" to 11" (150 to 270mm)<br>length: 28" (700mm) to more than 118' (3m) | Weight:<br>Material: | Shield plug and camera - 110-440 pounds<br>Carbon steel with lead shot concrete and lead fillers |
| **Dome** | | | |
| Dimensions: | Diameter: 6" (150mm)<br>Weight: 4.4 pounds (2kg) | Material: | Non browning glass |

The wall mounted R90 Series Mk3 Camera Control Unit is just one of a wide range of camera control unit options available The Rees R937 camera series can be specified to match a comprehensive range of different application requirements and preferences. Additional information is provided in the following data sheets:
**'Rees R937 Camera System Configurations'**
**'Rees R90 Series Mk3 Camera Control Units'**
**'Rees R90 Series Cables and Connectors'**
**'Rees R930VEU Video Enhancement Unit'**

**Video-tape**
A full presentation of the R937 thru-wall and roof viewing system is available on video-tape, the tape includes active assembly and maintenance demonstrations.

*The thru-wall and thru-roof liner systems used for the R937CME were designed and developed by Rees Instruments, under contract to, and based on, some outline designs by British Nuclear Fuels plc. However, the fully developed Rees system incorporates many new essential features to optimize performance and maximize ease of operation and deployment.*

## R937CME CAMERA PERFORMANCE AND SPECIFICATIONS

| **Mechanical (R937CME)** | | **Environmental** | | | **System Performance** | | **Optics** | | |
|---|---|---|---|---|---|---|---|---|---|
| Dimensions: | | Temperature: | | | Resolution: | >550 TV lines | Viewing angles (in air) | **Zoom Out** | **Zoom In** |
| maximum diameter: | 5" | Operating temperature: | -13°F to 130°F | -25° to 55°C | Sensitivity: | | Horizontal | 21° | 3° 3' |
| length: | 24" | Storage: | -13°F to 140°F | -25° to 60° | F3.6 | 50 lux | Vertical | 16° | 2° 40' |
| Weight: | 29 pounds | Humidity (non condensing): | | 95% | F32 | 4000 lux | Diagonal | 26° | 4° 20' |
| Total dose: | $2 \times 10^8$ | Radiation tolerance: | | | (full video amplitude, extended red newvicon, 80% average scene reflectivity, tungsten illumination 2856K) | | Focus range: | From glass dome to infinity | |
| Material: | Die-cast Aluminium | Total dose: | $2 \times 10^8$ Gy (Si) [Co60] ($2 \times 10^8$ rads) | | | | Rotate function: | ± 180° | |
| | | Dose rate: | >8Gys$^{-1}$ (Si) [Co60] ($3 \times 10^8$ rads per hour) | | | | Tilt axial to side | 90° | |
| | | | | | | | Zoom: | 25mm - 135mm | |
| | | | | | ND spot filter: | 18000 lux | Iris: | F3.6 | |
| | | | | | Signal to noise ratio: | | (T180 with ND spot): | F32 | |
| | | | | | (CCU standard gain): | >43 dB | | | |
| | | | | | (CCU high gain): | >36 dB | | | |

**Sensor Tubes:** $^2/_3$" (18mm) format
(Vidicon, Newvicon, Chalnicon and Pasecon tube types are all suitable, dependent on application.)
**Cable Length:** Camera to control unit separation 656' (200 metres)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# Rees R90 Series
# Cables and Connectors

## FEATURES

- Air and underwater appplications
- Radiation tolerant
- Wide range
- Specifically developed for nuclear operations
- Site reterminable connectors
- Field proven design

**Rees R90 Series Cables and Connectors are designed for use with all of the R90 Series nuclear cameras and have been specifically developed for nuclear applications underwater or in air.**

All the Rees R90 Series cameras have a very high radiation tolerance which is partly achieved by their dual unit construction with the majority of the camera electronics being contained in a separate camera control unit (CCU) positioned outside the active area. This design approach reduces radiation induced damage, while also ensuring easy service access. The camera control units are linked to their associated cameras by single composite camera cables - with matching connectors - which provide all the necessary power, control and signal functions.

### R90 SERIES CABLES

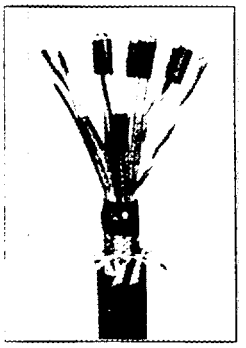
**Standard Cables**

| Cable | Separation (m) Camera to CCU | Operation Notes |
|---|---|---|
| TV36 102.00.019 17mm dia | 200 | Lighting current 6A max Full R937 options available |
| Minikeviar 102.00.027 11mm dia | 100 | Lighting current 6A max R937 has reduced options |

**Special Cables**

| Cable | Separation (m) Camera to CCU | Operation Notes |
|---|---|---|
| Minicable R000CAB014 8.8mm dia | 100 | Lighting current 5A max R937 has reduced options |
| Spiral cable 8.8mm dia 50mm dia coils | 100 | Lighting Current 5A max R937 has reduced options |
| Flatform Cable | Full application specifications are required before this cable can be considered. | |

### Rees TV36 102.00.019



36 core camera cable with kevlar braid, polyethylene cores and polyester elastomer jacket.

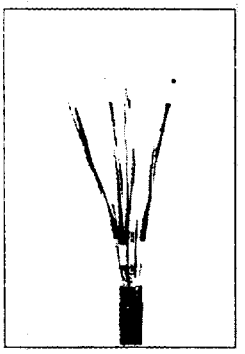
Cores:
3 coaxials 75 ohm
1 group of 14
(each 7 x 0.16mm)
1 screened group of 7
(each 7 x 0.16mm)
1 group of 4
(each 7 x 0.16mm)
1 screened group of 4
(each 7 x 0.32mm)
4 singles
(each 7 x 0.23mm)

**Characteristics**

Mechanical
Diameter 16.45mm (max 16.90mm)
Break strength: 1000 kg
Minimum Installation bend radius: 100mm
Continuous flexing bend radius: 240mm
Weight in air: 0.34kg per metre
Operating temp. range: -20° to 80°C
Total radiation dose: 2 x $10^8$ Gy (2 x $10^8$ rads)

Electrical
75 ohm coaxial:
Characteristic impedance: 75 ohms
Attenuation: 4.7 dB per 100m at 10 MHz
Polyethylene insulated Cores:-
dc resistance at 20°C
7 x 0.32: 3.59 ohms per 100 metres
7 x 0.23: 6.83 ohms per 100 metres
7 x 0.16: 14.4 ohms per 100 metres max

### Rees Minikeviar 102.00.027



31 core camera cable with kevlar strength member, PVC cores, and polyurethane elastomer jacket.

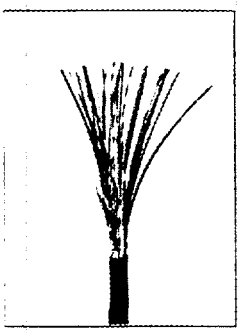
Cores:
2 coaxials 75 ohm
1 screened quad
(7 x 0.2mm)
2 groups of 7
(each 7 x 0.2mm)
1 group of 5
(each 7 x 0.2mm)
3 singles
(each 7 x 0.2mm)
3 earth returns
(each 16 x 0.2mm)
1 kevlar strength member

**Characteristics**

Mechanical
Diameter 11.30mm (±0.38mm)
Installation bend radius: 82mm min.
Continuous flexing bend radius: 165mm min.
Weight in air: 0.2kg per metre
Break strength: 324kg
Operating temp.range: -20° to 70°C
Total radiation dose: $10^8$ Gy ($10^8$ rads)

Electrical
75 ohm coaxial:-
Characteristic impedance: 75 ± 2 ohms
Attenuation: 5.7 dB per 100m at 10 MHz
PVC Insulated Cores:-
dc resistance: 8.8 ohms per 100m nominal
Earth returns:-
dc resistance: 4.0 ohms per 100m nominal

### Rees Minicable R000CAB014



A special 31 core camera cable with a very small diameter and bend radius, polyester tape cores and polyester elastomer jacket.

Cores:
2 coaxials 75 ohm
1 screened quad
(7 x 0.2mm)
21 singles
(each 7 x 0.2mm)
3 singles
(each 19 x 0.2mm)

**Characteristics**

Mechanical
Diameter: 8.8mm (±0.6mm)
Installation bend radius: 45mm min.
Continuous flexing bend radius: 90mm
Weight in air: 0.14kg per metre
Operating temp. range: -20° to 80°C
Total radiation dose: $10^8$ Gy ($10^8$ rads)

Electrical
75 ohm coaxials:-
Characteristic impedance: 75 ohm ± 2 ohms
Attenuation: 5.7 dB per 100m at 10 MHz

Polyester Tape insulated cores
dc resistance at 20°C:
7 x 0.2mm: 8.8 ohms per 100m
19 x 0.2mm: 3.2 ohms per 100m

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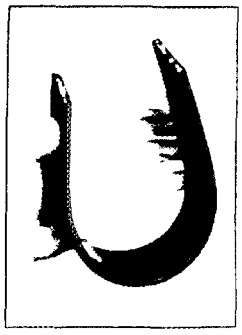
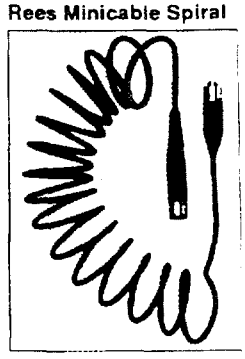
***EN 29001-1987***

## Rees Flatform Cables



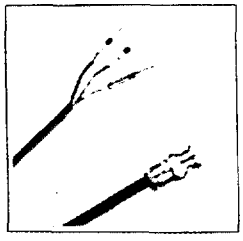
Flatform festoon cables are available to special order.

## Rees Minicable Spiral



Special expandable spiral versions of the Rees Minicable are available.

## Video and Control Cable CAB.00640



This cable combines a video cable and a two core control cable into *one figure of 8 assembly. Cores are constructed in PVC (cellular* polyethylene for the coaxial) with PVC jackets.
The CAB.00640 cable is designed for use in air and is mainly used in applications specifying Rees Operator Control Units, where it is used as the interconnecting cable to any master control and video switching matrix used, and where RS485 control system philosophies have been adopted. It is also used for thru-wall cameras fitted with Wall Mounted Mk3 CCU connected directly to an Operator Control Unit or to a master control and video switching matrix.

**Characteristics**

Cores: * screened twisted pair
* coaxial

Mechanical: diameters 6.15mm & 11.30mm

## Video Cable CAB.00650

This is a high quality coaxial cable intended for fixed installation. It comprises 1 x 1.15mm plain copper conductor with solid polyethylene dielectric, plain copper wire braid and black PVC sheath.

**Characteristics**

Mechanical: Diameter: 10.3mm
Minimum installation bend radius: 125mm
Weight in air: 0.15kg per metre
Operating temp. range: -30°C to 85°C

Electrical: Characteristic impedance: 75 ohms
Attenuation: 1.6 dB per 100m at 10 MHz

## R90 SERIES CONNECTORS

**Standard Site Reterminable Underwater Connectors**

Rees underwater connectors are constructed in chemically blackened stainless steel. All interconnections are protected by seals. Terminations are made using high quality contacts. All of the R90 series underwater connectors share the same, basic mechanical design with size and inserts dependent upon the camera cable and/or camera selected.

Depth rating: 100 metres
Minimum installation distance from camera connector to cable path perpendicular to cameras axis with
TV36: 270mm
*with Minikevlar: 205mm*
with Minicable: 170mm
Voltage rating: 600 V dc
Current rating: 5 A
Break strength with minikevlar or TV36: better than 75 kg

*Rees Site Reterminable Underwater Connector*

**Rees 90° Stainless Steel Connector**

Use of the 90° connector reduces the total bend radius from the back of the camera to the cable perpendicular to 75mm for all cable types.

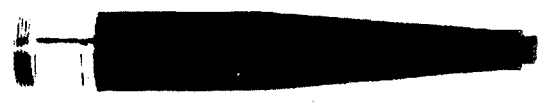
| Camera Connector | Insert | Contacts | Cable Centre | Diameter (mm) | Length (mm) |
|---|---|---|---|---|---|
| R930CNR04A | 24 pin | Solder | Minikevlar | 30 | 117 |
| R930CNR06A | 24 pin | Solder | TV36 | 33 | 117 |
| R937CNR04A | 40 pin | Crimp | TV36 | 49 | 122 |
| R930CNR08A | 24 pin | Solder | Minicable | 30 | 117 |

**CAMERA/CCU MATING CONNECTORS**

| CABLE TYPE | CAMERA | | CCU | | |
|---|---|---|---|---|---|
| | R937 (40 Way) | R93 (24 Way) | Mk2/Mk3 (24 Way) | Mk3 (48 Way) | PLUG END CCU (40 Way DPXA) |
| Minicable | R937CNR08A | R930CNR08A | R930CNR12A | R930CNR09A | R937CNR07A |
| Minikevlar | R937CNR06A | R930CNR04A | R930CNR10A | R930CNR05A | R937CNR07A |
| TV36 | R937CNR04A | R930CNR06A | R930CNR11A | R930CNR07A | R937CNR07A |

**Special Underwater Moulded Connectors**

A range of moulded connectors are available to special order. Moulded connectors cannot be reterminated, but they can operate to a depths in excess of 200 metres. The minimum installation distance from the back of the camera (with cable leaving at right angles) is 230mm with TV36, 210mm with Minikevlar, and 180mm with Minicable.
Break strength with minikevlar or TV36 is 75 kg.



*Rees Underwater Moulded Connector*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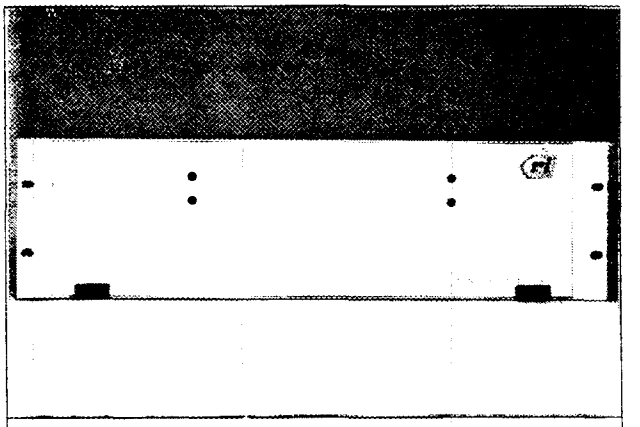
## Rees R90 Mark 3

# System Camera Control Units

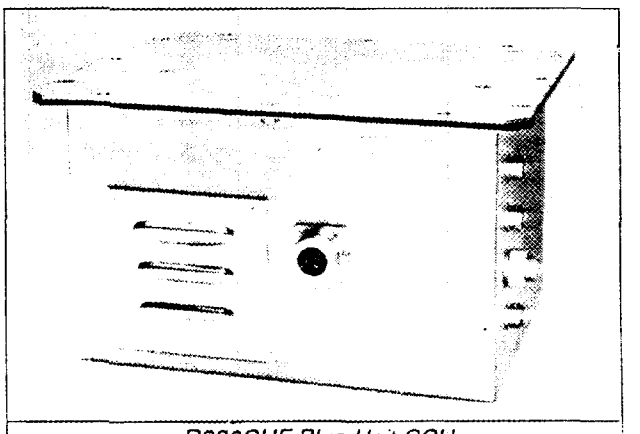
## FEATURES

- 19 inch 3U rack, wall-mount, or plug unit chassis
- Telemetry controlled
- Compatible with all Rees cameras
- Camera type selector switch
- Optional lighting and pan & tilt supplies
- Developed for use in radiation tolerant systems

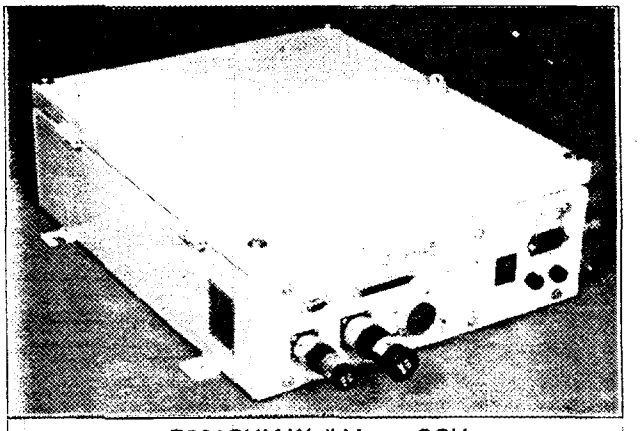
**The range of R90 Mk3 System Camera Control Units (CCU) are specifically designed for use in multi-camera systems and can drive all standard Rees Cameras. Dual and single rack-mounting, plug-end and wall mounting variants are available allowing maximum application versatility.**



*R930CUJ Rack Mounting CCU*



*R930CUF Plug Unit CCU*



*R930CUM Wall Mount CCU*

All the R90 MK 3 CCU are fully compatible with international video standards and can be integrated or locked to external sources, image processors or machine vision systems. All are compatible with the R930VEU Video Enhancement Unit which can increase camera sensitivity by 128:1

Models are available for 525 or 625 line tv standards, 100-120V ac or 200-240V ac power supplies, with remote control over twisted pair or coaxial video cables. The CCU are linked to cameras by multicore camera cables.

Remote function control and picture viewing can be via a central switching and control system from a master control room, or from either of two special Operator Control Units - one designed to be mounted directly on the cave or cell face wall and the other based on a mobile trolley. Both include a 12" picture monitor display. A separate and small free standing remote control unit is also available.

To maintain high resolution pictures innovative new circuits have been incorporated into the MK 3 CCU to significantly reduce the effects of radiation damage to the camera and induced noise, dark current temperature instability and tube-ageing.

The MK 3 Video Card includes an auto-black circuit that detects the darkest area of the viewed scene and uses this as a reference to set the grey scale for the rest of the picture. This optimizes the picture contrast independently of tube dark current variations caused by radiation effects or temperature change. When used in conjunction with the auto iris or auto target gain circuitry it also greatly improves the picture from scenes of low contrast.

The MK 3 Scan Card beam current stabilization circuit counters the effects of tube-ageing by sensing the limiter current and controlling the grid voltage to maintain a constant beam current under varying conditions. This automatically stabilizes the beam current producing an improved electron beam spot shape and high resolution.

The combined action of these circuits enables any Rees MK3 series camera to provide high resolution pictures for longer periods of time, to higher total absorbed radiation doses ($2 \times 10^6$ Gy (Si)[Co60]) and at higher temperatures.

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## Performance and Specifications

### R930CUJ System Camera Control Unit

**Dimensions**

| | | |
|---|---|---|
| Length: | 14.6 ins | (370mm) |
| Width: | 19 ins | (484mm) |
| Height: | 5.2 ins | (133mm) |
| Weight: | 18 lbs (single) | (8.3kg) |
| | 27 lbs (dual) | 12.4 kg) |
| **Operating temperature:** | 32° to 122°F | (0 to 50°C) |
| **Storage temperature:** | -13 to 140°F | (-25°C to 60°C) |
| **Humidity:** | 95% non condensing | |

**Features**

- 19 inch 3U Rack mounting chassis
- Specifically designed for system use
- Single and dual versions, for one or two cameras
- Compatible with all Rees cameras
- Options include caption generation, Telemetry, Lighting power supply, pan and tilt supply and position feedback

### R930CUF Plug End/Wall Camera Control Unit

**Dimensions**

| | | |
|---|---|---|
| Length: | 11.6 ins | (294mm) |
| Width: | 6.8 ins | (173mm) |
| Height: | 9.3 ins | (236mm) |
| Weight: | 17 lbs | (7.8kg) |
| **Operating temperature:** | 32° to 104°F | (0 to 40°C) |
| **Storage temperature:** | -13 to 140°F | (-25°C to 60°C) |
| **Humidity:** | 95% non condensing | |

**Features**

- Strong stainless steel enclosure
- Plug-end or wall mounting
- Position Feedback and Caption Generation options
- Telemetry fitted as standard

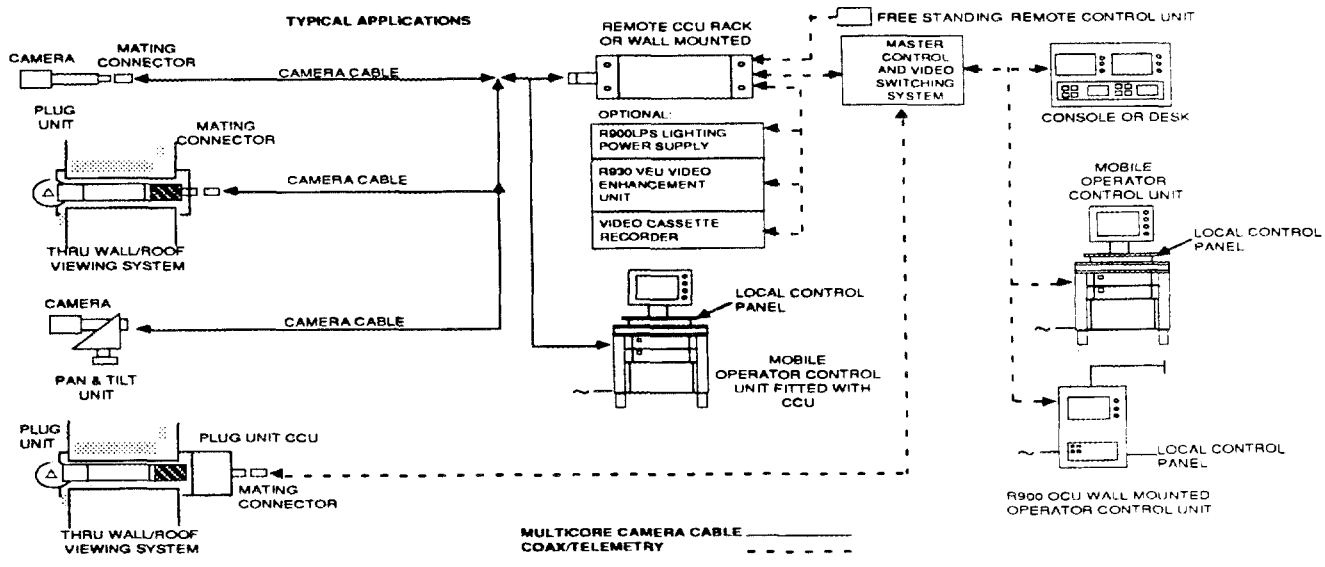
### R930CUM Wall Mount Camera Control Unit

**Dimensions**

| | | |
|---|---|---|
| Length: | 15 ins | (382mm) |
| Width: | 18 ins | (458mm) |
| Height: | 5.9 ins | (150mm) |
| Weight: | 36 lbs | (16.5kg) |
| **Operating Temperature:** | 32° to 122°F | (0 to 50°C) |
| **Storage Temperature:** | -13° to 140°F | (-25° to 60°C) |
| **Humidity:** | 95% non condensing | |

**Features**

- Strong steel enclosure
- Easy service access
- Wall mounting
- Position feedback, Caption Generation, Lighting Power Supply and Pan and Tilt Supply options
- Compatible with all Rees cameras
- Telemetry fitted as standard





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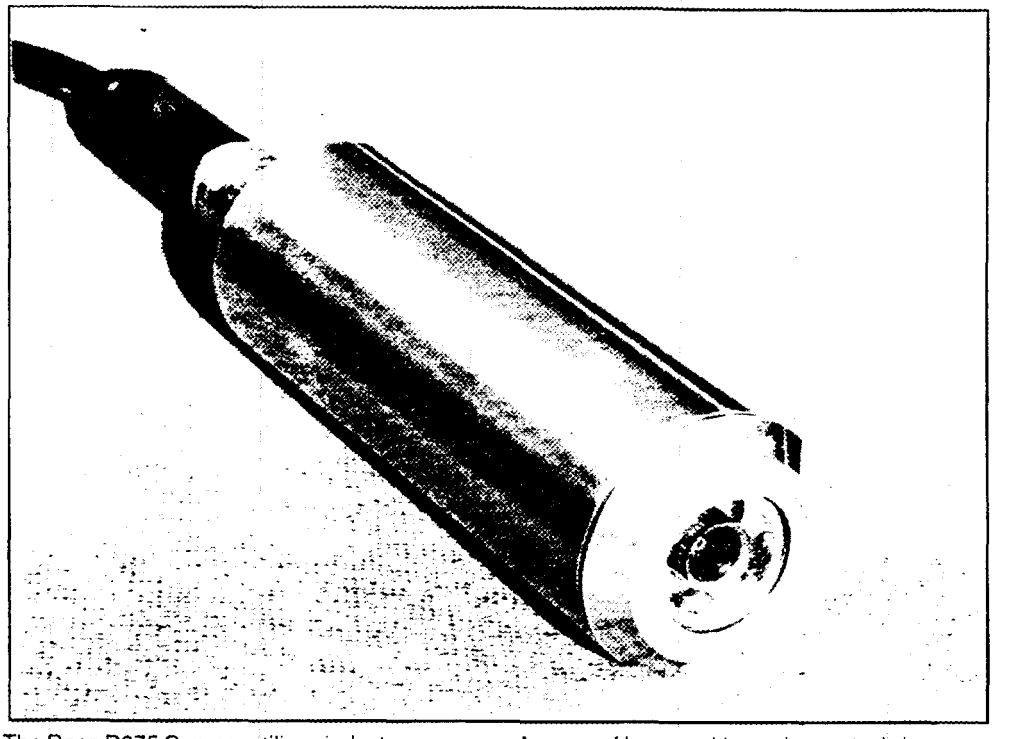
# Rees R975
# Single Unit Nuclear Camera

## FEATURES

- Remotely controlled
- Independently tested radiation tolerance to 2MGy (2 x $10^8$ rads)
- Dose rates >8Gys$^{-1}$ (>3 x $10^6$ rads per hour)
- Compact and light-weight
- Simplified cabling requirements
- Range of lenses to suit different viewing tasks
- Range of image sensor tube options
- 225W Local lighting option

**The Rees R975 Camera is a single unit device specifically developed for a wide range of viewing tasks in nuclear environments.**



The Rees R975 Camera utilizes industry proven radiation tolerant circuitry to provide high quality monochrome pictures in active areas. By using a single unit design concept, cabling requirements are simplified allowing remote control of optical functions via the R970 Multi Purpose Control Unit (MCU) or R970 Remote Control Unit (RCU). The camera can also be simply interchanged between control units without requiring set-up adjustments.

The camera is housed in a compact stainless steel case that protects all the drive circuitry, image sensor and optical components. This configuration enables the unit to be simply deployed and minimizes decontamination procedures should the unit require maintenance. The housing is also fully sealed to allow submersion to 220 feet (68 m) for pond applications.

Incorporated into the camera are special circuits that maintain video performance over an extended life. To ensure optimum operation, auto gain control and auto black level functions counter the effects of tube aging, radiation and poor lighting.

A range of lenses with varying optical characteristics are available to suit the viewing task. Additionally a range of $^2/_3$" (18mm) image sensor tubes can be selected to give high resolution, high temperature operation or high radiation dose rate capabilities.

The camera can be linked to its MCU by one of the range of purpose designed radiation tolerant cables depending on the users requirements. To produce local scene illumination the camera can be fitted with up to 225W of local lighting using a Rees Lighting Adaptor. The lighting adaptor fitting is controlled via the camera cable and MCU and powered by the matching Rees R905 Lighting Power Supply (LPS).

Fully compatible with international video standards, the R975 camera and R970MCU can be incorporated with, or locked to, external sources, image processors or machine vision systems for integrated system applications, remote control and picture viewing can be via a central switching and control system from a master control room, or from a trolley mounted or cave face Operator Control Unit.

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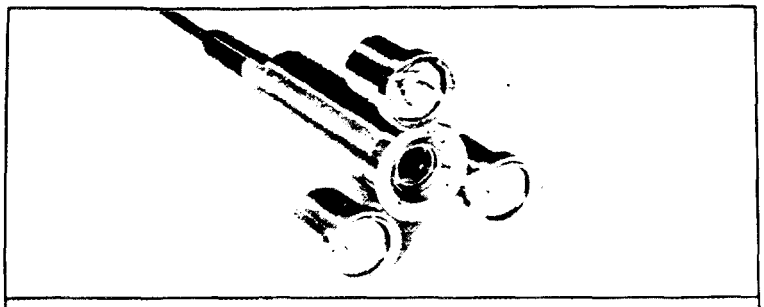
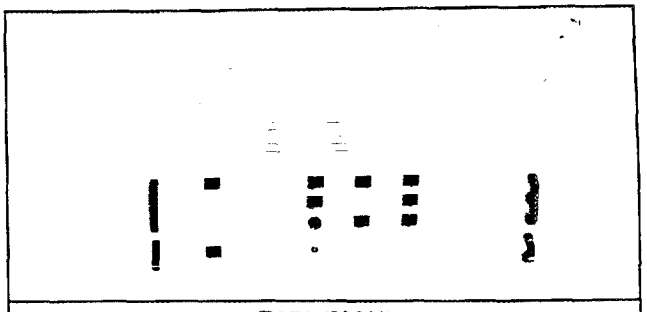


R975 with 225W Lighting Adaptor



R970 (MCU)

## PERFORMANCE AND SPECIFICATIONS

**Mechanical:**

| | | | |
|---|---|---|---|
| Length | 9.6" (244mm) | Weight | 4.5 pounds (2kg) |
| Length with connector | 11.2" (285mm | Case material | Stainless steel |
| Diameter | 2.75" (70mm) | Viewing windows | Standard or water corrected |

**Environment:**

Radiation tolerance (total dose) ..... 2MGy (Si) [Co60] total dose 2 x $10^8$ rads
Dose rate Vidicon ..... >8Gys$^{-1}$ (3 x $10^6$ rads per hour)
Newvicon/Chalnicon ..... 300m Gys$^{-1}$ (1 x $10^5$ rads per hour)
Operating temperature ..... -13°F - 122°F (-25 to 50°C)
Maximum operating depth ..... 220 feet (68m)

**Performance:**

Resolution (in air) ..... 500 tv lines (horizontal centre zone 1)
Signal to noise ratio ..... 56dB (200nA peak, 5MHz CCIR weighted RMS)
Output ..... 1 volt composite video
0.3 volt syncs
1.2 volt peak white clip
Interlace ..... 2:1
Linearity ..... 2%

**Optics:** Non-browning 9mm D mount auto iris lens fitted as standard. Optional non-browning 6mm and 25mm D mount lenses can also be specified.

| Lens | Typical Viewing Parameters | | | |
|---|---|---|---|---|
| | Horizontal | Vertical | Diagonal | Focus Range |
| Standard 9mm lens | 50° | 39° | 61° | 1" (25mm) to infinity |
| Optional 6mm lens | 73° | 58° | 85° | 0.2" (5mm) to infinity |
| Optional 25mm lens | 20° | 15° | 25° | 6.7" (170mm) to infinity |

| | | | | |
|---|---|---|---|---|
| **Cable length** | Minikevlar | 330 feet (100m max) | TV36 | 330 feet (100m max) |

**Local Camera Lighting**

Localized scene illumination is provided by the Rees lighting adaptor system. Different configurations can be selected to suit the viewing task and are powered by the R905 Lighting Power Supply.
Lightign output ..... up to 225W (flood or spot light combinations)

***Notes...***

1. ***Rees should be consulted with regard to very critical viewing requirements, or in cases where there are important lighting, resolution, environmental or viewing angle considerations.***
2. ***In applications where there are severe space constraints care should be taken to allow for the size of the camera cable mating connector and if necessary, the bend radius of the connecting camera cable. Please refer to the Rees R90 series cables and connectors datasheet.***
3. ***For applications requiring a zoom capability the R976 Zoom Camera combines the same video circuitry with a radiation tolerant zoom lens.***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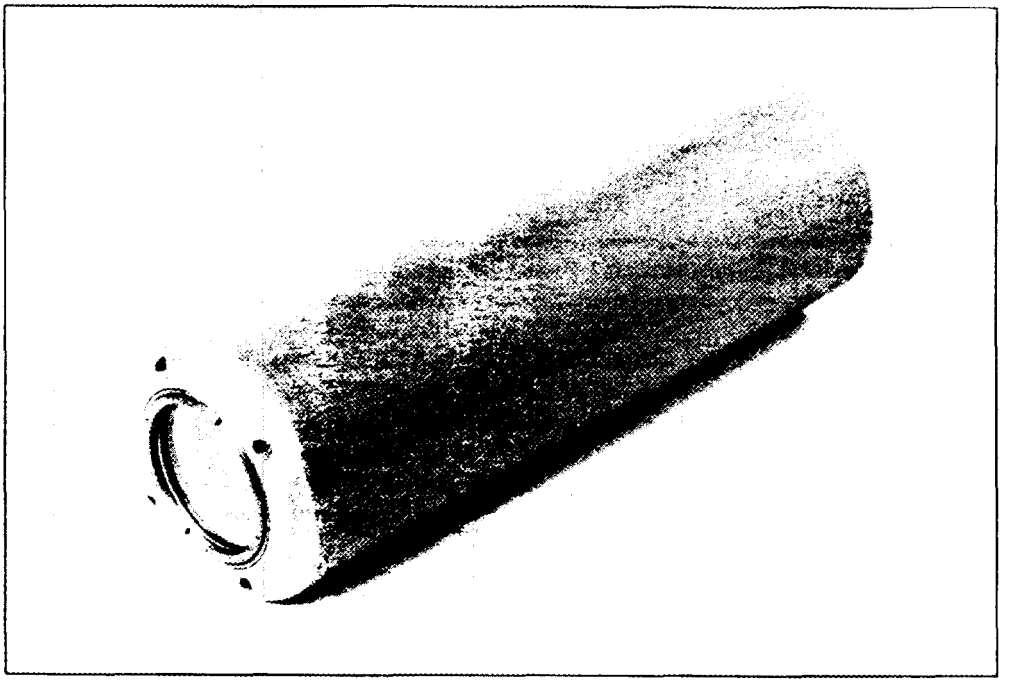
# Rees R976 Nuclear Zoom Camera

## FEATURES

- Remotely controlled
- Radiation tolerant to 1MGy ($10^8$ rads)
- Dose rates >10 $Gys^{-1}$ (>3 x $10^6$ rads per hour)
- 12-72mm or 24-144mm zoom lens systems
- Up to 225W camera lighting options
- Underwater applications to 660 ft (200m)
- Stainless steel and lightweight housings

**The Rees R976 Zoom Camera incorporates a radiation tolerant camera module, and non browning zoom lens for viewing a wide range of nuclear operations.**



The R976 Camera uses a radiation tolerant video module, coupled to a remotely controlled non-browning zoom lens to provide high quality monochrome pictures. By using a single unit video module the design ensures that cabling requirements are minimized. For example, in a simple surveillance application where remote control of lens functions is not required the minimum cable requirements are 1 coaxial for video and 2 conductors for camera power.

A further advantage of this type of design is that cameras can be simply interchanged between control units without the need for a control unit set-up procedure.

The video module and optics are housed in a tough industrial casing which is available in stainless steel or anodized aluminium versions. Both versions enable the unit to be deployed underwater to depths of 200 feet (60m) and minimize decontamination procedures where necessary. The anodized aluminum version is designed for weight critical applications such as manipulators and robotic arms.

Special circuitry is included in the video module to maintain video performance over an extended life. To ensure optimum operation auto gain control and auto black level functions counter the effects of tube aging, radiation and poor lighting.

The optical systems used by the R976 are based on field proven designs used in other Rees cameras. Two combinations can be utilized to give either a F1.8, 12 to 72mm zoom or F3.6, 24 to 144mm zoom capability. The lenses use non-browning glassware and have all optical functions (focus, zoom and iris) motorized to allow remote control.

To provide remote control of optical functions and the optional lighting units, two control units are available. These are the R970 Multi-purpose Control Unit (MCU) or R970 Remote Control Unit.

The R976 is linked to its MCU or RCU controller by one of the range of purpose designed Rees radiation tolerant cables. These give a choice of configurations to enable deployment via a cable reeler if required. The high break strength characteristics of the cables also allow direct deployment of the camera.

To produce local scene illumination the camera can be fitted with different lighting combinations with a total output up to 225W. These are fitted to the camera using a Rees Lighting Adaptor and controlled via the R970 MCU or RCU. Power is supplied by the Rees R905 Lighting Power Supply (LPS).

Fully compatible with international video standards, the R976 camera and R970 MCU or RCU can be incorporated with image processors or machine vision systems for integrated system applications. Remote control and picture viewing can be via a central switching and control system from a master control room, or from a trolley mounted or cave face Operator Control Unit.

***Rees Instruments is fully approved for the design and manufacture of CCTV equipment to the following international quality standards:***

***ANSI/ASQC Q91-1987***
***ISO 9001-1987***
***BS 5750: Part 1: 1987***
***EN 29001-1987***

## PERFORMANCE AND SPECIFICATIONS

**Mechanical:**

| | | | R976CMA03A | R976CMB03A |
|---|---|---|---|---|
| Length | 14.4" (365mm) | | | |
| Length with connector: | 19" (485mm) | Weight | 7.7 lbs (3.5kg) | 13.25 lbs (6kg) |
| Diameter | 4.2" (106mm) | Case material | Anodized aluminium | Stainless steel |

**Environment:**

Radiation tolerance ..... 1MGy ($H_2O$) [Co60] total dose ($10^8$ rads)
Dose rate Vidicon ..... >10Gys$^{-1}$ (3 x $10^6$ rads per hour)
Newvicon ..... 300m Gys$^{-1}$ ($10^5$ rads per hour)
Operating temperature ..... -25° to 50°C (-13°F to 122°F)
Maximum operating depth ..... 200 ft (special versions to 660 ft)

**Performance:**

Resolution (in air) ..... 500 tv lines (horizontal centre zone 1)
Signal to noise ratio ..... 56dB (200nA peak, 5MHz CCIR weighted RMS)
Output ..... 1 volt composite video
0.3 volt syncs
1.2 volt peak white clip
Interlace ..... 2:1
Linearity ..... 2%

**Optics:**

Non-browning F1.8, 12-72mm or F3.6, 24-144mm lens system (12-72mm motorized zoom lens fitted with removable x2 range extender). An auto iris function is available as an option for the R970 MCU

| Viewing Angles | 24 - 144mm lens system (with x2 range extender) | | | | 12 - 72mm lens system (without x2 range extender) | | | |
|---|---|---|---|---|---|---|---|---|
| | in air | | in water | | in air | | in water | |
| | Wide | Telephoto | Wide | Telephoto | Wide | Telephoto | Wide | Telephoto |
| Horizontal | 21° | 3.5° | 16° | 2.6° | 40° | 7.0° | 30° | 5.3° |
| Vertical | 16° | 2.6° | 12° | 2.0° | 31° | 5.2° | 23° | 3.9° |
| Diagonal | 26° | 4.4° | 19° | 3.3° | 49° | 8.7° | 37° | 6.6° |

Focus range (in air): ..... 40 inches (1m) to infinity
Cable length ..... Minikevlar 330 feet (100m) max (with 225W maximum lighting)
660 feet (200m) max (with 100W maximum lighting)

**Local camera lighting**

Localized scene illumination is provided by the Rees lighting adaptor system. Different configurations can be selectec to suit the viewing task with applications above 20W powered by the R905 Lighting Power Supply.
Lighting output options ..... 20, 40, 50, 60, 75, 100, 150 or 225W (flood or spot light combinations)

***Notes...***

1. ***Rees should be consulted with regard to very critical viewing requirements, or in cases where there are importar lighting, resolution, environmental or viewing angle considerations.***
2. ***In applications where there are severe space constraints care should be taken to allow for the size of the camera cabl mating connector and if necessary, the bend radius of the connecting camera cable. Please refer to the Rees R90 serie cables and connectors datasheet.***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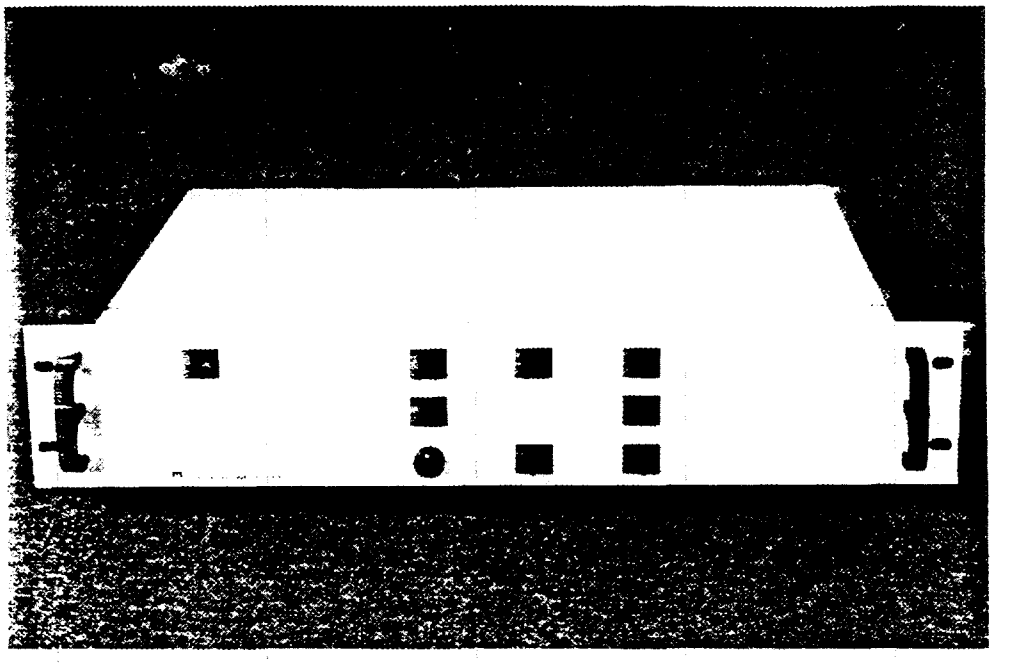
# Rees R970 MCU & R970 RCU
# Multi-purpose & Remote Control Units

## FEATURES

- Space saving 2U chassis
- Compatible with Rees single unit color and monochrome cameras
- Control of all remote camera functions
- Can be used as part of an integrated system
- Single and dual unit system versions
- Options include:
  - Auto iris
  - Pan & Tilt supply
  - 20W Internal lighting supply
  - Audio driver
  - Telemetry (R970 RCU)

**The Rees R970 Multi-purpose & R970 Remote Control Units are designed as the operator interface for Rees single unit color and monochrome cameras.**



The Rees R970 MCU and RCU are available in different configurations to suit both local and system control applications. Housed in a 2U nineteen inch rack mounting chassis, all versions are compatible with the standard industrial rack type consoles and provide control for Rees single unit color and monochrome cameras. The MCU or RCU drives the connected camera(s) via the appropriate multicore cable.

The R970 MCU is designed for local camera control and incorporates a control panel enabling remote control of standard and optional camera functions. When used with a Rees R905 Lighting Power Supply (LPS) and a camera lighting system, the MCU can be used to adjust the lighting output. Controls are available for:

| | |
|---|---|
| - AC Power | on/off |
| - Focus | near/far |
| - Zoom | in/out |
| - Iris | open/close |
| - Auto iris | on/off |
| - Lights | on/off |
| - Lighting level | up/down |
| - Rotate | cw/ccw |
| - Pan | left/right |
| - Tilt | up/down |

The R970 RCU is available in single or dual system versions and can be specified to interface to one or two single unit cameras. The R970 RCU is designed for integration into turnkey systems and utilizes telemetry control to drive the camera functions from a remote control panel. This provides remote control over twisted pair or coaxial video cables.

Remote function control and picture viewing can be via a central switching and control system from a master control room, or from either of two special Operator Control Units - one designed to be mounted directly on the cave or cell face wall and the other based on a mobile trolley. Both include a 12" picture monitor display.

The MCU and RCU use 525 or 625 line tv standards with universal ac power input.

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*ANSI/ASQC Q91-1987*
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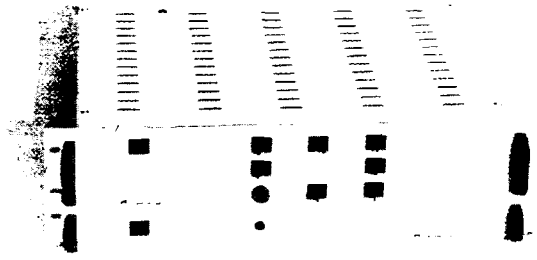
*BS 5750: Part 1: 1987*
*EN 29001-1987*



**R970 MCU & R905 LPS**

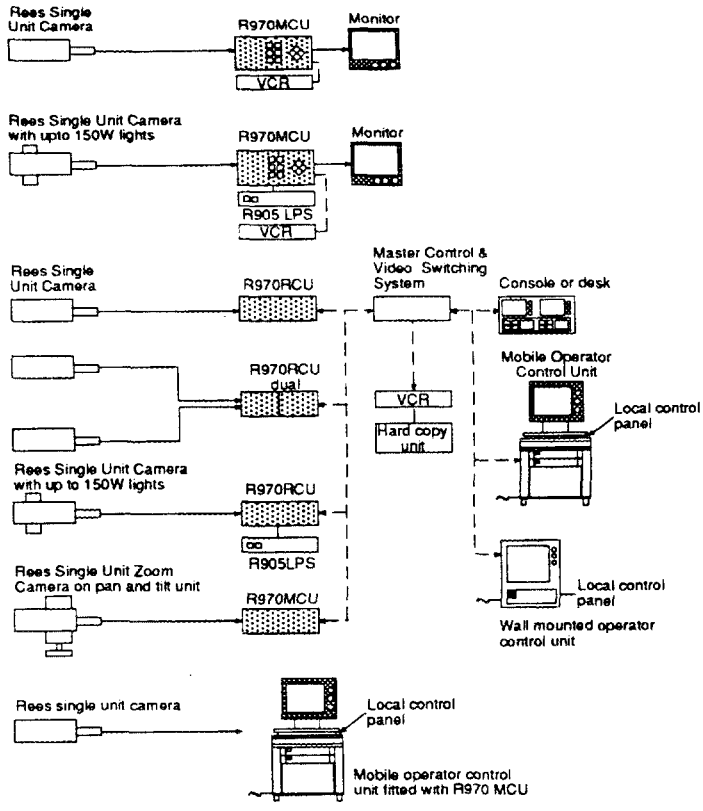
## COMPATIBILITY

Rees R970 MCU and R970 RCU are compatible with the following Rees camera types:

- R975 fixed focal length
- R976 Zoom
- RC93-S color R93
- RC977 color Zoom
- R500 Derivatives
- Special cameras based on R975 or RC93-S technology

The R970 MCU can be supplied in a tough transit case for mobile applications. The transit case will also accommodate the R905 Lighting Power Supply or other specified equipment.

## TYPICAL APPLICATIONS




## PERFORMANCE AND SPECIFICATIONS

### R970 MCU & R970 RCU DUAL & SINGLE

**Environment**

| | |
|---|---|
| Operating temperature | 32°F to 105°F (0° to 40°C) |
| Storage temperature | -13° to190°F (-25° to 60°) |
| Humidity | 95% non condensing |
| Power input | |
| AC | 90 to 264V |
| | 47 to 64Hz |

**Rear Connectors**

- IEC mains input
- Camera
- Lighting power input
- Audio output (optional)
- Y/C Output
- Composite video
- Telemetry (RCU only)
- Lighting switch

### R970 MCU MULTI-PURPOSE CONTROL UNIT

**Dimensions**

| | |
|---|---|
| Width | 19" (484mm) |
| Height (2U) | 3.5" (88mm) |
| Length | 14" (356mm) |
| Weight | 17.6lbs (8kg) (inc all options) |
| | 11lbs (5kg) (basic) |

**Front Panel Controls**

| | | | |
|---|---|---|---|
| AC power | on/off | Lights | on/off |
| Focus | near/far | Lighting level | up/down |
| Zoom | in/out | Rotate | CW/CCW |
| Iris | open/close | Pan | left/right |
| Auto iris | on/off | Tilt | up/down |

### R970 RCU REMOTE CONTROL UNIT

**Dimensions**

| | |
|---|---|
| Width | 19" (484mm) |
| Height (2U) | 3.5" (88mm) |
| Length | 14" (356mm) |
| Weight - Single | 17.6 lbs (8kg) (inc all options) |
| - Dual | 31 lbs (14kg) (inc all options) |

**Options**

Telemetry (type selectable), Auto iris, Audio driver, High and low light supply, Pan and tilt supply.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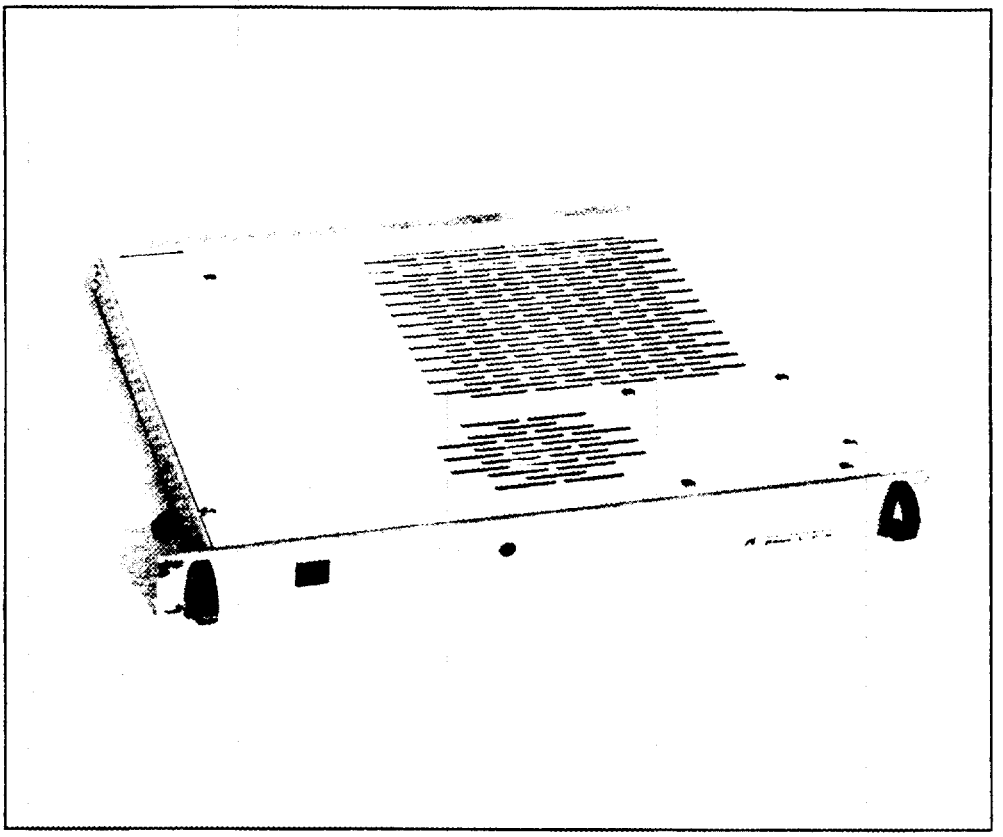
01-04/93

# Rees R905LPS
# Lighting Power Supply

## FEATURES

- 200 and 300 Watt output options
- Compatible with R90 Mk 3 CCU, R970 MCU and R970 RCU
- Remotely controlled
- Space saving 1U rack mounting chassis

**The Rees R905LPS Lighting Power Supply is designed to power the range of Rees camera lighting systems. Two versions are available providing up to 200W or 300W of power.**



Designed for remote on/off and lighting intensity control, the R905 LPS can be interfaced to any R90 Mk 3 Camera Control Unit (CCU), R970 Multi-function Control Unit (MCU) or R970 Remote Control Unit (RCU). This enables camera lights to be operated by the user via either the local control panel of the CCU or MCU, or via telemetry and remote operator control unit.

The R905 LPS is housed in a compact 1U high, nineteen inch rack mounting chassis suitable for free-standing, viewpack or industrial rack deployment. A single interconnection cable links the supply to the controlling CCU, MCU or RCU and allows the light supply to be routed to the camera by the camera cable.

The R905 LPS can be preset to drive various camera lighting configurations depending on the lighting output required. Typical Rees camera applications include:

- R93-02 100 watt head
- R93-03 100 watt head
- R936 Prismatic camera
- R938 Zoom camera with 80W lights
- R939 Zoom camera with 80W lights
- R940 Zoom camera with 80W lights
- R975 Single unit camera with up to 225W lights
- R976 Zoom camera with up to 225W lights
- RC977 Zoom camera with up to 225W lights

(If only on/off control is required a fixed current mode output can be specified and factory preset to the application requirements.)

The unit has universal ac power input capability accepting 90 to 264 volts, 47 to 64 Hz supplies.

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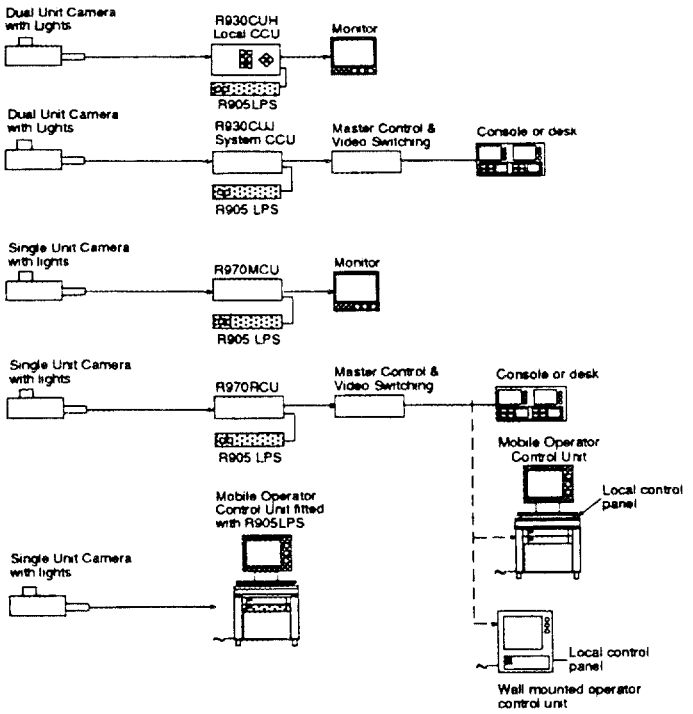
***BS 5750: Part 1: 1987***
***EN 29001-1987***

## TYPICAL APPLICATIONS




## PERFORMANCE AND SPECIFICATIONS

### Dimension

Width ..... 19" (484mm)
Height ..... 1.7" (44mm) (1U)
Length ..... 14" (356mm)
Weight ..... 11 lbs (5kg)

### Environmental

Operating Temperature ..... 32°F to 104°F (0°C to 40°C)
Storage Temperature ..... -13°F to 140°F (-25°C to 60°C)
Humidity ..... 95% non condensing

### Input/Output

ac mains input ..... 90 to 264V
47 to 64 Hz
Connector ..... 6A IEC
Output:
dc output ..... 6 to 52V
1 to 6.25A
Current output tolerance ..... ±1% variation over operating conditions
Output soft start delay ..... 0.5 seconds
Control input signals:
Lighting level ..... 0 to 2.5V @ 3µA
LPS off ..... 12 to 24V ± 10% @ 10mA maximum (open collector)
LPS supply ..... 12 to 24V ±10% @ 10mA

The R905LPS can be used to drive the following camera-lighting systems:

R93-02 100W
R93-03 100W
R936 Prismatic 80W
R938 Zoom with 80W lights
R939 Zoom with 80W lights
R940 Zoom with 80W lights
RC93-S 02 100W
RC93-S 03 100W
R975 Single Unit
R976 Single Unit Zoom
RC977 Color Zoom
} 40, 50, 60, 75 100, 150, 225W configurations

Camera lighting power on/off and lighting intensity can be controlled by linking the R905LPS to the following units:

- R930CUG Portable CCU
- R930CUH Local CCU
- R930CUJ System CCU, single
- R930CUJ System CCU, dual
  R970MCU Local
  R970RCU System, single
  R970RCU System, dual

- Optional card requried in CCU for remote intensity control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01-05/93

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| SVD-3 | System Drawing with Underwater Pan and Tilt and Lights. |
| | Radiation Test Report Cover Sheet on RCS-510. |
| RCS-510NBP | Radiation Tolerant Zoom Color Television Camera. |
| RCS-510NBP | System Drawing with UL-210 Lights. |
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| RCS-600 | 1" Diameter Remote Focus Color Camera. |
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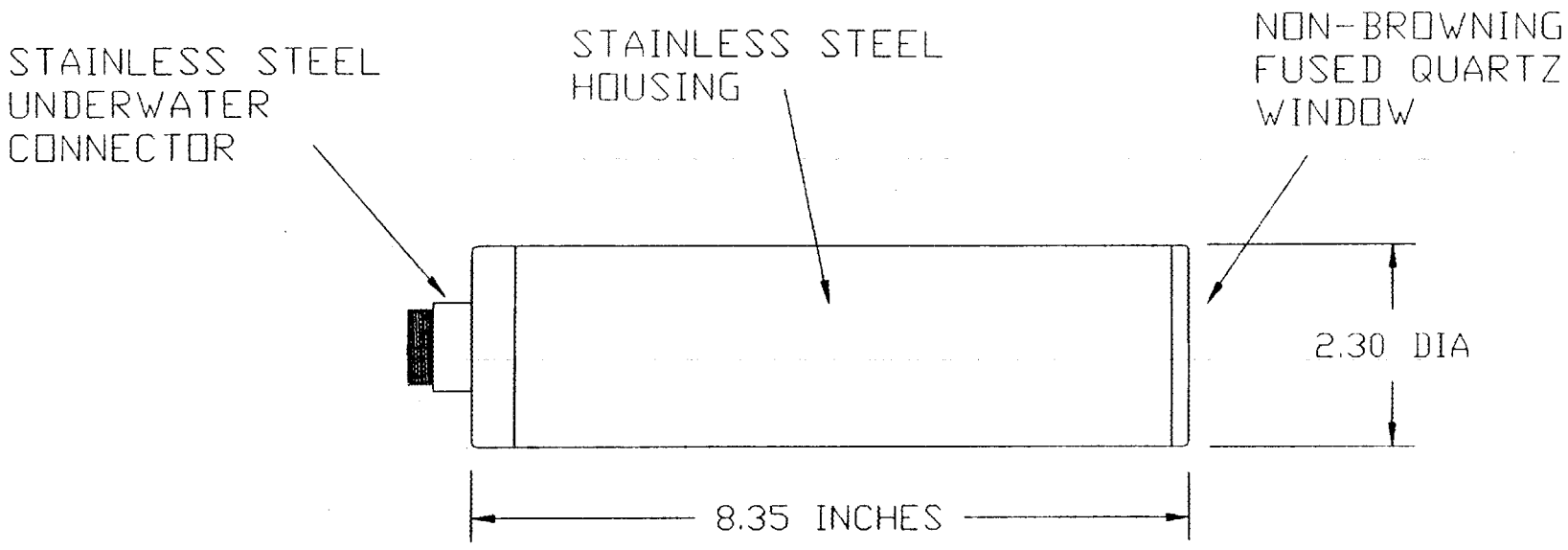
| UL-300 | Miniature Right Angle Light for Pole Mounting. |
| ST-400 | Miniature In-Air Light for Pole Mounting. |
| | Effective Underwater Scene Illumination for UL-210/ST-400 Lights. |




FEATURES:

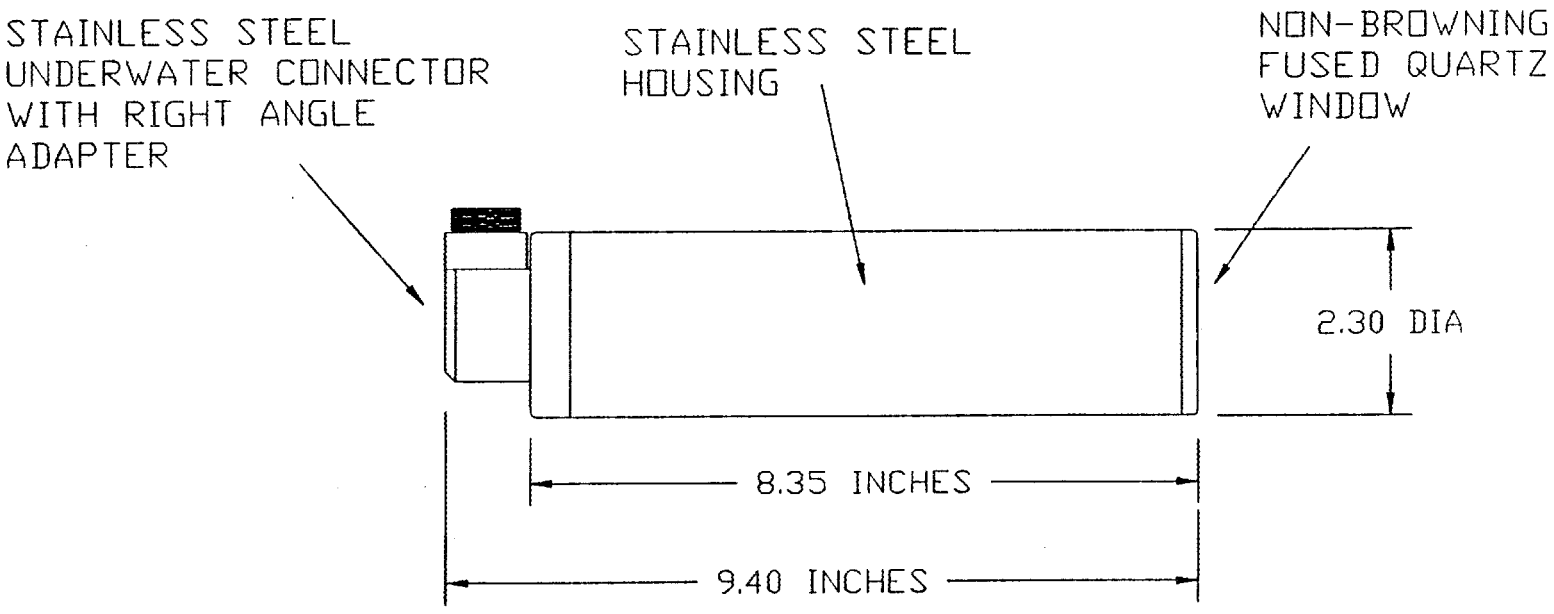
- HIGH RESOLUTION COLOR TV
- NON-BROWNING ZOOM LENS
- REMOTE FOCUS, ZOOM, & IRIS CONTROLS
- STAINLESS STEEL HOUSING
- NO EXPOSED THREADS OR RETAINING RINGS
- SMALL SIZE
- STAINLESS STEEL CONNECTOR
- DEPTH RATING OF 2,000 FEET

# SVD-2-NB UNDERWATER COLOR ZOOM TV CAMERA

# SPECIFICATIONS

## MODEL SVD2-NB CAMERA

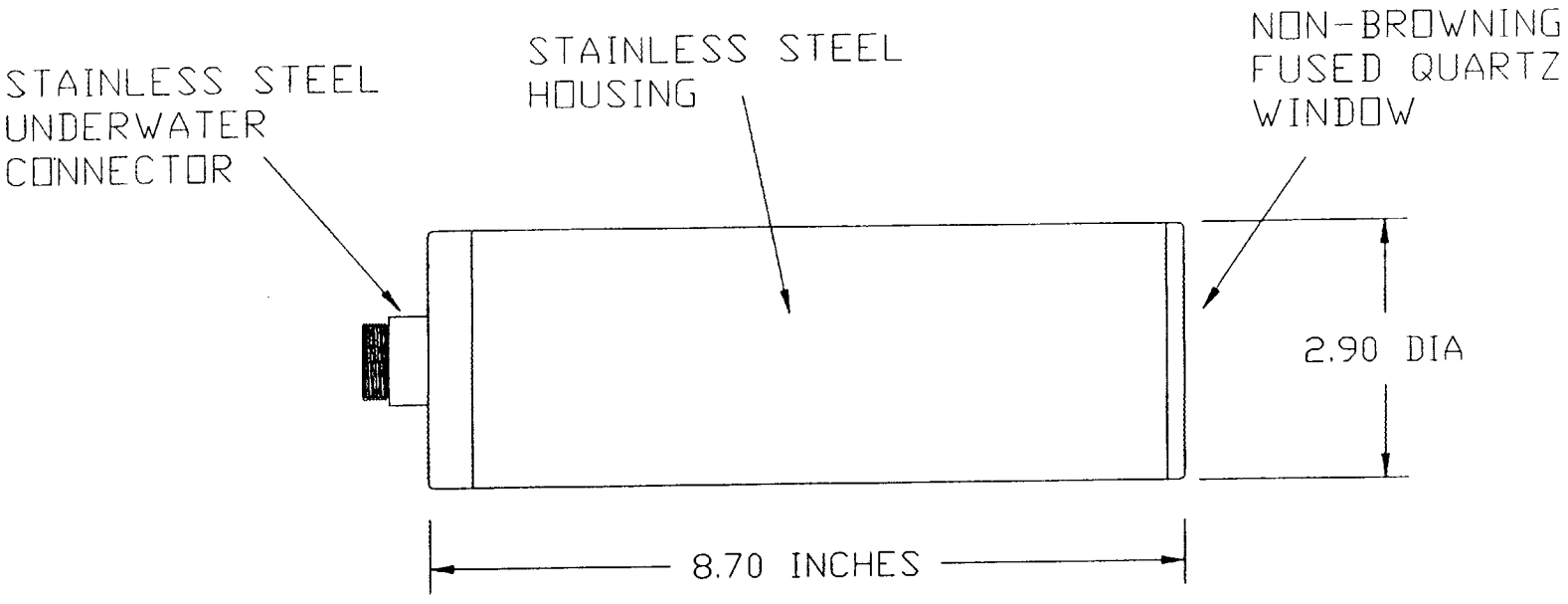
| | |
|---|---|
| POWER | 12 VDC supplied via model CU1410 controller |
| SENSOR | 1/2 in. interline transfer CCD |
| SCAN AREA | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION | 460 TV lines |
| MINIMUM SCENE ILLUMINATION | 60 lux at f/3.5 |
| RECOMMENDED SCENE ILLUMINATION | 800 lux at f/3.5 |
| S/N RATIO | 46 dB |
| OUTPUT IMPEDANCE | 75 Ohms |
| LENS | Special zoom lens with non-browning optics |
| ZOOM | 22-90mm remotely controlled |
| FOCUS | 10 inches to infinity remotely controlled |
| IRIS | f/3.5 to f/4.5 remotely controlled |
| SHUTTER | 1/60 sec to 1/10,000 sec remotely controlled |
| IN-AIR FIELD OF VIEW | 16.90 deg to 4.16 deg horizontal |
| UNDERWATER FIELD OF VIEW | 12.69 deg to 3.13 deg horizontal |
| HOUSING DIAMETER | 2.30 inches |
| HOUSING OVERALL LENGTH | 8.35 inches |
| IN AIR WEIGHT | 4.01 pounds |
| IN WATER WEIGHT | 2.76 pounds |
| HOUSING MATERIAL | 300 series stainless steel |
| WINDOW MATERIAL | Non-browning fused quartz |
| CONNECTOR | Model RCS-1501-BC stainless steel |
| MATING CONNECTOR | Model RCS-1501-CC |
| DEPTH RATING | 2000 feet |
| TEMPERATURE RATING | -10 to 40 deg C (14 to 104 deg F) |
| CABLE LENGTH | Up to 300 feet |




FEATURES:

- HIGH RESOLUTION COLOR TV
- NON-BROWNING ZOOM LENS
- REMOTE FOCUS, ZOOM, & IRIS CONTROLS
- STAINLESS STEEL HOUSING
- NO EXPOSED THREADS OR RETAINING RINGS
- SMALL SIZE
- STAINLESS STEEL CONNECTOR
- DEPTH RATING OF 2,000 FEET

SVD-2-NB UNDERWATER CAMERA WITH RIGHT ANGLE CONNECTOR




FEATURES:

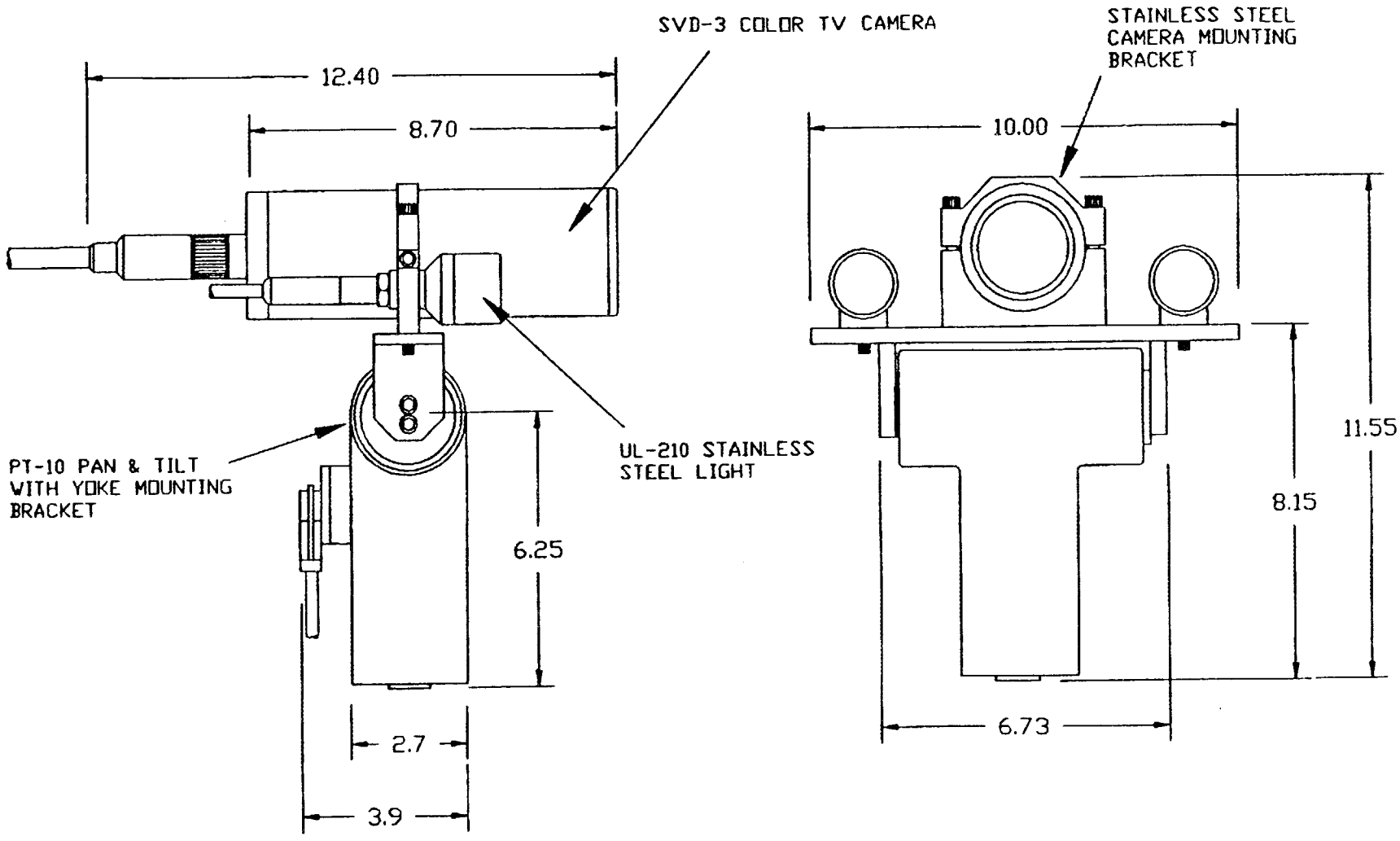
- HIGH RESOLUTION COLOR TV
- 8-48mm f/1.0 ZOOM LENS
- OPTIONAL 22-90mm NON-BROWNING LENS
- REMOTE FOCUS, ZOOM, & IRIS CONTROLS
- STAINLESS STEEL HOUSING
- NON-BROWNING QUARTZ WINDOW
- NO EXPOSED THREADS OR RETAINING RINGS
- SMALL SIZE
- STAINLESS STEEL CONNECTOR
- DEPTH RATING OF 500 FEET

# SVD-3 UNDERWATER COLOR ZOOM TV CAMERA

# SPECIFICATIONS

MODEL SVD-3 CAMERA

| | |
|---|---|
| POWER | 12 VDC supplied via model CU1410 controller |
| SENSOR | 1/2 in. interline transfer CCD |
| SCAN AREA | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION | 460 TV lines |
| MINIMUM SCENE ILLUMINATION | 5.9 lux at f/1.0 |
| RECOMMENDED SCENE ILLUMINATION | 78lux at f/1.0 |
| S/N RATIO | 46 dB |
| OUTPUT IMPEDANCE | 75 Ohms |
| ZOOM | 8-48 mm remotely controlled |
| FOCUS | 1 meter to infinity remotely controlled |
| IRIS | f/1.0 to closed remotely controlled |
| SHUTTER | 1/60 sec to 1/10,000 sec remotely controlled |
| IN-AIR FIELD OF VIEW | 43.6 deg to 7.6 deg horizontal |
| UNDERWATER FIELD OF VIEW | 32.4 deg to 5.7 deg horizontal |
| HOUSING DIAMETER | 2.90 inches |
| HOUSING OVERALL LENGTH | 8.70 inches |
| IN-AIR WEIGHT | 4.78 pounds |
| IN-WATER WEIGHT | 2.75 pounds |
| HOUSING MATERIAL | 300 series stainless steel |
| WINDOW MATERIAL | Non-browning fused quartz |
| CONNECTOR | Model RCS-1501-BC stainless steel |
| MATING CONNECTOR | Model RCS-1501-CC |
| DEPTH RATING | 500 feet |
| TEMPERATURE RATING | -10 to 40 deg C (14 to 104 deg F) |
| CABLE LENGTH | Up to 300 feet |



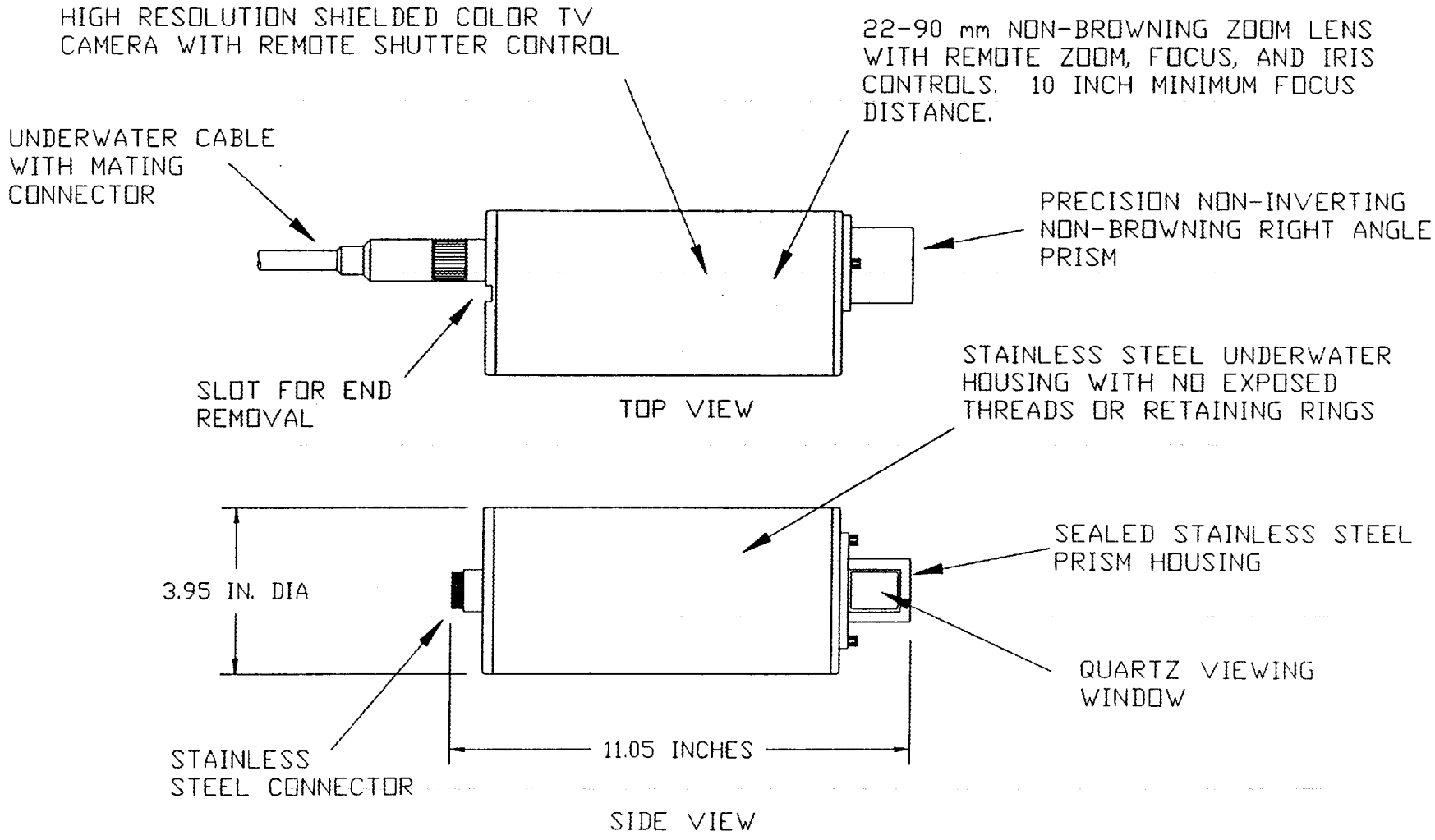

SVD-3 CAMERA INSPECTION SYSTEM DIMENSIONS

# Radiation Dose Rate Test Report
# for the
# RCS-510 Shielded Underwater Color Camera

August 4, 1992

Stephen Bayne
Fuel Examination Technology

General Electric Company
175 Curtner Avenue
San Jose, CA 95125

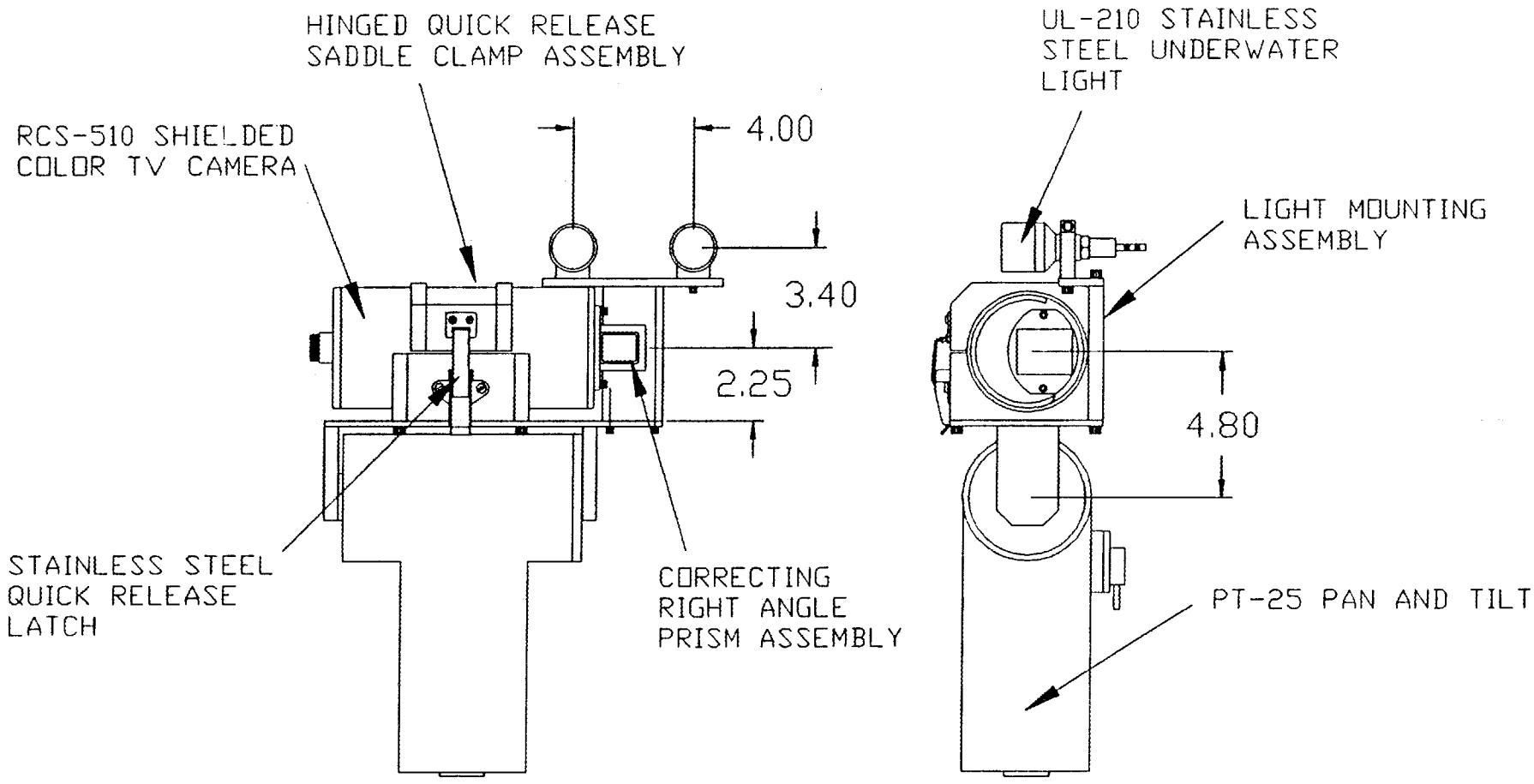



RCS-510NBP RADIATION TOLERANT COLOR TV CAMERA

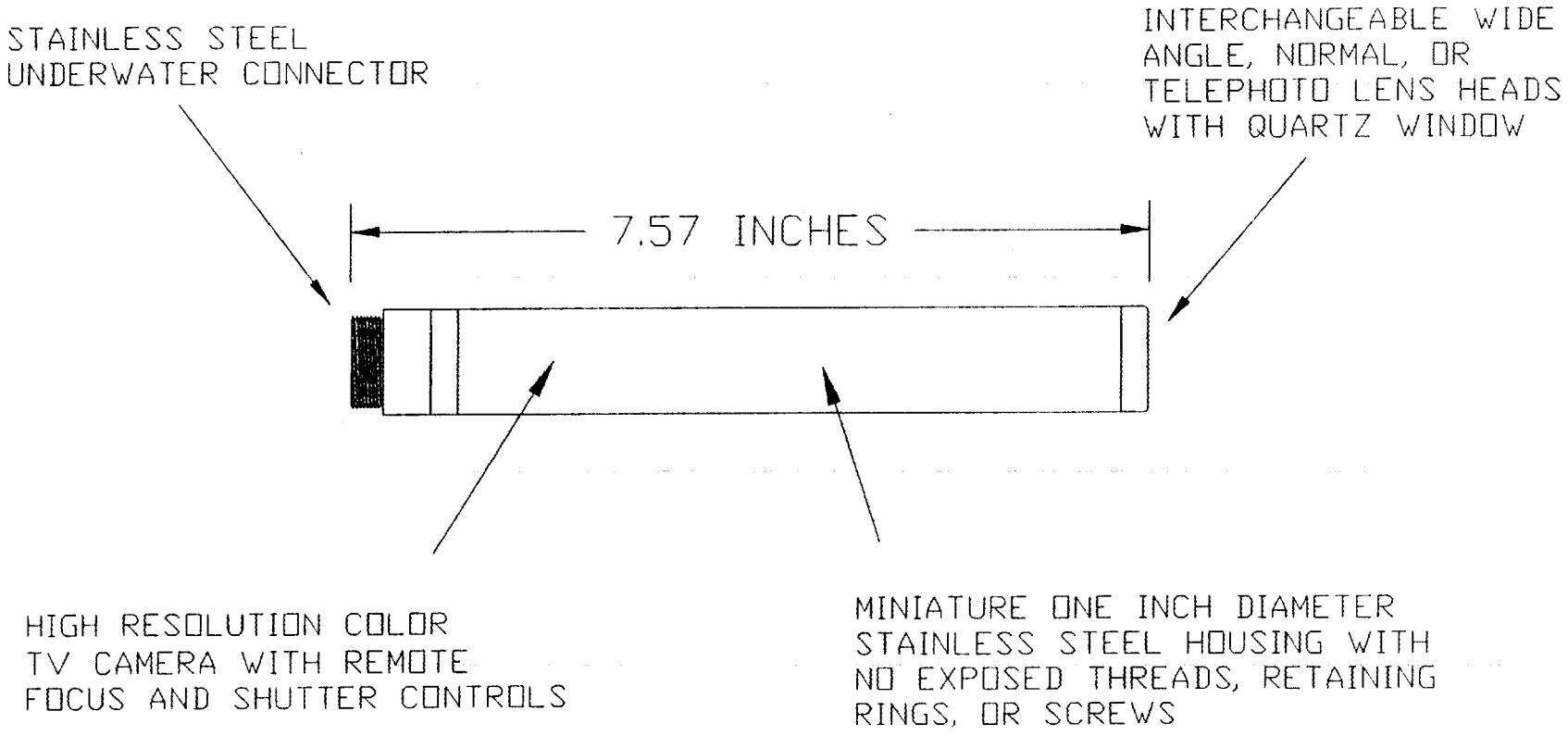
# SPECIFICATIONS

## MODEL RCS-510NBP CAMERA

| | |
|---|---|
| POWER | 12 VDC supplied via model CU1410 controller |
| SENSOR | 1/2 in. interline transfer CCD |
| SCAN AREA | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION | 460 TV lines |
| MINIMUM SCENE ILLUMINATION | 72 lux at f/3.5 |
| RECOMMENDED SCENE ILLUMINATION | 960 lux at f/3.5 |
| S/N RATIO | 46 dB |
| OUTPUT IMPEDANCE | 75 Ohms |
| LENS | Special zoom lens with non-browning optics |
| ZOOM | 22-90mm remotely controlled |
| FOCUS | 10 inches to infinity remotely controlled |
| IRIS | f/3.5 to f/4.5 remotely controlled |
| SHUTTER | 1/60 sec to 1/10,000 sec remotely controlled |
| PRISM | AMICI non-browning right angle roof prism |
| IN-AIR FIELD OF VIEW | 16.55 deg to 4.07 deg horizontal |
| UNDERWATER FIELD OF VIEW | 12.43 deg to 3.06 deg horizontal |
| HOUSING DIAMETER | 3.95 inches |
| HOUSING OVERALL LENGTH | 11.05 inches |
| IN AIR WEIGHT | 26.0 pounds |
| IN WATER WEIGHT | 22.3 pounds |
| HOUSING MATERIAL | 300 series stainless steel |
| WINDOW MATERIAL | Non-browning fused quartz |
| CONNECTOR | Model RCS-1501-BC stainless steel |
| MATING CONNECTOR | Model RCS-1501-CC |
| DEPTH RATING | 150 feet |
| TEMPERATURE RATING | -10 to 40 deg C (14 to 104 deg F) |
| RADIATION TOLERANCE (1 MEV) | $1.4 \times 10^4$ rad/hr, $4.6 \times 10^5$ rad total |
| RADIATION TOLERANCE (0.5 MEV) | $1.8 \times 10^6$ rad/hr, $5.9 \times 10^7$ rad total |
| CABLE LENGTH | Up to 300 feet |




MOUNTING FOR RCS-510 CAMERA AND UL-210 LIGHTS




MODEL RCS-600 REMOTE FOCUS COLOR TV CAMERA

# SPECIFICATIONS

## MODEL RCS-600 CAMERA

| | |
|---|---|
| POWER | 12 VDC supplied via model CU1410 controller |
| SENSOR | 1/2 in. interline transfer CCD |
| SCAN AREA | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION | 460 TV lines |
| MINIMUM SCENE ILLUMINATION | 15 lux at f/1.6 |
| RECOMMENDED SCENE ILLUMINATION | 200 lux at f/1.6 |
| S/N RATIO | 46 dB |
| OUTPUT IMPEDANCE | 75 Ohms |
| LENS | 7.5 mm, f/1.6 (4.0 mm & 15 mm options) |
| FOCUS | 0.3 inch to infinity remotely controlled |
| IRIS | f/1.6 manually adjustable |
| SHUTTER | 1/60 sec to 1/10,000 sec remotely controlled |
| IN-AIR FIELD OF VIEW | 36.4 x 48.2 deg (vertical x horizontal) |
| UNDERWATER FIELD OF VIEW | 27.2 x 35.8 deg (vertical x horizontal) |
| HOUSING DIAMETER | 1.00 inches |
| HOUSING LENGTH | 7.57 inches |
| CAMERA IN-AIR WEIGHT | 1.08 pounds (490 grams) |
| CAMERA IN-WATER WEIGHT | 0.86 pounds (393 grams) |
| HOUSING MATERIAL | 300 series stainless steel |
| WINDOW MATERIAL | Fused quartz |
| CONNECTOR | Model RCS-1501-BC-20 |
| MATING CONNECTOR | Model RCS-1501-CC-20 |
| DEPTH RATING | 2,000 feet |
| TEMPERATURE RATING | -10 to 50 deg C (14 to 122 deg F) |
| CABLE LENGTH | Up to 300 feet |

# RADIATION TOLERANT ZOOM COLOR TV CAMERA

RCS-510NBP

## GENERAL DESCRIPTION

The model RCS-510NBP camera uses a miniature high resolution Y-C format camera, a precision non-browning right angle correcting prism, and extensive lead shielding to achieve a high radiation tolerance of $1.4 \times 10^4$ rad/hour and a total accumulated dose tolerance of $4.6 \times 10^5$ rads with a 1 MEV source. A 22-90mm zoom lens with non-browning optics and a very short near focal distance of 10 inches makes the RCS-510NBP camera ideal for close-up detail color inspections in a high radiation field.

The stainless steel housing is completely sealed for underwater use up to 150 feet. Modular construction is utilized throughout for easy replacement of the camera, lens, prism assembly, or underwater connector.

The radiation tolerance of the RCS-510NBP camera for gamma radiation of various MEV levels is attached.

The RCS-510NBP camera is designed specifically to operate with the model CU 1410 rack mountable controller. This unit provides appropriate power to the camera and incorporates remote controls for the zoom, focus, iris, and shutter functions.

When model R12364 polyurethane-jacketed cable is used to interconnect the camera and controller, they can be separated up to 300 feet.

# SPECIFICATIONS

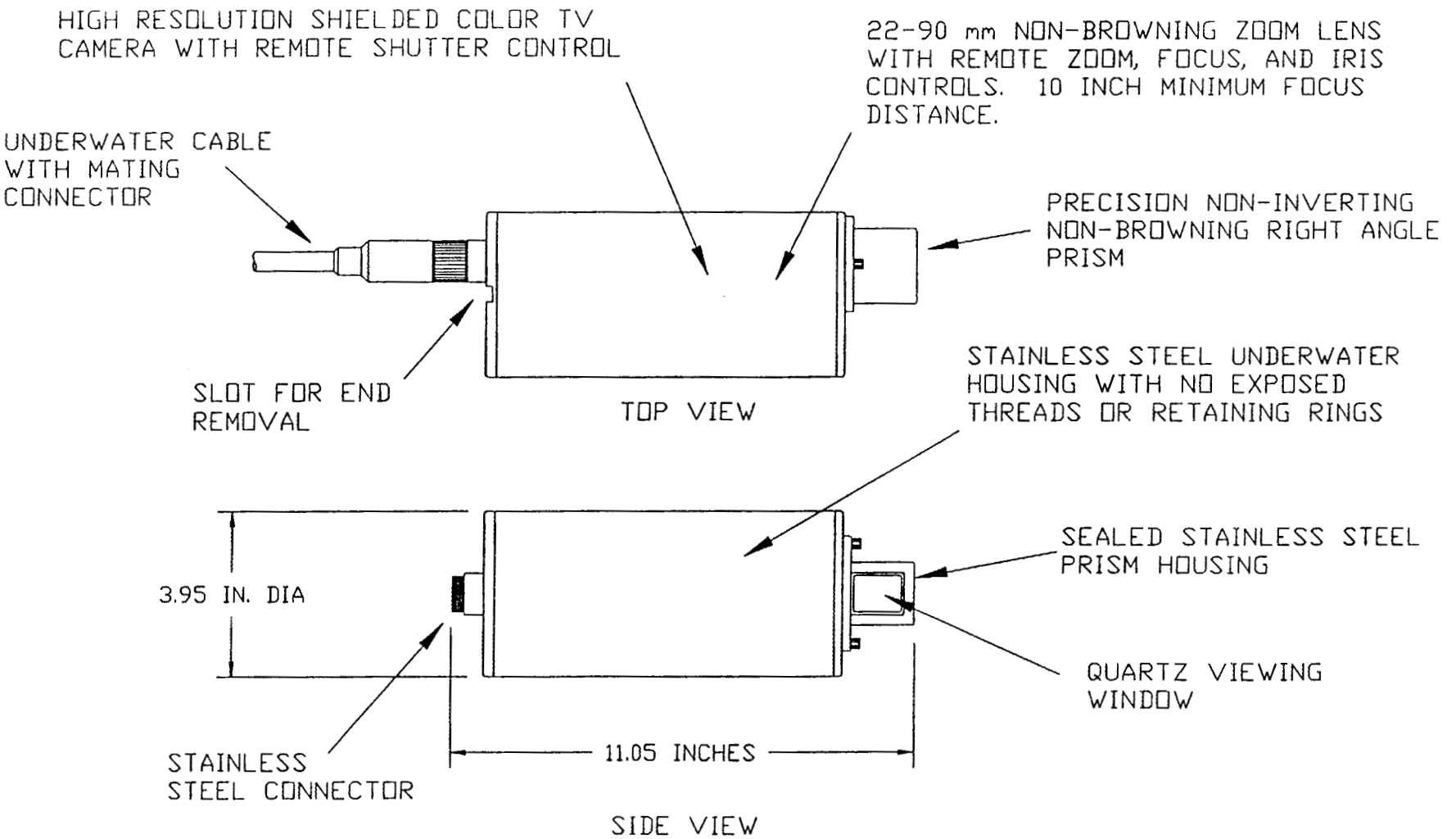
## MODEL RCS-510NBP CAMERA

| | |
|---|---|
| POWER | 12 VDC supplied via model CU1410 controller |
| SENSOR | 1/2 in. interline transfer CCD |
| SCAN AREA | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION | 460 TV lines |
| MINIMUM SCENE ILLUMINATION | 72 lux at f/3.5 |
| RECOMMENDED SCENE ILLUMINATION | 960 lux at f/3.5 |
| S/N RATIO | 46 dB |
| OUTPUT IMPEDANCE | 75 Ohms |
| LENS | Special zoom lens with non-browning optics |
| ZOOM | 22-90mm remotely controlled |
| FOCUS | 10 inches to infinity remotely controlled |
| IRIS | f/3.5 to f/4.5 remotely controlled |
| SHUTTER | 1/60 sec to 1/10,000 sec remotely controlled |
| PRISM | AMICI non-browning right angle roof prism |
| IN-AIR FIELD OF VIEW | 16.55 deg to 4.07 deg horizontal |
| UNDERWATER FIELD OF VIEW | 12.43 deg to 3.06 deg horizontal |
| HOUSING DIAMETER | 3.95 inches |
| HOUSING OVERALL LENGTH | 11.05 inches |
| IN AIR WEIGHT | 26.0 pounds |
| IN WATER WEIGHT | 22.3 pounds |
| HOUSING MATERIAL | 300 series stainless steel |
| WINDOW MATERIAL | Non-browning fused quartz |
| CONNECTOR | Model RCS-1501-BC stainless steel |
| MATING CONNECTOR | Model RCS-1501-CC |
| DEPTH RATING | 150 feet |
| TEMPERATURE RATING | -10 to 40 deg C (14 to 104 deg F) |
| RADIATION TOLERANCE (1 MEV) | $1.4 \times 10^4$ rad/hr, $4.6 \times 10^5$ rad total |
| RADIATION TOLERANCE (0.5 MEV) | $1.8 \times 10^6$ rad/hr, $5.9 \times 10^7$ rad total |
| CABLE LENGTH | Up to 300 feet |

# RADIATION TOLERANCE

**TOLERANCE OF RCS-510 CAMERA TO GAMMA RADIATION**

| MEV LEVEL | MAX DOSE RATE | ACCUM. DOSE TO COLOR LOSS | ACCUM. DOSE TO IMAGE LOSS |
|---|---|---|---|
| 0.5 | $1.8 \times 10^6$ rad/hr | $5.9 \times 10^7$ rad | $1.7 \times 10^8$ rad |
| 0.6 | $6.6 \times 10^5$ rad/hr | $2.1 \times 10^7$ rad | $6.0 \times 10^7$ rad |
| 0.7 | $9.6 \times 10^4$ rad/hr | $3.1 \times 10^6$ rad | $8.7 \times 10^6$ rad |
| 0.8 | $3.9 \times 10^4$ rad/hr | $1.3 \times 10^6$ rad | $3.6 \times 10^6$ rad |
| 0.9 | $2.0 \times 10^4$ rad/hr | $6.4 \times 10^5$ rad | $1.8 \times 10^6$ rad |
| 1.0 | $1.4 \times 10^4$ rad/hr | $4.6 \times 10^5$ rad | $1.3 \times 10^6$ rad |




RCS-510NBP RADIATION TOLERANT COLOR TV CAMERA

# VIDEO STICK
# TV INSPECTION SYSTEM

RCS-900

## GENERAL DESCRIPTION

The Video Stick is a miniature articulating color TV probe. With a camera head diameter of only 0.8 inches and full articulation in any direction, it allows detailed inspection and observation in places that are difficult to reach. It incorporates a high resolution Y-C format color TV camera in the articulating head, and is controlled by the hand grip on the opposite end of a 3/4 inch diameter anodized aluminum pole. The standard six foot long insertion pole can be extended in six foot increments.

The head angle is adjusted from straight ahead to straight back along the pole by sliding the angle adjustment knob on the hand grip. By rotating the hand grip, viewing is possible in any direction.

The splashproof camera housing is anodized aluminum for corrosion resistance, and allows manual external focus adjustment before insertion of the probe. Modular construction inside allows easy maintenance or replacement of the CCD camera or other components if necessary.

The camera control unit for the Video Stick operates on 120 VAC, and incorporates the remote shutter controls.

The Light Stick (model RCS-1000) and Ring Light (model RL-250) can be used with the Video Stick if additional lighting is needed. The Light Stick incorporates a sealed omni-directional quartz halogen 35 Watt 12 volt lamp on the end of a six foot pole. The Ring Light incorporates eight miniature high intensity lights and attaches directly to the Video Stick. Both lights are designed for use with the model PS-160 variable intensity power supply.

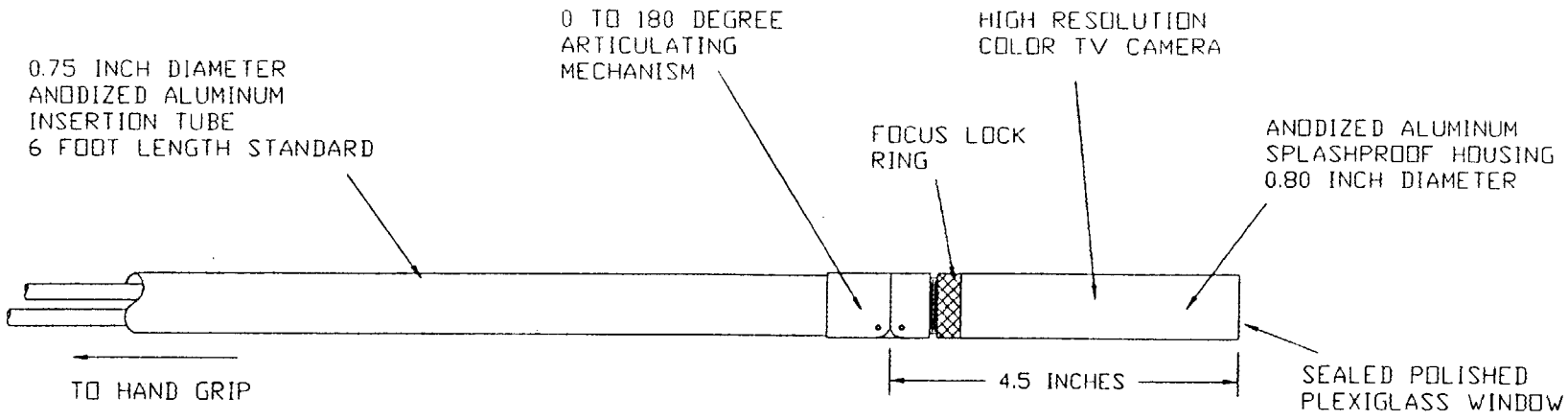
# SPECIFICATIONS

## VIDEO STICK (MODEL RCS-900)

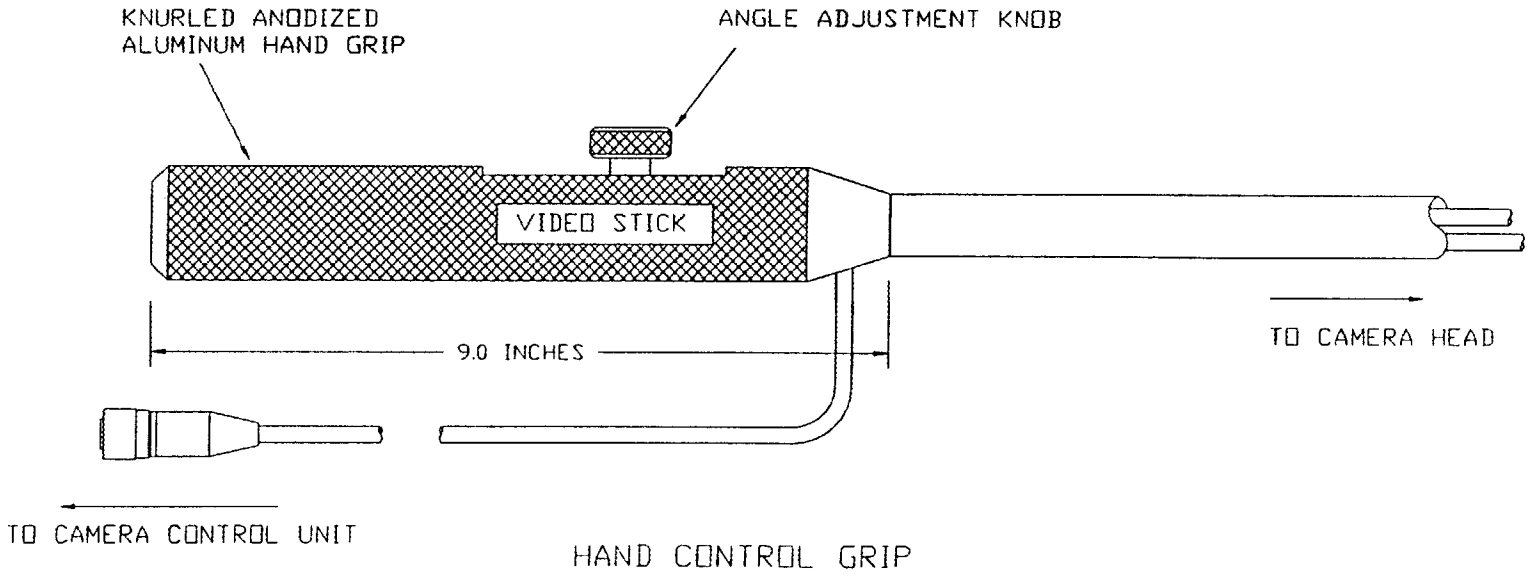
| | |
|---|---|
| POWER | 12 VDC supplied via camera control unit |
| SENSOR | 1/2 in. interline transfer CCD |
| SCAN AREA | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION | 460 TV lines |
| MINIMUM SCENE ILLUMINATION | 30 lux at f/2 |
| RECOMMENDED SCENE ILLUMINATION | 400 lux at f/2 |
| S/N RATIO | 46 dB |
| OUTPUT IMPEDANCE | 75 Ohms |
| LENS | 4 mm, f/2 |
| FOCUS | 0.2 inch to infinity manually adjustable |
| IRIS | f/2 manually adjustable |
| SHUTTER | 1/60 sec to 1/10,000 sec remotely controlled |
| FIELD OF VIEW | 69.1 x 92.1 deg (vertical x horizontal) |
| ARTICULATION ANGLE | 0 to 180 degrees |
| HOUSING DIAMETER | .80 inches |
| HOUSING LENGTH | 4.40 inches to pivot |
| INSERTION TUBE DIAMETER | 0.75 inches |
| INSERTION TUBE LENGTH | 6.0 feet (standard) |
| WEIGHT | 2.0 pounds |
| MATERIAL | Anodized aluminum |
| WINDOW MATERIAL | Polished acrylic |
| TEMPERATURE RATING | -10 to 50 deg C (14 to 122 deg F) |

## RING LIGHT (MODEL RL-250)

| | |
|---|---|
| VOLTAGE | 0-15 Volts |
| POWER | 8.8 Watts |
| LAMP TYPE | High intensity incandescent bi-pin (8 each) |
| LAMP LIFETIME | 30 hours @ full power |
| SIZE | 1.5 in. long x 1.25 in. dia. |
| WEIGHT | 0.1 pounds |
| MATERIAL | 6061-T6 anodized aluminum |
| CABLE LENGTH (standard) | 20 feet |
| CONNECTOR | Amphenol 97-3106A-14S-1P |

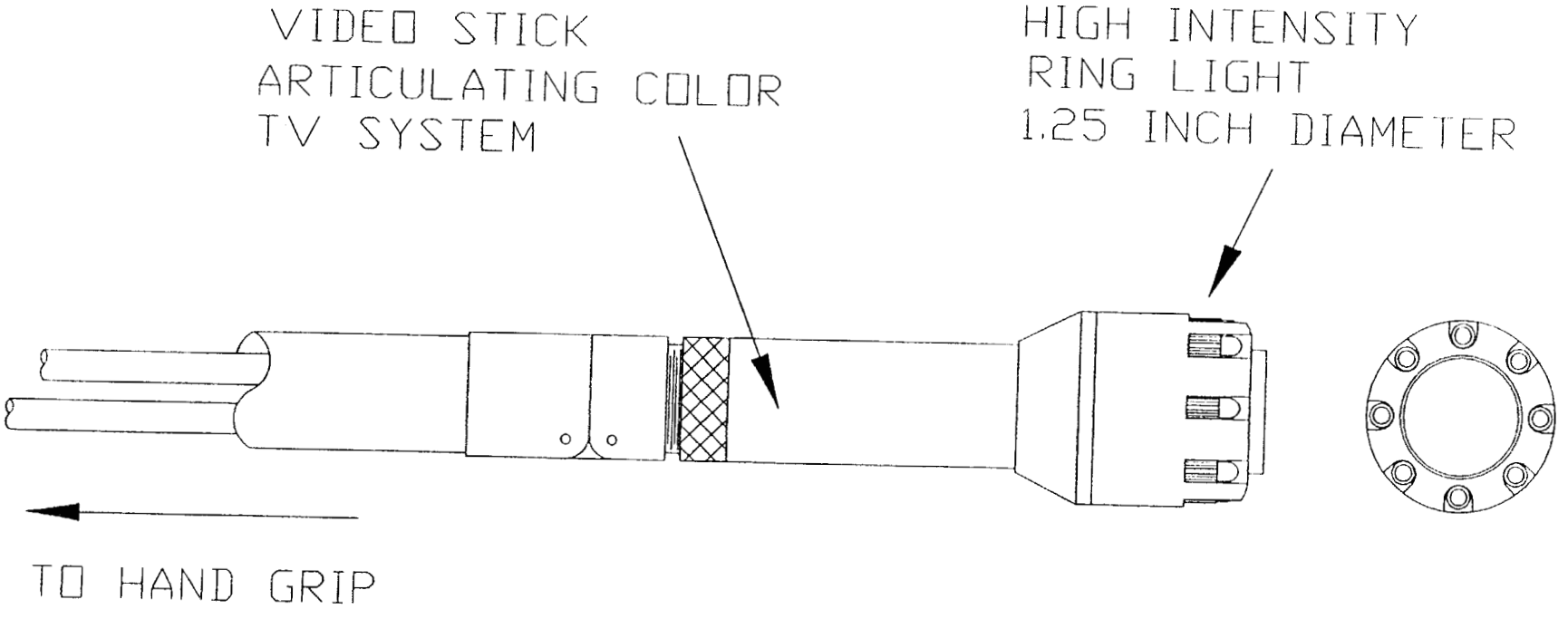



ARTICULATING CAMERA HEAD




HAND CONTROL GRIP

# VIDEO STICK A MINIATURE ARTICULATING COLOR TV PROBE




RING LIGHT ATTACHED TO VIDEO STICK

# ZOOM COLOR TV CAMERA

Model SVD-3

## GENERAL DESCRIPTION

The model SVD-3 camera uses a miniature high resolution Y-C format camera and an 8-48mm zoom lens in a stainless steel underwater housing. The housing has no exposed threads or retaining rings, and incorporates a non-browning fused quartz window. Modular construction is utilized throughout for easy replacement of the camera, lens, or other system components.

Attached is a dimensional drawing of the SVD-3 camera, and information on the in-air and underwater fields of view for the wide angle (zoomed out) and narrow angle (zoomed in) lens positions.

As an option, the SVD-3 camera can be supplied with a 2X lens adapter which will increase the lens focal length range to 16-96mm. This will increase the magnification by approximately two times, and will reduce the field of view to about half. The SVD-3 camera can also be supplied with a 22-90mm non-browning lens for use in higher radiation fields.

The SVD-3 is designed to operate with the model CU 1410 rack mountable controller. This unit provides appropriate power to the camera and incorporates remote controls for the zoom, focus, iris, and shutter functions.

If the Model R12364 polyurethane-jacketed cable is used to interconnect the camera and controller, they can be separated up to 300 feet.

# SPECIFICATIONS

MODEL SVD-3 CAMERA

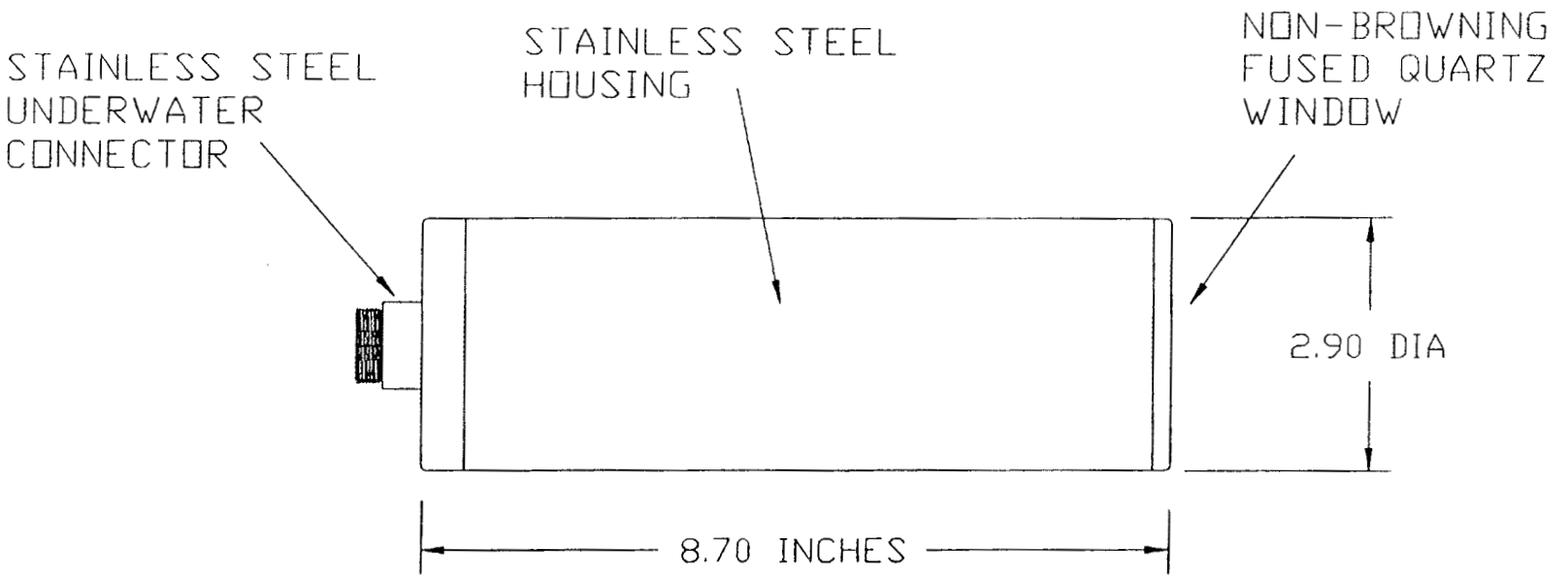
| | |
|---|---|
| POWER | 12 VDC supplied via model CU1410 controller |
| SENSOR | 1/2 in. interline transfer CCD |
| SCAN AREA | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION | 460 TV lines |
| MINIMUM SCENE ILLUMINATION | 5.9 lux at f/1.0 |
| RECOMMENDED SCENE ILLUMINATION | 78lux at f/1.0 |
| S/N RATIO | 46 dB |
| OUTPUT IMPEDANCE | 75 Ohms |
| ZOOM | 8-48 mm remotely controlled |
| FOCUS | 1 meter to infinity remotely controlled |
| IRIS | f/1.0 to closed remotely controlled |
| SHUTTER | 1/60 sec to 1/10,000 sec remotely controlled |
| IN-AIR FIELD OF VIEW | 43.6 deg to 7.6 deg horizontal |
| UNDERWATER FIELD OF VIEW | 32.4 deg to 5.7 deg horizontal |
| HOUSING DIAMETER | 2.90 inches |
| HOUSING OVERALL LENGTH | 8.70 inches |
| IN-AIR WEIGHT | 4.78 pounds |
| IN-WATER WEIGHT | 2.75 pounds |
| HOUSING MATERIAL | 300 series stainless steel |
| WINDOW MATERIAL | Non-browning fused quartz |
| CONNECTOR | Model RCS-1501-BC stainless steel |
| MATING CONNECTOR | Model RCS-1501-CC |
| DEPTH RATING | 500 feet |
| TEMPERATURE RATING | -10 to 40 deg C (14 to 104 deg F) |
| CABLE LENGTH | Up to 300 feet |

CAMERA FIELD OF VIEW

| | | | |
|---|---|---|---|
| SENSOR FORMAT SIZE | 0.5 inch | h= | 6.40 mm |
| LENS FOCAL LENGTH | 48 mm | v= | 4.80 mm |
| | | d= | 8.00 mm |

| | | |
|---|---|---|
| HORIZONTAL FOV (in air) | = | 7.63 degrees |
| VERTICAL FOV (in air) | = | 5.72 degrees |
| DIAGONAL FOV (in air) | = | 9.53 degrees |
| HORIZONTAL FOV (in water) | = | 5.73 degrees |
| VERTICAL FOV (in water) | = | 4.30 degrees |
| DIAGONAL FOV (in water) | = | 7.16 degrees |

| | FIELD SIZE IN AIR | | | FIELD SIZE IN WATER | | |
|---|---|---|---|---|---|---|
| DISTANCE (ft) | horiz | vert | diag | horiz | vert | dia |
| 2 | 0.27 | 0.20 | 0.33 | 0.20 | 0.15 | 0.2 |
| 4 | 0.53 | 0.40 | 0.67 | 0.40 | 0.30 | 0.5 |
| 6 | 0.80 | 0.60 | 1.00 | 0.60 | 0.45 | 0.7 |
| 8 | 1.07 | 0.80 | 1.33 | 0.80 | 0.60 | 1.0 |
| 10 | 1.33 | 1.00 | 1.67 | 1.00 | 0.75 | 1.2 |
| 12 | 1.60 | 1.20 | 2.00 | 1.20 | 0.90 | 1.5 |
| 14 | 1.87 | 1.40 | 2.33 | 1.40 | 1.05 | 1.7 |
| 16 | 2.13 | 1.60 | 2.67 | 1.60 | 1.20 | 2.0 |
| 18 | 2.40 | 1.80 | 3.00 | 1.80 | 1.35 | 2.2 |
| 20 | 2.67 | 2.00 | 3.33 | 2.00 | 1.50 | 2.5 |
| 22 | 2.93 | 2.20 | 3.67 | 2.20 | 1.65 | 2.7 |
| 24 | 3.20 | 2.40 | 4.00 | 2.40 | 1.80 | 3.0 |
| 26 | 3.47 | 2.60 | 4.33 | 2.60 | 1.95 | 3.2 |
| 28 | 3.73 | 2.80 | 4.67 | 2.80 | 2.10 | 3.5 |
| 30 | 4.00 | 3.00 | 5.00 | 3.00 | 2.25 | 3.7 |




FEATURES:

- HIGH RESOLUTION COLOR TV
- 8-48mm f/1.0 ZOOM LENS
- OPTIONAL 22-90mm NON-BROWNING LENS
- REMOTE FOCUS, ZOOM, & IRIS CONTROLS
- STAINLESS STEEL HOUSING
- NON-BROWNING QUARTZ WINDOW
- NO EXPOSED THREADS OR RETAINING RINGS
- SMALL SIZE
- STAINLESS STEEL CONNECTOR
- DEPTH RATING OF 500 FEET

# SVD-3 UNDERWATER COLOR ZOOM TV CAMERA

[illegible]
[illegible]
[illegible]

# REMOTE FOCUS UNDERWATER COLOR TV CAMERA WITH INTEGRAL LIGHTING

## RCS-1800

## GENERAL DESCRIPTION

The model RCS-1800 TV camera is a miniature, high resolution, high sensitivity S-video TV camera with a built-in ring of high intensity lights. It is specifically designed for internal pipeline and for general underwater and in-air applications requiring small size.

The camera housing is very small (see illustration) and is constructed from 300 series stainless steel. The viewing windows are made of non-browning fused quartz. The housing is completely sealed for underwater use to 200 foot depths and for easy decontamination.

Use of separate windows for the camera and lights allow long range viewing without image degradation due to multiple reflections in the camera window. With the standard 7.5mm f/1.6 lens and with the lights adjusted on high, the in-air viewing range is approximately ten feet.

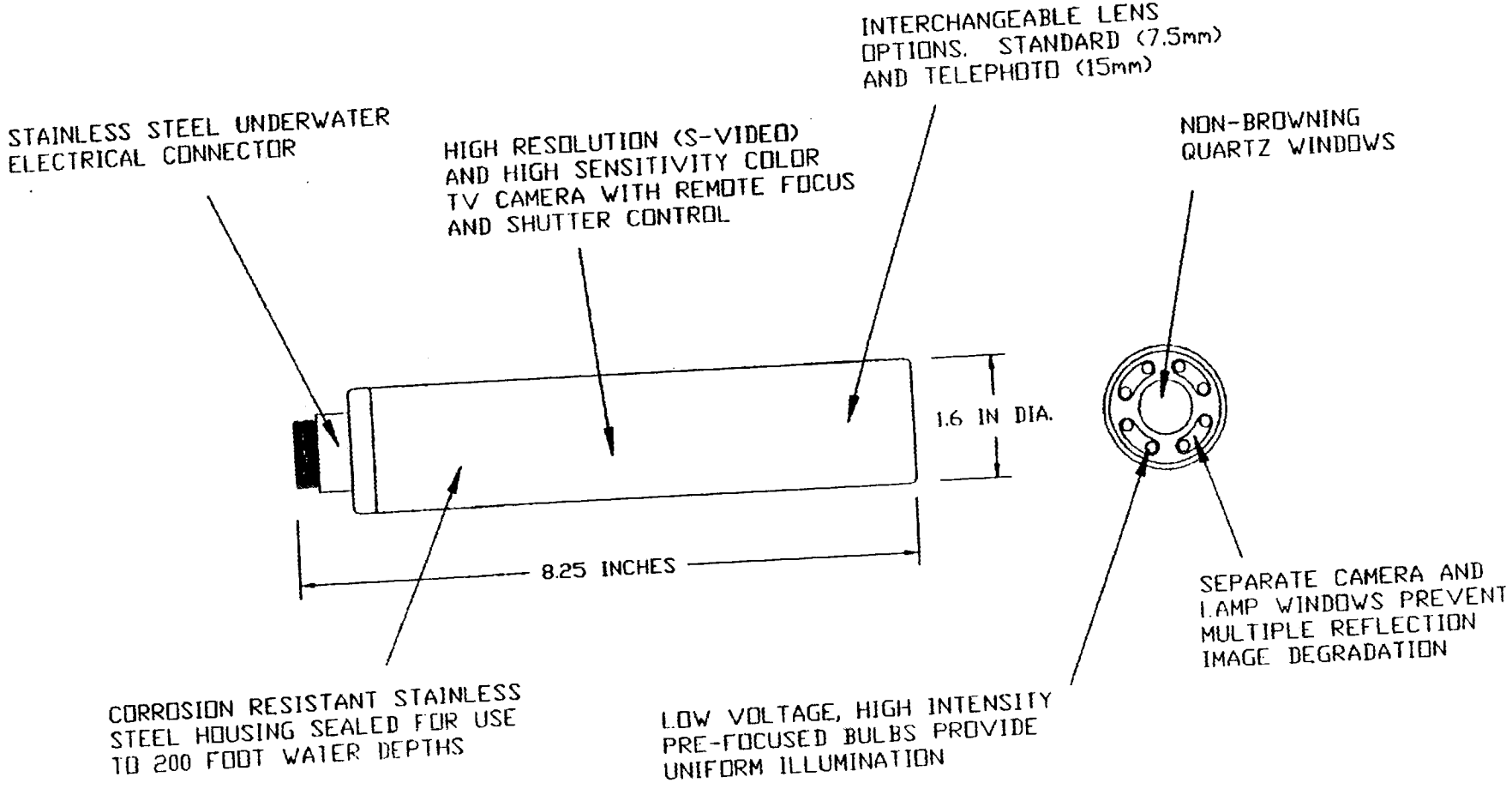
For applications requiring higher magnification, the standard 7.5mm lens can be exchanged with a 15mm f/2.0 telephoto lens.

A quick disconnect stainless steel underwater connector is used on the RCS-1800. The mating cable and controller are compatible with the RCS-600 remote focus color TV camera and the RCS-510 radiation shielded fuel inspection color TV camera camera.

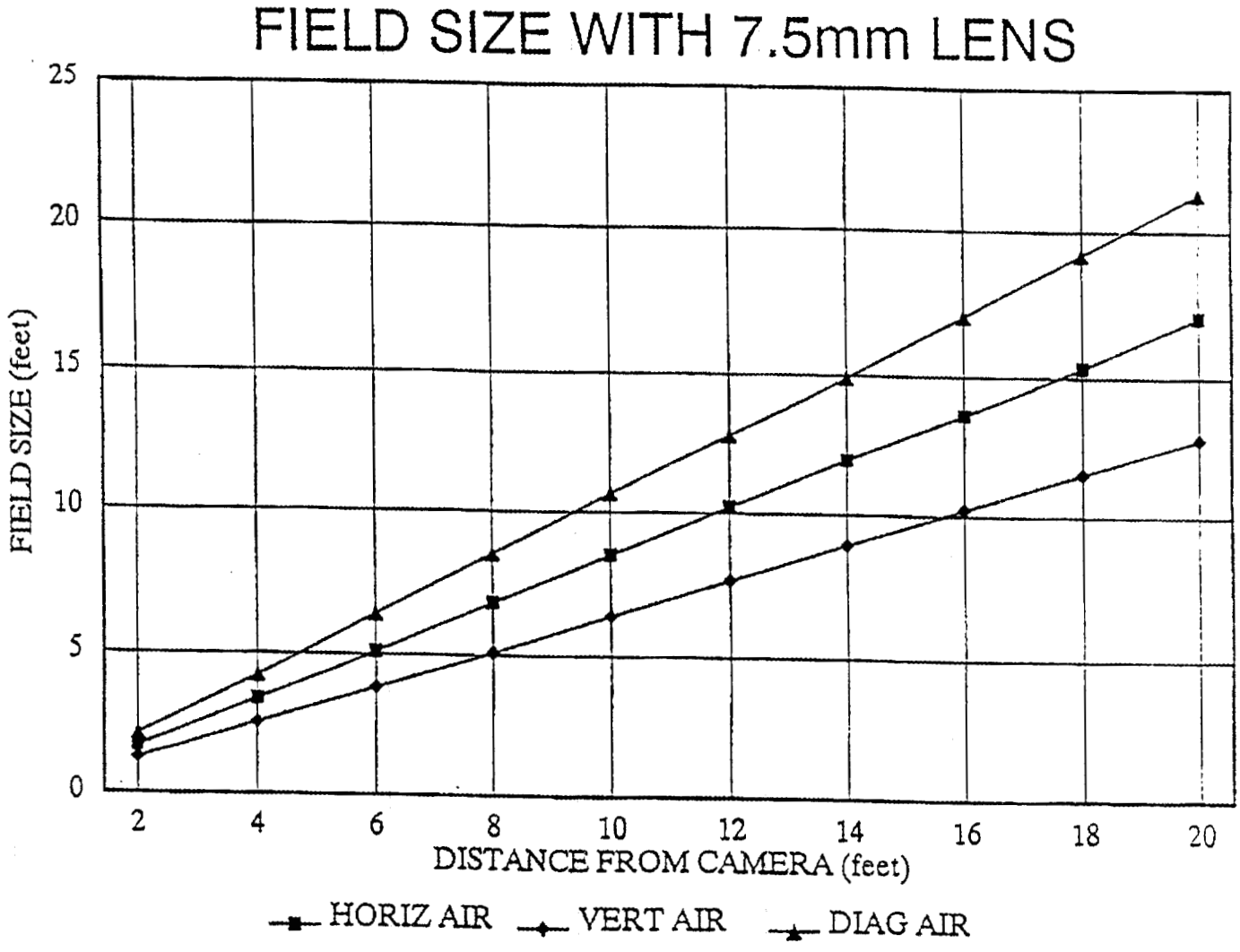
# SPECIFICATIONS

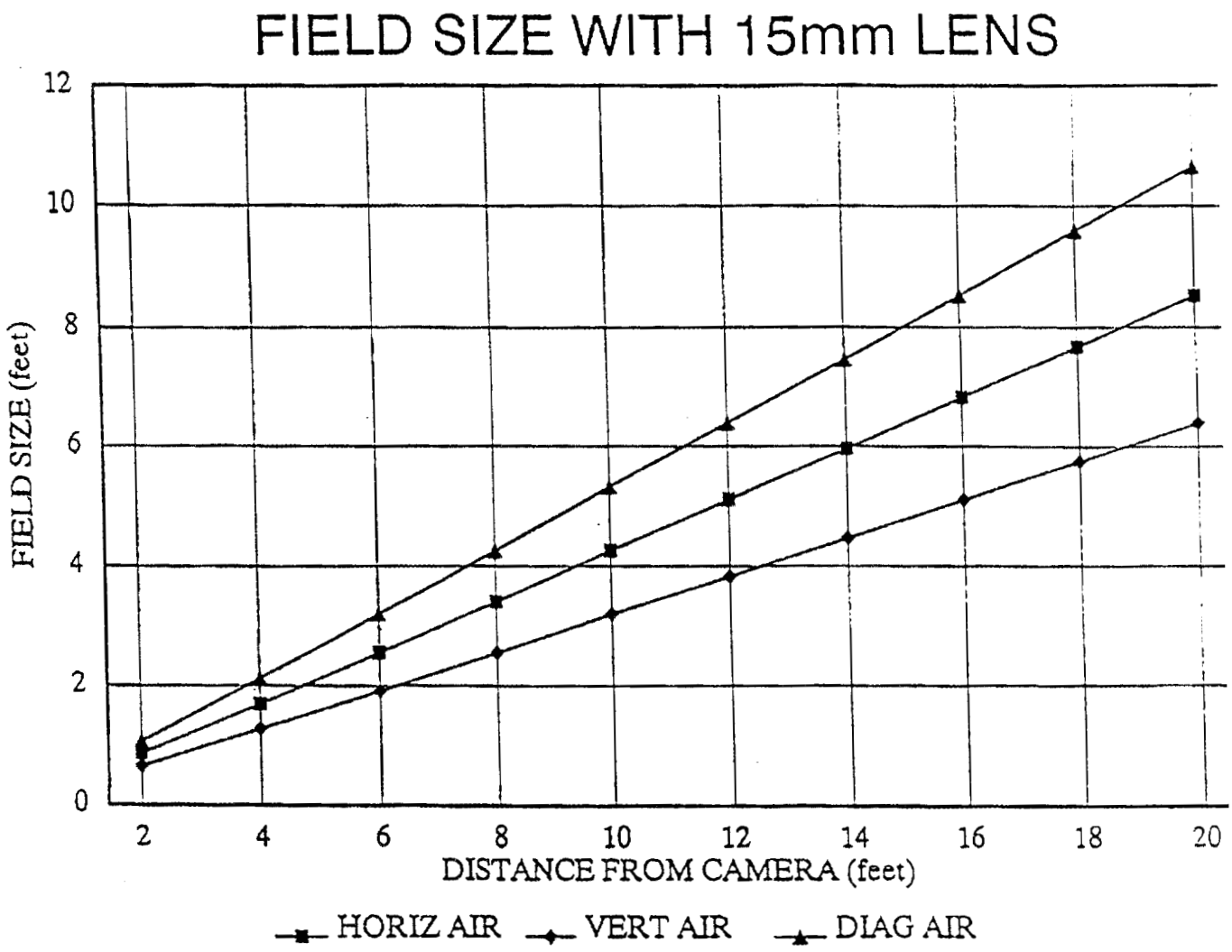
**TV CAMERA MODEL RCS-1800**

| | |
|---|---|
| POWER | Low voltage control signals supplied via camera control unit |
| SENSOR | 1/2 in. interline transfer CCD |
| SCAN AREA | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION | 470 TV lines |
| MINIMUM SCENE ILLUMINATION | 5 lux at f/1.6 |
| S/N RATIO | 48 dB |
| OUTPUT IMPEDANCE | 75 Ohms |
| STANDARD LENS | 7.5 mm, f/1.6 (modified) |
| FOCUS | 0.5 inches to infinity remotely controlled |
| IN AIR FIELD OF VIEW | 35.5 x 46.2 deg (vertical x horizontal) |
| UNDERWATER FIELD OF VIEW | 26.5 x 34.3 deg (vertical x horizontal) |
| LIGHTS | 8 ea. high intensity pre-focused |
| LIGHT RING VOLTAGE | 0-30 volts |
| HOUSING DIAMETER | 1.60 inches (1.90 in. at rear) |
| OVERALL LENGTH | 8.25 inches |
| WEIGHT | 2.9 pounds |
| HOUSING MATERIAL | Stainless steel |
| WINDOW MATERIAL | Fused quartz |
| ELECTRICAL CONNECTOR | Model RCS-1501-BC-20 Stainless steel |
| MATING CONNECTOR | Model RCS-1501-CC-20 |
| DEPTH RATING | 200 feet |
| TEMPERATURE RATING | -10 to 50 deg C (14 to 122 deg F) |




RCS-1800 UNDERWATER COLOR TV CAMERA WITH INTERNAL LIGHTS


FIELD SIZE WITH 7.5mm LENS
FIELD SIZE (feet)
25
20
15
10
5
0
2
4
6
8
10
12
14
16
18
20
DISTANCE FROM CAMERA (feet)
HORIZ AIR
VERT AIR
DIAG AIR


FIELD SIZE WITH 15mm LENS
FIELD SIZE (feet)
0
2
4
6
8
10
12
2
4
6
8
10
12
14
16
18
20
DISTANCE FROM CAMERA (feet)
HORIZ AIR
VERT AIR
DIAG AIR

# MINIATURE COLOR TV CAMERA

RCS-600

## GENERAL DESCRIPTION

The model RCS-600 camera is a miniature high resolution Y-C format color TV camera with remote focus and shutter control. It can be used in air or underwater to depths of 100 feet. With an outside diameter of one inch and a focus control range of 0.3 inches to infinity, the RCS-600 is ideal for inspection and surveillance applications where space is at a premium.

The RCS-600 is equipped with a replaceable lens head. It is normally supplied with a 7.5 mm lens head which provides a horizontal field of view of 48.2 degrees in air and 35.8 degrees in water. Also available are a 4.0 mm wide angle lens head (horizontal FOV of 92.1 degrees in air and 65.5 degrees in water) and a 15 mm telephoto head (horizontal FOV of 24.4 degrees in air and 18.3 degrees in water). These lens heads can easily be interchanged to accommodate specific viewing requirements.

The RCS-600 incorporates a stainless steel underwater connector for complete system portability and easy maintenance or repair.

The camera housing is made of stainless steel. It is completely sealed for use to depths of 2000 feet, and incorporates a front viewing window of fused quartz. Modular construction is utilized throughout for easy replacement of the CCD camera, focus motor, or other components.

The RCS-600 camera is designed specifically to operate with the model CU 1410 rack mountable controller. This unit provides appropriate power to the camera and incorporates remote controls for focus and shutter functions.

When the model R12364 polyurethane-jacketed cable is used to interconnect the camera and standard controller, they can be separated up to 300 feet. For deeper applications or those requiring greater cable lengths, the CCU can be packaged in a separate housing and connected to the camera control station by a much longer cable.

# SPECIFICATIONS

## MODEL RCS-600 CAMERA

| | |
|---|---|
| POWER | 12 VDC supplied via model CU1410 controller |
| SENSOR | 1/2 in. interline transfer CCD |
| SCAN AREA | 6.54 x 4.89 mm |
| HORIZONTAL RESOLUTION | 460 TV lines |
| MINIMUM SCENE ILLUMINATION | 15 lux at f/1.6 |
| RECOMMENDED SCENE ILLUMINATION | 200 lux at f/1.6 |
| S/N RATIO | 46 dB |
| OUTPUT IMPEDANCE | 75 Ohms |
| LENS | 7.5 mm, f/1.6 (4.0 mm & 15 mm options) |
| FOCUS | 0.3 inch to infinity remotely controlled |
| IRIS | f/1.6 manually adjustable |
| SHUTTER | 1/60 sec to 1/10,000 sec remotely controlled |
| IN-AIR FIELD OF VIEW | 36.4 x 48.2 deg (vertical x horizontal) |
| UNDERWATER FIELD OF VIEW | 27.2 x 35.8 deg (vertical x horizontal) |
| HOUSING DIAMETER | 1.00 inches |
| HOUSING LENGTH | 7.57 inches |
| CAMERA IN-AIR WEIGHT | 1.08 pounds (490 grams) |
| CAMERA IN-WATER WEIGHT | 0.86 pounds (393 grams) |
| HOUSING MATERIAL | 300 series stainless steel |
| WINDOW MATERIAL | Fused quartz |
| CONNECTOR | Model RCS-1501-BC-20 |
| MATING CONNECTOR | Model RCS-1501-CC-20 |
| DEPTH RATING | 2,000 feet |
| TEMPERATURE RATING | -10 to 50 deg C (14 to 122 deg F) |
| CABLE LENGTH | Up to 300 feet |

# UNDERWATER SCENE ILLUMINATION
## ATTENUATION COEFFICIENT ALPHA = 0.1

0.1
**1300 Candela**

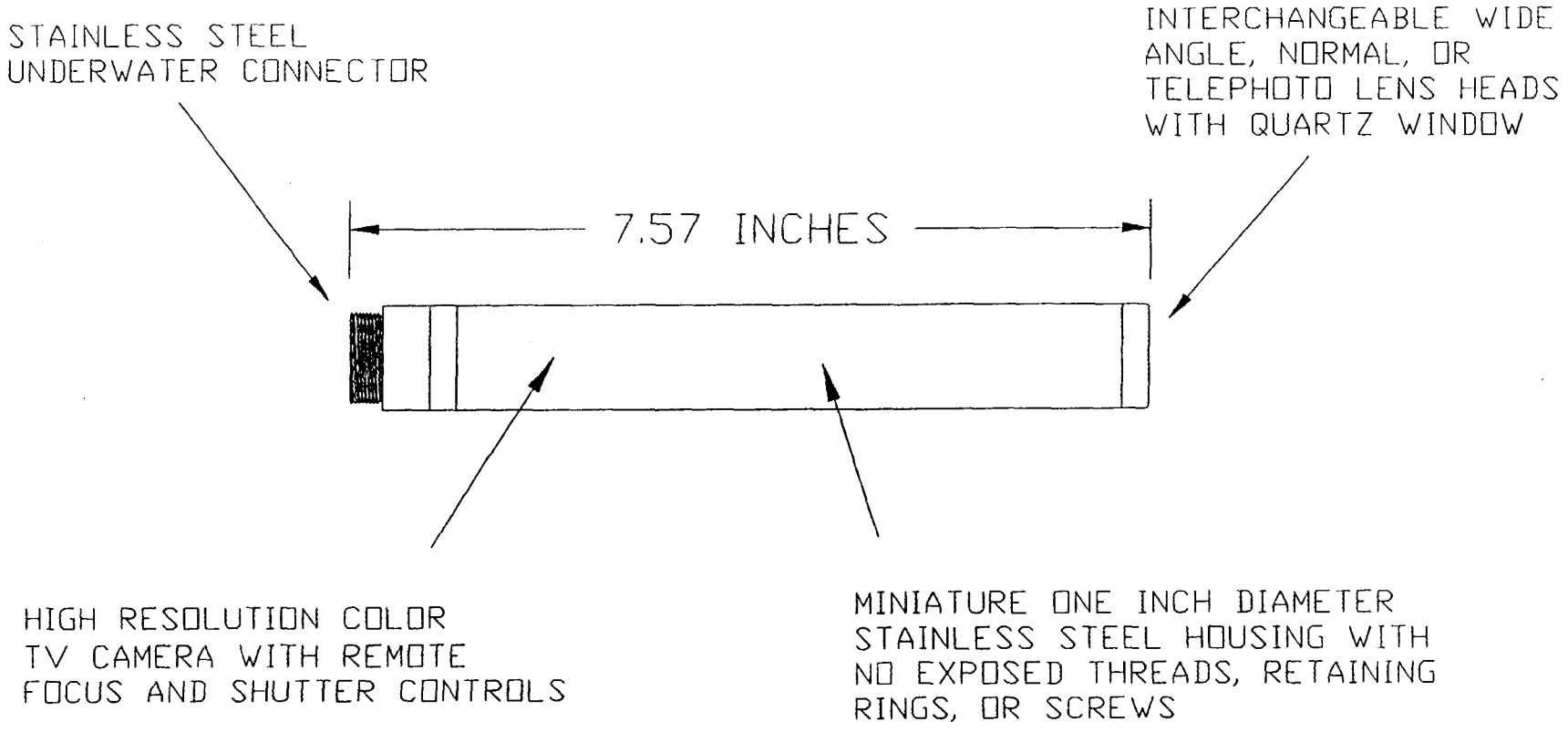
| RANGE (Feet) | ILLUMINATION (Lux) |
|---|---|
| 5 | 412.67 |
| 10 | 76.06 |
| 15 | 24.92 |
| 20 | 10.34 |
| 25 | 4.88 |
| 30 | 2.50 |
| 35 | 1.35 |
| 40 | 0.76 |
| 45 | 0.44 |
| 50 | 0.27 |
| 55 | 0.16 |
| 60 | 0.10 |
| 65 | 0.06 |

0.1
**2750 Candela**

| RANGE (Feet) | ILLUMINATION (Lux) |
|---|---|
| 5 | 872.95 |
| 10 | 160.90 |
| 15 | 52.72 |
| 20 | 21.87 |
| 25 | 10.32 |
| 30 | 5.28 |
| 35 | 2.86 |
| 40 | 1.62 |
| 45 | 0.94 |
| 50 | 0.56 |
| 55 | 0.34 |
| 60 | 0.21 |
| 65 | 0.13 |

0.1
**5850 Candela**

| RANGE (Feet) | ILLUMINATION (Lux) |
|---|---|
| 5 | 1857.00 |
| 10 | 342.28 |
| 15 | 112.16 |
| 20 | 46.51 |
| 25 | 21.95 |
| 30 | 11.24 |
| 35 | 6.09 |
| 40 | 3.44 |
| 45 | 2.00 |
| 50 | 1.20 |
| 55 | 0.73 |
| 60 | 0.45 |
| 65 | 0.28 |




MODEL RCS-600 REMOTE FOCUS COLOR TV CAMERA

# UNDERWATER LIGHT

Model UL-210

## GENERAL DESCRIPTION

The model UL-210 underwater light is intended for applications requiring small size and high intensity, and where low voltage operation is preferred for safety.

It incorporates a smooth stainless steel housing and a non-browning quartz window. The depth rating for the housing is 500 feet.

The UL-210 light can be provided with three different lamps which are standard. These provide beam patterns of 30 degrees, 20 degrees, or 10 degrees, each measured as the full angle to the half power (or intensity) points. These lamps are rated for use at 12 volts, and have a power rating of 35 watts. Each of the lamps incorporates a highly efficient reflector.

Bulb changing is very easy. Simply unscrew the forward section of the housing, unplug the old lamp, plug in the new one, and screw back on the front housing section.

A dimensional drawing of the UL-210 light, and information on the in-air and underwater illumination for the three standard lamps is attached. The underwater illumination takes account of both spreading losses and the two way attenuation losses in water with an attenuation factor (alpha) of 0.1

Power to the UL-210 underwater light is provided by Crestone Products PS-160 variable voltage power supply, or similar supply which provides the required voltage and power.

# SPECIFICATIONS

**MODEL UL-210 LIGHT**

| | |
|---|---|
| VOLTAGE | 12 volts |
| POWER | 35 watts standard |
| OPERATING DEPTH | 500 feet |
| DIAMETER | 1.60 inches |
| HOUSING LENGTH | 2.60 inches |
| OVERALL LENGTH | 4.76 inches |
| WEIGHT IN AIR | 0.59 pounds |
| WEIGHT IN WATER | 0.47 pounds |
| STANDARD BEAM PATTERNS | 30 degrees<br>20 degrees<br>10 degrees |
| RATED INTENSITY | 1300 candela (30 deg. beam)<br>2750 candela (20 deg. beam)<br>5850 candela (10 deg. beam) |
| RATED LAMP LIFE | 3000 hours |
| CONNECTOR | Impulse IE2M-BC |
| MATING CONNECTOR | Impulse IE2F-5/8 |
| WINDOW MATERIAL | Fused Quartz |
| HOUSING MATERIAL | 300 series stainless steel |

# IN AIR SCENE ILLUMINATION

0
1300 Candela

| RANGE (Feet) | ILLUMINATION (Lux) |
|---|---|
| 5 | 559.72 |
| 10 | 139.93 |
| 15 | 62.19 |
| 20 | 34.98 |
| 25 | 22.39 |
| 30 | 15.55 |
| 35 | 11.42 |
| 40 | 8.75 |
| 45 | 6.91 |
| 50 | 5.60 |
| 55 | 4.63 |
| 60 | 3.89 |
| 65 | 3.31 |

0
2750 Candela

| RANGE (Feet) | ILLUMINATION (Lux) |
|---|---|
| 5 | 1184.03 |
| 10 | 296.01 |
| 15 | 131.56 |
| 20 | 74.00 |
| 25 | 47.36 |
| 30 | 32.89 |
| 35 | 24.16 |
| 40 | 18.50 |
| 45 | 14.62 |
| 50 | 11.84 |
| 55 | 9.79 |
| 60 | 8.22 |
| 65 | 7.01 |

0
5850 Candela

| RANGE (Feet) | ILLUMINATION (Lux) |
|---|---|
| 5 | 2518.76 |
| 10 | 629.69 |
| 15 | 279.86 |
| 20 | 157.42 |
| 25 | 100.75 |
| 30 | 69.97 |
| 35 | 51.40 |
| 40 | 39.36 |
| 45 | 31.10 |
| 50 | 25.19 |
| 55 | 20.82 |
| 60 | 17.49 |
| 65 | 14.90 |

RJ ELECTRONICS
5504 VAL VIEW DR. SE.
TURNER, OR 97392
TEL: (503) 743-3709/3706

# Radiation Dose Rate Test Report for the RCS-510 Shielded Underwater Color Camera

August 4, 1992

Stephen Bayne
Fuel Examination Technology

General Electric Company
175 Curtner Avenue
San Jose, CA 95125

## Summary

On May 29, 1992, Fuel Examination Technology conducted a test at the General Electric Vallecitos Nuclear Facility to determine the frontal dose rate the RCS-510 Shielded Underwater Color Camera can withstand before its picture becomes appreciably affected. The radiation source was 323 curies of cobalt 60. The test concluded the RCS-510 camera can be used facing radiation fields up to 3,000 rad/hr with no degradation of the picture quality. The camera can be used facing fields up to 10,000 rad/hr with no loss in picture clarity and only slight loss in picture quality due to noise in the form of "snow." The amount of accumulated dose which will permanently degrade picture quality has not been established.

## Scope/Limitations

The test was designed to study the effects of dose rate on the picture quality of the camera and did not study the effects of accumulated dose.

During the test, the source was kept in front of the camera on the shielded side as the purpose of the test was to study the performance of the shielding. Note that the camera is much more susceptible to radiation from other directions. In normal use, however, the shielded side will face the high radiation source.

## Equipment and Setup

The camera was controlled using an RJ Electronics CU1410 unit and the signal was displayed on a Panasonic color video monitor (CT-1030M). Color prints were made using a Hitachi color video printer (VY-1260) and a video tape was made on a Panasonic VCR (AG-1260). A Knox K12 character generator was used to create the titles.

The radiation source was 323 curies of cobalt 60 (teletherapy standard # 20-47). The radiation detector was a Technical Associates Hi Range Probe (# 064185). The radiation meter was a Technical Associates Cutie Pie Mark III, Model CPMU.

The camera was placed in the cell 2 interlock, looking at a test pattern and a color standard. The test setup is shown below in Fig. 1. The electronic equipment was placed directly outside of the hot cell. The camera cable entered the hot cell through a pass-through port. The source was handled by a remote manipulator. The background radiation level in the hot cell was approximately 80 rad/hr.

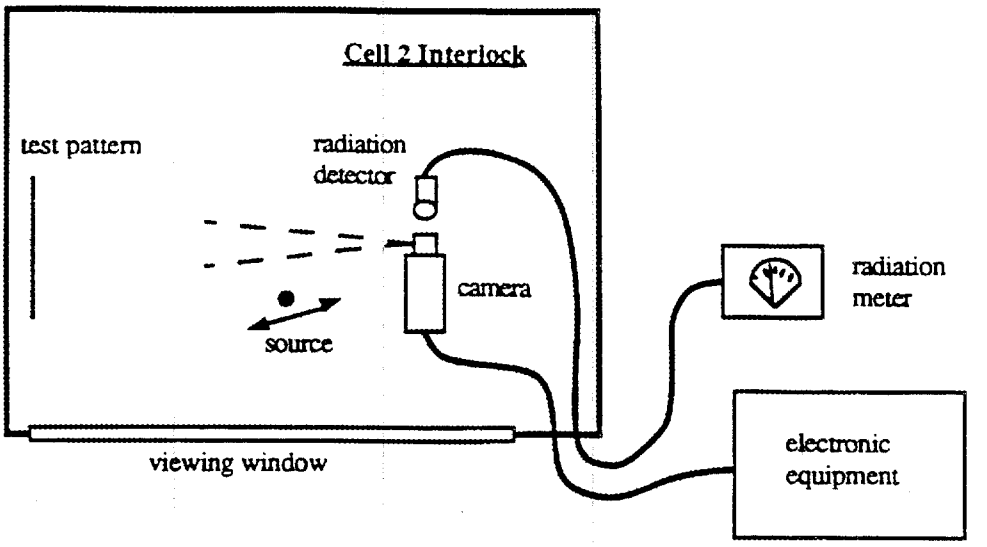



Figure 1: Test setup at Vallecitos

## Test Procedure

After setting up the equipment, the background dose rate was recorded and the source removed from its shielded container. While running the video tape, we moved the source towards the camera pausing at desired camera dose rates. During each pause, we updated the screen title and made a color print. We achieved the maximum dose rate of 10,000 rad/hr by placing the source directly adjacent to the camera. We also made prints at specific camera dose rates while moving the source away from the camera. The camera received an accumulated dose of approximately 200 - 300 rad. The test was conducted by Pete Peterson and Stephen Bayne.

## Test Results

We observed a small amount of "snow" in the picture that became noticeable at a dose rate of about 3,000 rad/hr (see Figs. 2 - 6). The noise intensity increased with the dose rate. We observed no other effects on the resolution, color or picture quality.

## Conclusions

We conclude that the RCS-510 camera can be used facing radiation fields up to 3,000 rad/hr with no degradation of the picture quality. The camera can be used facing fields up to 10,000 rad/hr with no loss in picture clarity and only slight loss in picture quality due to noise in the form of "snow." The amount of accumulated dose which will permanently degrade picture quality has not been established.

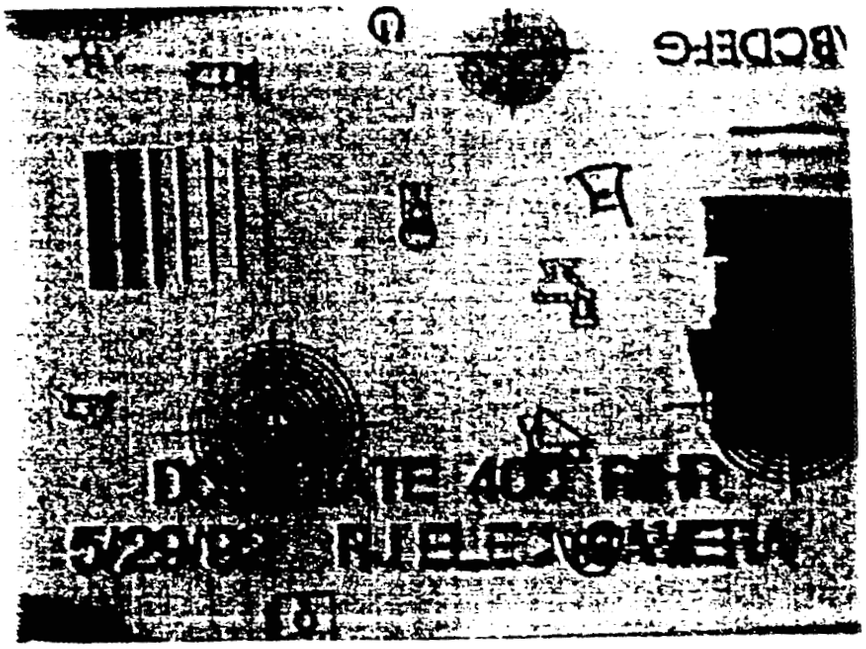


Figure 2: Picture from RCS-510 camera at 400 rad/hr

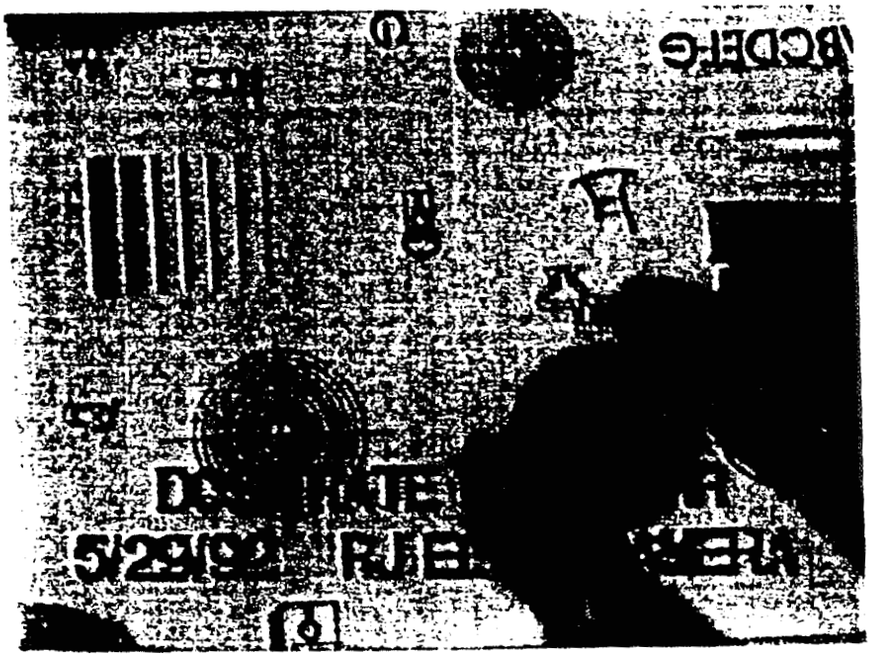


Figure 3: Picture from RCS-510 camera at 1,000 rad/hr

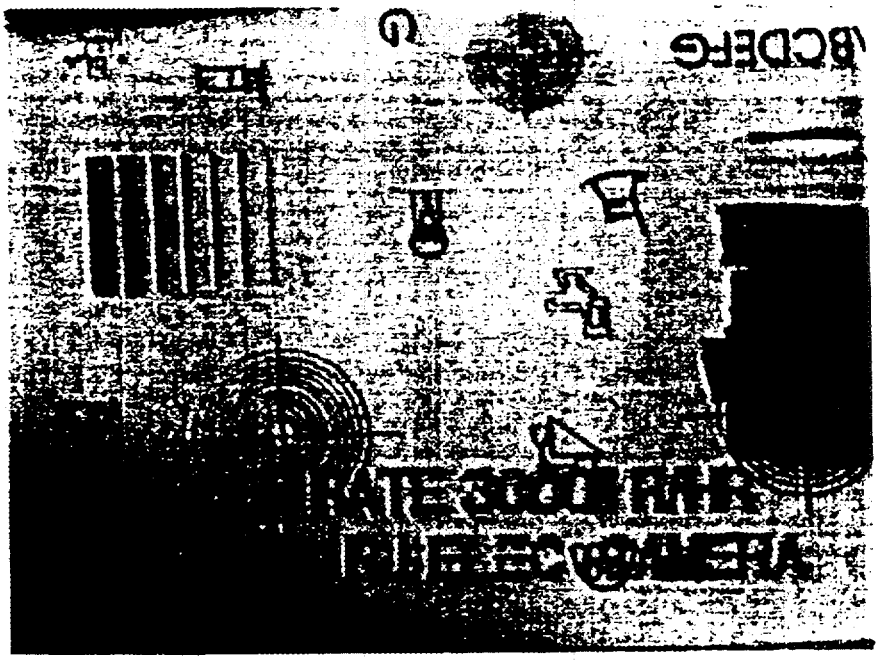


Figure 4: Picture from RCS-510 camera at 3,000 rad/hr

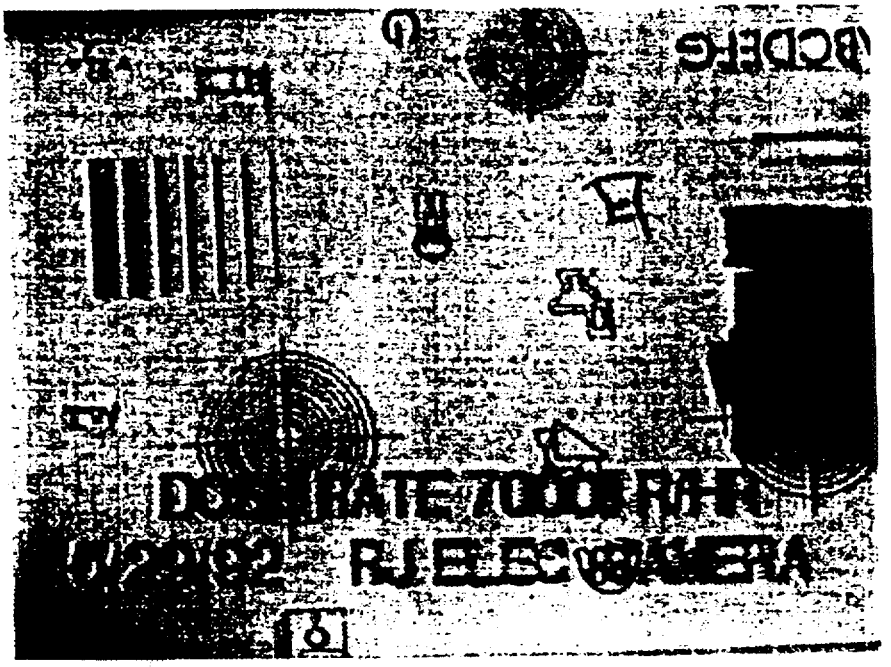


Figure 5: Picture from RCS-510 camera at 7,000 rad/hr

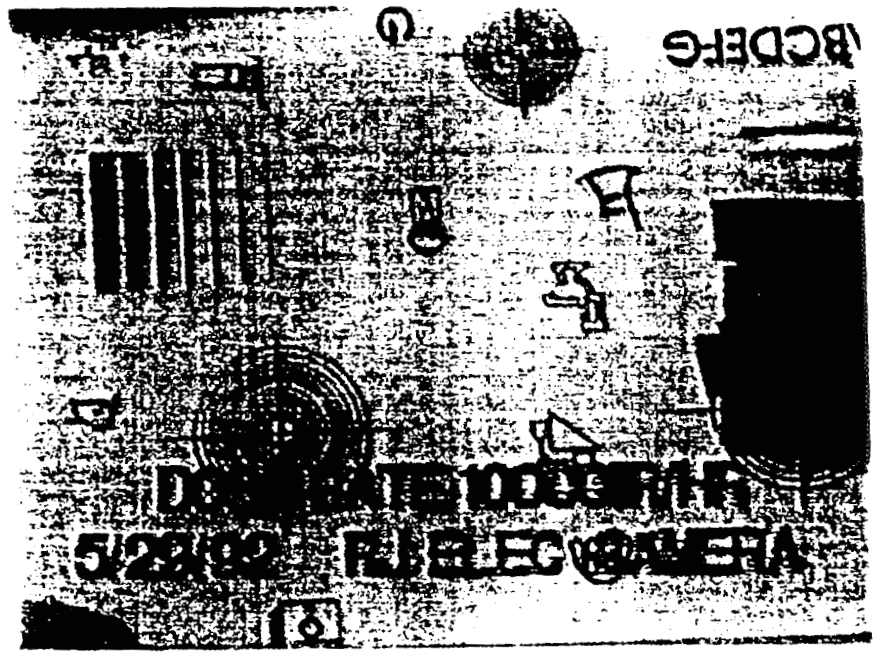


Figure 6: Picture from RCS-510 camera at 10,000 rad/hr

# APPENDIX D
# ANGULAR POSITION MEASUREMENT SYSTEMS

**BEI MOTION SYSTEMS COMPANY**
**Precision Systems & Space Division**

# FACSIMILE MESSAGE

Fax Log No. _____

TO: Mr. David Halcomb

Oak Ridge National Laboratory
Oak Ridge, TN

FAX NO. 615-574-4058

PHONE NO. 615-576-7889

DATE: 17 January 1994

BEI'S FAX NO. (501) 851-5476

FROM: Sam Berg

PHONE NO. (501) 851-4000

TOTAL PAGES: 14
COVER (1) PLUS _____

MESSAGE: Subject: An Encoder designed to operate in a nuclear waste tank environment
Reference: Your and my telecon 1-10-94

During our telecon on 1-10-94, I promised you I would ask our Mr. Tim Malcolm to call you to discuss your unique encoder needs. I gather from talking to Tim that you two had a fruitful discussion - he has given me a preliminary technical proposal that I fax on to you in its original form. Along with it I fax two of our 3700-Series product publications: 1) a 2-page short-form catalog piece and 2) a more thorough specification (No. 5-014C). After you have had time to peruse our data, please give me a call (or call Tim if you like) and we'll try to firm up what we can furnish to you.

Best Regards,

Sam Berg

Sam Berg
Inside Sales Manager

P.O. Box 3838 • Little Rock, AR 72203 • (501) 851-4000 • FAX (501) 851-5476
Maumelle Industrial Park • 1100 Murphy Drive • Maumelle, AR 72113

# BEI TECHNICAL PROPOSAL

January 14, 1994

Prepared For:

David Holcomb
Oak Ridge National Laboratory
Instrumentation and Controls Division
P.O. Box 2008, Bldg 3500
Oak Ridge, TN 37831-6010
PH (615)576-7889
FAX (615)574-4058

Prepared By:

T. Malcolm
BEI Reliability Manager

# TECHNICAL PROPOSAL

## Statement of Problem:

David Holcomb, Oak Ridge National Laboratory, Instrumentation and Controls Division, has a need for an encoder design which is less than four inches in diameter, can withstand 1MegRad(Si) total dose radiation, can operate at +100°C, and is resistant to environments with a pH of about 12. The application is for a robot arm for use in nuclear waste tanks. No neutrons are anticipated.

## Proposed Solution:

BEI manufactures a standard encoder line of ruggedized incremental encoders, well-suited for demanding applications. The 3700-Series encoders offer counts up to $2^{16}$ per revolution. These units are sealed, have an integral LED light source, operate off a single 5 volt power supply, and offer a number of output data options. For this application BEI proposes a 4096 code disk with an 8X multiplication for a total count of $2^{15}$ per revolution. In order to meet the specified environments, several changes would need to be made to the standard model:

1). Replace the aluminum cover and bearing housing with stainless steel, chromium-plated for maximum corrosion resistance.
2). Replace the seals and o-rings with extended temperature materials.
3). Replace the connector with a nickel-plated fully sealed Mil-Spec version.
4). Replace the internal IC's with rad-hard versions. LED and photodetectors do not require any upgrade.
5). Adjust the calibration procedure to allow for the high-temperature operation.

## Cost Considerations:

The standard unit P/N 3736E8ZS sells for about $4000 (qty 1). The additional options listed above which are required to survive the specified environment, are estimated to cost an additional $1000 per encoder, plus or minus 50%. BEI will further definitize the cost once detailed current quotes for materials and parts are available. A non-recurring engineering time charge to document the changes would also be required.

## Summary:

BEI believes that the proposed encoder represents a cost-effective solution for angle measurement in a very severe environment. This solution has the advantage of outputting digital signals at the proposed resolution so that simple pulse counting can be used to determine position, as compared to an inductive solution, which would output analog signals and would require external interpretation electronics. BEI has considerable experience in designing encoders for space and military applications, and is familiar with the difficulties involved in surviving the high radiation environment.

# 3700-SERIES
## RUGGEDIZED INCREMENTAL ENCODERS

BEI's 3700-Series incremental encoders feature a field-proven high-reliability design that provides a highly accurate conversion of rotary position change into a complementary digital output signal that can be used for position or motion sensing and control.

The ruggedized design insures the highest level of immunity to shock, vibration, heavy shaft loading, and electrical noise. The heavy-duty cover provides reliable protection for the electronics and optics assemblies and is sealed at the flange and at the connector to withstand water spray and oil mist. An optional (at no extra cost) shaft seal provides additional protection from fluid contamination.

OPTIONS:
- Side connector
- Shaft seal
- Wider operating temperature range
- Operating frequency above 100 kHz
- HNL/CMOS
- Special shaft configuration
- Hard anodized housing finish (MIL-A-8625, type 3, class 1)
- Other disk resolutions

FEATURES:
- Resolution to 65,536 cycles per turn
- Incremental output code on two count tracks phased 90 degrees apa
- Optional zero-reference track
- Single LED light source
- Aluminum bearing flang
- All units are 100% inspected for all testable and inspectable functions
- Meets or exceeds applicable portions of MIL-STD-202C, MIL-STD-810C, MIL-E-5272C(ASG), MIL-E-5400L, MIL-E-16400F
- Complementary digital outputs from type DM8830, AM26LS31, or SN75183 line drivers
- Dual resolution models have complementary mode selection control

## MODEL NUMBER STRUCTURE

**SINGLE RESOLUTION**

| Model | Counts/Turn | Model | Counts/Turn | Model | Counts/Turn |
|---|---|---|---|---|---|
| 3700-3 | 100 | 3705 | 1024 | 3736 | 4096 |
| 3700-4 | 256 | 3732 | 1500 | 3737 | 8192 |
| 3700 | 360 | 3733 | 1600 | | |
| 3730 | 400 | 3733-1 | 1800 | | |
| 3731 | 500 | 3706 | 1905 | **DUAL RESOLUTION** | |
| 3701 | 508 | 3734 | 2000 | 3750 | 400/508 |
| 3702 | 625 | 3707 | 2032 | 3751 | 500/635 |
| 3703 | 635 | 3708 | 2048 | 3752 | 1500/1905 |
| 3704-2 | 900 | 3735 | 2500 | 3753 | 1600/2032 |
| 3704 | 1000 | 3709 | 2540 | 3754 | 2000/2540 |
| 3704-3 | 1200 | 3710 | 3175 | 3755 | 2500/3175 |

NOTE: Any disk resolution less than 8192 counts/turn is available with any of the standard options on special order.

3 7 [ ] [ ] [ ] [ ] [ ] [ ]

**Electronics Options:**
- A Schmitt trigger quadrature outputs at disk resolution
- B One-shot outputs with 2-line direction sensing at disk resolution
- C One-shot outputs with 2-line direction sensing at twice the disk resolution
- D One-shot outputs with 2-line direction sensing at 4 times the disk resolution
- E Schmitt trigger quadrature outputs at 5 to 8 times disk resolution (E5 or E8)

Consult factory for higher resolutions

Z Zero-reference output pulse

S Shaft seal

Number denotes special resolution or other special features

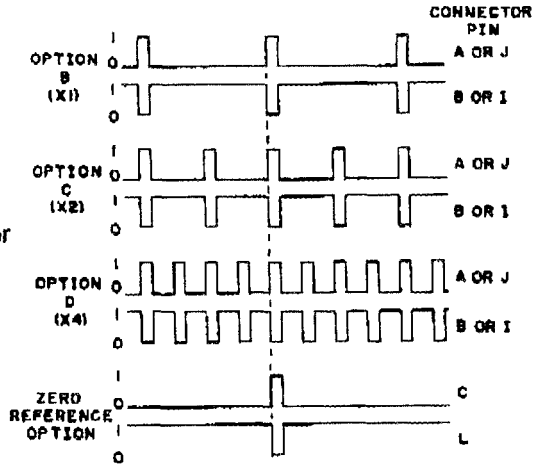
BEI MOTION SYSTEMS COMPANY
Precision Systems and Space Division
P.O. Box 3828 • Little Rock, AR 72203 • (501) 851-4000

# 3700-SERIES
## RUGGEDIZED INCREMENTAL ENCODERS

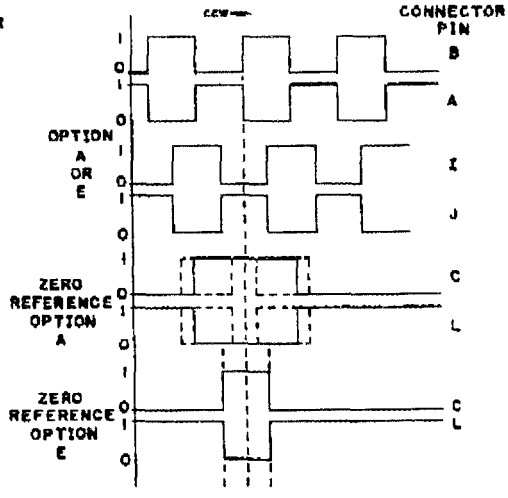
### CONNECTOR PIN FUNCTIONS

| PIN | FUNCTION |
|---|---|
| A | A count-signal output |
| B | $\overline{A}$ count-signal output |
| C | C zero-reference signal output (or spare) |
| D | Ground — internally tied together |
| E | Ground |
| F | +5 Vdc input — internally tied together |
| G | +5 Vdc input |
| H | M mode input or spare |
| I | B count-signal output |
| J | $\overline{B}$ count-signal output |
| K | Shield ground |
| L | $\overline{C}$ zero-reference signal output (or spare) |
| M | Case ground |
| N | $\overline{M}$ mode input or spare |

ONE-SHOT OUTPUT WAVESHAPES




SCHMITT TRIGGER OUTPUT WAVESHAPES




**Power Required:** 5.0 ± 0.25 Vdc, up to 560 mA, depending upon electronics option

**Mode Selection Control for dual resolution models:**
Binary 1 (for higher resolution): +2.0 to +5.5 Vdc sourcing 80μA at +2.4 V
Binary 0 (for lower resolution): 0 to +0.8 Vdc sinking 3.2mA at +0.4 V

**Output Characteristics (single and dual resolution)**

| | | |
|---|---|---|
| **Binary 1 minimum dc output voltage, sourcing current:** | +2.4V, 0.8mA, +1.8V, 40mA | +2.5V,20mA |
| **Binary 0 maximum dc output voltage, sinking current:** | +0.4V, 32mA, +0.5V, 40mA | +0.5V,20mA |

| Electronics Options | A | B | C | D | E |
|---|---|---|---|---|---|
| Accuracy, arcsec rms max error | | | | | |
| bit-to-bit | 3 | 3 | 5 | 21 | 4 |
| absolute | 31 | 31 | 31 | 32 | 16 |

Pulse width (one-shot options B,C,D) count tracks 2.75 ± 0.75 μsec
zero-reference pulse 4.25 ± 0.75 μsec

**Risetime and falltime:** 200 nsec max, measured from 10% to 90% levels

**Bearing fatigue life:** 6.05 x $10^8$ revolutions at maximum readout speed

**Output frequency range:** Options A and B, 0 to 50 kHz or 5000 rpm; Options C and D, 0 to 100 kHz or 5000 rpm; Option E, 0 to 250 kHz or 5000 rpm

**Electronics MTBF:** 115,055 hrs. calculated per MIL-HDBK-217D for Model 3735AZS, 3-channel encoder

**Temperature, operating:** 0 to +55°C (−55 to +70°C optionally available for options A, B, C, D)

**Temperature, storage:** −55 to +85°C

**Altitude:** to 70,000 ft (21,335 m)

**Vibration:** 30 g from 99 to 2000 Hz

**Shock:** 50 g at 11 msec

**Weight:** 32 oz. (0.9 kg) max

**Shaft load, maximum**
radial: 35 lb (15.9 kg)
axial: 40 lb (18.1 kg)

**Relative humidity:** to 98% without seal (avoid condensation)
to 100% with seal (avoid immersion)

**Torque:** at 21°C, oz-in maximum with shaft seal: 8.0, starting, 4.0, running
**Without shaft seal:** 5.0 starting, 2.5 running

**Moment of inertia:** 0.0017 oz-in-sec², maximum

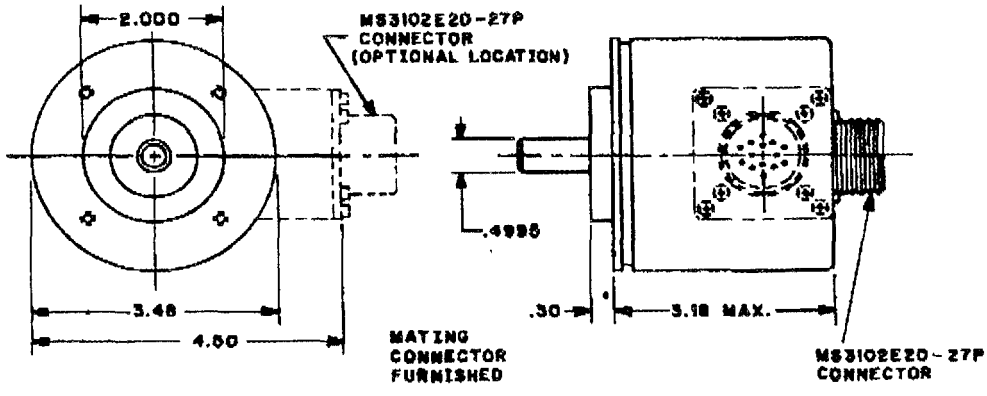
**Acceleration:** 456,000 rad/sec², maximum

**Slew speed:** 15,000 rpm, maximum

**Request Specification No. 5-014 for additional data**

## Additional items supplied with encoder:

- Mating connector (MS3106A20-27S)
- Connector cable clamp (MS3057-12A)
- Schematic diagram
- Wiring diagram
- Outline drawing
- Mechanical and electrical test reports
- Warranty statement
- Caution notice




BEI MOTION SYSTEMS COMPANY
Digital Products Division Precision Systems and Space Division
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Precision Systems & Space Division → ~~Digital Products Division~~

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Little Rock, Arkansas 72203
*Plant and Office Location*
1100 Murphy Drive
Maumelle Industrial Park
Maumelle, Arkansas 72113
(501) 851-4000 ~~[illegible]~~
FAX 501-851-5476

# Specification

5-014 C

HIGH RELIABILITY

3700 SERIES

SINGLE LED

RUGGEDIZED INCREMENTAL ENCODERS

This specification is valid for Electronic Options A, B, C & D, but not E.
The spec. was written before E options were added to the 3700 Series.
Sam Berg
11-17-93

Notice: The design and specifications of the instruments and accessories illustrated and described in this publication are subject to improvement without notice.

| REV | DESCRIPTION | DATE | | |
|---|---|---|---|---|
| | | | PREP BY | |
| | | | CHK | |
| C | INSERTED NEW PARA. 7.1.2 DELETED PARA. 7.3 | 12-19-79 | APPD | |
| B | FORMAT CHANGE ONLY | 12-12-79 | © 1979 BEI Electronics, Inc. | |

5-014 SHEET 1 OF 9 REV C

## 1.0 General

The BEI 3700-Series incremental encoders described herein belong to a field-proven, high-reliability design featuring a single LED light source. 3700-Series encoders are built around an unusually robust bearing assembly which incorporates an R-10 pair in back-to-back preload and a 1/2-inch shaft. The bearing assembly, in conjunction with light-collimating optics and push-pull detection permitting 0.012" to 0.018" disk-to-grating spacing, insures the highest level of immunity to shock, vibration, and heavy axial shaft load. A cover of better than 0.060" thickness protects the encoder PC boards and optics assembly. The cover is sealed at the flange and the connector to withstand water spray and oil mist. An optional-at-no-extra-cost shaft seal provides further protection from fluid contamination. All electronics employ complementary linedriver output IC'S which augment the inherent noise immunity of 3700-Series encoders.

1.1 See paragraph 6.0, page 6 of 8, for ordering instructions for the various resolutions and options defined herein.

## 2.0 Applications

Incremental analog-to-digital encoders are devices for measuring position and movement of a mechanical input. Rotation of the shaft of the devices described herein causes a sensing of motion and direction with an output of incremental data in the form of digital voltage levels. By algebraically accumulating these increments, movement from an origin may be determined to provide position and/or control information.

## 3.0 Requirements

### 3.1 Mechanical:

3.1.1 Encoder outline: See Figures 1 and 2, page 7 of 8.
3.1.2 Weight: 32 oz max. (0.91 kg. max.)
3.1.3 Starting torque:
a) Optional shaft seal: 8 oz-in at 21 C max. (0.057 Nm max.)
b) Standard, without seal: 5 oz-in at 21 C max. (0.035 Nm max.)
3.1.4 Running torque:
a) Optional shaft seal: 4 oz-in at 21 C max. (0.028 Nm max.)
b) Standard, without seal: 2.5 oz-in at 21 C max. (0.018 Nm max.)
3.1.5 Moment of inertia: 0.0017 oz-in-sec$^2$ max. ($12 \times 10^{-6}$ kg·m$^2$ max.)
3.1.6 Slew speed: 15,000 rpm max.
3.1.7 Acceleration: 456,000 rad/sec$^2$ max.

3.1.8 Materials:
a) Cover: Aluminum, gray.
b) Bearing flange: Aluminum.

3.1.9 Shaft runout: See Figures 1 and 2, page 7 of 8. (0.076 mm Max)

3.1.10 Design shaft load:
a) Radial: 35 lb max. (156 N max.)
b) Axial: 40 lb max. (178 N max.)

3.1.11 Resolution: To 12,700 cpt.

3.2 Electrical:

3.2.1 Power requirements:

3.2.1.1 Connector pin functions: See Table 1, page 8 of 8.

3.2.1.2 Supply voltage and current:

| Electronics Option | Single resolution +5 Vdc ± 5% | Dual resolution +5 Vdc ± 5% |
|---|---|---|
| A | 143 mA | 150 mA |
| AZ | 151 mA | 158 mA |
| B | 261 mA | 268 mA |
| BZ | 269 mA | 276 mA |
| C | 265 mA | 272 mA |
| CZ | 273 mA | 280 mA |
| D | 265 mA | 272 mA |
| DZ | 273 mA | 280 mA |

NOTE: Type DM8830 or SN75183 linedrivers are used on all electronics options. Typical line receivers are DM8820 or SN75182. Outputs may be operated in the single-ended mode.

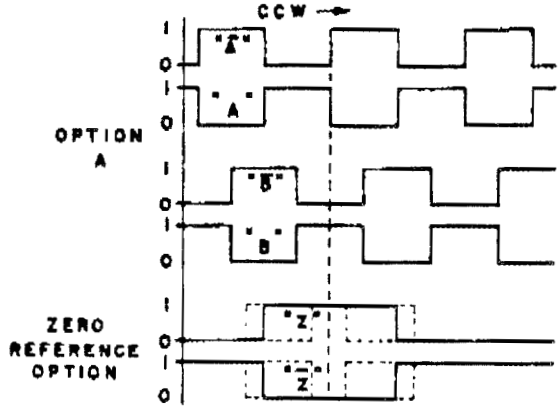
3.2.2 Code: Incremental on two count tracks phased 90 electrical degrees apart. Zero-reference track is optional.

3.2.3 Output logic levels with A or AZ electronics:

3.2.3.1 Binary "1":
a) Open-circuit voltage: +3.1 Vdc min.
b) Output impedance: 11 ohms, typical.
c) Risetime and falltime: 20 nsec max (measured from 10% to 90% level).

3.2.3.2 Binary "0":
a) Open-circuit voltage: +0.5 Vdc max.
b) Sinking current: +40 mA max

3.2.3.3 Typical waveforms, Schmitt-trigger output:




NOTE: Schmitt-trigger outputs appear simultaneously on two connector pins.

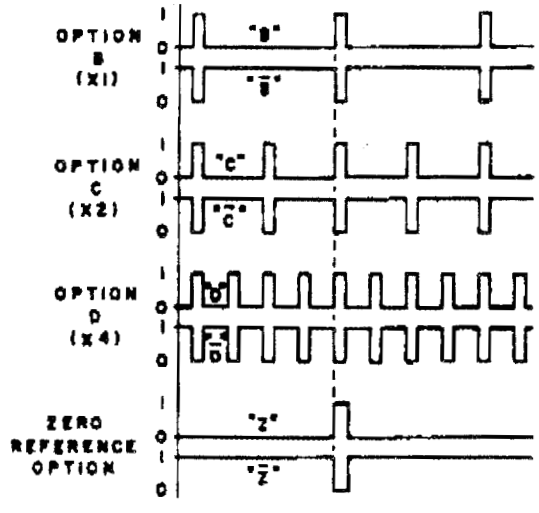
3.2.4 Output logic levels with B, BZ, C, CZ, D or DZ electronics:

3.2.4.1 Binary "1":
- a) Open-circuit voltage: +3.1 Vdc min
- b) Output impedance: 11 ohms, typical.
- c) Risetime and falltime: 20 nsec max (measured from 10% to 90% level).
- d) Pulse width (measured at the 50% level): 2.75 usec ±0.75 usec. count; 4.25 usec ±0.75 usec, zero reference.

3.2.4.2 Binary "0":
- a) Open-circuit voltage: +0.5 Vdc max
- b) Sinking current: 40 mA max.

NOTE: The zero-reference pulse occurs coincidentally with a count pulse for encoders with BZ, CZ, or DZ electronics.

3.2.4.3 Typical waveforms, pulsed output:




NOTE: Pulsed outputs appear on one of two connector pins, depending on direction of shaft rotation.

3.2.5 Mode control logic (applicable to dual resolution option):

3.2.5.1 Binary "1": +2 Vdc to +5.5 Vdc; input current is 80 uA max at +2.4 Vdc.
3.2.5.2 Binary "0": 0 Vdc to +0.8 Vdc; input current is -3.2 mA max at +0.4 Vdc.
3.2.5.3 Mode selection: Complementary inputs M and $\overline{M}$ are required. With M in the binary "1" state, the encoder will operate at the higher resolution.

3.2.6 Output characteristics of dual resolution encoders: All levels are identical to those of single resolution units.

3.2.7 Output frequency range:

3.2.7.1 Minimum: All models - 0 Hz.
3.2.7.2 Maximum:
a) Options A, AZ, B and BZ - 50 kHz or 5000 rpm, whichever occurs first.
b) Options C, CZ, D and DZ - 100 kHz or 5000 rpm, whichever occurs first.

3.2.8 Accuracy:

| Option | A or B | C | D |
|---|---|---|---|
| 3.2.8.1 Bit-to-bit (arcsec) rms, typical: | 3 | 5 | 21 |
| 3.2.8.2 Absolute (arcsec) rms, typical: | 31 | 31 | 32 |

NOTE: Accuracy figures were derived from model 3754 encoders coupled to a Moore dividing engine at 21 C.

3.3 Reliability:

3.3.1 Bearing fatigue life: 6.05 X $10^8$ revolutions at maximum readout speed.
3.3.2 Light source: Single LED.
3.3.3 Electronics MTBF: 115,055 hr, 3735AZS, calculated per MIL-HDBK-217B for three-channel encoder.

3.4 Environmental:

3.4.1 Operating temperature: 0 C to +55 C (-55 C to +70 C option available at additional cost).
3.4.2 Storage temperature: -55 C to +85 C.
3.4.3 Altitude: 70,000 ft max.
3.4.4 Vibration: 30 g's from 99 to 2000 Hz. Meets or exceeds requirements of MIL-STD-810C, Method 514.2, Procedure V, Part 1, Figure 514.2-5, Curve T. Also meets or exceeds MIL-E-5400L, MIL-E-5272C (ASG), and MIL-E-16400F.

3.4.5 Shock: 50 g's at 11 msec; meets or exceeds MIL-STD-202C, Method 202C, Condition C.

3.4.6 Humidity:
a) Without seal option: 98% rh max, avoid condensation.
b) With seal option: 100% rh, avoid immersion.

## 4.0 Quality Assurance Provisions

4.1 Inspection (100% inspection is made for the paragraphs listed below):
a) Electrical: 3.2.1, 3.2.2., 3.2.3, 3.2.4, and 3.2.7.
b) Mechanical: 3.1.3, 3.1.4, and 3.1.9.

## 5.0 Accessories and Information Supplied with Encoder

5.1 Software:

5.1.1 Schematic diagrams.
5.1.2 Mechanical and electrical test reports.
5.1.3 Wiring diagram.
5.1.4 Caution notice.
5.1.5 Warranty statement.
5.1.6 Outline drawing.

5.2 Hardware:

5.2.1 Mating connector (MS3106A20-27S).
5.2.2 Connector cable clamp (MS3057-12A).

| TITLE | NO. | REV |
|---|---|---|
| 3700-SERIES RUGGEDIZED INCREMENTAL ENCODERS | 5-014 | C |
| | PAGE 7 | |

## 6.0 Ordering Information

| 3 | 7 | | | | | |
|---|---|---|---|---|---|---|

### MODEL NUMBER AND STANDARD DISK RESOLUTION

SINGLE RESOLUTION

| Model | Counts/Turn | Model | Counts/Turn |
|---|---|---|---|
| 3700-3 | 100 | 3706 | 1905 |
| 3700-4 | 256 | 3734 | 2000 |
| 3700 | 360 | 3707 | 2032 |
| 3730 | 400 | 3708 | 2048 |
| 3731 | 500 | 3735 | 2500 |
| 3701 | 508 | 3709 | 2540 |
| 3702 | 625 | 3710 | 3175 |
| 3703 | 635 | | |
| 3704-2 | 900 | DUAL RESOLUTION | |
| 3704 | 1000 | | |
| 3704-3 | 1200 | 3750 | 400/508 |
| 3705 | 1024 | 3751 | 500/635 |
| 3732 | 1500 | 3752 | 1500/1905 |
| 3733 | 1600 | 3753 | 1600/2032 |
| 3733-1 | 1800 | 3754 | 2000/2540 |
| | | 3755 | 2500/3175 |

NOTE: Any disk resolution less than 3175 counts/turn is available with any of the standard options on special order.

### INTERNAL ELECTRONICS OPTIONS

Option
"A" Schmitt trigger waveform outputs.
"B" One-shot waveform outputs and two-line direction sensing at 1X* disk resolution.
"C" One-shot waveform outputs and two-line direction sensing at 2X disk resolution.
"D" One-shot waveform outputs and two-line direction sensing at 4X disk resolution.

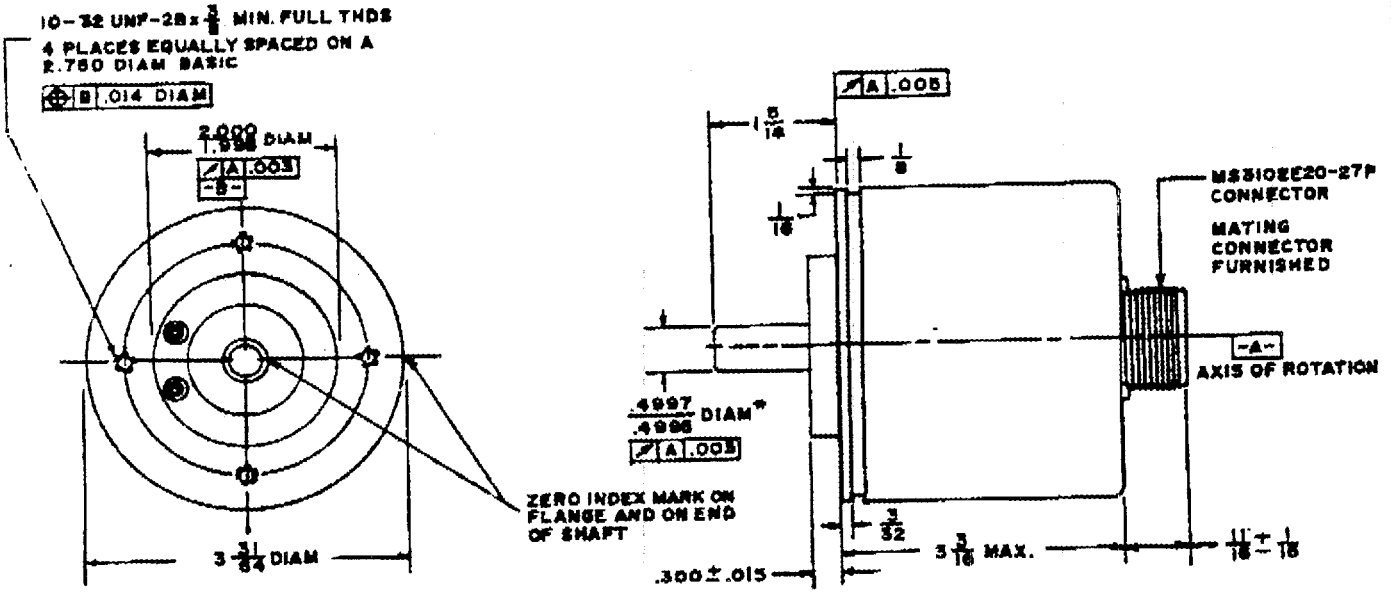
*X denotes electronic multiplication. (Example, 4X=4 times disk resolution.)

Place a "Z" here if model with zero reference is required

Place a "S" here if model with shaft seal is required.

| TITLE | NO. | REV |
|---|---|---|
| 3700-SERIES RUGGEDIZED INCREMENTAL ENCODERS | 5-014 | C |
| | PAGE 8 | |

## ENCODER OUTLINE, END-EXIT CONNECTOR

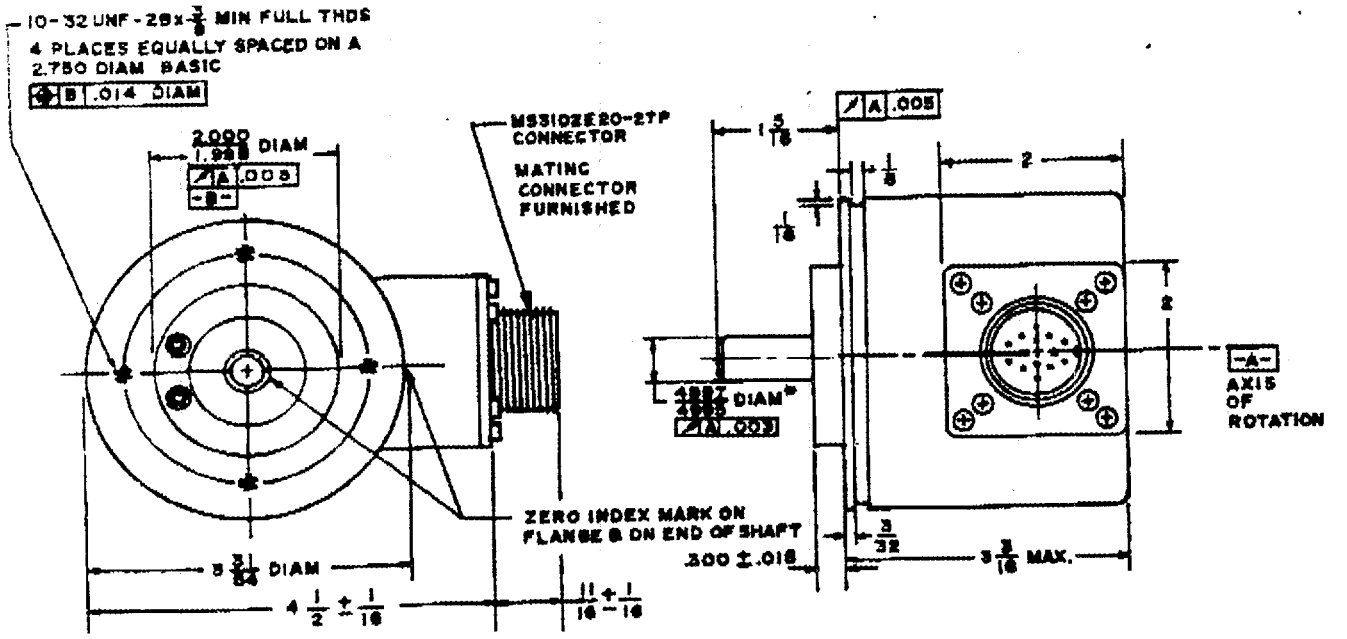



NOTE: UNLESS OTHERWISE SPECIFIED TOLERANCES ARE ± 1/32

* MEASURED 1/2 INCH FROM PILOT FACE

FIGURE 1

## ENCODER OUTLINE, SIDE-EXIT CONNECTOR (OPTIONAL AT ADDITIONAL COST)




NOTE: UNLESS OTHERWISE SPECIFIED TOLERANCES ARE ± 1/32

* MEASURED 1/2 INCH FROM PILOT FACE

FIGURE 2

| TITLE | NO. | REV |
|---|---|---|
| 3700-SERIES RUGGEDIZED INCREMENTAL ENCODERS | 5-014 | C |
| | PAGE 9 | |

## 7.0 Notes

7.1 Special options available at additional cost:

7.1.1 Side-exit connector (see Figure 2).

7.1.2 Standard side-exit-connector configuration has painted housing; It is also offered with hard-anodized finish on housing (hard anodized per MIL-A-8625,Type 3, class 1, sealed in dichromate) at additional cost.

7.1.3 Other disk resolutions.

7.1.4 Wider operating temperature range.

7.1.5 Operating frequency above 100 kHz.

7.1.6 HNL/CMOS.

7.1.7 Special shaft configuration.

7.2 Power supply: Discontinued. S. B.

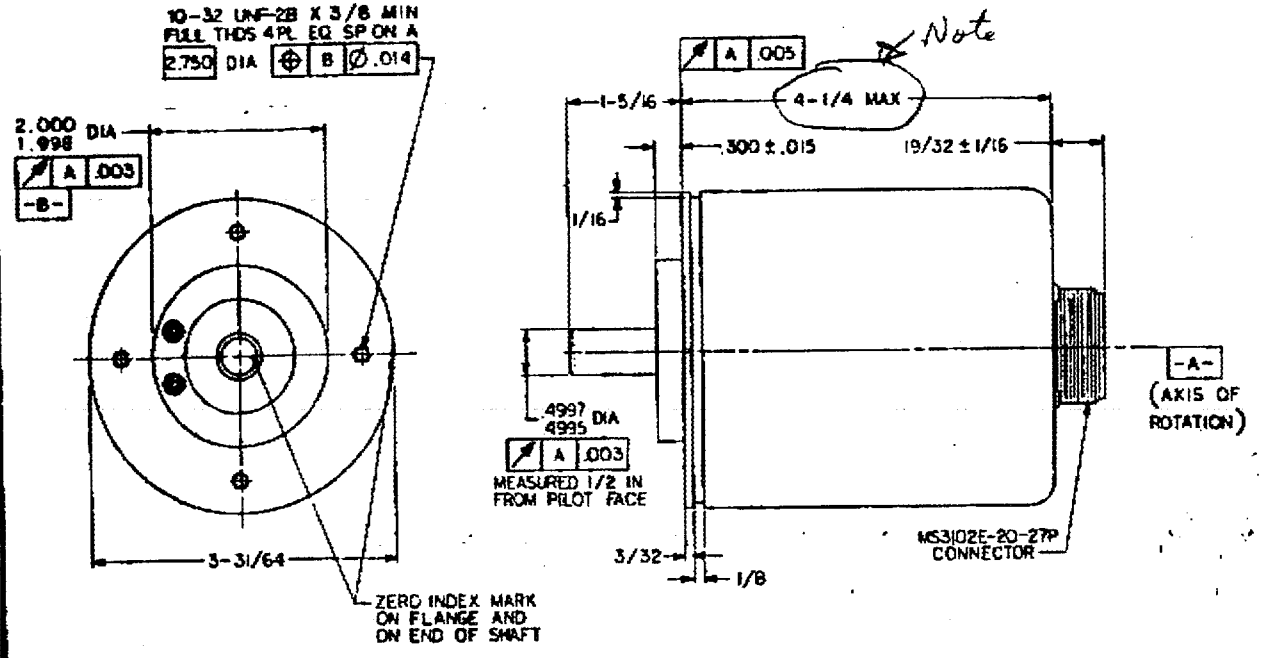
~~7.2.1 BEI Model P5V is available to supply power for any 3700-Series encoder.~~ SB

MS3102E20-27P CONNECTOR PIN FUNCTIONS

| Pin Designation | FUNCTION |
|---|---|
| A | A count-signal output |
| B | $\overline{A}$ count-signal output |
| C | C zero-reference signal output (or spare) |
| D | Ground > internally tied together |
| E | Ground |
| F | +5 Vdc input > internally tied together |
| G | +5 Vdc input |
| H | M mode input or spare |
| I | $\overline{B}$ count-signal output |
| J | B count-signal output |
| K | Shield ground |
| L | $\overline{C}$ zero-reference signal output (or spare) |
| M | Case ground |
| N | $\overline{M}$ mode input or spare |

TABLE 1

| REVISIONS | | | | | |
|---|---|---|---|---|---|
| SYM | ZONE | LTR | DESCRIPTION | DATE | APPROVED |




Outline for 3700-Series Encoders
with E5 or E8
electronics option
Sam Berg
11-17-93

NOTICE: FOLLOWING ECO'S FORM A PART OF THIS DRAWING

BEI Electronics, Inc.
MEDICAL PRODUCTS DIVISION LITTLE ROCK, AR

ENCODER OUTLINE

| SIZE | FSCM NO. | | REV |
|---|---|---|---|
| C | 12050 | 905-18232 | |
| SCALE 1:1 | WT. | SHEET 1 OF 1 | |

# Fiber Optics Group
# Computer Optical Products, Inc.

Fiber Optic & Electro Optic Encoders
for
Military, Aircraft, and Industrial Applications

## Rotary and Linear Position Sensors
Product Selection Guide

**FIBER OPTICS GROUP**
Computer Optical Products, Inc.
*"MOTION CONTROL WITH FIBERS"*

*Subsidiary of Hathaway Corp.*

9305 Eton Avenue, Chatsworth, CA 91311

Telephone: (818) 882-0424 Fax: (818) 882-0492

FIBER OPTIC POSITION SENSORS

TECHNICAL SUMMARY

The *Fiber Optics Group* of Computer Optical Products, Inc. manufactures a variety of standard fiber optic encoders. The technology employed in these new products offers high performance rotary and linear position sensing at prices competitive with resolvers, LVDT's, and electrical encoders.

Combining proprietary optical encoder technology and rugged multi-fiber bundles, the *Fiber Optics Group* offers a line of position sensors with unsurpassed performance characteristics including:

- Low cost
- Small size
- Serviceability
- EMI/RFI Proof
- Inherent Redundancy
- Design & System Flexibility
- High temperature operation - 450°C (850°F)
- Increased reliability (passive readhead design)
- Intrinsically Safe for Explosion Proof Equip.

The result is a rugged, EMI immune, position sensor ideal for applications such as commutating motors in PWM and vector drive systems. This technology can be combined with wavelength-division multiplexing (WDM) for multi-sensor applications.

How it works: Multi-fiber optical bundles relocate the sensitive opto-electronics to a place where it can be protected from harsh environments (can be mounted in NEMA enclosures or even in a connector backshell). The multi-fiber construction increases reliability due to it's inherent redundancy. In addition, the electronics assembly becomes less costly to manufacture and package.

Special configurations include the **Fiber Optic Position Modulator** designed to work with standard (100/140) telecommunication grade fiber over long distances (300 ft). The **FDMS** series is a multi-axis system ideal for applications requiring more than one position sensor. This offers cost savings over individual encoding devices by using common electronics with multiple readheads. Another configuration is the **FD100** for operation in confined, high temperature areas. For remote applications, position information can be linked to programmable controllers via 4-20 mA loop, RS-422 or 232, or fiber optic data links.

**COMPUTER OPTICAL PRODUCTS, INC.**
*Subsidiary of Hathaway Corp.*
**Fiber Optics Group**
*"MOTION CONTROL WITH FIBER OPTICS"*
9305 Eton Avenue, Chatsworth, California 91
(818) 882-0424 • FAX: (818) 882-0492

# FD22I-R1 Series

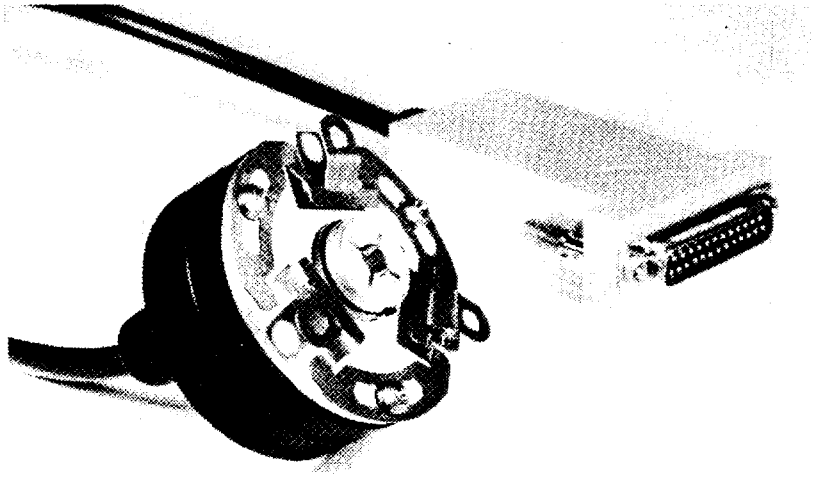
## Fiber Optic ROTARY INCREMENTAL ENCODER

### Description

The FD22I-R1 Series is a size 22, **Fiber Optic Incremental Encoder**. Designed for applications requiring high temperature speed and positioning sensing in EMI/RFI sensitive environments. This model features our standard fiber optic connector for use in single or multi-axis systems (see Model FDMS). This model comes with 6 inches of fiber optic cable which is easily extended using our inexpensive bundled fiber cables. For long haul applications, the cable can be extended using our standard bundle-to-single fiber adapters. Operation is rated from -40°C to +125°C.

### Features

- Fiber Optic Construction
- Standard Fiber Optic Connectors
- Electrical Outputs
- Heavy Duty
- Resolutions to 2000 Cycles
- 125°C Operating Temperature



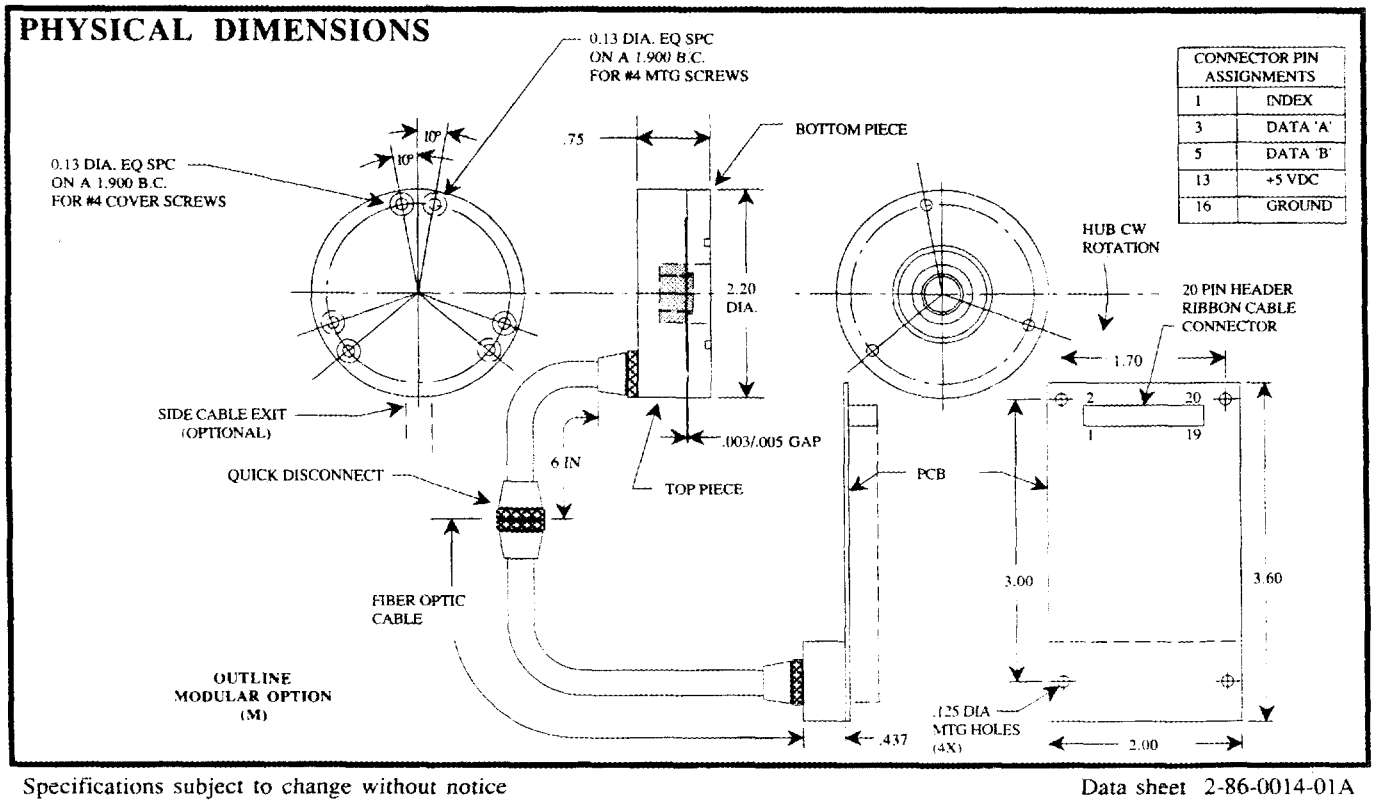
### Applications

- Machine Tools
- Digital Servo Systems
- Coordinate Measurement
- Radar Antennas
- Ground Support Systems
- Automatic Weight Logging

### Options

- Heavy Duty Fiber Optic Cable
- Hollow Shaft
- Cable Extensions
- High Temp.(up to 300°C)
- Multi-axis Electronics
- Long Distance Interface
- Analog/Digital Outputs
- Fiber Optic Data Link

### PHYSICAL DIMENSIONS



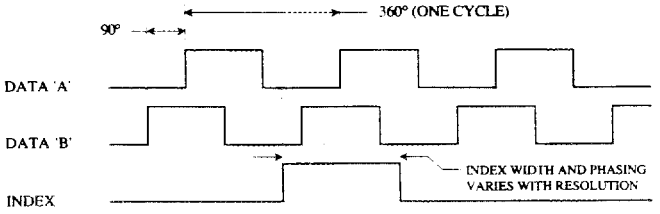

| CONNECTOR PIN ASSIGNMENTS | |
|---|---|
| 1 | INDEX |
| 3 | DATA 'A' |
| 5 | DATA 'B' |
| 13 | +5 VDC |
| 16 | GROUND |

## MECHANICAL SPECIFICATIONS

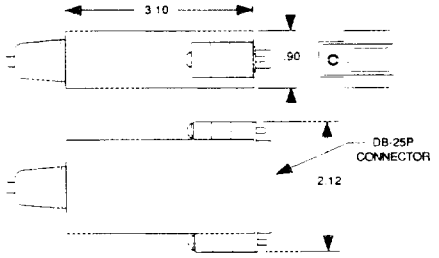
| | FD22I--M | FD22I--H T | FD22I--S |
|---|---|---|---|
| resolution | 1 to 1600 cycles | 1 to 2000 cycles | |
| output | A&B (std.)<br>A&B, Index (opt.) | | |
| format options | Open collector (std.)<br>Line driver (opt.) | | |
| operating freq. | 50kHz (std.)<br>100kHz (opt.) | | |
| operating temp. sensor | -40 to 125°C (std.)<br>200°C (opt.) | | |
| operating temp. electronics | -10 to +70°C (std.)<br>-55 to +85°C (opt.) | | |
| mounting options | 2.2 inch dia. (std) | 2.2 inch dia (std.)<br>2.5 inch flange (opt.)<br>2.5 inch servo (opt.) | |
| shaft/hub size | .375" max hub inside dia. | .250, .375 & .500 dia. | .375" max inside dia. |
| starting torque | N/A | 1.0 in-oz max.<br>2.5 in-oz max with shaft seal | |
| shaft loading | N/A | 10 lbs. axial and radial | |
| weight | 5 oz max. | 9 oz max. | |
| cable options | Up to 50ft PVC jacket (std)<br>Interlocking metal (opt) | | |
| shock/vibration | 50 G's for 11 msec duration<br>5 to 2000 Hz @ 20 G's | | |

## ELECTRICAL SPECIFICATIONS

| | OPEN COLLECTOR (DB-25P) | LINE DRIVER (DB-25P) | OPEN COLLECTOR (PCB) |
|---|---|---|---|
| input power | 5V dc ± 5%<br>100 mA max. | 5V dc ± 5%<br>140 mA max. | 5V dc ± 5%<br>100 mA max. |
| output circuitry | TTL/CMOS compatible w/ 2K pull-ups | MC3487 or equivilent RS-422 compatible | TTL/CMOS compatible w/ 4.7K pull-ups |
| output connector | DB-25P | | 20 pin header |
| light source | GaAlAs LED | | |
| illumination life | 100,000 hrs | | |




SHAFT OR HUB CW ROTATION




| DB-25 PIN ASSIGNMENTS | | | |
|---|---|---|---|
| 2 | 5V out | 20 | DATA 'A' |
| 4 | 5V in | 21 | DATA 'B' |
| 6 | Case Ground | 22 | DATA 'B' |
| 7 | Ground | 23 | DATA 'Z' |
| 16 | V in (12V) | 24 | DATA 'A' |
| | | 25 | DATA 'Z' |

DB-25P OPTION (E2) OR (P2)

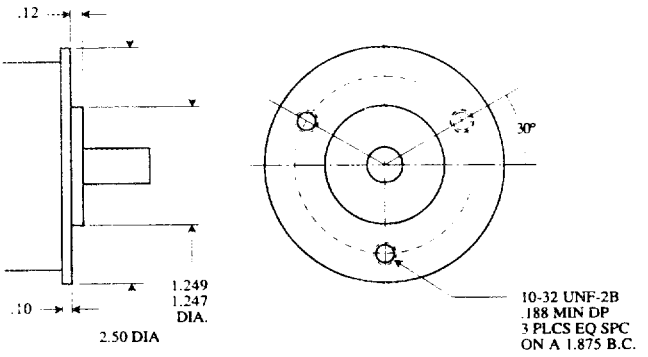
## ORDERING INFORMATION

FD22I [Output Format] [Style] – [Resolution] [Mounting] [Electro Optics] – [Shaft/Hub Diameter] [Shaft Seal] – [Cable Length] [Cable Type] – [Voltage] R1

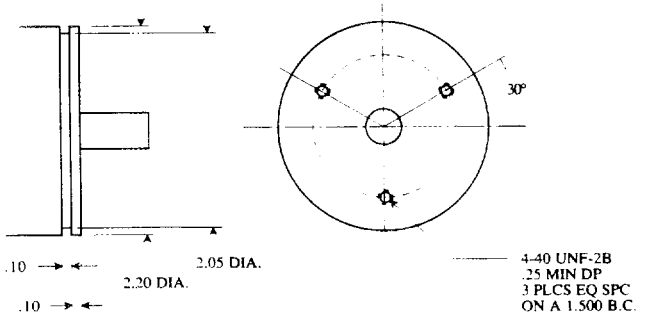
- Output Format / Style: BI = A & B channels; BZ = A, B, & Index
- Mounting: M = Modular; H = Housed; T = Thru Shaft; S = Hollow Shaft
- Resolution: Resolution in number of cycles per revolution*
- Mounting: blank = Modular or no adapter; R = 2.2 inch Round; F = 2.5 inch Flange; S = 2.5 inch Servo
- Electro Optics: E1 = Open Collector (PCB); E2 = Open Collector (DB-25P); P1 = Line Driver (PCB); P2 = Line Driver (DB-25P)
- Shaft/Hub Diameter: Hub Dia .250 & .375 inch & 8 mm (M); Shaft Dia of .250 or .375 (H or T); Hollow Shaft I.D. .250 & .375 inch (S)
- Shaft Seal: blank = no shaft seal; Y = Shaft Seal
- Cable Length: Cable length in feet
- Cable Type: blank = PVC Monocoil; A = Interlocking Metal; B = High Temperature
- Voltage: 5 = +5 Vdc; 12 = +8 to 16 Vdc

* Number of counts/turn is equal to the number of cycles/turn times the number of edges/cycle. With A & B in phase quadrature there are 4 edges/cycle.

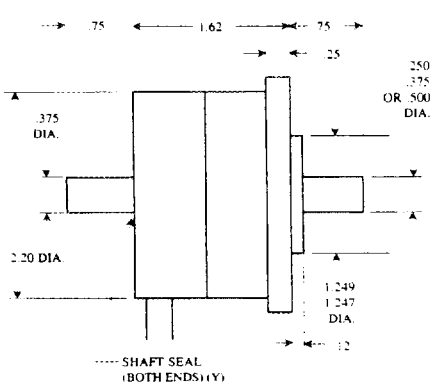
| | HUB I.D. +.0003 -.0000 | SHAFT O.D. +.0000 -.0003 |
|---|---|---|
| 250 | .2498 | .2497 |
| 312 | .3123 | .3122 |
| 375 | .3748 | .3747 |
| 500 | .4998 | .4997 |



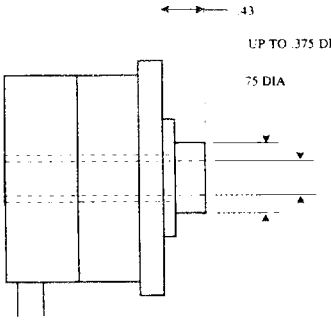

2.5" SERVO OPTION (S)



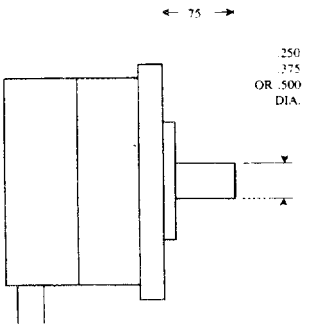

2.2" ROUND OPTION (R)



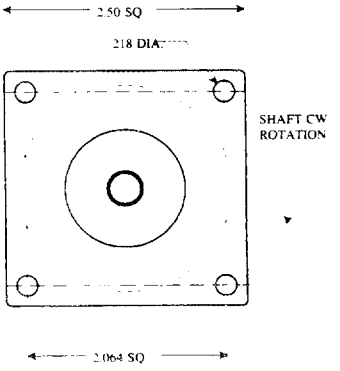

OUTLINE
THRU SHAFT OPTION
(T)




OUTLINE
THRU SHAFT OPTION
(T)




OUTLINE
HOLLOW SHAFT OPTION
(S)




2.5" FLANGE OPTION
(F)

COMPUTER OPTICAL PRODUCTS, INC.
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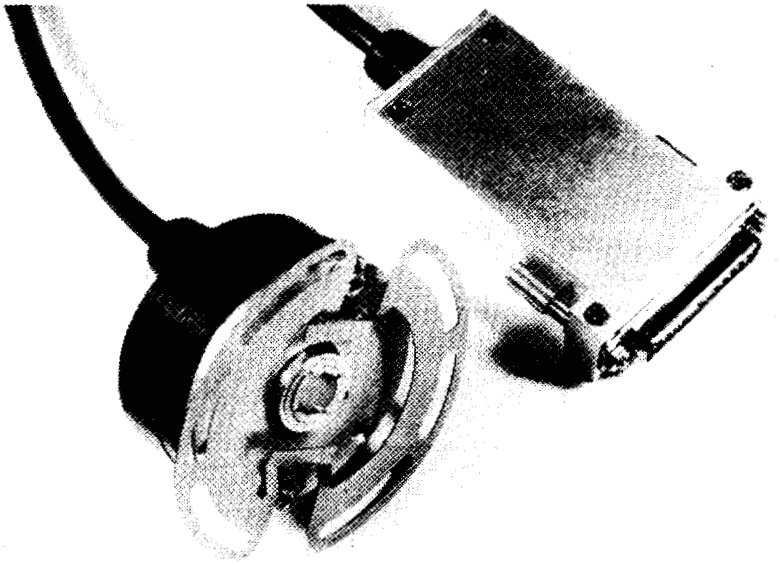
# FD22A-R1 Series

## Fiber Optic ROTARY ABSOLUTE ENCODER

### Description

The FD22A-R1 Series is a size 22, 12 bit, **Fiber Optic Absolute Encoder**. Designed for applications requiring high temperature speed and positioning sensing in EMI/RFI sensitive environments. This model features our standard fiber optic connector for use in single or multi-axis systems (see our Model FDMS). Operation is rated from -40°C to +125°C. Unit comes with up to 20 feet of fiber optic cable and complete electronics.



### Features

- Fiber Optic Construction
- Electrical Outputs
- Heavy Duty
- Resolutions to 4096 Counts
- 125°C Operating Temperature

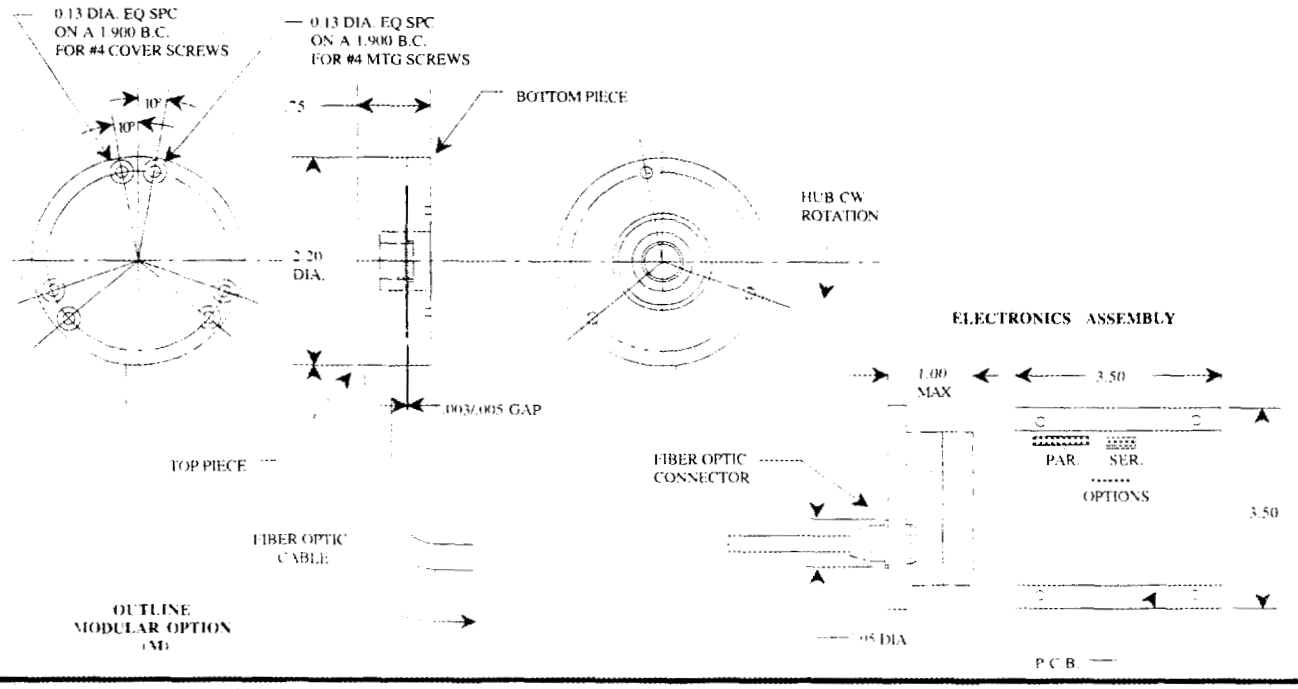
### Applications

- Machine Tools
- Digital Servo Systems
- Coordinate Measurement
- Labratory Equipment
- Ground Support Systems
- Automatic Weight Logging

### Options

- Heavy Duty F.O. Cable
- Hollow Shaft
- Thru Shaft
- High Temp.(up to 300°C)
- Multi-axis Electronics
- Fiber Optic Data Link
- Non-conductive F.O. Cable construction

### PHYSICAL DIMENSIONS



## MECHANICAL SPECIFICATIONS

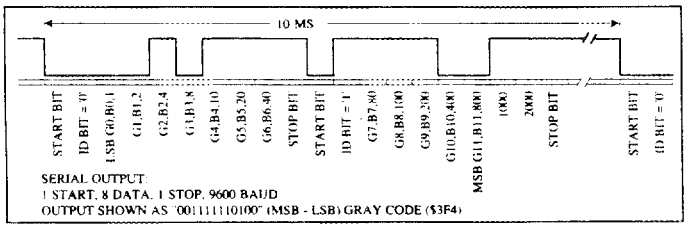
| | FD22A--M | FD22A--H T | FD22A--S |
|---|---|---|---|
| resolution | up to 10 bits | up to 12 bits | |
| output | gray code (std.)<br>natural binary & BCD (opt.) | | |
| output circuitry | parallel TTL (std.)<br>serial RS-422 (opt.)<br>fiber optic data link (opt.) | | |
| data update | 10 msec | | |
| operating temp. sensor | 125°C (std)<br>200°C (opt.) | | |
| operating temp. electronics | -10 to +70°C (std.)<br>-55 to +85°C (opt.) | | |
| mounting options | 2.2 inch dia. | 2.2 inch dia (std.)<br>2.5 inch flange (opt.)<br>2.5 inch servo (opt.) | |
| shaft/hub size | .375" max hub inside dia. | .250, .375 & .500 dia. | .375" max inside dia. |
| starting torque | N/A | 1.0 in-oz max.<br>2.5 in-oz max with shaft seal | |
| shaft loading | N/A | 10 lbs. axial and radial | |
| weight | 5 oz max. | 9 oz max. | |
| cable options | up to 20ft PVC monocoil (std)<br>Interlocking metal (opt) | | |
| shock/vibration | 50 G's for 11 msec duration<br>5 to 2000 Hz @ 20 G's | | |

## ELECTRICAL SPECIFICATIONS

| | PARALLEL OUTPUT | SERIAL OUTPUT | FIBER OPTIC LINK |
|---|---|---|---|
| input power | 5V dc ± 5%<br>75 mA max. | 5V dc ± 5%<br>110 mA max. | 5V dc ± 5%<br>85 mA max. |
| output circuitry | TTL/CMOS compatible<br>(74HCT04) | 26LS31 or equivilent<br>RS-422 compatible | 100/140 fiber |
| light source | GaAlAs LED | | |

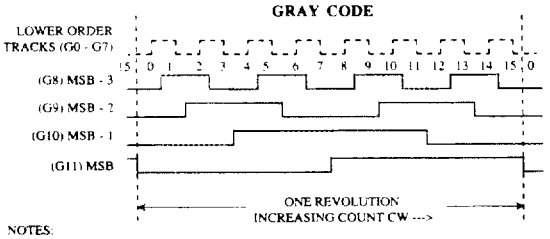
| PARALLEL CONNECTOR | | | | | | SER CONN | | OPTIONS CONN | |
|---|---|---|---|---|---|---|---|---|---|
| G0,B0,1 | - 19 | G7,B7,80 | - 7 | INU OUT | - 4 | SER OUT | - 1 | CALIB.* | - 4 |
| G1,B1,2 | - 20 | G8,B8,100 | - 10 | CALIB.* | - 12 | SER OUT' | - 2 | DIR. | - 7 |
| G2,B2,4 | - 17 | G9,B9,200 | - 6 | POWER | - 1 | POWER | - 5 | | |
| G3,B3,8 | - 18 | STROBE** | - 8 | GROUND | - 11 | GROUND | - 3 | | |
| G4,B4,10 | - 15 | SER OUT | - 5 | GROUND | - 13 | GROUND | - 4 | | |
| G5,B5,20 | - 16 | SER OUT' | - 3 | GROUND | - 14 | | | | |
| G6,B6,40 | - 9 | INU IN | - 2 | | | | | | |

* See installation instructions ** Data valid on rising edge of Strobe. Data not valid when Strobe is low (1ms pulse).




SERIAL OUTPUT:
1 START, 8 DATA, 1 STOP, 9600 BAUD
OUTPUT SHOWN AS "001111110100" (MSB - LSB) GRAY CODE ($3F4)

## GRAY CODE




NOTES:
1. MSB AND MSD - 1 ARE SAME RESOLUTION.
2. EACH ADDED LOWER ORDER TRACK IS TWICE THE RESOLUTION OF THE PREVIOUS TRACK.
3. GRAY CODE IS NON-AMBIGUOUS (ONLY ONE TRACK CHANGES PER COUNT CHANGE).
4. BY INVERTING THE MSD TRACK, INCREASING COUNT DIRECTION CAN BE CHANGED.

## ORDERING INFORMATION

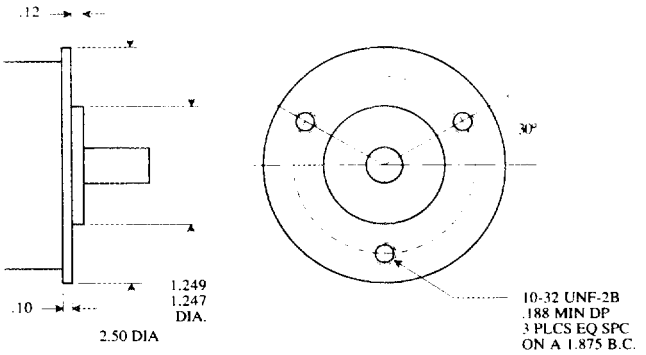
**FD22A** [Output Format | Style] – [Resolution | Mounting] – [Shaft/Hub Diameter | Shaft Seal] – [Cable Length | Cable Type] – [Voltage] **R1**

- Output Format: GC = Gray Code; NB = Natural Binary; BD = BCD
- Style: M = Modular; H = Housed; T = Thru Shaft; S = Hollow Shaft
- Resolution: Resolution in number of bits (number of counts for BD option)
- Mounting: blank = Modular or no adapter; R = 2.2 inch Round; F = 2.5 inch Flange; S = 2.5 inch Servo
- Shaft/Hub Diameter: Hub Dia .250 & .375 inch & 8 mm (M); Shaft Dia of .250 or .375 (H or T); Hollow Shaft I.D. .250 & .375 inch (S)
- Shaft Seal: blank = no shaft seal; Y = Shaft Seal
- Cable Length: Cable length in feet
- Cable Type: blank = PVC Monocoil; A = Interlocking Metal; B = High Temperature
- Voltage: 5 = +5 Vdc

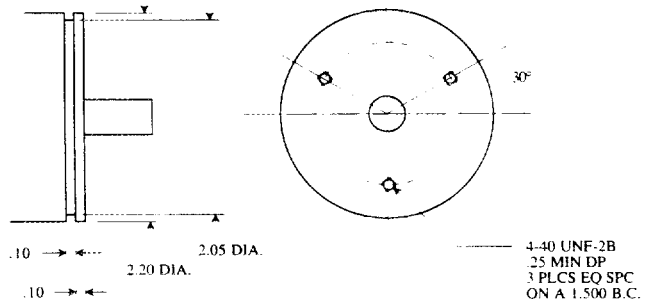
| | HUB I.D. +.0003 -.0000 | SHAFT O.D. +.0000 -.0003 |
|---|---|---|
| .250 | .2498 | .2497 |
| .312 | .3123 | .3122 |
| .375 | .3748 | .3747 |
| .500 | .4998 | .4997 |

## MODULAR INSTALLATION INSTRUCTIONS

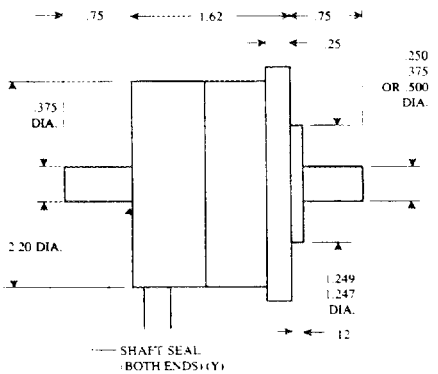
1. MOUNT BOTTOM PIECE USING SUPPLIED #4 HARDWARE (3X).
2. WITHOUT FULLY TIGHTENING MOUNTING HARDWARE, INSTALL CODE DISK UPSIDE DOWN. HUB WILL CENTER BOTTOM PIECE ABOUT AXIS OF ROTATION.
3. TIGHTEN MOUNTING HARDWARE AND RE-INSTALL CODE DISK RIGHT-SIDE UP AND GAP IT.
4. INSTALL TOP PIECE WITH REMAINING HARDWARE.
5. WITH FIBER OPTIC CONNECTOR IN PLACE AND ELECTRONICS POWERED UP, GROUND THE CALIBRATION PIN AND ROTATE THE SHAFT ONE REVOLUTION. REMOVE GROUND FROM THE CALIBRATION PIN. UNIT IS READY.



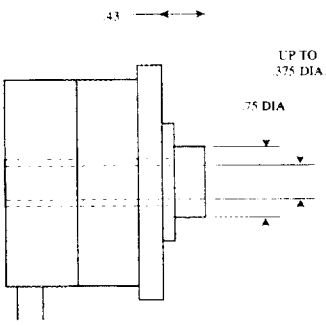

2.5" SERVO OPTION (S)



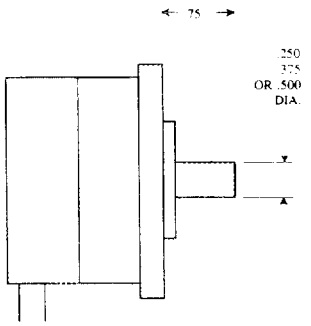

2.2" ROUND OPTION (R)



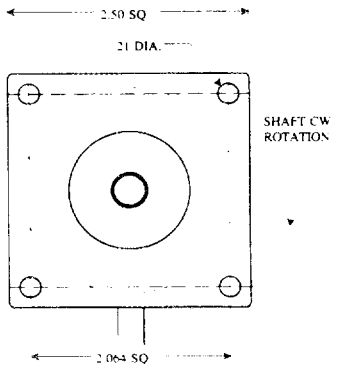

OUTLINE
THRU SHAFT OPTION
(T)




OUTLINE
HOLLOW SHAFT OPTION
(S)




OUTLINE
HOUSED OPTION
(H)




2.5" FLANGE OPTION
(F)

Specifications subject to change without notice

2-86-0015-02A

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# FD22MT-R1 Series

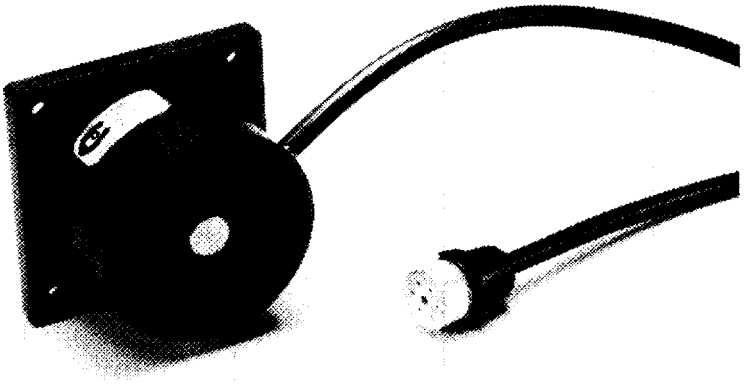
## Fiber Optic MULTI-TURN ABSOLUTE ENCODER

### Description

The FD22MT-R1 Series is a size 22, 12 bit, **Fiber Optic Absolute Encoder** with **Multi-Turn** capability built into the electronics. A rechargable, sealed lead acid battery makes this unit immune to power interuptions for up to five days, without loss of position information even when movement occurs. Designed for applications requiring positioning sensing in EMI/RFI sensitive or high temperature environments. Operation is rated from -40°C to +125°C. Unit comes with up to 20 feet of fiber optic cable and complete electronics.

### Features

- Intrinsically Safe Construction
- Electrical Outputs
- Heavy Duty
- Resolutions to 4096 Counts per/turn
- Infinite Turns Capability



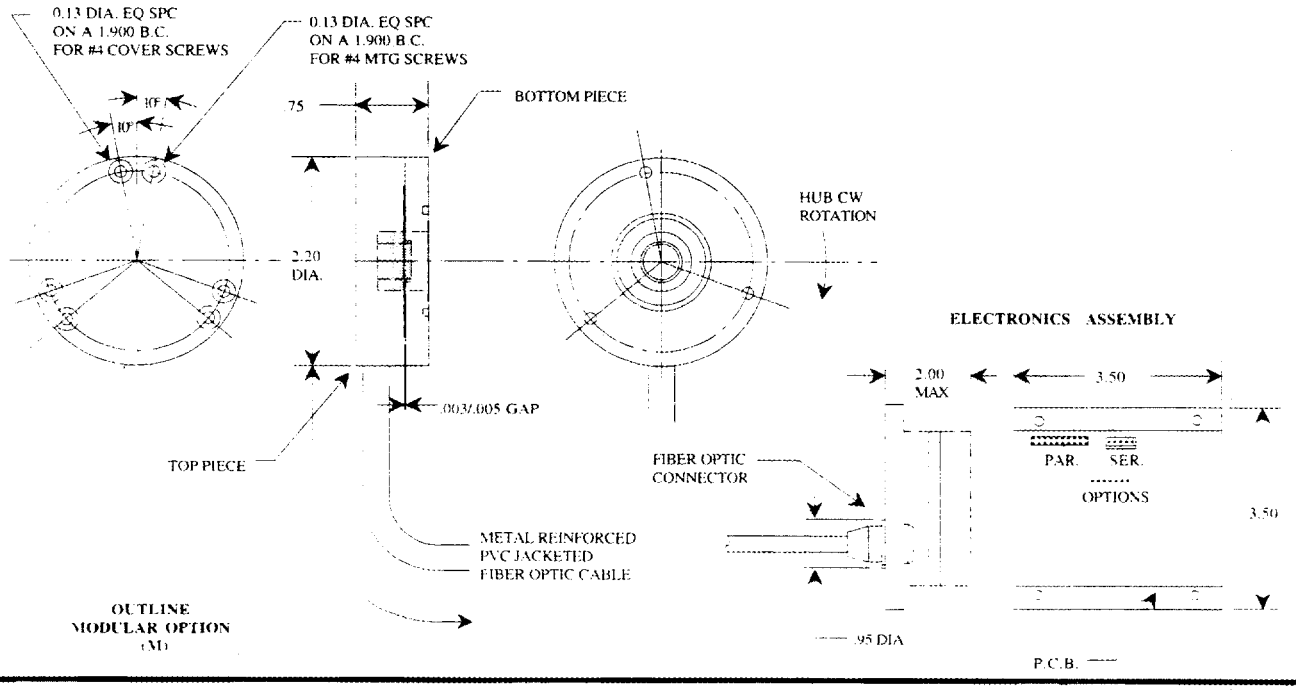
### Applications

- Machine Tools
- Hoists
- Coordinate Measurement
- Robitics
- Conveyors
- Elevators

### Options

- Heavy Duty F.O. Cable •Hollow Shaft •Thru Shaft •High Temp. (up to 200°C)
- Multi-axis Electronics •Fiber Optic Data Link •Non-conductive F.O. Cable construction

### PHYSICAL DIMENSIONS



## MECHANICAL SPECIFICATIONS

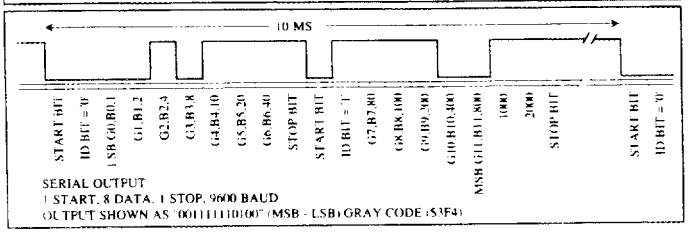
| | FD22MT--M | FD22MT--H, T | FD22MT--S |
|---|---|---|---|
| resolution | up to 10 bits | up to 12 bits | |
| output | gray code (standard)<br>natural binary & BCD (opt.) | | |
| output circuitry | parallel TTL (std.)<br>serial RS-422 (opt.)<br>fiber optic data link (opt.) | | |
| data update | 10 msec | | |
| operating temp. sensor | 125°C (std)<br>200°C (opt) | | |
| operating temp. electronics | -10 to +70°C (std)<br>-55 to +85°C (opt) | | |
| mounting options | 2.2 inch dia. | 2.2 inch dia (std)<br>2.5 inch flange (opt)<br>2.5 inch servo (opt) | |
| shaft/hub size | .375" max hub inside dia. | .250, .375 & .500 dia. | .375" max inside dia. |
| starting torque | N/A | 1.0 in-oz max.<br>2.5 in-oz max with shaft seal | |
| shaft loading | N/A | 10 lbs. axial and radial | |
| weight | 5 oz max. | 9 oz max. | |
| cable options | up to 20ft PVC monocoil (std)<br>Interlocking metal (opt) | | |
| shock/vibration | 50 G's for 11 msec duration<br>5 to 2000 Hz @ 20 G's | | |

## ELECTRICAL SPECIFICATIONS

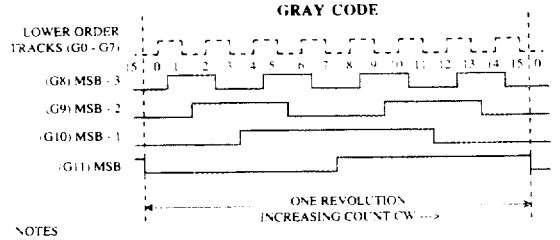
| | PARALLEL OUTPUT | SERIAL OUTPUT | FIBER OPTIC LINK |
|---|---|---|---|
| input power | 5V dc ± 5%<br>75 mA max. | 5V dc ± 5%<br>110 mA max. | 5V dc ± 5%<br>85 mA max. |
| output circuitry | TTL/CMOS compatible<br>(74HCT04) | 26LS31 or equivilent<br>RS-422 compatible | 100/140 fiber |
| light source | GaAlAs LED | | |

| PARALLEL CONNECTOR | | | | | | SER CONN | | OPTIONS CONN | |
|---|---|---|---|---|---|---|---|---|---|
| G0,B0,1 | 19 | G7,B7,80 | 7 | INU OUT | 4 | SER OUT | 1 | CALIB.* | 4 |
| G1,B1,2 | 20 | G8,B8,100 | 10 | CALIB.* | 12 | SER OUT | 2 | DIR. | 7 |
| G2,B2,4 | 17 | G9,B9,200 | 6 | POWER | 1 | POWER | 5 | | |
| G3,B3,8 | 18 | STROBE** | 8 | GROUND | 11 | GROUND | 3 | | |
| G4,B4,10 | 15 | SER OUT | 5 | GROUND | 13 | GROUND | 4 | | |
| G5,B5,20 | 16 | SER OUT | 3 | GROUND | 14 | | | | |
| G6,B6,40 | 9 | INU IN | 2 | | | | | | |

* See installation instructions. ** Data valid on rising edge of Strobe. Data not valid when Strobe is low (1ms pulse).




## GRAY CODE




NOTES
1. MSB AND MSD - 1 ARE SAME RESOLUTION.
2. EACH ADDED LOWER ORDER TRACK IS TWICE THE RESOLUTION OF THE PREVIOUS TRACK.
3. GRAY CODE IS NON-AMBIGUOUS (ONLY ONE TRACK CHANGES PER COUNT CHANGE).
4. BY INVERTING THE MSD TRACK, INCREASING COUNT DIRECTION CAN BE CHANGED.

## ORDERING INFORMATION

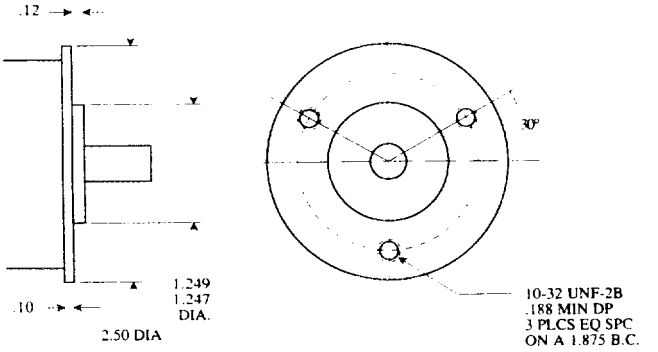
FD22MT [Output Format | Scale] – [Resolution | Mounting] – [Shaft/Hub Diameter | Shaft Seal] – [Cable Length | Cable Type] – [Voltage] R1

- Output Format: GC = Gray Code; NB = Natural Binary; BD = BCD
- Mounting: M = Modular; H = Housed; T = Thru Shaft; S = Hollow Shaft
- Resolution: Resolution in number of bits, or counts for BCD, per turn
- Mounting: blank = Modular or no adapter; R = 2.2 inch Round; F = 2.5 inch Flange; S = 2.5 inch Servo
- Shaft/Hub Diameter: Hub Dia .250 & .375 inch & 8 mm (M); Shaft Dia of .250 or .375 (H or T); Hollow Shaft I.D. .250 & .375 inch (S)
- Shaft Seal: blank = no shaft seal; Y = Shaft Seal
- Cable Length: Cable length in feet
- Cable Type: blank = PVC Monocoil; A = Interlocking Metal; B = High Temperature
- Voltage: 5 = +5 Vdc

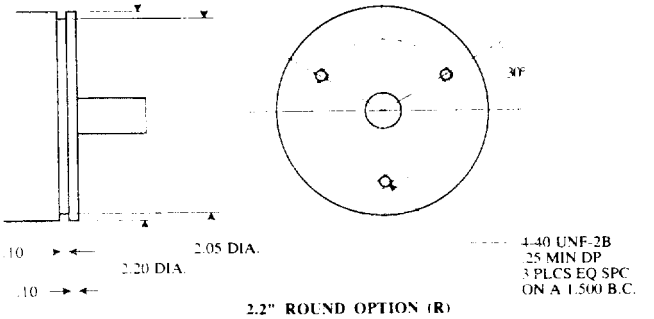
| | HUB I.D. +.0003 -.0000 | SHAFT O.D. +.0000 -.0003 |
|---|---|---|
| 250 | .2498 | .2497 |
| 312 | .3123 | .3122 |
| 375 | .3748 | .3747 |
| 500 | .4998 | .4997 |

## MODULAR INSTALLATION INSTRUCTIONS

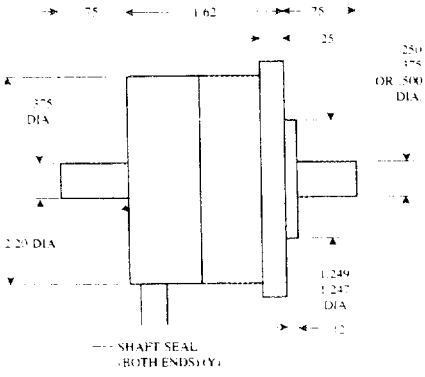
1. MOUNT BOTTOM PIECE USING SUPPLIED #4 HARDWARE (3X).
2. WITHOUT FULLY TIGHTENING MOUNTING HARDWARE, INSTALL CODE DISK UPSIDE DOWN. HUB WILL CENTER BOTTOM PIECE ABOUT AXIS OF ROTATION.
3. TIGHTEN MOUNTING HARDWARE AND RE-INSTALL CODE DISK RIGHT-SIDE UP AND GAP IT.
4. INSTALL TOP PIECE WITH REMAINING HARDWARE.
5. WITH FIBER OPTIC CONNECTOR IN PLACE AND ELECTRONICS POWERED UP, GROUND THE CALIBRATION PIN AND ROTATE THE SHAFT ONE REVOLUTION. REMOVE GROUND FROM THE CALIBRATION PIN. UNIT IS READY.



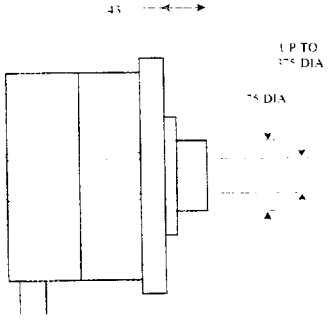

2.5" SERVO OPTION (S)



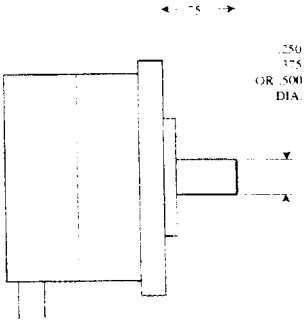

2.2" ROUND OPTION (R)



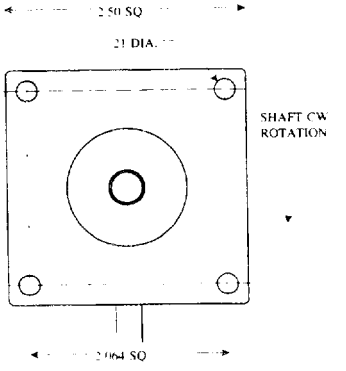

OUTLINE
THRU SHAFT OPTION
(T)




OUTLINE
HOLLOW SHAFT OPTION
(S)




OUTLINE
HOUSED OPTION
(H)




2.5" FLANGE OPTION
(F)

Specifications subject to change without notice

2-86-0020-02

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# FD11A Series
## Fiber Optic ROTARY HOUSED ABSOLUTE ENCODER

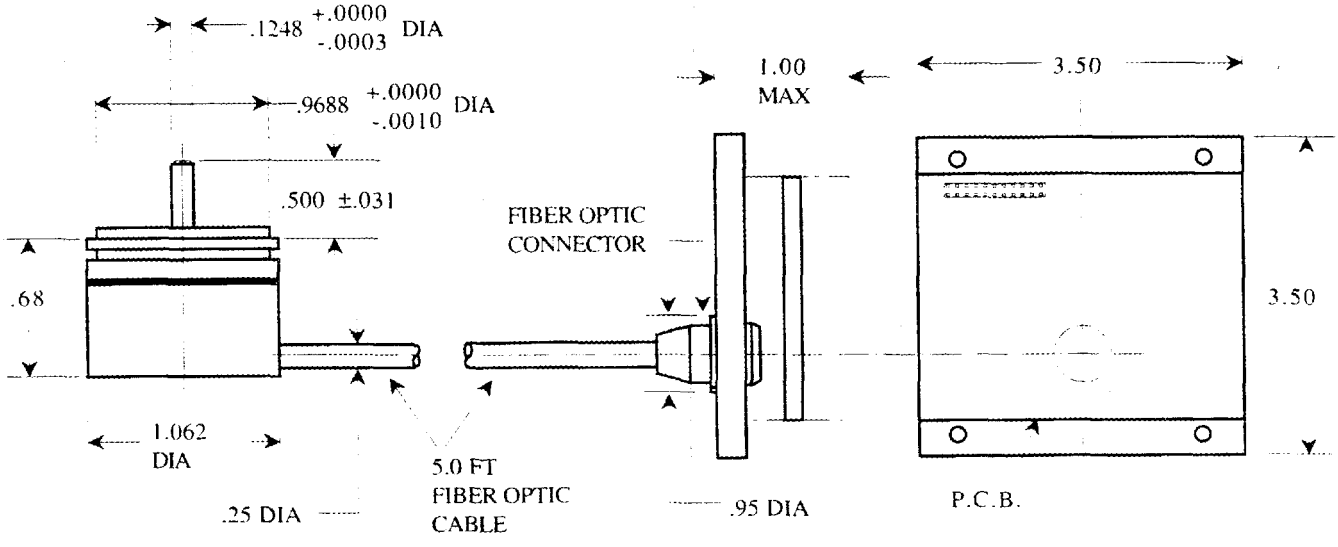
### Description
The FD11A Series is a size 11, 10 bit **Fiber Optic Absolute Encoder**. Designed for applications requiring small size and absolute position sensing. Operation is rated at 125°C making it ideal for elevated temperature and high EMI/RFI environments. Data output is available as gray, natural binary, or BCD code and either in parallel or serial format.

### Features
- Fiber Optic Construction
- High Resolution
- Small Size
- Light Weight
- EMI/RFI Immunity
- No possibility of Spark Ignition

### Applications
- Engine Control
- Cockpit Instrumentation
- Actuators
- Resolver or RVDT retrofit
- Medical

### Options
- Serial Output
- Special Shaft Configurations
- Custom Cable Lengths
- Temperature to 300°C
- Line Driver Output

### PHYSICAL DIMENSIONS




SENSING ELEMENT (NOT TO SCALE) ELECTRONICS ASSEMBLY

## MECHANICAL SPECIFICATIONS

| | *FD11A--R1* |
|---|---|
| resolution | up to 10 bits |
| output | gray code (std.)<br>natural binary & BCD (opt.) |
| output circuitry | parallel TTL (std.)<br>serial RS-422 (opt.)<br>fiber optic data link (opt.) |
| data update | 10 msec |
| operating temp. sensor | 125°C (std) 200°C (opt.) |
| operating temp. electronics | -10 to +70°C (std.)<br>-55 to +85°C (opt.) |
| starting torque | 0.3 in-oz max. |
| shaft loading | 3 lbs. axial and radial |
| weight | 5 oz max. |
| cable options | up to 20ft PVC monocoil (std.)<br>Interlocking metal (opt.) |
| shock/vibration | 50 G's for 11 msec duration<br>5 to 2000 Hz @ 20 G's |

## ELECTRICAL SPECIFICATIONS

| | |
|---|---|
| input power | 5V dc ± 5% @ 110 mA max. |
| output circuitry | parallel TTL/CMOS (std.)<br>serial RS-422 (opt.)<br>fiber optic link 100/140 (opt.) |
| light source | GaAlAs LED |

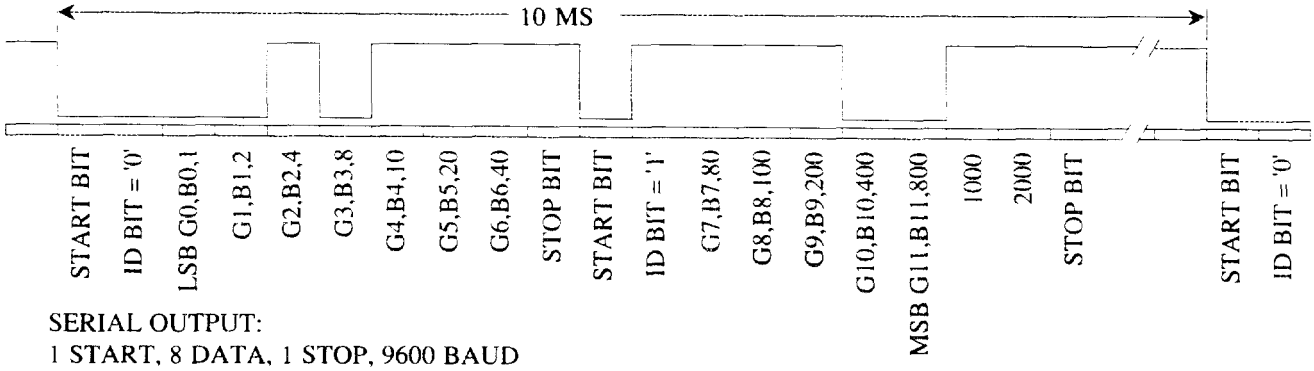
*PARALLEL CONNECTOR*

| | | | | | |
|---|---|---|---|---|---|
| G0,B0,1 | 19 | G7,B7,80 | 7 | INV OUT | 4 |
| G1,B1,2 | 20 | G8,B8,100 | 10 | CALIB. | 12 |
| G2,B2,4 | 17 | G9,B9,200 | 6 | POWER | 1 |
| G3,B3,8 | 18 | STROBE* | 8 | GROUND | 11 |
| G4,B4,10 | 15 | SER OUT | 5 | GROUND | 13 |
| G5,B5,20 | 16 | SER OUT' | 3 | GROUND | 14 |
| G6,B6,40 | 9 | INV IN | 2 | | |

*Data valid on rising edge. Data not valid when low (1ms pulse width).

| *SERIAL CONN.* | | *OPTIONS CONN.* | |
|---|---|---|---|
| SER OUT | 1 | CALIB. | 4 |
| SER OUT' | 2 | DIR. | 7 |
| GROUND | 3 | | |
| GROUND | 4 | | |
| POWER | 5 | | |

Recalibration is accomplished by grounding this pin and turning the shaft of the Sensing Element one or more revolutions and then un-grounding the pin.




SERIAL OUTPUT:
1 START, 8 DATA, 1 STOP, 9600 BAUD
OUTPUT SHOWN AS "001111110100" (MSB - LSB) GRAY CODE ($3F4)

## ORDERING INFORMATION

**FD11A** [Output Format] [Style] – [Resolution] – [Cable Length] [Cable Type] – [Voltage] **R1**

Output Format:
- GC = Gray Code
- NB = Natural Binary
- BD = BCD

Style:
- M = Modular
- H = Housed
- T = Thru Shaft
- S = Hollow Shaft

Resolution: Resolution in number of bits (number of counts for BD option)

Cable Length: Cable length in feet

Cable Type:
- blank = PVC Monocoil
- A = Interlocking Metal
- B = High Temperature

Voltage: 5 = +5 Vdc

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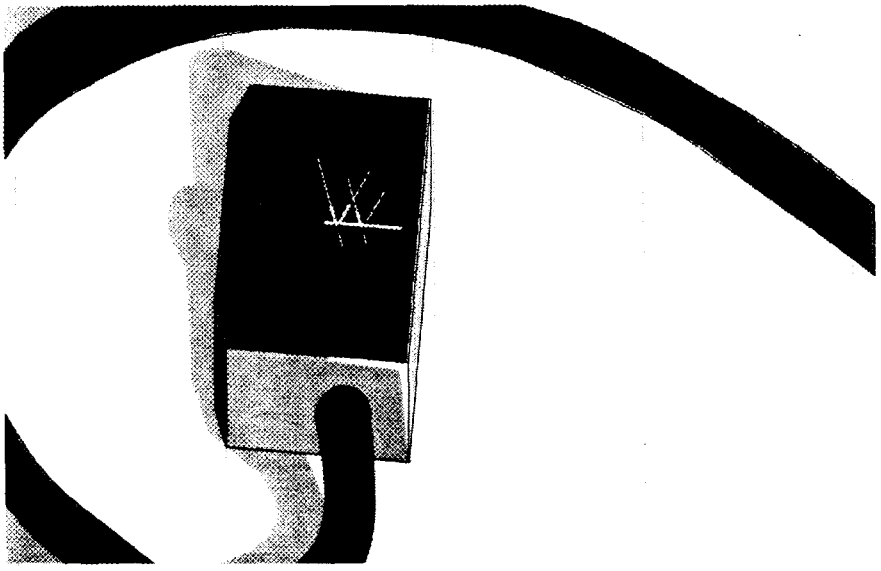
# FD100
## Fiber Optic LINEAR/ROTARY MODULAR READHEAD

### Description
The Model FD100 three channel **Fiber Optic Modular Readhead** is designed for use in positioning systems requiring improved reliability and EMI/RFI immunity. Used with an appropriate code disk or scale, the three channels are useful for motor commutation or position sensing via quadrature outputs and index marker pulse. Unit comes with Electronics Assembly.

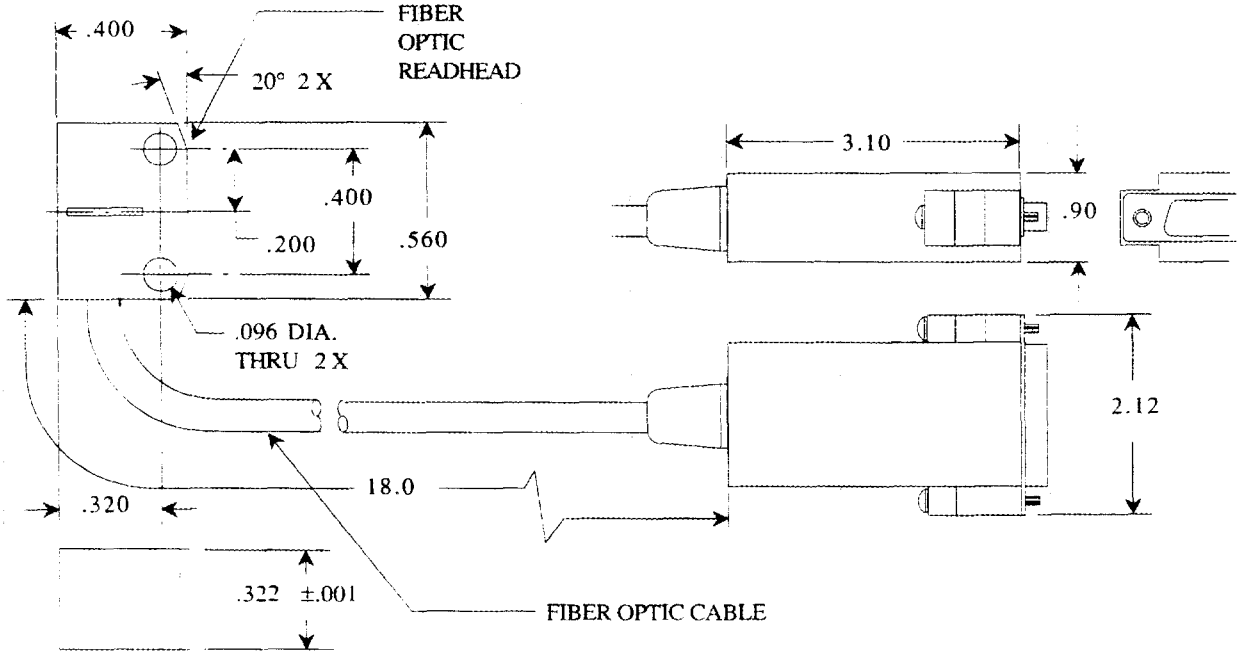


### Features
- Fiber Optic Construction
- Standard Fiber Optic Connector
- Electrical Outputs
- Extremely Rugged
- Standard Resolutions of .0012"
- 125°C Operating Temperature
- Submersible

### Applications
- Instrumentation
- Machine Tools
- Medical Electronics
- Motor Speed Control
- Robotics
- Servo Systems

### Options
- Higher resolution (.0009")
- Additional Channels
- High Temperature (up to 300°C)
- Multi-axis Electronics
- Digital Outputs
- Long Distance Interface
- Heavy Duty Cable

### PHYSICAL DIMENSIONS



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"MOTION CONTROL WITH FIBER OPTICS"
9305 Eton Avenue, Chatsworth, California 91
(818) 882-0424 • FAX: (818) 882-0492

# FD10A & I Series

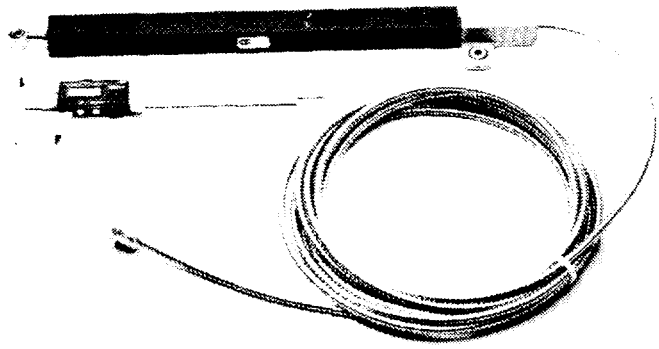
## Fiber Optic ABSOLUTE LINEAR ENCODER

### Description

The Model FD10A is a **Fiber Optic Absolute/Incremental Linear Encoder** designed for applications requiring high temperature linear displacement sensing in EMI/RFI sensitive environments. Optional analog output makes this an ideal replacement for LVDT's where EMI and elevated temperatures are a problem. Operation is rated from -55°C to +150°C. Unit comes with electronics assembly which provides serial or parallel data formats.

### Features

- Fiber Optic Construction
- Standard F.O. Connectors
- Serial / Parallel Electrical Outputs
- 8-Bit Resolution
- 150°C Operating Temperature



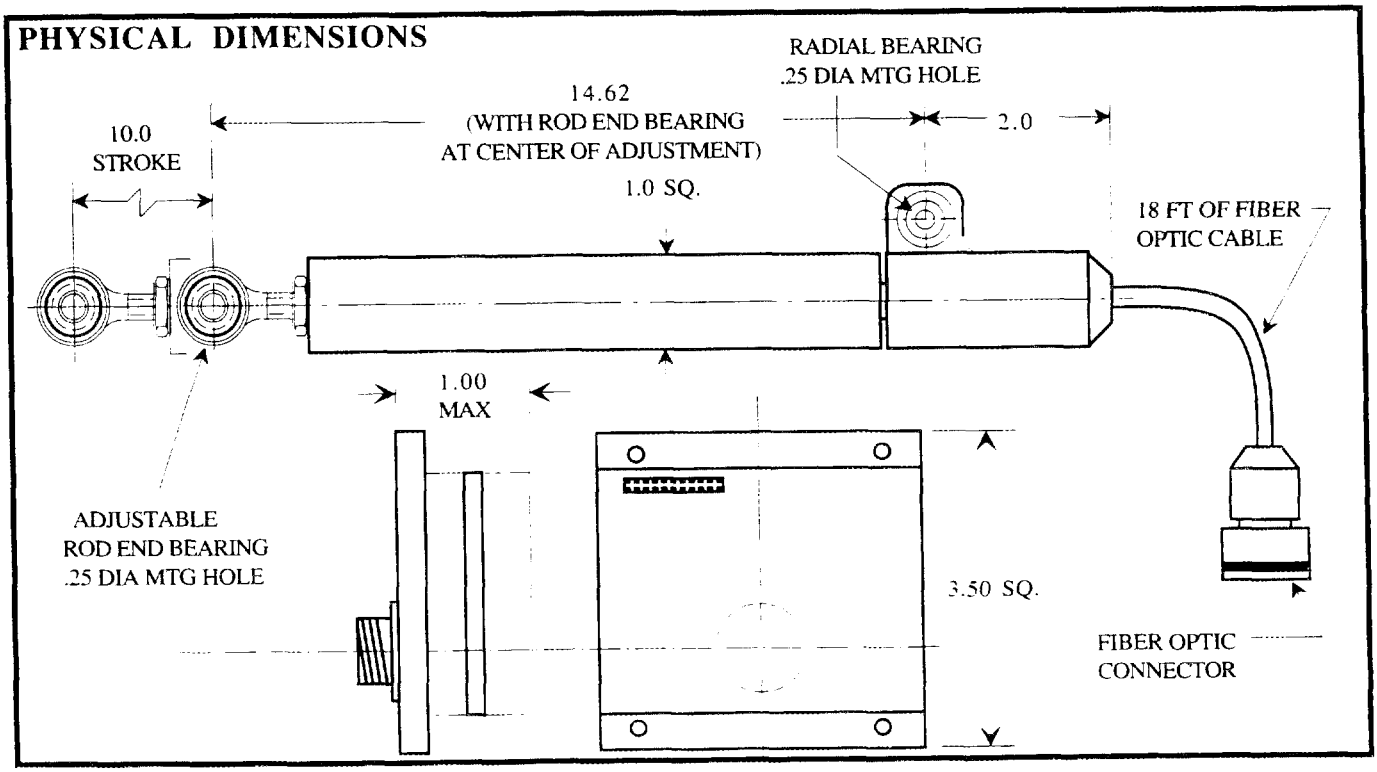
### Applications

- Machine Tools
- Fluid Level Systems
- Take up Reels
- Catapult Systems
- Ground Support Systems
- Automatic Weight Logging

### Options

- Higher Resolution
- Multi-axis Electronics
- Stroke Lengths
- Digital Outputs
- High Temp.(up to 300°C)
- Fiber Optic Data Link

### PHYSICAL DIMENSIONS




Specifications subject to change without notice

Data sheet 2-86-0019

COMPUTER OPTICAL PRODUCTS, INC.
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Fiber Optics Group
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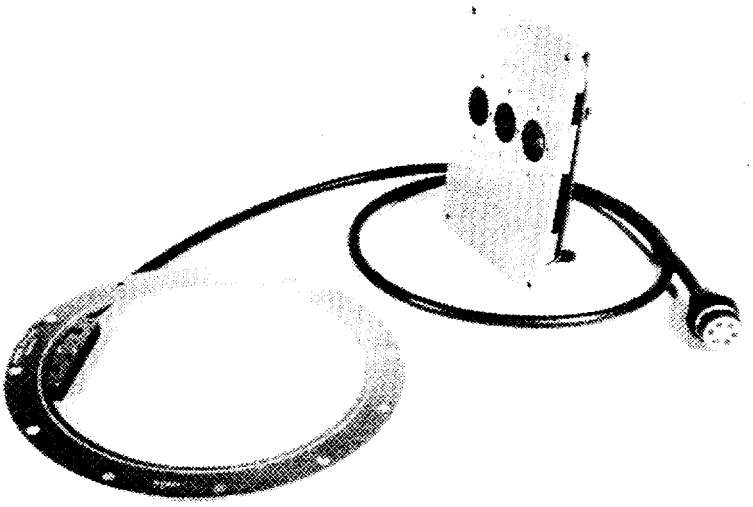
# FDMS Series
## Fiber Optic MULTI-AXIS MODULAR INCREMENTAL ENCODER SYS.

### Description
The FDMS Series represents one of the most advanced ways fiber optics can be used to achieve cost effective position sensing. Illustrated here is the flexibility inherent in this approach. The position sensors can either be identical units or a combination of modular, house, rotary, or linear types. The fiber optic readhead senses motion without active components in difficult to service places.

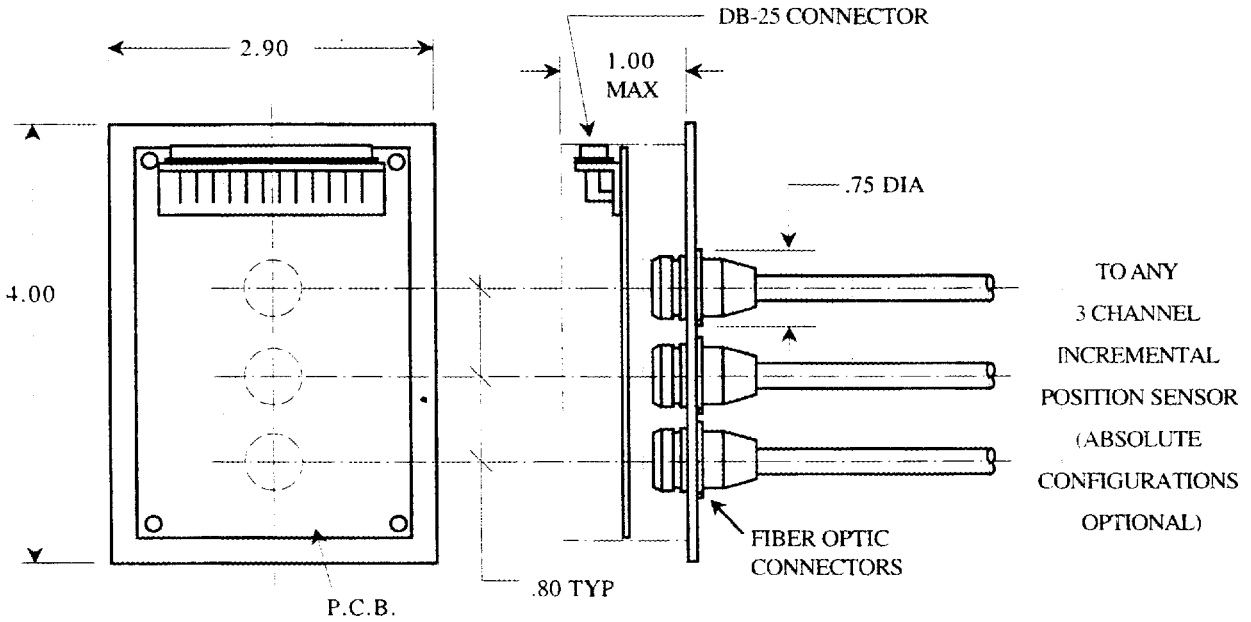
### Features
- Fiber Optic Construction
- Flexibility
- Low Cost
- EMI/RFI Immunity
- No possibility of Spark Ignition
- Serviceability

### Applications
- Multi-axis Gimbal Systems
- Factory Automation
- Robotics
- Medical

### Options
- Custom Cable Lengths
- Additional Axii
- Special Mounting Configurations
- Temperatures to 300°C
- Line Driver Output



### PHYSICAL DIMENSIONS




THREE AXIS ELECTRONICS ASSEMBLY

COMPUTER OPTICAL PRODUCTS, INC.
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# FDPM14-256R1

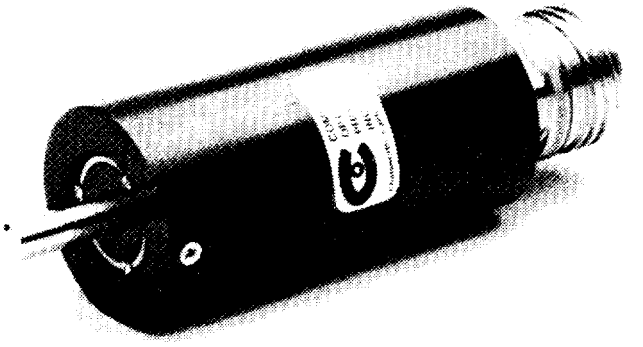
## Fiber Optic ROTARY HOUSED POSITION MODULATOR

### Description

The Model FDPM14-256R1 is a size 14, **Fiber Optic Rotary Light Modulator**. Designed for applications requiring high temperature speed and position sensing. This model features a MIL-C-38999 fiber optic connector to interface to 100/140 fibers. Long distance fiber optic position sensing is possible. Operation is rated from -55°C to +200°C. Two optical channels are amplitude modulated in phase quadrature as a function of shaft rotation.

### Features

- Fiber Optic Construction
- High Temperature
- Resolutions up to 500 Cycles
- Small Size
- EMI/RFI Immunity
- No possibility of Spark Ignition
- MIL-C-38999 Connector
- Redundancy



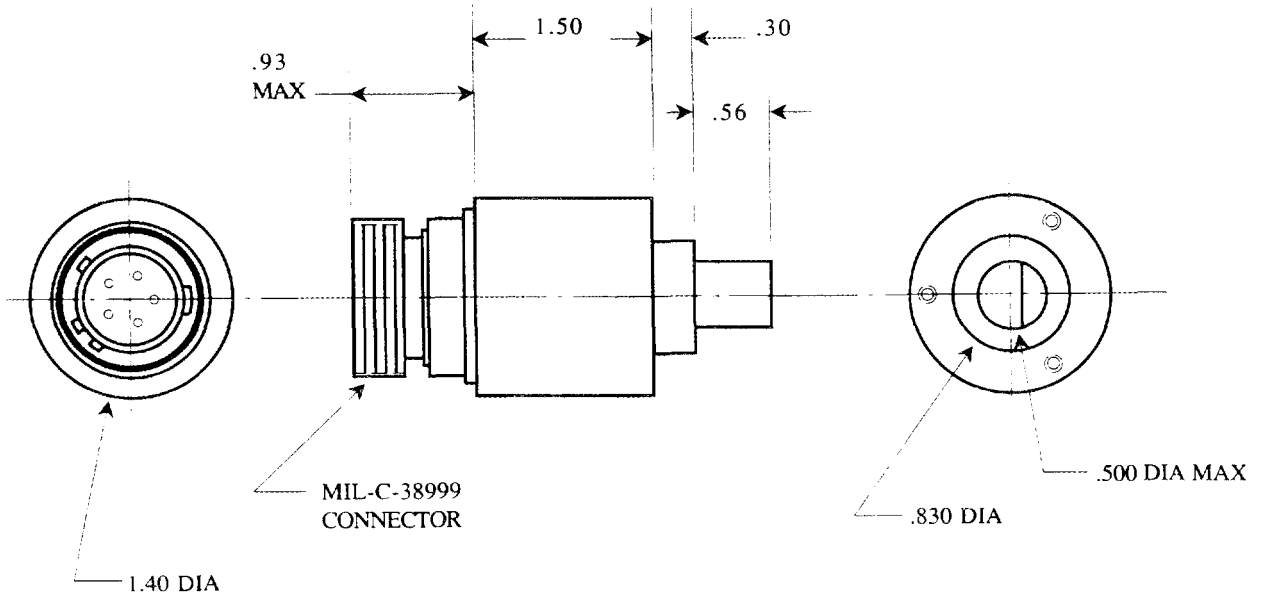
### Applications

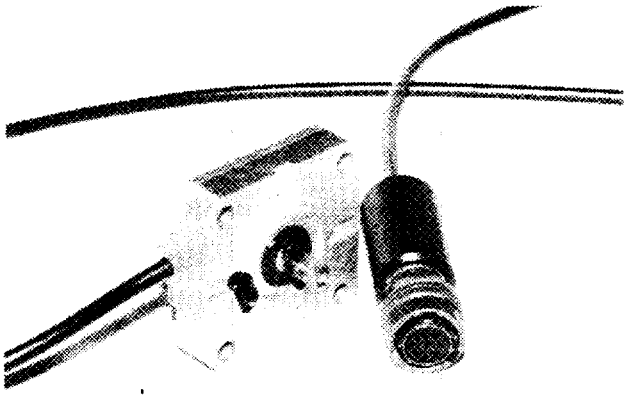
- Anti-skid Systems
- Fly-by-light
- Speed and position Control
- Medical

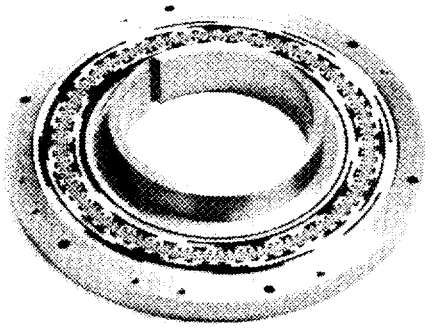
### Options

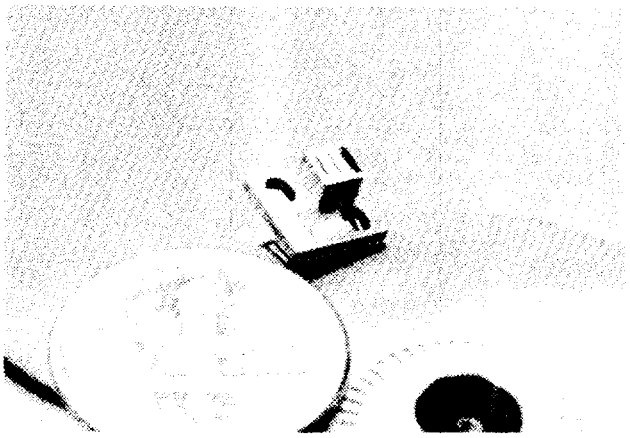
- Special Shaft Configurations

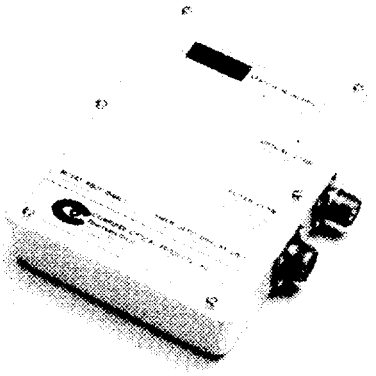
### PHYSICAL DIMENSIONS












**WEST COAST**

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# Computer Optical Products, Inc.

The innovator of a large variety of optical positioning devices. COPI has pioneered the application of specialized analog-output encoders in the computer peripherals industry. COPI designs and products perfected for disk drives, printers, tape drives etc. are being used on a large scale worldwide.This experience in the control of LED intensity over life and temperature,beam angles and materials choice has been applied to the manufacture of state-of-the-art housed encoders with unsurpassed price/performance ratios.

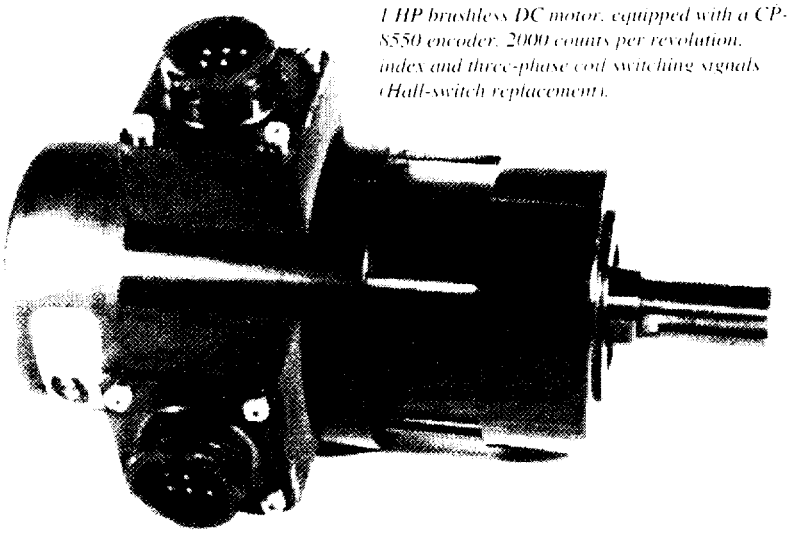
The basic optical design of one single, intensity-controlled light source and one single integrated monolithic sensor array has yielded incremental encoders offered at prices normally associated with modular encoders, and absolute encoders offered at prices normally associated with incremental encoders.

Integral processors for models such as the CP-850-12DIS allow tailor-made specifications and characteristics by custom programming for specialized applications.
For a line of multiturn encoders, traditionally a large and complicated mechanical design containing gears, multiple disks and numerous discrete electro-optical components, COPI substituted a processor and electronics for an extremely reliable electronical multi-turn (CP-850-22-MT).

Encoders for especially hostile environments (temperature, flammable gases, RFI/EMI, radar antenna positioning) have been developed utilizing fiberoptics. COPI designed and produced parts are being used in such diverse applications as linear absolute encoders for aircraft carrier steam catapults and rotary absolute encoders for large industrial brushless DC motor commutation and proportional drive circuits.

For a single source of motor/encoders, COPI encoders are available factory-mounted on a wide range of COPI manufactured PMDC motors (1.5", 2", 3" and 4" diameter) as well as on Hathaway Motion Control Group manufactured brushless DC motors. For information on these BDC motors contact Hathaway Motion Control. (918) 438 7800, fax (918) 438 7629.

Although the catalog shows standard designs, there are no restrictions on specifying special requirements such as custom electrical specification, power supply voltages and mounting configurations. Please contact our applications engineering department, we'll be most pleased to quote your special needs.



*1 HP brushless DC motor, equipped with a CP-8550 encoder, 2000 counts per revolution, index and three-phase coil switching signals (Hall-switch replacement).*

# CP-200-xxxx

sine / cosine infinite resolution incremental encoder

## description

The CP-200 encoder/ transducer is a cost-effective feedback device especially suited for applications where continuous position information is required, such as low and ultra-low speed servo control loops. As opposed to digital encoders where no information is available between transitions, the CP-200 supplies continuous information about the angular position of the system with a resolution only restricted by the digitizing electronics. With a guaranteed linearity of better than 1% up to the 45° crossover points it is possible, even with relatively simple digitizing schemes, to obtain equivalent resolutions of 256,000 discrete points per revolution. For "ditherless" detenting into a zero-crossing or an offset zero-crossing, either the A or B channel can be directly switched into the error amplifier of the system.This unit interfaces directly with the SGS™ low-cost servo-control L-290, L291& L292 chipset.

Ordering information:
CP-200-(counts/revolution)-(hub size, inch or mm)-(cable lenghth in inch or cm). Maximum hubsize is .3935 or 10 mm. Max. shaft length is .55",for through shaft specify hole in cover.

## standard counts/revolution

16, 50, 96,100,110,120,128,155,192, 200, 210
240, 254, 256, 280, 288, 300, 360, 384, 400, 480
500, 576, 720, 850, 1000.

## ratings

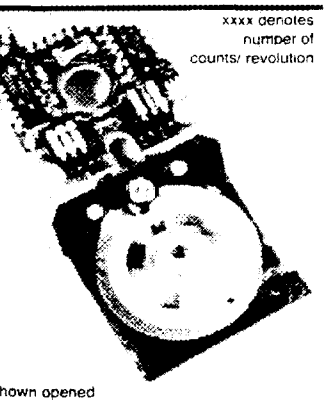
| | |
|---|---|
| supply voltage | ± 18 Vdc max, ± 12 Vdc nominal |
| operating temperature range | -30 C to +85 C |
| storage temperature | -40 C to +95 C |
| operating relative humidity | 90% @ 35 C |
| storage relative humidity | 80% @ 45 C |
| moment of inertia | 0.2 x 10⁻³ in.oz sec² |
| frequency response | ± 0.424 dB @ 20 kHz |
| output current | 10 mA sink or source |
| output voltage | Vp nom = ± 0.5 V, zero centered.Other output levels are optional. |

## options

-available with a wide range of factory mounted PMDC motors, brushless DC motors, stepper motors.
-cable options
-digital version, see datasheet # 120-3
-tachometer version: datasheet # 120-2
-application notes : see datasheet # 210

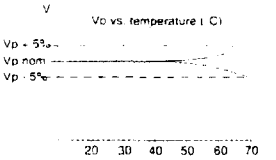
shown without cover

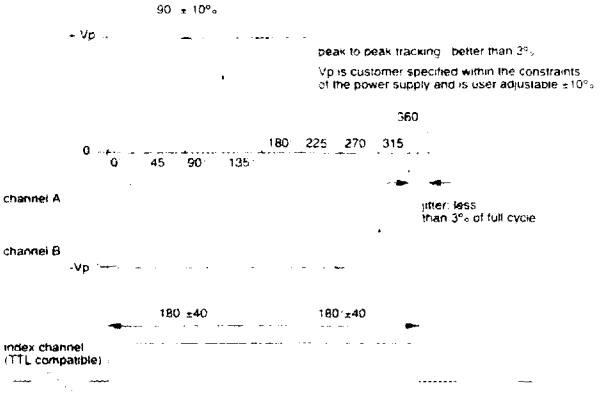
xxxx denotes number of counts/ revolution



shown opened

temperature characteristics

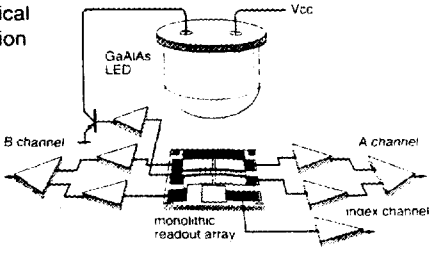


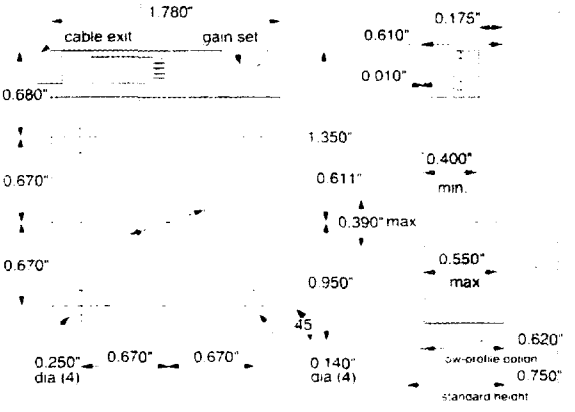




shown is a typical index channel other configurations are optional

*waveforms, ccw seen from cover end*

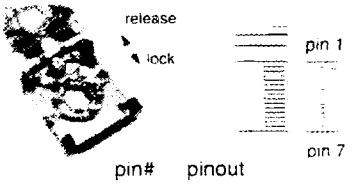
optoelectrical configuration




## mounting instructions

1 open cover by gently prying the cover off with a small screwdriver at the slot opposite the wire exit. *Leave the PCB in place*
2 loosely mount the encoder to a motor with four mounting screws through the PCB
3 unlock the locking ring by turning ccw (view from encoder end), *access ring from the side*
4 gently press down hub and lock the hub by turning locking ring clockwise
5 tighten set screw
6 tighten the four mounting screws
7 unlock the locking ring by turning ccw until it stops
8 snap on cover




| pin# | pinout | |
|---|---|---|
| 1 | shield | |
| 2 | index | (green) |
| 3 | ch. B | (black) |
| 4 | ch. A | (yellow) |
| 5 | - 12 Vdc | (white) |
| 6 | open | |
| 7 | + 12 Vdc | (red) |

Molex™ 22-01-3077, 7 pin, 0.1" center, cable length 24" ± 0.5"

# CP-250-xxxx

modular incremental encoder

## description

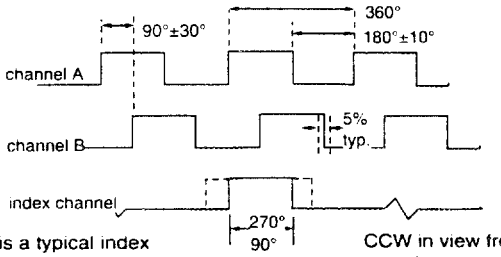
The CP-250 encoder is a cost-effective feedback device that mounts easily on a motor platform. The LED light source is servo-controlled for constant light output to insure thermal and long-term stability.

Ordering information:
CP-250-(c/r)-(SE/RE/C)-(hub size,inch or mm)*-(cable length in inch or cm, if applicable).
Max. shaft length is .55",for through shaft specify hole in cover.
* maximum hub size : 0.3935" or 10 mm.

xxxx number of counts/ revolution

shown without cover

waveform (CW from encoder end)




Shown is a typical index channel,other configurations are optional

CCW in view from encoder cover side

## standard counts/revolution (c/r)

16, 32, 50, 96,100,110,120,128,155,192, 200, 210, 220, 240, 254, 256, 280, 288, 300, 310, 360, 384, 400, 480 500, 508, 512, 560, 576, 600, 720, 768, 800, 850, 960, 1000, 1024, 2000.

## ratings

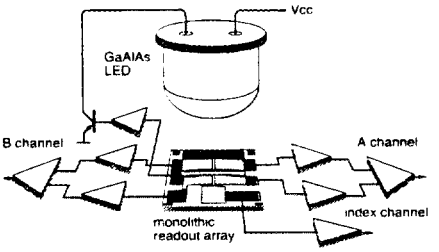
supply voltage: 5 V @ 50 mA maximum
operating temp. range: -30°C to +85°C
storage temperature: -40°C to +95°C
operating relative humidity: 90% @ 35°C
storage relative humidity: 80% @ 45°C
moment of inertia: 0.2 x $10^{-4}$ in.oz $sec^2$
frequency response: 100 kHz ( A & B)
50 KHz (index)
output format: incremental
output: open collector with 4.7kΩ pullup resistors

## options

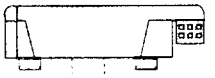
-available with a wide range of factory mounted PMDC motors, brushless DC motors, stepper motors.
-cable options
-analog version, see datasheet # 121-1

-application notes : see datasheet # 210

optoelectrical configuration

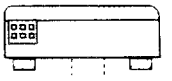



side exit pin option ordering: (SE)




pin 1: A channel
pin 2: + Vdc
pin 3: ground
pin 4: B channel
pin 5: index
pin 6: n/c

rear exit pin option ordering: (RE)



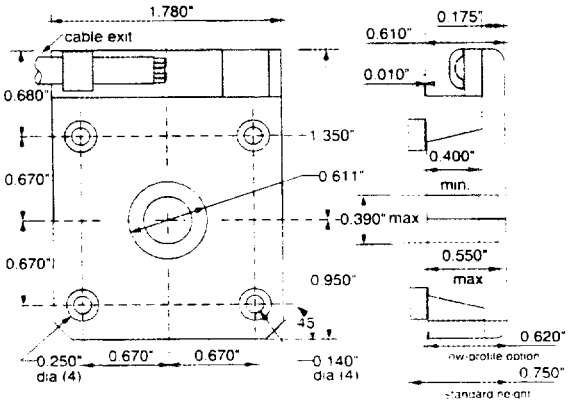

pin 1: ground
pin 2: + Vdc
pin 3: index
pin 4: n/c
pin 5: A channel
pin 6: B channel

cable option ordering: (C)

connector: Molex™ p/n 22-10-2071 cable length 24" standard. different cable lenghts and terminations available on request.

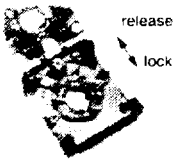
pin 1: n/c
pin 2: index
pin 3: B channel
pin 4: A channel
pin 5: + Vdc
pin 6: ground

pinouts




## mounting instructions

1/ open cover by gently prying the cover off with a small screwdriver at the slot opposite the wire exit. *Leave the PCB in place.*
2/ loosely mount the encoder to a motor with four mounting screws through the PCB
3/ unlock the locking ring by turning ccw (view from encoder end), access ring from the side
4/ gently press down hub and lock the hub by turning locking ring clockwise
5/ tighten set screw
6/ tighten the four mounting screws
7/ unlock the locking ring by turning ccw until it stops
8/ snap on cover




mounting interface requirements (500 c/r typical):

axial play: 0.001" max
runout: 0.002" TIR
squareness to mounting surface: 0.002"
recommended shaft diameter from .125" to .390" (3 to 10 mm)

# CP-260-xxxx

modular brushless DC tachometer with incremental encoder

## description

The CP-260 encoder/ transducer is a cost-effective feedback device especially suited for servo control loops where continuous speed information is required.

In addition to position information, the unit generates a linear DC tachometer signal with low ripple, usable to less than one RPM (for a 1000 c/r unit).

The absence of contacting elements such as brushes etc. makes this device an excellent feedback counterpart for high reliability brushless DC motor-based incremental motion systems.

Ordering information:
CP-260-(c/r)-(hub size.inch or mm)*-(RPM at Vtach=10 Vdc desired)-(LD=linedriver option installed.blank if not)
Max. shaft length is .55".for through shaft specify hole in cover.
* maximum hub size : 0.3935" or 10 mm.

## standard counts/revolution

16, 50, 96,100.110.120,128,155,192, 200, 210
240, 254, 256, 280, 288, 300, 360, 384, 400, 480
500, 576, 720, 850, 1000.

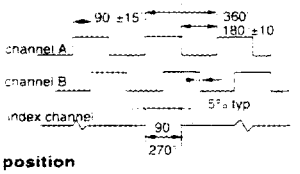
## ratings

| | |
|---|---|
| supply voltage | ± 18 Vdc max. ± 12 Vdc nominal @ 50 mA maximum |
| operating temp. range | -30°C to +85°C |
| storage temperature | -40°C to +95°C |
| operating relative humidity | 90% @ 35°C |
| storage relative humidity | 80% @ 45°C |
| moment of inertia | 0.2 x $10^{-4}$ in.oz $sec^2$ |
| frequency response | 100 kHz ( A & B) |
| output $V_{tach}$ | 10 mA sink or source, $V_{out}$ = ± 10Vdc |
| output A, B and Index channels | LM 339 with 4.7 kOhm pull-ups |

## options

-line driver outputs (no- charge option)
-available with a wide range of factory mounted PMDC motors, brushless DC motors, stepper motors.
-cable options
-analog version, see datasheet # 120-1
-digital version, see datasheet # 120-3
-application notes : see datasheet # 210

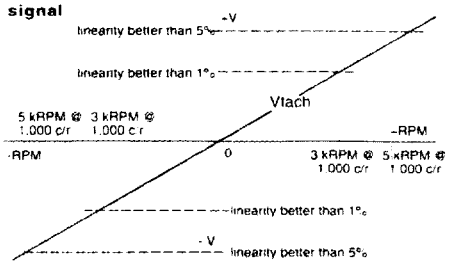
xxxx : number of counts/ revolution



**position signals**

shown without cover

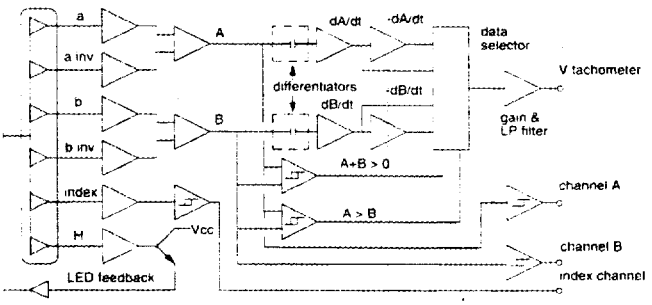
**tachometer signal**



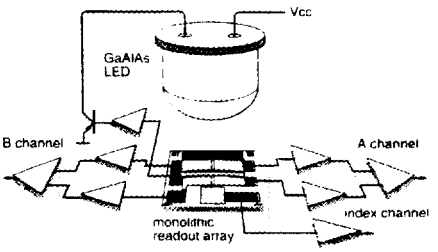

- default setting is 5 V/kRPM, other settings optional
- ripple is less than 10mV
- maximum setting* is 10V @ 100 RPM
- 1% linearity point = $3.10^{-6}$ / c/r (RPM)
- 5% linearity point = $5.10^{-6}$ / c/r (RPM)
- maximum absolute $V_{tach}$ = ±10 Vdc

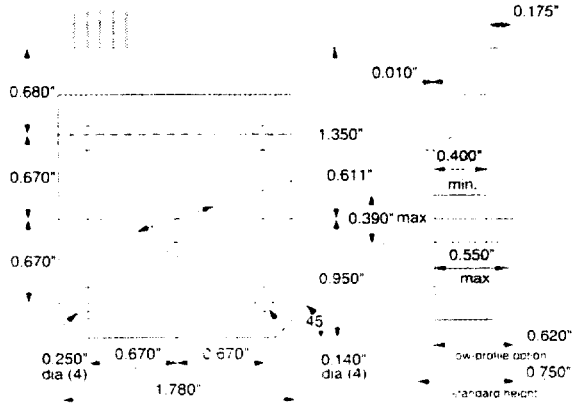
* @ 1.000 c/r encoder

**block diagram**




**optoelectrical configuration**



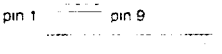

## mounting instructions

1/ open cover by gently prying the cover off with a small screwdriver at the slot opposite the wire exit. *Leave the PCB in place.*
2/ loosely mount the encoder to a motor with four mounting screws through the PCB
3/ unlock the locking ring by turning ccw (view from encoder end), access ring from the side
4/ gently press down hub and lock the hub by turning locking ring clockwise
5/ tighten set screw
6/ tighten the four mounting screws
7/ unlock the locking ring by turning ccw until it stops
8/ snap on cover

Pinouts:

1 inverted index*
2 index
3 A channel
4 inverted A channel*
5 inverted B channel*
6 - 15 Vdc
7 B channel
8 ground
9 $V_{tach}$ output
10 + 15 vDC

* linedriver version



# CP-350-xxxx

incremental
shaft encoder

## Description

The CP 350 encoder is a precision,high performance device specifically designed for applications where high accuracy and low cost are prime considerations. The package form factor is identical to that of a 39 mm stepper motor.

## Features

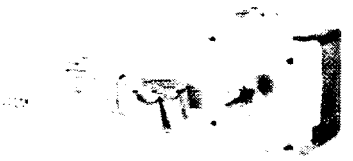
- high performance
- rugged package
- linedriver outputs (MC 3487/26LS31)
- monolithic sensor array
- single LED light source
- up to 1,500 counts per turn
- competitive pricing

## Applications

- medical equipment
- light machine tools
- wire handling equipment
- laboratory instrumentation
- factory automation
- robotics
- flow metering
- computer peripherals

## Options

- TTL / open collector outputs
- custom cable/connector configurations
- through-shaft
- extended temperature range (-30°C to +100°C)
- custom shaft configurations



## ordering information:

CP-350-(linecount)-(1)-(2)-(3)
(1) : linedriver=L,TTL=T,open collector=O
(2) : through-shaft with slot=X
(3) : high temperature version=H

## standard linecounts (xxxx):

256,360,500,600,1000,1024 c/r. Special linecounts and index configurations available on request.

## mechanical data

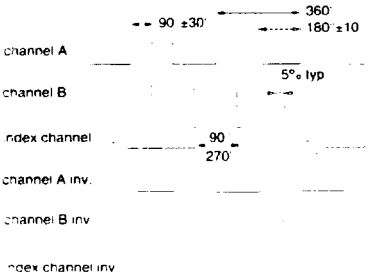
| | |
|---|---|
| shaft diameter: | 6.342 / 6.337 mm |
| shaft options: | 6 mm |
| shaft loading: | 10 N axial , 20 N radial |
| shaft runout: | .00125 mm T.I.R. |
| starting torque: | 0.1 Ncm @20°C max |
| shaft rotation: | continuous,reversible |
| slew speed: | 160 rev/sec² |
| bearings: | ABEC 5 |
| shaft material: | 416 stainless |
| housing material: | diecast aluminum |
| cover material: | Ryton 4,1.5 mm wall |
| bearing life: | manufacturer's specs |
| moment of inertia: | 1.7 gcm² |
| weight: | approx. 0.120 kg |

## electrical data

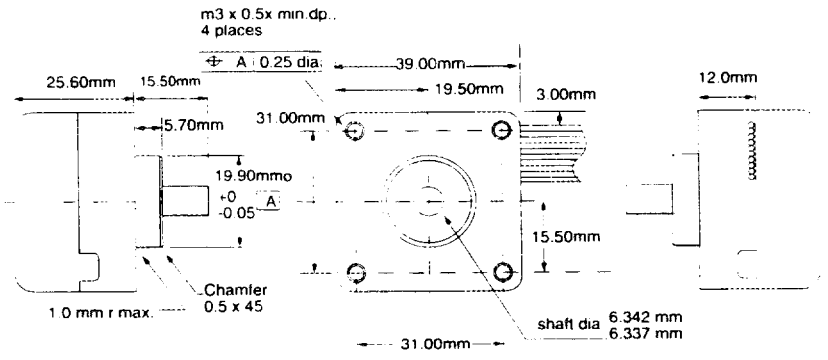
| | |
|---|---|
| code: | incremental |
| cycles per revolution: | up to 1,500 |
| power supply: | +5Vdc @ 50mA |
| output format: | A & B channel in quadrature,index |
| output: | linedriver |
| frequency response: | 100 KHz |

## environmental data

| | |
|---|---|
| temperature: | operating: -20°C to+90°C |
| shock: | 50 G's @ 11 ms |
| vibration: | 5-2,000 Hz @ 20 G's |
| humidity: | 98% without condensation |




waveforms
(CW from shaft end)




pinout line drivers:

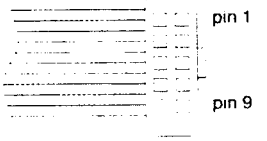
1 +5 Vdc
2 -5 Vdc
3 channnel A inv.
4 channel A
5 channel B inv.
6 channel B
7 index channel
8 ground
9 index channel inv.
10 ground

pinout TTL:

1 channel A
2 + 5 Vdc
3 ground
4 ground
5 ground
6 ground
7 + 5Vdc
8 channel B
9 n/c
10 index channel

cable.
3M™ p/n 3365 /10.
20 cm ± 1 cm long

connector.
3M™ p/n 3473-6610



# CP-350-08GC

8 bit absolute encoder, Gray code

## Description

The CP-350-08GC is a small size absolute encoder with a natural binary output. For low power consumption applications, the unit can be strobed by means of the 5 Vdc supply line with a settling time of 2 µsec. For bus connection, a version without internal pullups is available. Up to 10 encoders can be connected this way in parallel with the 5 Vdc as address line.

### Ordering information:

CP-350-08GC-(85=85°C,100=100°C)-(R=with pullups, blank if no pullups)-(T= through shaft with screwdiver slot,blank = without through shaft)

For custom shaft applications, contact the factory.

## Features

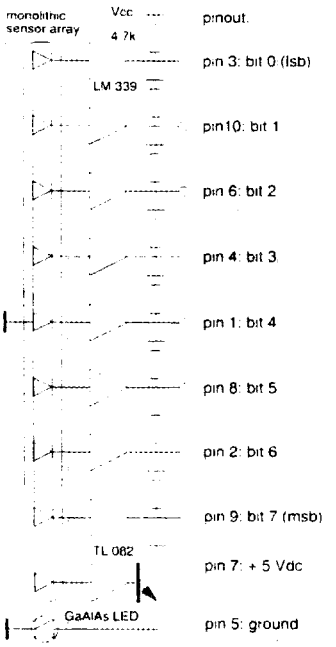
- rugged package, through shaft option
- monolithic sensor array
- single servo-controlled LED light source
- competitive pricing

## Applications

- medical equipment
- machine tools
- laboratory instrumentation
- factory automation
- robotics
- flow metering

## Options

- extended temperature range (-55°C to +100°C)
- custom shaft configurations
- custom cable configurations




## mechanical data

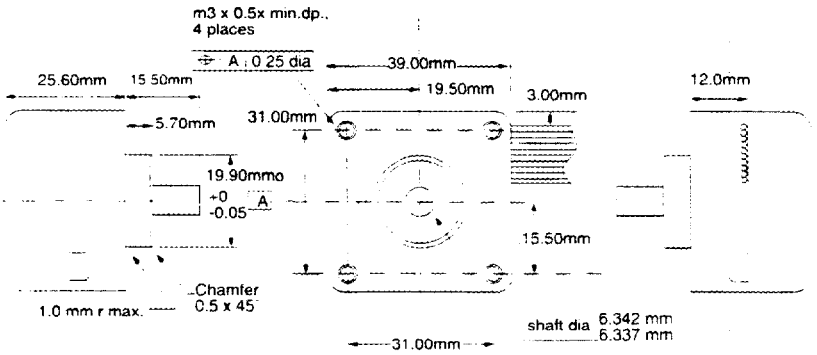
| | |
|---|---|
| shaft diameter: | 6.342 / 6.337 mm |
| shaft options: | 6 mm |
| shaft loading: | 10 N axial , 20 N radial |
| shaft runout: | .00125 mm T.I.R. |
| starting torque: | 0.1 Ncm @20°C max |
| shaft rotation: | continuous,reversible |
| slew speed: | 160 rev/sec² |
| bearings: | ABEC 5 |
| shaft material: | 416 stainless |
| housing material: | diecast aluminum |
| cover material: | Ryton 4,1.5 mm wall |
| bearing life: | manufacturer's specs |
| moment of inertia: | 1.7 gcm² |
| weight: | approx. 0.120 kg |

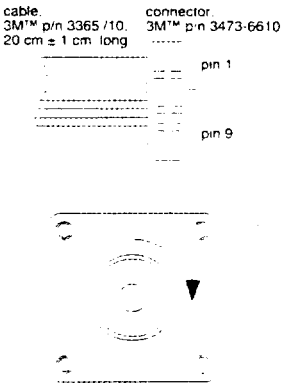
## electrical data

| | |
|---|---|
| code: | Gray code |
| power supply: | +5Vdc @ 50mA |
| output format: | 8 bit paralell |
| output: | open collector |
| frequency response: | 100 KHz data rate |

## environmental data

| | |
|---|---|
| temperature: | operating: -20°C to+85°C |
| shock: | 50 G's @ 11 ms |
| vibration: | 5-2,000 Hz @ 20 G's |
| humidity: | 98% without condensation |




cw rotation of shaft for increasing count

# CP-350-08NB

8 bit absolute encoder, binary

## Description

The CP-350-08NB is a small size absolute encoder with a natural binary output. For low power consumption applications, the unit can be strobed by means of the 5 Vdc supply line with a settling time of 2 µsec. For bus connection, a version without internal pullups is available. Up to 10 encoders can be connected this way in parallel with the 5 Vdc as address line.

### Ordering information:

CP-350-08NB-(85=85°C,100=100°C)-(R=with pullups, blank if no pullups)-(T= through shaft with screwdiver slot,blank = without through shaft)

For custom shaft applications, contact the factory.

## Features

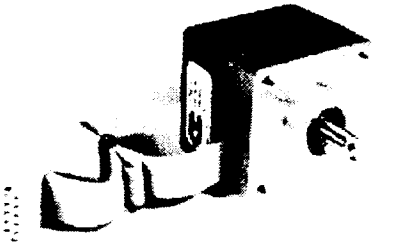
- rugged package, through shaft
- monolithic sensor array
- single servo-controlled LED light source
- competitive pricing

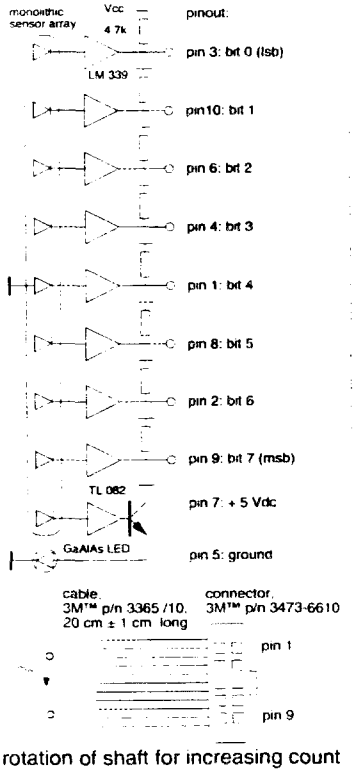
## Applications

- medical equipment
- machine tools
- laboratory instrumentation
- factory automation
- robotics
- flow metering

## Options

- extended temperature range (-55°C to +100°C)
- custom shaft configurations
- custom cable configurations






CW rotation of shaft for increasing count

## mechanical data

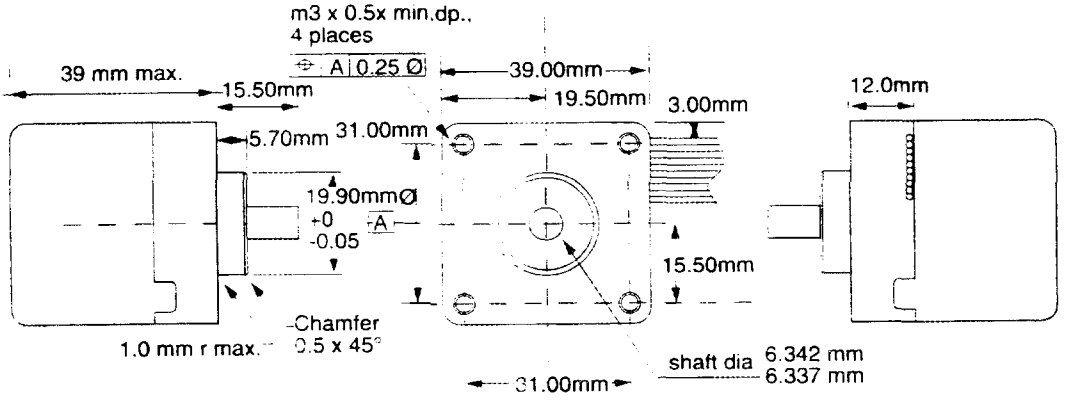
| | |
|---|---|
| shaft diameter: | 6.342 / 6.337 mm |
| shaft options: | 6 mm |
| shaft loading: | 10 N axial , 20 N radial |
| shaft runout: | .00125 mm T.I.R. |
| starting torque: | 0.1 Ncm @20°C max |
| shaft rotation: | continuous,reversible |
| slew speed: | 160 rev/sec $^2$ |
| bearings: | ABEC 5 |
| shaft material: | 416 stainless |
| housing material: | diecast aluminum |
| cover material: | Ryton 4.1.5 mm wall |
| bearing life: | manufacturer's specs |
| moment of inertia: | 1.7 gcm $^2$ |
| weight: | approx. 0.120 kg |

## electrical data

| | |
|---|---|
| code: | natural binary |
| power supply: | +5Vdc @ 50mA |
| output format: | 8 bit paralell |
| output: | open collector with 4.7 kΩ pullups |
| frequency response: | 100 KHz data rate |

## environmental data

| | |
|---|---|
| temperature: | operating: -20°C to+85°C |
| shock: | 50 G's @ 11 ms |
| vibration: | 5-2,000 Hz @ 20 G's |
| humidity: | 98% without condensation |



# CP-350-08AN

8 bit optical potentiometer

## Description

The CP-350-08AN is an optical potentiometer specifically designed for applications where excessive wear would make traditional mechanical potentiometers impractical or unreliable.Standard output is a 0 to 10 Vdc signal, optional 4 - 20 Ma current over 360° mechanical. For custom patterns ( e.g. for valve control applications), please contact the factory.

Ordering information:

CP-350-08AN-(CS=current source output in addition to 0-10V output)-(85=85°C, 100=100°C).
For shaft options, please contact the factory.

## Features

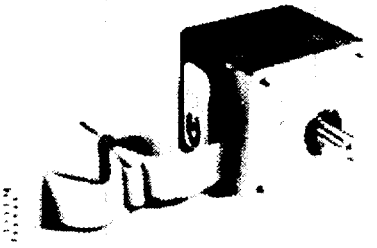
- rugged package
- monolithic sensor array
- single servo-controlled LED light source
- competitive pricing

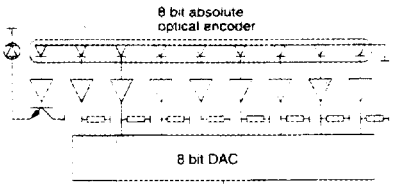
## Applications

- medical equipment
- machine tools
- laboratory instrumentation
- factory automation
- robotics
- flow metering

## Options

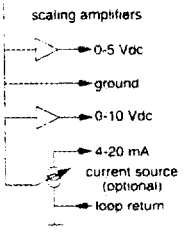
- extended temperature range (-55°C to +100°C)
- custom shaft configurations
- custom cable configurations






pin assignments:

| | |
|---|---|
| pin 1 | n/c |
| pin 2 | + 12 Vdc |
| pin 3 | n/c |
| pin 4 | n/c |
| pin 5 | direction control |
| pin 6 | power ground |
| pin 7 | 4-20 mA out |
| pin 8 | 0-5 Vdc out |
| pin 9 | 0-10 Vdc out |
| pin 10 | loop return |




### mechanical data

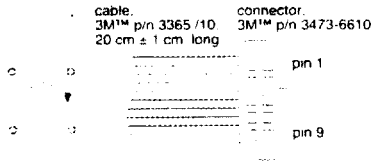
| | |
|---|---|
| shaft diameter: | 6.342 / 6.337 mm |
| shaft options: | 6 mm |
| shaft loading: | 10 N axial , 20 N radial |
| shaft runout: | .00125 mm T.I.R. |
| starting torque: | 0.1 Ncm @20°C max |
| shaft rotation: | continuous,reversible |
| slew speed: | 160 rev/sec $^2$ |
| bearings: | ABEC 5 |
| shaft material: | 416 stainless |
| housing material: | diecast aluminum |
| cover material: | Ryton 4,1.5 mm wall |
| bearing life: | manufacturer's specs |
| moment of inertia: | 1.7 gcm $^2$ |
| weight: | approx. 0.120 kg |

### electrical data

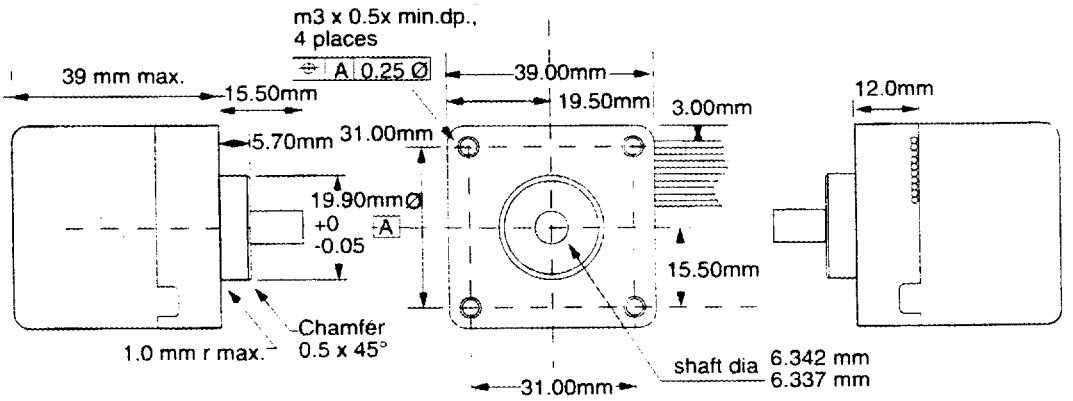
| | |
|---|---|
| resolution: | 8 bit |
| power supply: | + 12.6 to 16.6 Vdc @ 100 mA max |
| output: | 0 - 5 Vdc & 0 -10 Vdc, 4 - 20 mA (opt) |
| stability: | ± 1% (std), ± 0.2%(opt) |
| dir. control input: | TTL/CMOS (5 V) |

### environmental data

| | |
|---|---|
| temperature: | operating: -20°C to+85°C |
| shock: | 50 G's @ 11 ms |
| vibration: | 5-2,000 Hz @ 20 G's |
| humidity: | 98% without condensation |




cw rotation of shaft for increasing Vout or I out at dir control = "0", decreasing at dir control = "1"



# CP-800-xxxx

sine / cosine incremental shaft encoder

## Description

The CP-800 sine/cosine encoder is a size 25 housed encoder with linecounts of up to 3750 counts per revolution.The unit was specifically designed to yield stable and precise signals suitable for high resolution digitizing and DC tachometer signal generation. Inexpensive external circuitry is available to yield up to one million measuring points per revolution.

### Ordering information:

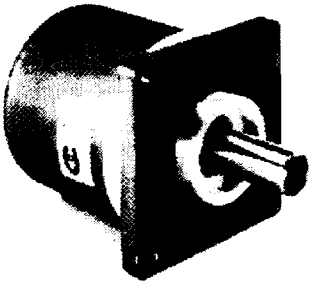
CP-800-(xxxx)-(Vpp desired)-(F=flange, S=servo mount)-(cable length in inch or cm)

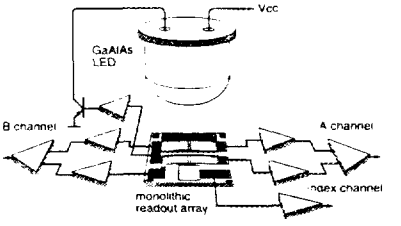
## Features

- infinite resolution
- excellent temperature characteristics
- monolithic sensor array
- single servo controlled LED light source
- up to 3750 counts per turn

## Applications

- high resolution servo systems
- NC machine tools
- Instrumentation
- Robotics
- Measuring equipment
- Computer peripherals






optoelectrical configuration

## mechanical data

| | |
|---|---|
| shaft diameter: | .3745" / .3748" |
| shaft loading: | 40 lbs axial, 35 lbs radial |
| shaft runout: | .0005" T.I.R. |
| starting torque: | 1.5 oz.in max @20°C |
| shaft rotation: | continuous.reversible |
| slew speed: | 160 RPS |
| bearings: | ABEC 7.sealed |
| shaft material: | 416 stainless |
| housing material: | aluminum |
| cover material: | aluminum |
| bearing life: | manufacturer's specs |
| moment of inertia: | $4.1 \times 10^{-4}$ oz.in.sec$^2$ |
| weight: | approx. 13 oz |

## electrical data

| | |
|---|---|
| code: | incremental |
| cycles per revolution: | up to 3750 |
| power supply: | +5 ,±15Vdc@ 50mA |
| output format: | A & B channel in quadrature,index |
| output: | opamp TIL 084 |
| frequency response: | 100 KHz |

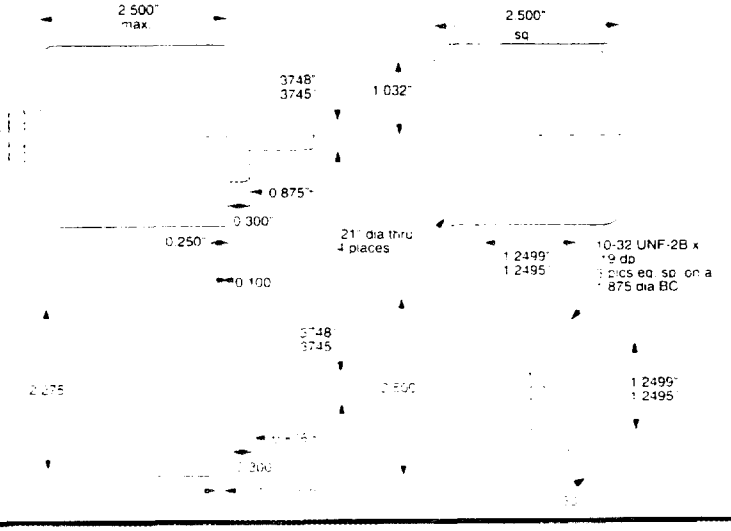
## environmental data

| | |
|---|---|
| temperature: | operating: -20°C to +90°C |
| shock: | 50 G's @ 11 ms |
| vibration: | 5-2,000 Hz @ 20 G's |
| humidity: | 98% without condensation |

## standard linecounts (xxxx):

16,50,96,100,110,120,128,155,192, 200,210,220,240,254,256,280,288,300, 310,360,384,400,480,500,576,600,720, 800,850,1000,1100,1800,2000, & 3750 full A and B cycles per revolution.

Special linecounts and index configurations available on request.

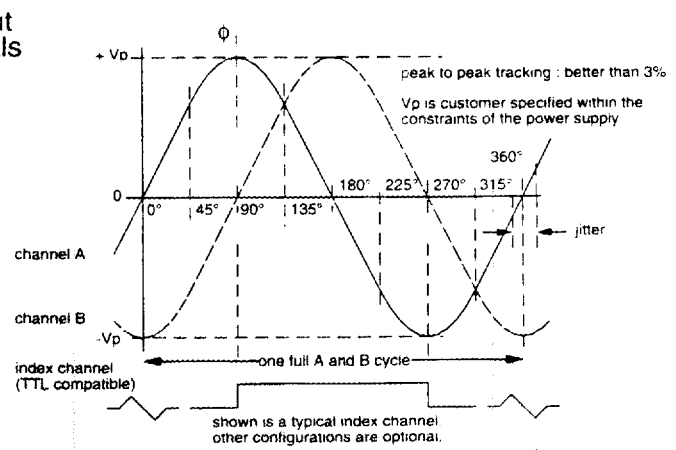


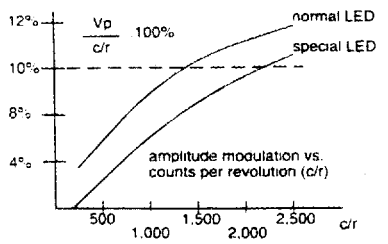

### Wire color assignments:

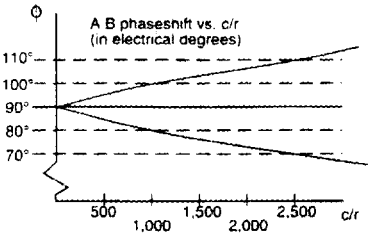
| | |
|---|---|
| channel A | white/orange stripe |
| channel B | blue/white stripe |
| index channel | green/white stripe |
| + 5Vdc | white/gray stripe |
| ground | gray/white stripe |
| + 15Vdc | brown/white stripe |
| - 15Vdc | white/brown stripe |
| chassis | cable shield |

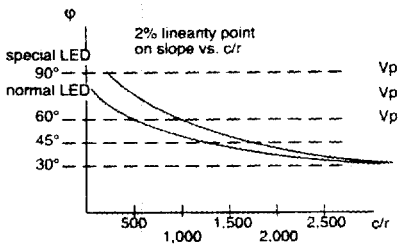
for connector options.contact factory

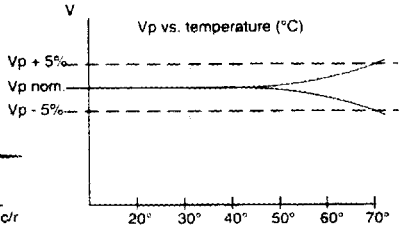
## output signals

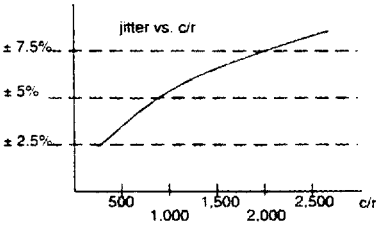


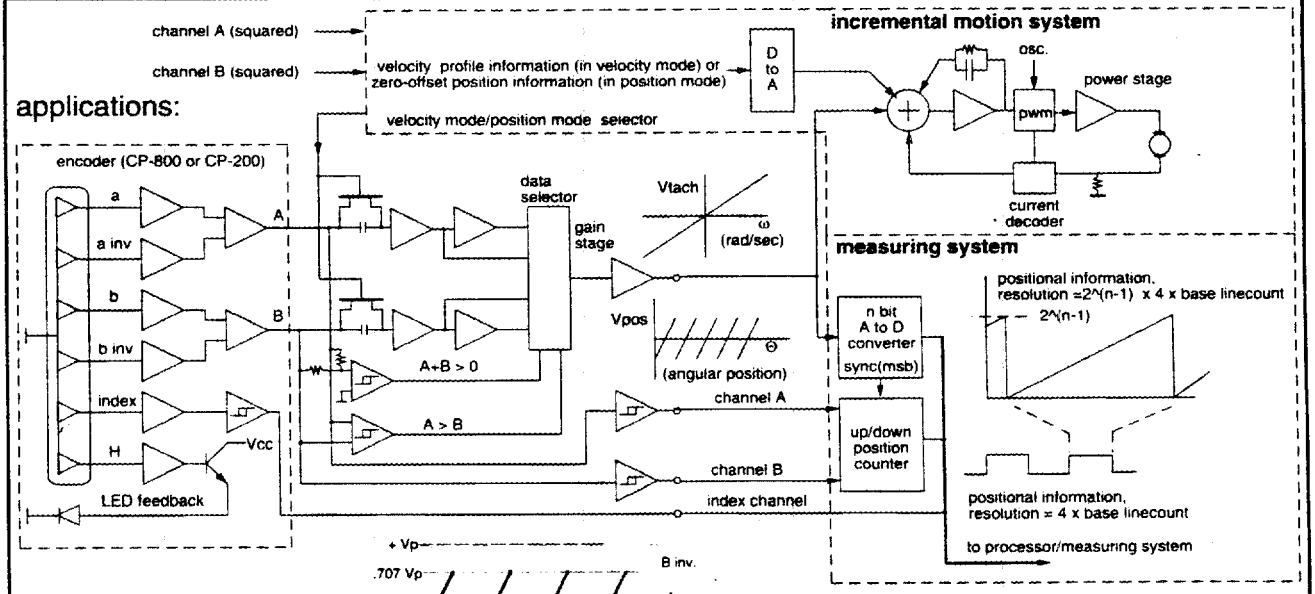



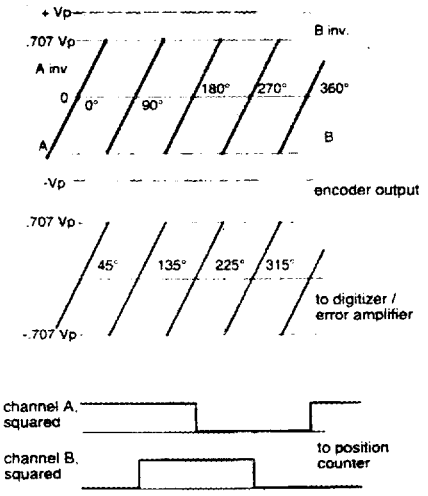




## applications:




The velocity extraction scheme shown requires a linear ramp with the 2% linearity point at or above 45° (electrical). Other extraction methods are possible that require perfect sine/cosine output waveforms. COPI encoders can be equipped with either a point source LED or a conventional LED to accomodate both triangular wave or sine/cosine waveform requirements.




supported motion control chips:

L 6515, SGS-Thomson, Vout = 2.6 Vpp centered at 2.8V,

L-290/292/292,SGS-Thomson, Vout =1 Vpp, zero-centered

For further technical support and conversion information, please contact the factory.

# CP-850-xxxx

incremental
shaft encoder

## Description

The CP-850 is a size 25, low cost housed encoder with resolution of up to 10,000 full A and B cycles per revolution (40,000 measuring steps).

The monolithic sensor array and integral LED stabilization yield superior performance over time and temperature.

### Ordering information:

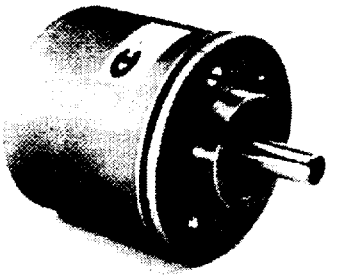
CP-850-(linecount)-(F=flange, S=servo mount)-(cable length in inch or cm).

## Features

- versatile
- linedriver outputs (MC 3487/26LS31)
- monolithic sensor array
- single servo controlled LED light source
- up to 10,000 counts per turn
- competitive pricing

## Applications

- Digital servo systems
- NC machine tools
- Instrumentation
- Robotics
- Measuring equipment
- Computer peripherals



### standard linecounts:

16,32,50,96,100,110,120,128,155,192, 200,210,220,240,254,256,280,288,300, 310,360,384,400,480,500,508,512,560, 576,600,720,768,800,850,960,1000,1152, 1200,1440,1700,2000,3600,3750,4000,7200, 7500, 10000 c/r.

Special linecounts and index configurations available on request.

## mechanical data

| | |
|---|---|
| shaft diameter: | .3745" / .3748" |
| shaft loading: | 40 lbs axial, 35 lbs radial |
| shaft runout: | .0005" T.I.R. |
| starting torque: | 1.5 oz.in max @20°C |
| shaft rotation: | continuous,reversible |
| slew speed: | 160 RPS |
| bearings: | ABEC 7,sealed |
| shaft material: | 416 stainless |
| housing material: | aluminum |
| cover material: | aluminum |
| bearing life: | manufacturer's specs |
| moment of inertia: | $4.1 \times 10^{-4}$ oz.in.sec$^2$ |
| weight: | approx. 13 oz |

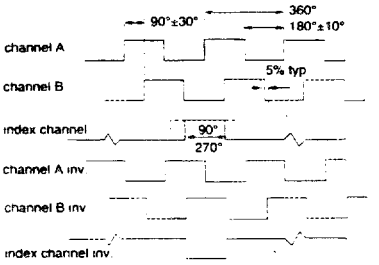
## electrical data

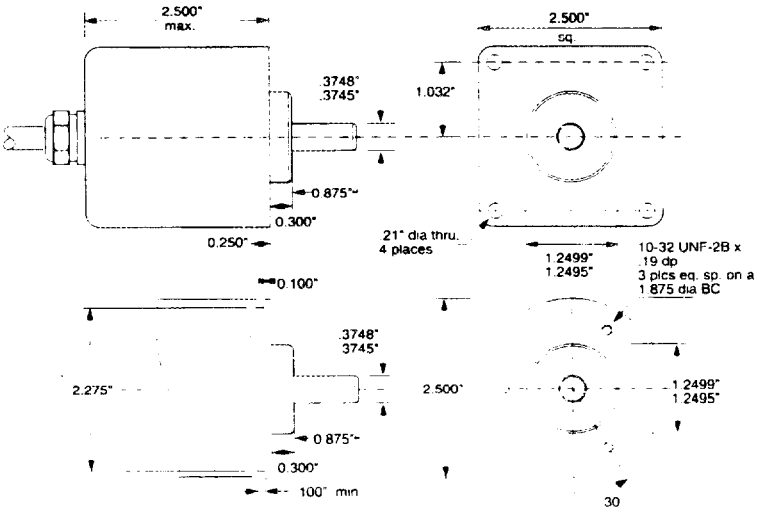
| | |
|---|---|
| code: | incremental |
| cycles per revolution: | up to 10,000 |
| power supply: | +5Vdc @ 50mA |
| output format: | A & B channel in quadrature,index |
| output: | linedriver |
| frequency response: | 150 KHz min. |

## environmental data

| | |
|---|---|
| temperature: | operating: -20°C to+90°C |
| shock: | 50 G's @ 11 ms |
| vibration: | 5-2,000 Hz @ 20 G's |
| humidity: | 98% without condensation |

## waveforms




### Wire color assignments:

| | |
|---|---|
| channel A | white/orange stripe |
| channel A inv. | orange/white stripe |
| channel B | blue/white stripe |
| channel B inv. | white/blue stripe |
| index channel | green/white stripe |
| index chan. inv. | white/green stripe |
| + 5Vdc | white/gray stripe |
| ground | gray/white stripe |
| chassis | cable shield |

for connector options,contact factory

# CP-850-12GC

absolute twelve bit
shaft encoder, Gray code

## Description

The CP-850-12GC is a size 25,12 bit Gray code housed encoder with outstanding stability. The single, intensity controlled light source and monolithic sensor array assure superior performance over a wide temperature range. Due to the efficient optical design, the cost of this unit is at a level normally associated with incremental encoders.

Ordering information:

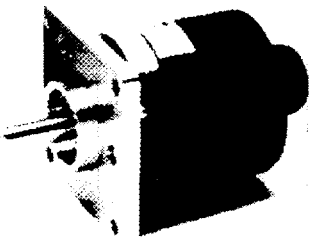
CP-850-12GC-(F=flange, S=servo mount)-(cable length in inch or cm). For connector, shaft and cable options, contact the factory.

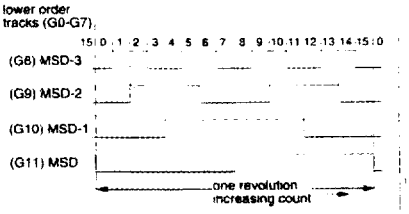
## Features

- no loss of position information on power down
- extremely reliable
- versatile / low power consumption
- TTL/CMOS compatible outputs
- monolithic sensor array
- single servo controlled LED light source
- competitive pricing

## Applications

- Digital servo systems
- Brushless DC motor positioning, commutation and proportional drive
- NC machine tools
- Instrumentation
- Robotics
- Measuring equipment
- Computer peripherals






waveforms

## mechanical data

shaft diameter: .3745" / .3748"
shaft loading: 40 lbs axial, 35 lbs radial
shaft runout: .0005" T.I.R.
starting torque: 1.5 oz.in max @20°C
shaft rotation: continuous,reversible
slew speed: 160 rev/sec²
bearings: ABEC 7,shielded
shaft material: 416 stainless
housing material: aluminum
cover material: aluminum
bearing life: manufacturer's specs
moment of inertia: $4.1 \times 10^{-4}$ oz.in.sec²
weight: approx. 13 oz

## electrical data

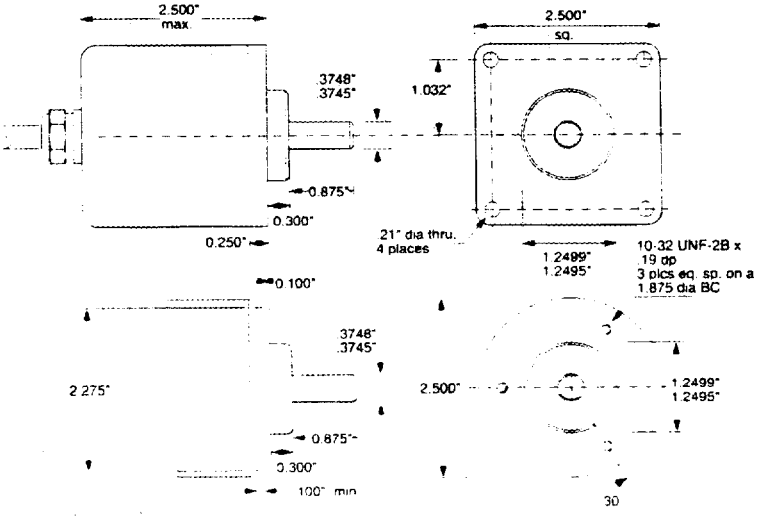
code: absolute Gray code
power supply: +5Vdc @ 75 mA
output format: 12 bit parallel
output: open collector with 4.7 kΩ pullup
frequency response: 100 Kcounts datarate max.

## environmental data

temperature: operating: -20°C to+90°C
shock: 50 G's @ 11 ms
vibration: 5-2,000 Hz @ 20 G's
humidity: 98% without condensation

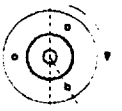
Gray code to natural binary conversion

| | |
|---|---|
| G0 | B0 |
| G1 | B1 |
| G2 | B2 |
| G3 | B3 |
| G4 | B4 |
| G5 | B5 |
| G6 | B6 |
| G7 | B7 |
| G8 | B8 |
| G9 | B9 |
| G10 | B10 |
| G11 direction select | B11 |




wire color assignments*

| | |
|---|---|
| G0 | black/white |
| G1 | brown/white |
| G2 | red/white |
| G3 | orange/white |
| G4 | yellow/white |
| G5 | green/white |
| G6 | blue/white |
| G7 | violet/white |
| G8 | grey |
| G9 | white |
| G10 | orange |
| G11 | yellow |
| + 5Vdc | red |
| ground | black |
| chassis | green |



cw rotation of shaft for inceasing count

*for connector options,contact factory

# CP-850-12NB

absolute twelve bit
shaft encoder, binary

## Description

The CP-850-12NB is a size 25,12 bit binary code housed encoder with outstanding stability. The single, intensity controlled light source and monolithic sensor array assure superior performance over a wide temperature range. Due to the efficient optical design, the cost of this unit is at a level normally associated with incremental encoders.

### Ordering information:

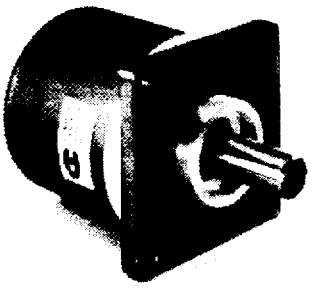
CP-850-12NB-(F=flange, S=servo mount)-(cable length in inch or cm). For connector, shaft and cable options, contact the factory.

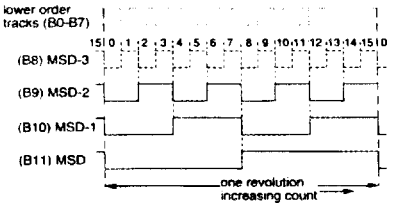
## Features

- no loss of position information on power down
- extremely reliable
- versatile / low power consumption
- TTL/CMOS compatible outputs
- monolithic sensor array
- single servo controlled LED light source
- competitive pricing

## Applications

- Digital servo systems
- Brushless DC motor positioning, commutation and proportional drive
- NC machine tools
- Instrumentation
- Robotics
- Measuring equipment
- Computer peripherals






waveforms

## mechanical data

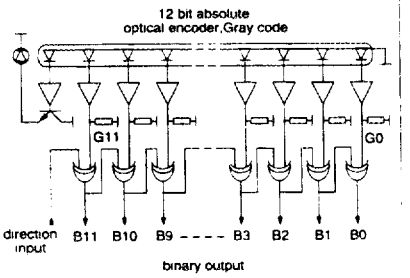
shaft diameter: .3745" / .3748"
shaft loading: 40 lbs axial, 35 lbs radial
shaft runout: .0005" T.I.R.
starting torque: 1.5 oz.in max @20°C
shaft rotation: continuous,reversible
slew speed: 160 rev/sec²
bearings: ABEC 7,shielded
shaft material: 416 stainless
housing material: aluminum
cover material: aluminum
bearing life: manufacturer's specs
moment of inertia: $4.1 \times 10^{-4}$ oz.in.sec²
weight: approx. 13 oz

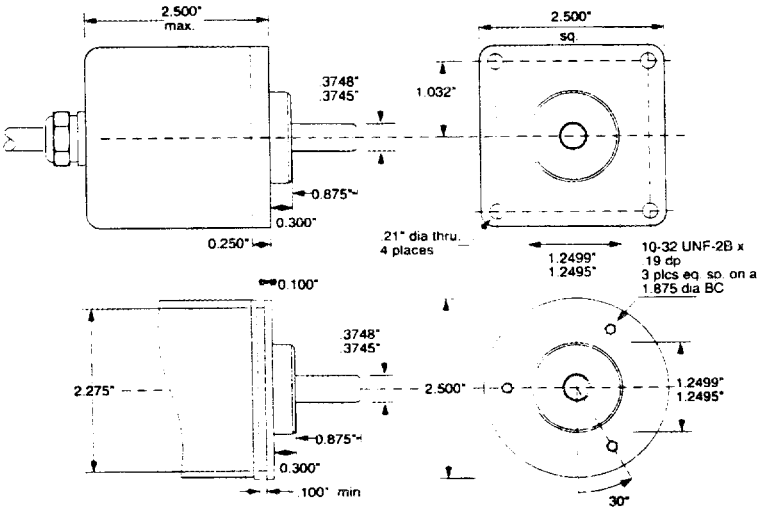
## electrical data

code: absolute Gray code
power supply: +5Vdc @ 75 mA
output format: 12 bit parallel
output: TTL / CMOS compatible
frequency response: 100 Kcounts datarate max.

## environmental data

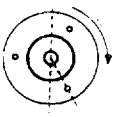
temperature: operating: -20°C to+90°C
shock: 50 G's @ 11 ms
vibration: 5-2,000 Hz @ 20 G's
humidity: 98% without condensation




## wire color assignments*

| | |
|---|---|
| B0 | black/white |
| B1 | brown/white |
| B2 | red/white |
| B3 | orange/white |
| B4 | yellow/white |
| B5 | green/white |
| B6 | blue/white |
| B7 | violet/white |
| B8 | grey |
| B9 | white |
| B10 | orange |
| B11 | yellow |
| + 5Vdc | red |
| ground | black |
| chassis | shield |
| direction select | green |



cw rotation of shaft for increasing count at direction select input signal low

*for connector options,contact factory

# CP-850-12DIS

absolute twelve bit encoder
with integral display

## Description

The CP-850-12DIS is a size 25,12 bit Gray code absolute housed encoder with an integral 4 digit decimal display. The standard version provides a 12 bit parallel output with optional RS 232 or RS 422 serial outputs, formatted either as BCD or Gray code.Standard display formats are 3600 or 4096 positions per revolution.Standard power supply is 5Vdc, 8 Vdc through 40 Vdc optional.

### Ordering information:

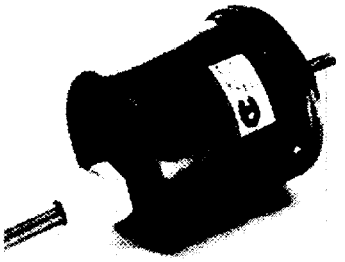
CP-850-12DIS-(3600 or 4096)-(RS 232 or RS422, if desired)-(F-flange or S-servo mount)-(cable length in inch)-(5 for 5 Vdc, 8 for 8 through 40 Vdc).For further options,contact the factory.

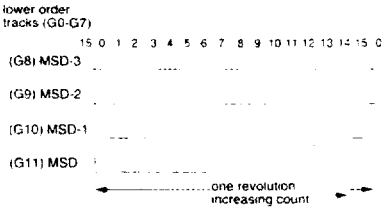
## Features

- integral 4 digit LED display, viewable from the rear of the encoder
- excellent accuracy and stability
- TTL/CMOS compatible outputs
- monolithic sensor array
- single servo controlled LED encoder light source
- competitive pricing

## Applications

- Digital servo systems
- NC machine tools
- Instrumentation
- Robotics
- Measuring equipment
- Computer peripherals






waveforms

## mechanical data

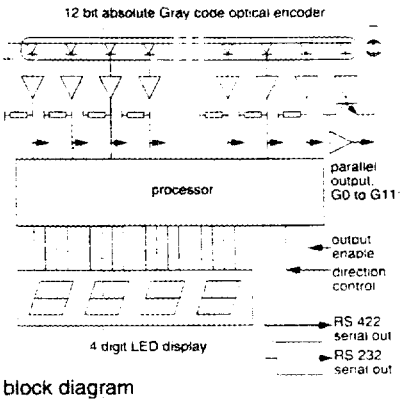
| | |
|---|---|
| shaft diameter: | .3745" / .3748" |
| shaft loading: | 40 lbs axial, 35 lbs radial |
| shaft runout: | .0005" T.I.R. |
| starting torque: | 1.5 oz.in max @20°C |
| shaft rotation: | continuous,reversible |
| slew speed: | 160 rev/sec² |
| bearings: | ABEC 7,shielded |
| shaft material: | 416 stainless |
| housing material: | aluminum |
| cover material: | aluminum |
| bearing life: | manufacturer's specs |
| moment of inertia: | $4.1 \times 10^{-4}$ oz.in.sec² |
| weight: | approx. 13 oz |

## electrical data

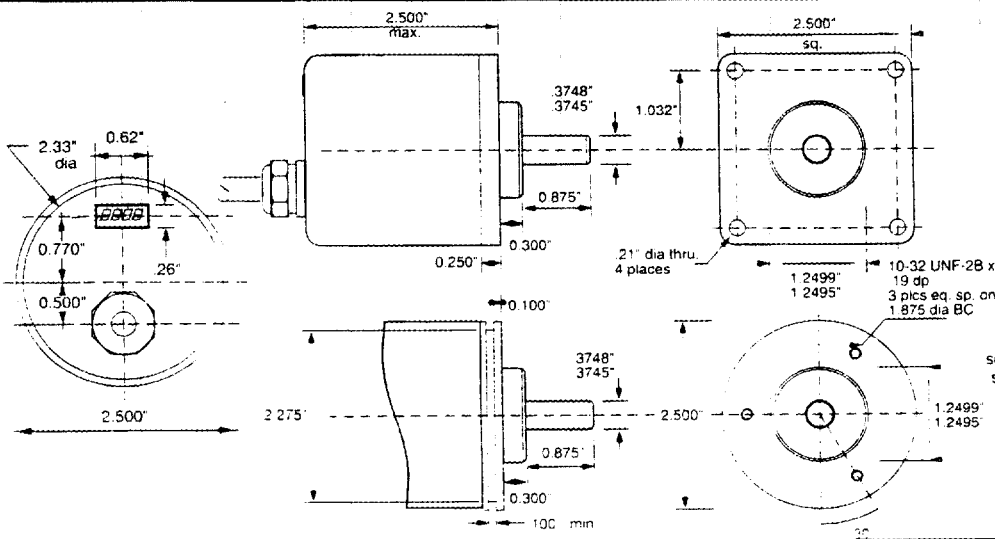
| | |
|---|---|
| code: | absolute Gray code |
| power supply: | +5Vdc @ 400 mA<br>8 - 40 Vdc optional |
| output format: | 12 bit parallel |
| output: | open collector<br>without pull-ups |
| frequency response: | 100 Kcounts max. |

## environmental data

| | |
|---|---|
| temperature: | operating: -20°C to+90°C |
| shock: | 50 G's @ 11 ms |
| vibration: | 5-2,000 Hz @ 20 G's |
| humidity: | 98% without condensation |




block diagram




### wire color assignments*

| | |
|---|---|
| G0 | black/white |
| G1 | brown/white |
| G2 | red/white |
| G3 | orange/white |
| G4 | yellow/white |
| G5 | green/white |
| G6 | blue/white |
| G7 | violet/white |
| G8 | grey |
| G9 | white |
| G10 | orange |
| G11 | yellow |
| + 5Vdc | red |
| ground | black |
| chassis | shield |
| direction select | green |
| enable | grey/white |
| serial out RS 232/422 | orange |
| serial out RS 422 not | yellow |

cw rotation of shaft for increasing count at direction select input signal low.

*for connector options contact factory

# CP-850-12ANx

optical potentiometer,
12 bit resolution

## Description

The CP-850-12ANx is a high performance optical potentiometer specifically designed for applications where accuracy and reliability are prime considerations.The unit is suited in applications where repetitive motion over a small angle makes mechanical potentiometers unreliable.The package form factor is identical to that of a size 25 encoder. Standard output is 0-10 Vdc, optional current output of 4 - 20 mA over 360 mechanical degrees (optional: 180° and 90°).

Ordering information:

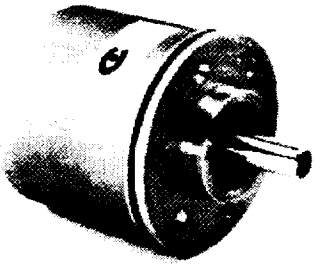
CP-850-12AN (90,180 or 360)-(F=flange, S=servo mount)-(cable length in inch or cm).

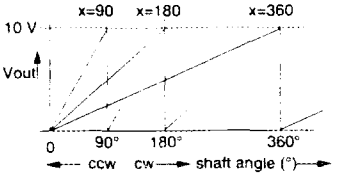
## Features

- rugged package
- monolithic sensor array
- single servo-controlled LED light source
- competitive pricing

## Applications

- mechanical potentiometer replacement
- medical equipment
- machine tools
- laboratory instrumentation
- factory automation
- robotics
- flow metering
- valve position control






| options: | x=90 | x=180 | x=360 |
|---|---|---|---|
| rotation | 90° | 180° | 360° |
| resolution | 5.28 arcmin | 5.28 arcmin | 5.28 arcmin |
| mV/step | 9.77 mV | 4.88 mV | 2.44 mV |

## mechanical data

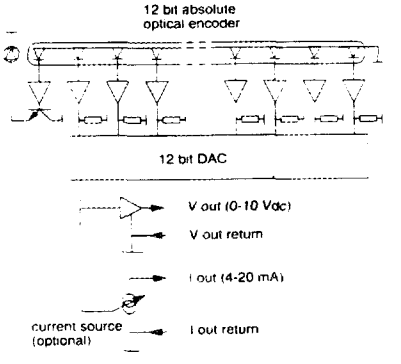
| | |
|---|---|
| shaft diameter: | .3745" / .3748" |
| shaft loading: | 40 lbs axial, 35 lbs radial |
| shaft runout: | .0005" T.I.R. |
| starting torque: | 1.5 oz.in max @20°C |
| shaft rotation: | continuous,reversible |
| slew speed: | 160 rev/sec² |
| bearings: | ABEC 7,shielded |
| shaft material: | 416 stainless |
| housing material: | aluminum |
| cover material: | aluminum |
| bearing life: | manufacturer's specs |
| moment of inertia: | $4.1 \times 10^{-4}$ oz.in.sec² |
| weight: | approx. 13 oz |

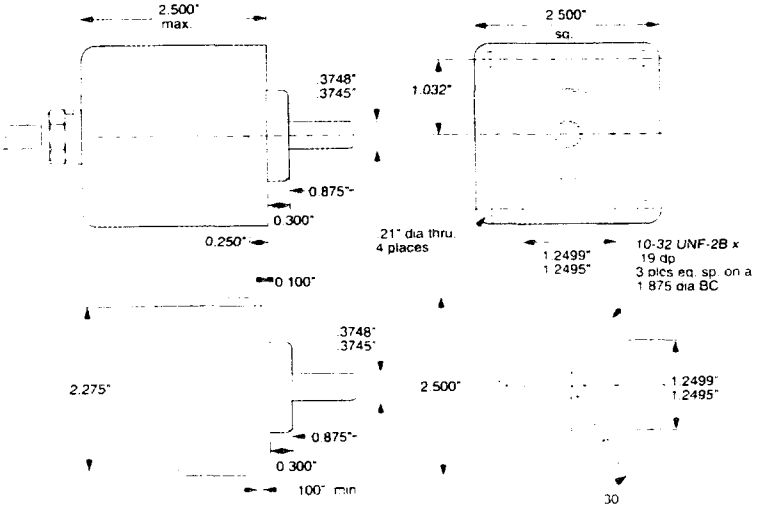
## electrical data

| | |
|---|---|
| resolution: | 12 bit |
| power supply: | + 12.6 to 16 Vdc @ 100 mA max |
| output: | 0 -10 Vdc, 4 - 20 mA (opt) |
| direction control input: | TTL/CMOS (5 V) |

## environmental data

| | |
|---|---|
| temperature: | operating: -20°C to+90°C |
| shock: | 50 G's @ 11 ms |
| vibration: | 5-2,000 Hz @ 20 G's |
| humidity: | 98% without condensation |




### wire color assignments*

| | |
|---|---|
| I out | blue / white stripe |
| I out return | white / blue stripe |
| V out | orange / white stripe |
| V out return | white / orange stripe |
| direction input | green / white stripe |
| + 15 V dc | white / grey stripe |
| n/c | white / brown stripe |
| ground | gray / white stripe |
| chassis | cable shield |

cw rotation of shaft for inceasing current or output voltage at direction control bit=0, decreasing at direction control bit=1

*for connector options,contact factory

# CP-855-xxxx

incremental/absolute shaft encoder

## Description

The CP-855 is a size 25 housed encoder with resolution of up to 7,500 counts/revolution incrementally and four independent variable outputs for commutating brushless DC motors, custom index patterns etc. The same unit (CP-8550-xxx , size: 2.2" diameter, 1" high) is available as a kit encoder to be no-charge factory-mounted as an integral part of a customer supplied motors.Absolute commutation accuracy is better than 30 arcminutes.

### Ordering information:

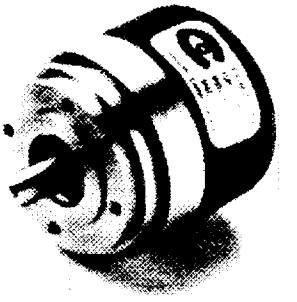
Please contact the factory.

## Features

- accurate commutation for BDC motors
- high current sink (300 mA) capacity open collector outputs (ULN 2803), optional linedrivers for all channels
- monolithic sensor array
- single servo controlled LED light source
- up to 7,500 counts per turn
- competitive pricing

## Applications

- Brushless DC motor feedback
- NC machine tools
- Instrumentation
- Robotics
- Measuring equipment
- Computer peripherals



### standard linecounts (xxxx = incremental c/r):

1,000 c/r incremental + single index + three bit commutation signal for an eight pole, three phase motor.
Linecounts from 100 to 7,500 c/r and custom commutation/index configurations tooled on request. Please contact factory with linecount, number of poles and phases.

## mechanical data

| | |
|---|---|
| shaft diameter: | .3745" / .3748" |
| shaft loading: | 40 lbs axial, 35 lbs radial |
| shaft runout: | .0005" T.I.R. |
| starting torque: | 1.5 oz.in max @20°C |
| shaft rotation: | continuous,reversible |
| slew speed: | 160 RPS |
| bearings: | ABEC 7,sealed |
| shaft material: | 416 stainless |
| housing material: | aluminum |
| cover material: | aluminum |
| bearing life: | manufacturer's specs |
| moment of inertia: | $4.1 \times 10^{-4}$ oz.in.sec$^2$ |
| weight: | approx. 13 oz |

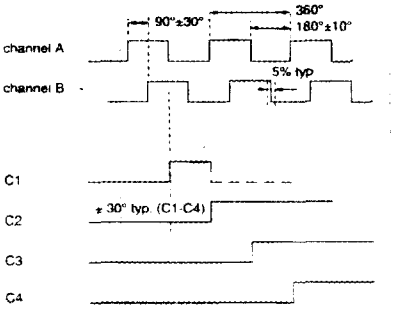
## electrical data

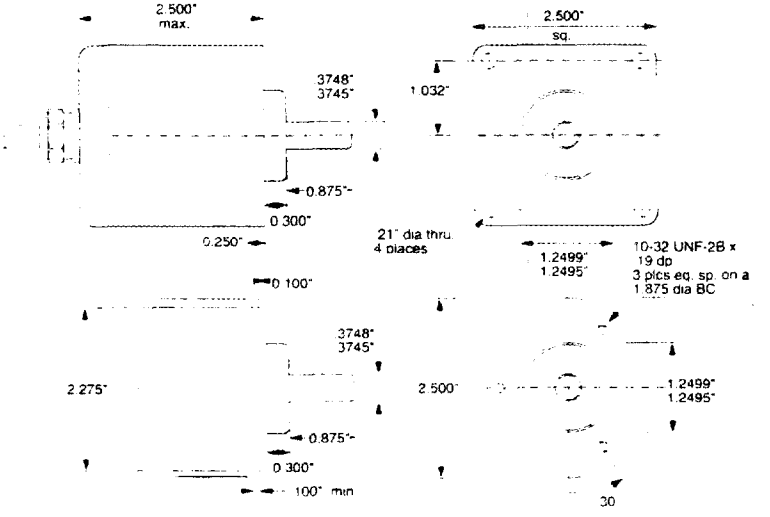
| | |
|---|---|
| code: | incremental/absolute |
| cycles per revolution: | up to 7,500 |
| power supply: | +5Vdc @ 50mA |
| output format: | A & B quadrature, C1-C4 channels |
| output: | open collector |
| frequency response: | 100 KHz |

## environmental data

| | |
|---|---|
| temperature: | operating: -20°C to+90°C |
| shock: | 50 G's @ 11 ms |
| vibration: | 5-2,000 Hz @ 20 G's |
| humidity: | 98% without condensation |

## waveforms




### Wire color assignments:

| | |
|---|---|
| channel A | white/orange stripe |
| channel B | orange/white stripe |
| channel C1 | blue/white stripe |
| channel C2 | white/blue stripe |
| channel C3 | green/white stripe |
| channel C4 | white/green stripe |
| + 5Vdc | white/gray stripe |
| ground | gray/white stripe |
| chassis | cable shield |

for connector options,contact factory

# CP-850-22MT

absolute 22 bit
multiturn shaft encoder

## Description

The CP-850-22MT is a size 25, low cost 22 bit absolute multiturn housed encoder with outstanding temperature characteristics.

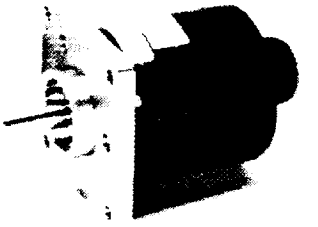
The basic resolution per turn is 12 bits (4096 positions) at 1024 turns, standard coding for the output is natural binary or Gray code.A reset input is provided to electronically set the position to zero.Information is formatted as either a serial RS 422 datalink or as a paralell 22 bit word. The serial format is a string of 6 words, organized with one startbit, three word ID bits,five databits (LSB first) and one stopbit. The last word is a "breakword".

## Features

- small size, up to 1024 c/r encoded
- paralell or serial output
- monolithic sensor array
- single servo controlled LED light source
- competitive pricing

## Applications

- Digital servo systems
- NC machine tools
- Instrumentation
- Robotics
- Measuring equipment
- Moving belt positioning



## Ordering information:

CP-850-22MT- _ - _ -

natural binary:NB
Gray code:GC

5 Vdc:5
12 Vdc:12

paralell output:P
serial output:S

## mechanical data

| | |
|---|---|
| shaft diameter: | .3745" / .3748" |
| shaft loading: | 40 lbs axial, 35 lbs radial |
| shaft runout: | .0005" T.I.R. |
| starting torque: | 1.5 oz.in max @20°C |
| shaft rotation: | continuous,reversible |
| slew speed: | 160 rev/sec² |
| bearings: | ABEC 7,shielded |
| shaft material: | 416 stainless |
| housing material: | aluminum |
| cover material: | aluminum |
| bearing life: | manufacturer's specs |
| moment of inertia: | 4.1x10⁻⁴oz.in.sec² |
| weight: | approx. 13 oz |

## electrical data

| | |
|---|---|
| code: | Gray code or natural binary |
| power supply: | +5 or 12 Vdc @ 150 mA |
| output format: | paralell or serial |
| frequency response: | 50 K counts datarate max.(paralell),131Kbaud (serial) maximum |

## environmental data

| | |
|---|---|
| temperature: | operating and storage: -20°C to +85°C |
| shock: | 50 G's @ 11 ms |
| vibration: | 5-2,000 Hz @ 20 G's |
| humidity: | 98% RH without condensation |

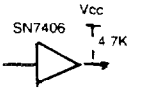
## signals

paralell:

- bit 0 through 22
- reset input
- "data valid" signal
- chassis
- power (5/12 Vdc)
- ground

serial:

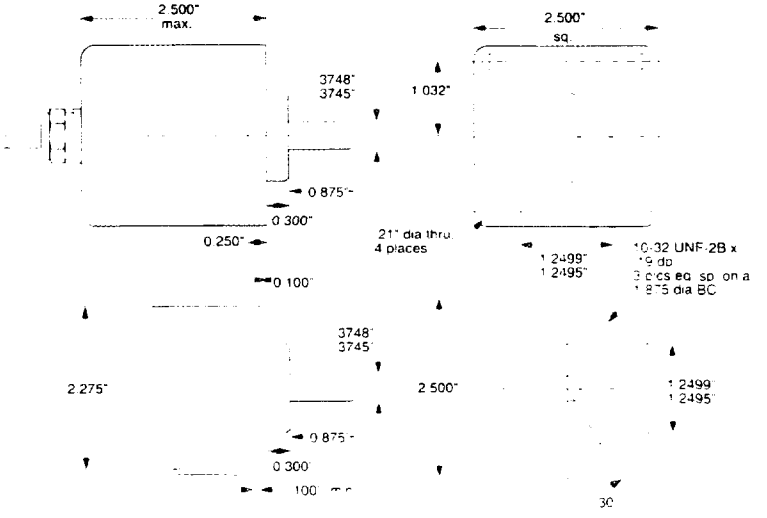
- EIA 422 output
- EIA 422 complementary output
- reset input
- chassis
- power (5/12 Vdc)
- ground




all output signals:

current source: 40 mA max
current sink: 1 mA (Vcc = 5 Vdc)
current sink: 2.5 mA (Vcc = 12 Vdc)

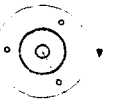
reset input: 1 TTL load




unterminated cable output*:

paralell output: 37 conductor cable,insulation displacement connector compatible

serial output: 15 conductor, shielded round cable



cw rotation of shaft for inceasing count

*for connector options contact factory

# CP-850-HCE-xxx

high-count incremental shaft encoder

## Description

The CP-850-HCE is a size 25 incremental encoder.The high resolution allows accurate contol of slow and ultra-slow motion as well as positioning with a 10 arcsecond repeatability. Proprietary electronics and an efficient optical design makes this encoder an affordable alternative to devices currently on the market. A "kit" version is available (CP-8500-HCE) for mounting on customer supplied motors/torquers.

Ordering information:

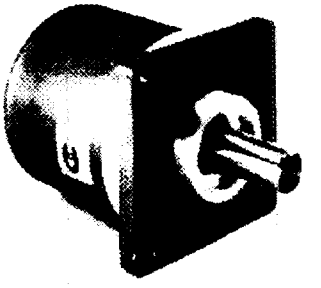
CP-850-HCE-(F=flange, S=servo mount)-(cable length in inch or cm).

## Features

- up to 524.288 measuring steps per revolution (131.072 full A and B cycles)
- linedriver outputs (MC 3487/26LS31)
- monolithic sensor array
- single servo controlled LED light source
- competitive pricing

## Applications

- digital servo systems
- NC machine tools
- instrumentation
- robotics
- measuring equipment
- computer peripherals
- scanners



## standard linecounts:

16,000 (xxx=016): 16,384 (xxx=163)
32,000 (xxx=032): 32,768 (xxx=327)
64,000 (xxx=064):65536 (xxx=655).
128,000 (xxx=128) & 131,072 (xxx=131)
full A and B cycles per revolution.

Special linecounts and index configurations available on request.

## mechanical data

| | |
|---|---|
| shaft diameter: | .3745" / .3748" |
| shaft loading: | 40 lbs axial. 35 lbs radial |
| shaft runout: | .0005" T.I.R. |
| starting torque: | 1.5 oz.in max @20°C |
| shaft rotation: | continuous.reversible |
| slew speed: | 160 RPS |
| bearings: | ABEC 7.sealed |
| shaft material: | 416 stainless |
| housing material: | aluminum |
| cover material: | aluminum |
| bearing life: | manufacturer's specs |
| moment of inertia: | $4.1 \times 10^{-4}$ oz.in.sec$^2$ |
| weight: | approx. 13 oz |

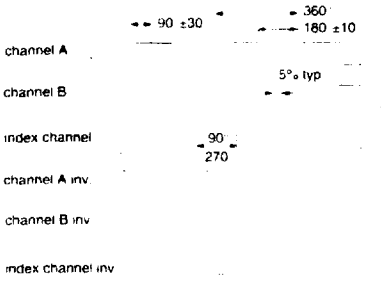
## electrical data

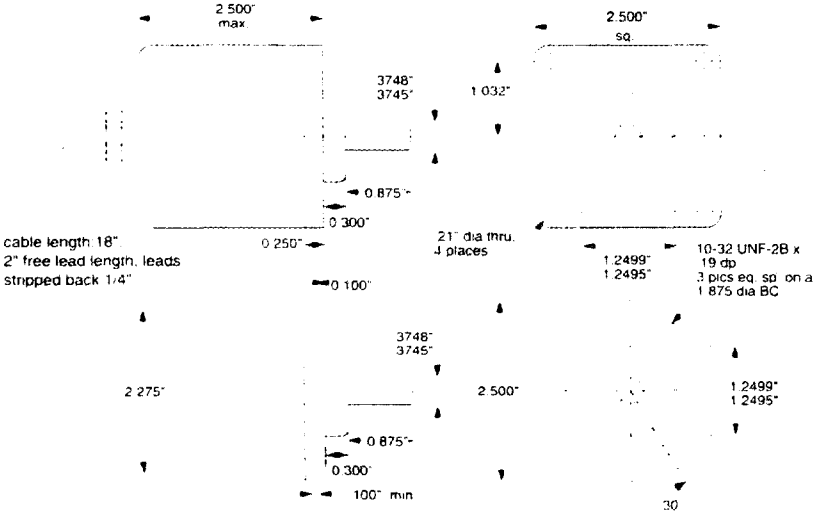
| | |
|---|---|
| code: | incremental |
| cycles per revolution: | up to 131,072 |
| power supply: | +5Vdc @ 250mA |
| output format: | A & B channel in quadrature,index |
| output: | linedriver |
| max. bitrate: | 750 kHz |

## environmental data

| | |
|---|---|
| temperature: | operating: -20°C to+90°C |
| shock: | 50 G's @ 11 ms |
| vibration: | 5-2,000 Hz @ 20 G's |
| humidity: | 98% without condensation |

## waveforms




## Wire color assignments:

| | |
|---|---|
| channel A | white/orange stripe |
| channel A inv. | orange/white stripe |
| channel B | blue/white stripe |
| channel B inv. | white/blue stripe |
| index channel | green/white stripe |
| index chan. inv. | white/green stripe |
| + 5Vdc | white/gray stripe |
| ground | gray/white stripe |
| chassis | cable shield |

for connector options,contact factory

# *FD22I-R1*

fiberoptic rotary
incremental encoder

## Description:

The size 22 FD22I-R1 series fiberoptic encoder is a cost effective solution for speed and position sensing in situations where high ambient temperature, EMI or RFI are a concern. COPI standard fiberoptic connectors are used for flexibility in configuring cables for specific applications. For multi-axis applications, refer to the FDMS series.

## Features:

- heavy duty fiberoptic construction
- standard fiberoptic connectors
- electrical signal outputs
- resolution of up to 2000 cycles
- 200 °C operating temperature

## Applications:

- machine tools
- servo systems
- coordinate measurements
- radar antennas
- ground support systems
- automatic weight logging

## Options:

- metric versions
- heavy duty cables
- cable extensions
- high temperature (up to 300 °C)
- multi-axis electronics
- long distance interface
- analog / digital outputs
- fiber optic data link

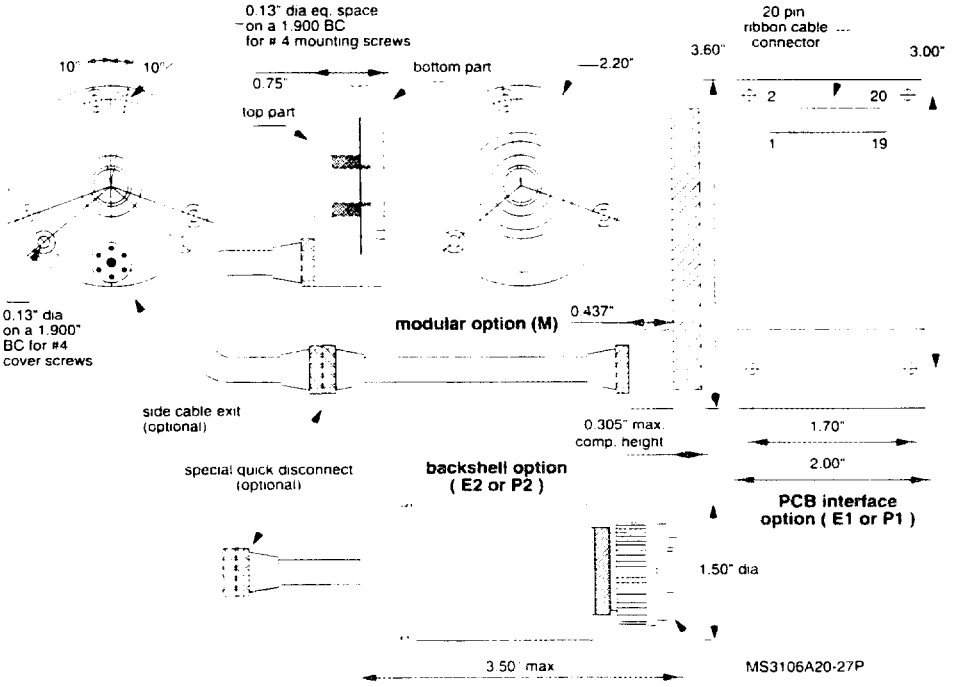
## Other COPI products:

- Absolute encoders
- High resolution encoders
- Hollow-shaft encoders
- Modular encoders

Avalable linecounts:

16,50,96,100,110,120,128,155,192, 200,210,220,240,254,256,280,288,300, 310,360,384,400,480,500,576,600,720, 800,850,1000,1100,1800, 2000 c/r.

Special linecounts and index configurations available on request.




| 20 pin ribbon cable pin assignments | |
|---|---|
| 1 | index channel |
| 2 | clock * |
| 3 | channel A |
| 4 | index select * |
| 5 | channel B |
| 7 | channel A select * |
| 10 | channel B select * |
| 11 | up/down * |
| 13 | + V |
| 16 | ground |

* used for factory alignment

| MS3106A20-27P connector pin assignments | |
|---|---|
| A | channel A |
| B | channel A inverted |
| C | channel B |
| D | channel B inverted |
| E | index channel |
| F | index channel inverted |
| G | channel A select * |
| H | channel B select * |
| I | index select * |
| J | clock * |
| K | up/down * |
| L | + V |
| M | ground |
| N | chassis |

* used for factory alignment

| FD22I | output format | style | – | resolution | mounting | electro optics | – | shaft/hub diameter | shaft seal | – | cable length | temp. option | – | temp. rating electronics | R1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

BI = A & B channels
BZ = A B & I chann

M =modular
H =housed
T=through shaft
S = hollow shaft

resolution in number of cycles per revolution

blank=modular or no adapter
R = 2.2" round
F = 2.5" flange
S = 2.5" servo

E1 = open collector PCB interface
E2 = open collector backshell
P1 = line driver PCB interface
P2 = line driver in backshell

70 = -10 C to + 70 C
85 = -55 C to + 85 C

A = interlocking metal
B = high-temp interlocking metal

cable lenghth in feet

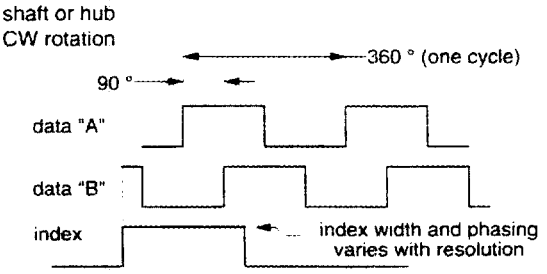
blank = no shaft seal, Y = shaft seal

| | | hub I.D.+ .0003 -.0000 | shaft O.D.+ .0000 - .0003 |
|---|---|---|---|
| 250 | M.H.T.S | .2498 | .2497 |
| 312 | M | .3123 | .3122 |
| 375 | M.H.T.S | .3748 | .3747 |

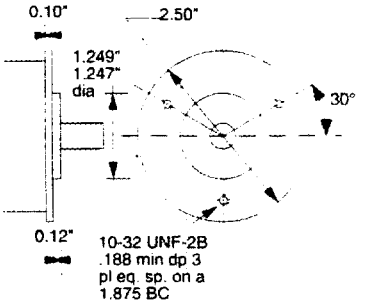
**ordering information**

| general specifications | FD 22 I--M | FD 22I--H/T | FD 22I--S |
|---|---|---|---|
| resolution | 1 to 1600 cycles | 1 to 2000 cycles | |
| output | A & B channels standard. A.B and Index (optional) | | |
| format options | open collector, line driver | | |
| freq. response | 100 kHz | | |
| operating temp. sensor | 200°C<br>300°C for high-temperature option | | |
| operating temp. electronics | - 10° to + 70°C for standard electronics.<br>-55°C to + 85°C optional | | |
| mounting options | 2.2" dia standard | 2.2" dia standard<br>2.5" flange optional<br>2.5" servo optional | |
| shaft / hub size | .375" max hub I.D...375 max. shaft OD | | |
| starting torque | n/a | 1.0 oz.in max. 2.5 oz.in max. with shaft seal | |
| shaft loading | n/a | 10 lbs axial and radial | |
| weight | 5 oz. max | 9 oz. max | |
| cable option | up to 20 feet | | |
| shock-vibration | 50 G's for 11 ms ; 50 to 2000 Hz @ 20 G's | | |

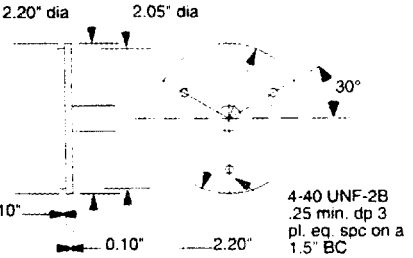
| electrical specifications | open collector | line driver |
|---|---|---|
| input power | 5Vdc±5%@100 mA | 5Vdc±5%@140 mA |
| output circuitry | TTL/CMOS compatible w/2K pull-ups | 26LS31 or equivalent RS-422 compatible |
| output connector | MS3106A20-27P / 20 pin ribbon | |
| light source | GaAlAs or GaAs LED | |
| source life | 100,000 hrs | |

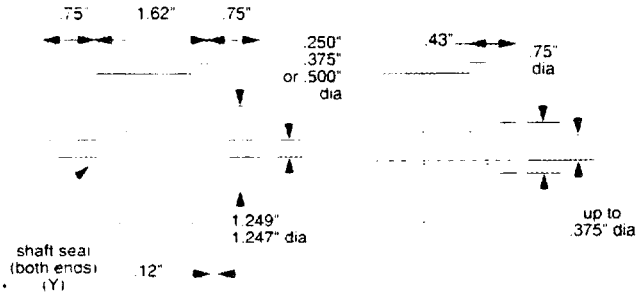



**2.5" servo option (S)**

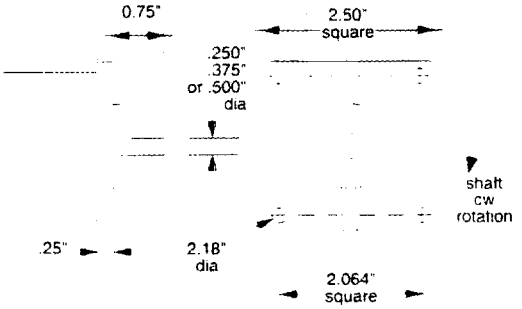



**2.2" round option (R)**




**through shaft option (T)** **hollow shaft option (S)**



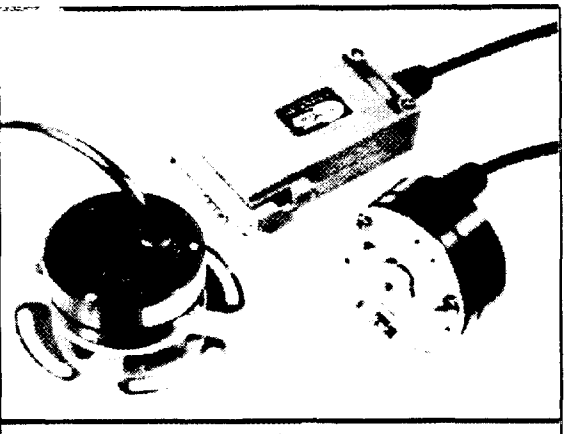

**housed option (H)** **2.5" flange option (F)**

# FD22I----R6

incremental hollow shaft
fiberoptic encoder

## Description

The FD22---IR6 hollow shaft fiberoptic encoder was specifically designed for environments with high levels of electrical noise. The compact, dual bearing and flexmount configuration provides a cost-effective solution to position sensing for brushless DC motors, DC motors and stepper motors.Flexible mounts are available for NEMA 23, 34 and 42 size motor housings.The electronics are remotely mounted in a DB-25P backshell and linked to the transducer via a fiberoptic cable. The cable and transducer are immune to all sources of EMI/RFI radiation.Position data is provided as two quadrature signals and an optional once per revolution Index marker. Standard output circuitry is open collector with internal pullup resistors. Complementary outputs are provided. The illumination source is a solid-state light emitting diode.



## mechanical data

| | |
|---|---|
| hub diameter: | 0.250",0.312" & 0.375" dia. |
| moment of inertia: | 4.1 x 10 $^{-4}$ oz.in.sec $^{2}$ |
| starting torque: | 1.0 oz.in. max |
| shaft loading: | 6 lbs axial and radial |
| weight (sensor): | 9 oz max. |
| cable construction: | PVC (std),metal(opt) |
| mounting options: | NEMA 23 (F1),NEMA 34 (F2),NEMA 42 (F2) |

## Avalable linecounts:

16,50,96,100,110,120,128,155,192,200,210,220,240,254,256,280,288,300,310,360,384,400,480,500,576,600,720,800,850,1000,1100,1800 & 2000 c/r.

Special linecounts and index configurations available on request.

## electrical data

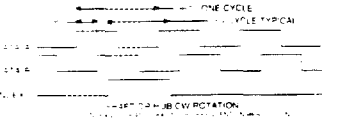
| | |
|---|---|
| input power: | 5 Vdc ± 5%@ 100 mA max (8-17 Vdc optional) |
| output cicuitry: | TTL/CMOS compatible open collector w. 470Ω pull-ups (5 Vdc 88C30 linedriver optional) |
| output connector: | DB-25P |
| light source: | Ga Al As LED |
| illumination life: | 100,000 hrs min. |
| output: | A & B standard, A,B and Index optinal |
| format options: | open collector |
| frequency response: | 50 KHz (data channels and index) |

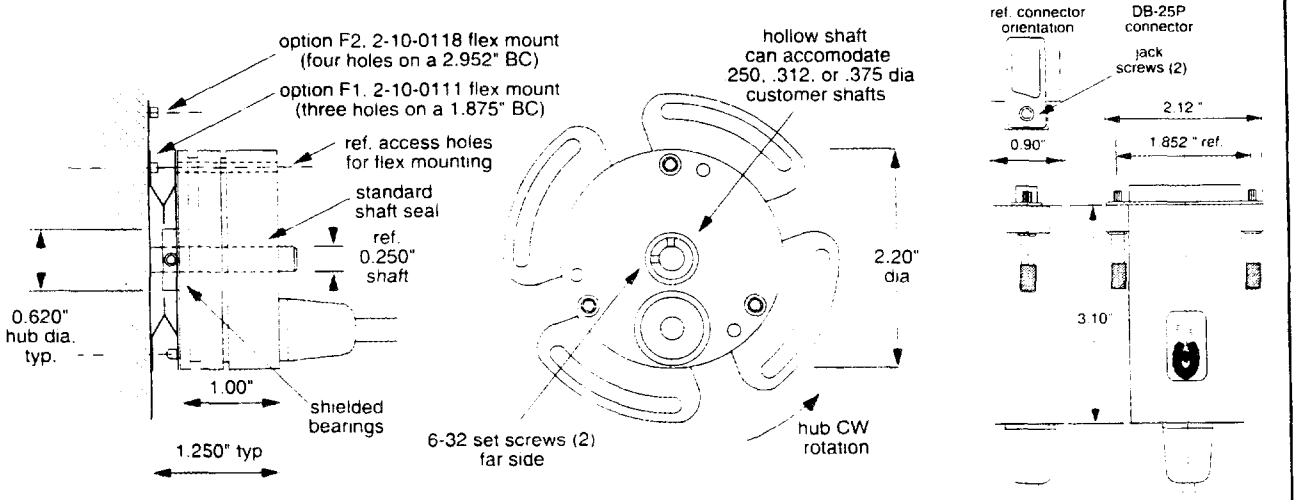
## environmental data

| | |
|---|---|
| operating temperature: | sensor: -25 to + 85 °C<br>electronics: -10 to + 70 °C |
| shock/vibration: | 50 g's for 11 msec, 5 to 2000 Hz @ 20 g's |

## DB-25P backshell pin assignments

| | | |
|---|---|---|
| 1: n/c | 10: ground* | 18: n/c |
| 2: 5 Vdc out | 11: ground* | 19: n/c |
| 3: n/c | 12: n/c | 20: n/c |
| 4: 5 Vdc in | 13: n/c | 21: data B |
| 5: data A inv. | 14: n/c | 22: data B inv. |
| 6: ground* | 15: n/c | 23: data I inv |
| 7: ground* | 16: ---- (pull-up common) | 24: n/c |
| 8: ground* | | 25: data I |
| 9: ground* | 17: data A | * connected to backshell |





## MODEL NUMBER CONSTRUCTION CHART and ORDERING INFORMATION

FD22I [Output Format | Style] – [Resolution | Mounting] – [Hollow Shaft Inside Dia] – [Cable Length | Cable Type] – [Voltage] R6

BI = A & B open collector
BZ = A, B, & Index open collector
BILD A & B line driver
BZLD = A, B, & Index line driver

S = Hollow Shaft

(For other styles, consult factory)

* Resolution in number of cycles per revolution

F1 = Flex Mount for NEMA 23 (1.875 BC)
F2 = Flex Mount for NEMA 34 & NEMA 42 (2.952 BC)

5 = 5Vdc
15 = 8-17 Vdc

blank = PVC Jacket
A = Interlocking Metal

Total cable length (in feet)

| | HUB I.D. +.0003 -.0000 |
|---|---|
| 250 | .2498 |
| 312 | .3123 |
| 375 | .3748 |

# Fiberoptic Encoders

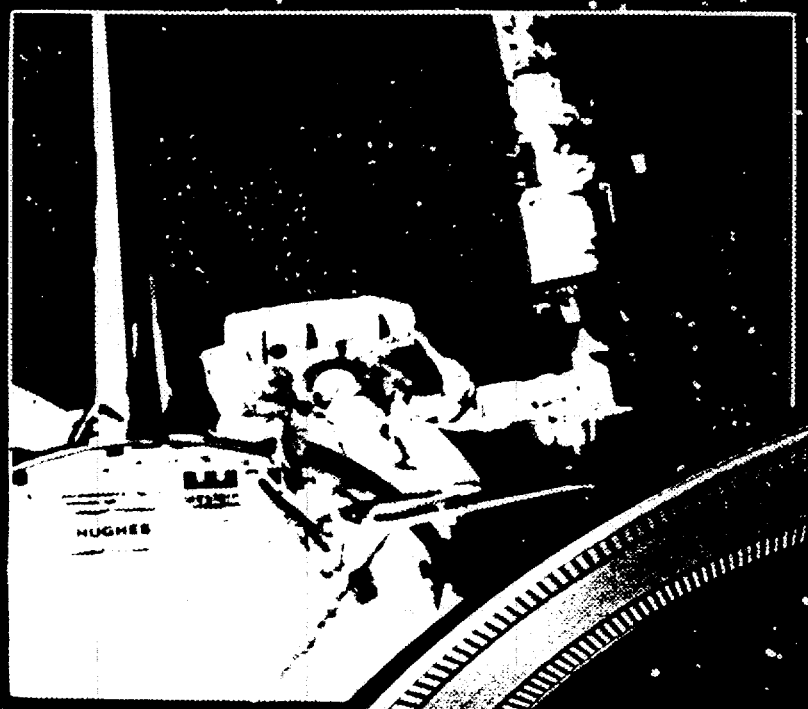
Combining proprietary optical encoder technology and rugged, multi-fiber arrays, COPI offers a line of position sensors with unsurpassed performance characteristics including:

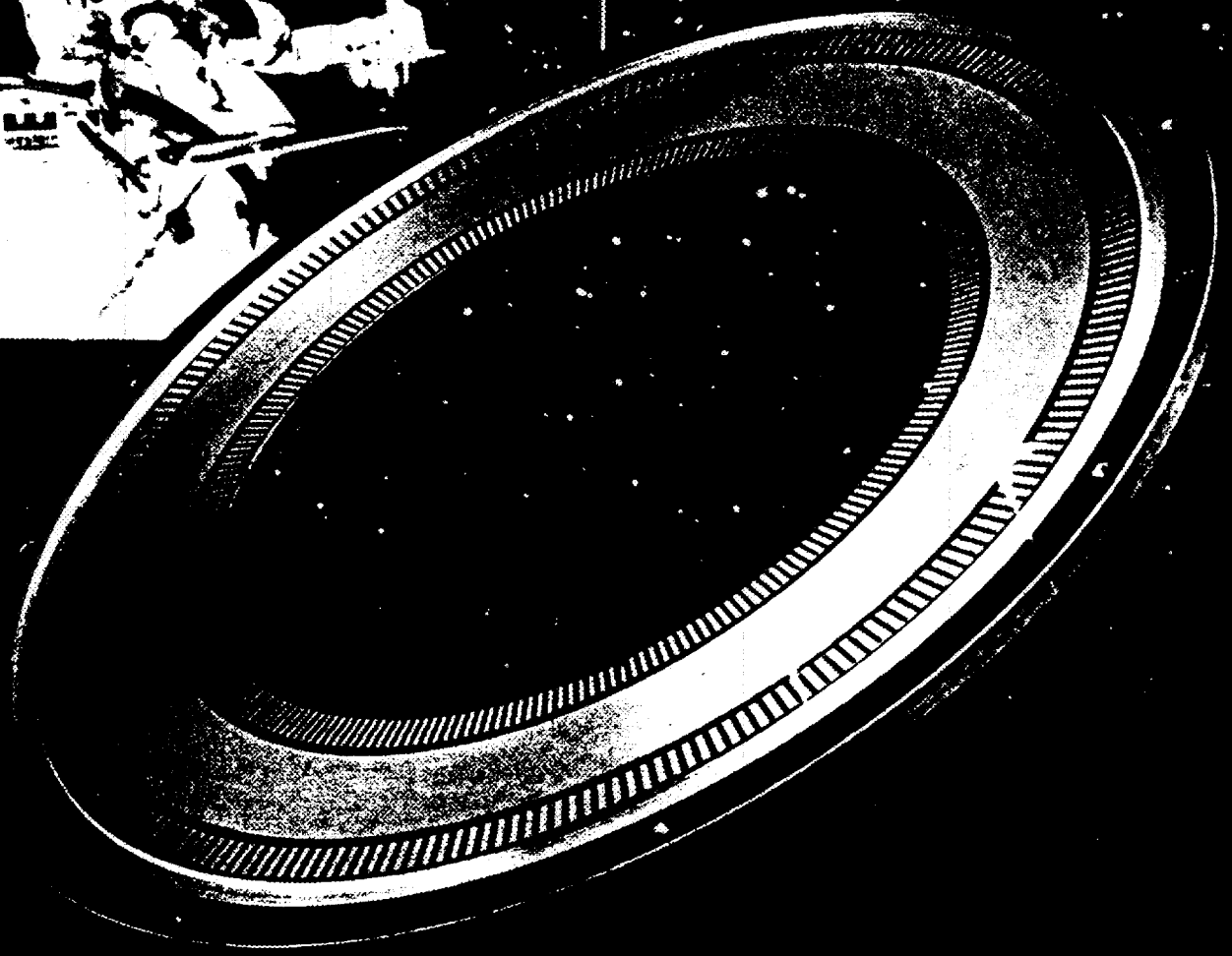
- small size
- serviceability
- moderate cost
- EMI / RFI proof
- inherent redundancy
- design & systems flexibility
- high temperature operation ( up to 450°C )
- extreme reliability (passive read-head design)
- intrinsically safe for explosion-proof equipment

The multi-fiber optical bundles relocate the temperature and noise sensitive opto-electronics to a place where it can be protected from harsh environments such as a NEMA enclosure or connector backshell.The multi-fiber construction is inherently redundant and increases reliability. In addition, the electronics package becomes less critical to manufacture and will be therefore less costly.

The result is a position sensor ideal for applications such as commutating motors in PWM and vector drive systems,high-temperature valve position control in jet engines and aircraft braking systems. The technology can be combined with wavelength multiplexing (WDM) for multi-sensor applications.

Special configurations include the Fiber Optic Position Modulator designed to wotrk with standard (100/140) telecommunication grade fiber over long distances (100 m+). The FDMS series is a multi-axis system ideal for applications requiring more than one position sensor. This offers cost savings over individual encoding devices by using common electronics with multiple read heads. Another configuration is the FD 100 for operation in confined, high-temperature areas. For remore applications, position information can be linked to programmable controllers via a 4-20 mA loop, RS-422 or 232 serial interface or fiberoptic datalink.

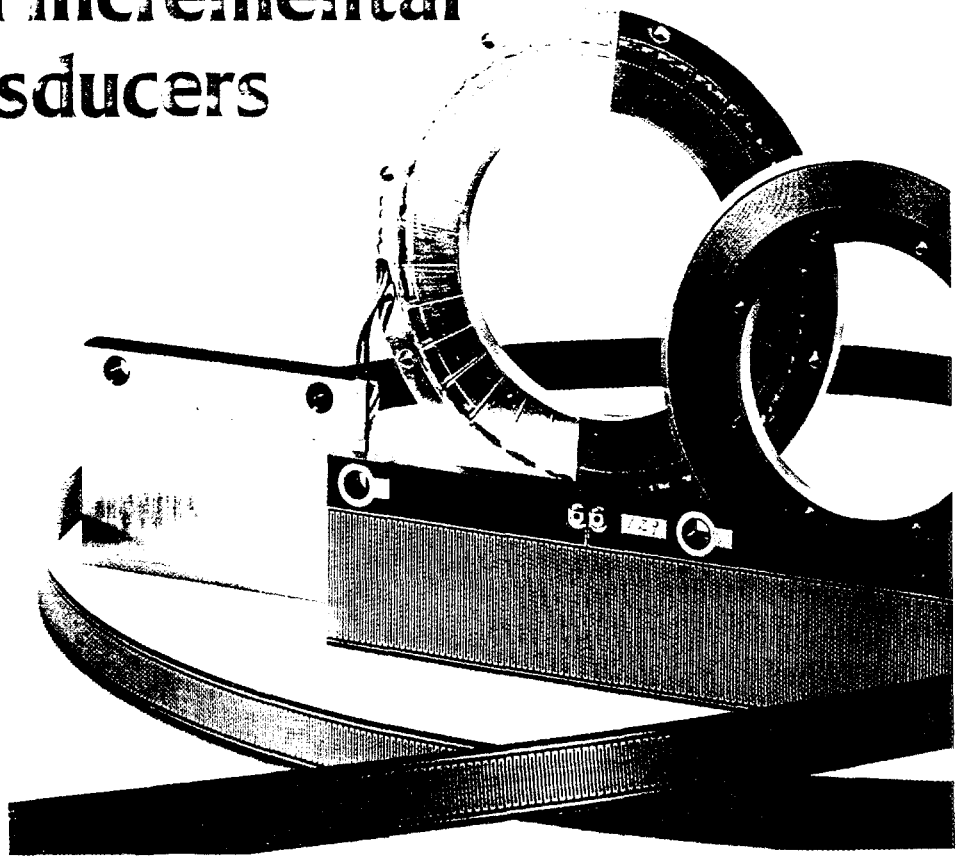


# FARRAND INDUCTOSYN®
# Absolute and Incremental Position Transducers
*for military and aerospace applications*

FARRAND CONTROLS

# FARRAND INDUCTOSYN®
# Absolute and Incremental Position Transducers



INDUCTOSYN® position transducers are extremely rugged scale elements used for accurate measurement of angular or linear displacement. They are currently used in many military, aerospace, satellite, radar, training, navigational, and fire control systems, where their electrical output signals drive numerical readout displays, generate computer input data, and provide servo feedback signals. INDUCTOSYN transducers, combining accuracy and reliability, have, for over 30 years, been depended upon in critical defense and aerospace equipment for successful performance in harsh field environments.

## TYPICAL DEFENSE AND AEROSPACE APPLICATIONS

INDUCTOSYN transducers can be designed to be unaffected by dust, oil films, vapors, sea water, light, radiation, extreme pressure, temperature from 10°K to 150°C, and other harsh environments. They have operated at full accuracy for extended periods in space, immersed in liquid nitrogen, in strong magnetic fields, and immersed in 200 meters of sea water.

**Altazimuth pedestals, gimbals, and yokes for mounting theodolites, optical trackers, laser fire control directors,** radar and radiotelescope antennas. Examples range from the Very Large Array (VLA) radiotelescope to compact, field transportable radars. Because rotary INDUCTOSYN transducers are flat and compact, new designs based on them have achieved dramatic reductions in envelope size and simplified mechanical design as well as improved accuracy.

**Turrets and pedestals for guns and missile launchers.** Fixed, naval, vehicular, and tank applications. Resistance to repeated shock and vibration is vital. Size of the structures involved in some cases has inspired methods of wrapping flexible INDUCTOSYN tape transducers around cylindrical components to achieve partial or full (360°) readout.

**Space rated applications.** Position readouts of scanners, radiometers, and antennas are similar to ground based applications. Akin to robotics, the remote manipulator (RMS) arm of the space shuttle uses a total of six special 3" (75 mm) rotary INDUCTOSYN transducers in the shoulder, elbow, and wrist joints for servo feedback control.

**Manufacturing and Inspection.** Rotary INDUCTOSYN transducers are widely used in gyro test tables and rate tables as well as in rotary inspection tables and machine tools. One application uses a one piece, 96' (29.3m) linear tape transducer to control drilling and riveting of aircraft wing spars.

**COVER PHOTO:**
The shoulder, elbow, and wrist joints of the Remote Manipulator System arm installed in the Space Shuttle contain a total of six INDUCTOSYN rotary transducers.
Built by Spar Aerospace Ltd., Toronto, Canada under contract to the National Research Council of Canada and NASA.

## RUGGED, RELIABLE, AND ACCURATE

INDUCTOSYN transducers operate on principles of inductive or capacitive coupling between conductive patterns bonded to rigid substrates of steel, titanium, or virtually any other structural material.

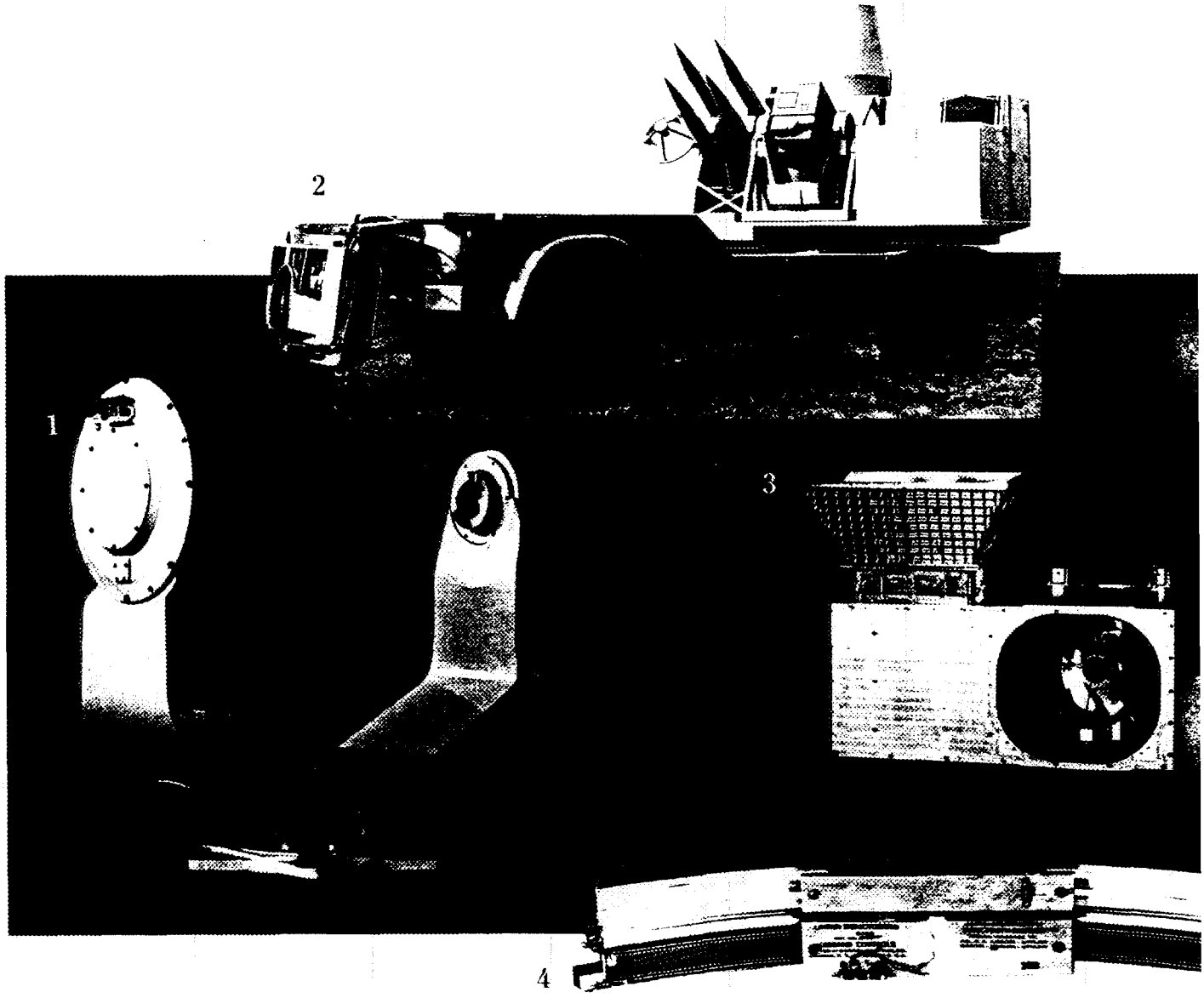
Since they contain no moving parts or active electronic components, INDUCTOSYN transducers are extremely reliable. Noncontacting elements provide zero wear, and maintain original accuracy indefinitely. Attached directly, they eliminate backlash and coupling errors while tolerating practical levels of assembly misalignment.

Extreme accuracy is achieved by averaging the signal output over many cycles of precise scale patterns.

Accuracy achieved for several models:

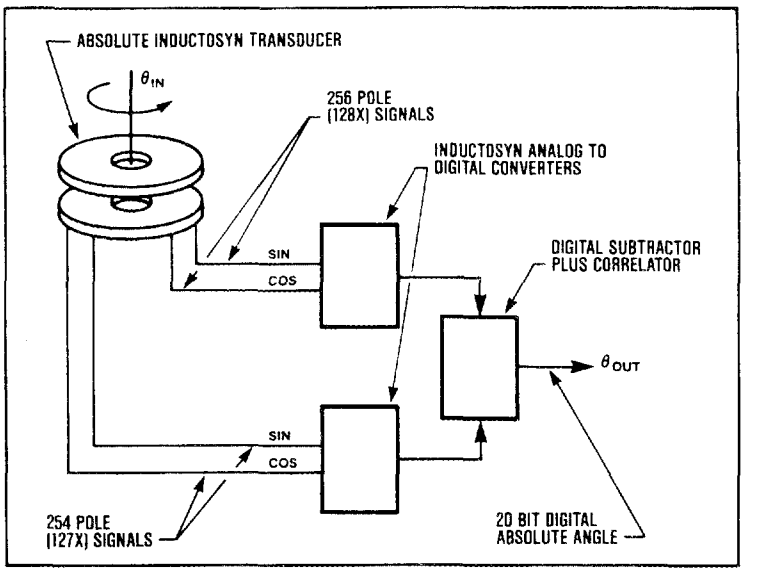
| | ACCURACY |
|---|---|
| **Rotary Types** | |
| 3" (75 mm) dia., 360 pole (180x) | ± 3 arc sec |
| 4" (100 mm) dia., 512 pole (256x) | ± 2 arc sec |
| 7" (175 mm) dia., 720 pole (360x) | ± 1 arc sec |
| 12" (300 mm) dia., 720 pole (360x) | ± 0.5 arc sec |
| 12" (300 mm) dia., 1024 pole (512x) | ± 1 arc sec |
| **Linear Types** | |
| 10" (250 mm) bar scale | ± 0.000040" (± 0.001 mm) |
| Tape, to 100' (30 meters) or more | 0.000100"/foot T.I.R. (0.008 mm/meter T.I.R.) |
| Adjustable Linear INDUCTOSYN scale, maximum travel 115" (2920 mm) | Length errors associated with the scale can be virtually zero over full length. Adjustment is limited by accuracy of standard and resolution of readout or numerical control system. |

Resolution is a function of INDUCTOSYN analog to digital converters available from Farrand or other manufacturers.
EXAMPLE: A 1024 pole (512x) rotary INDUCTOSYN transducer has $2^9$ cycles. Interfaced to a $2^{12}$ bit INDUCTOSYN analog to digital converter yields a system with $2^{21}$ bits of resolution equivalent to 0.62 arc sec.

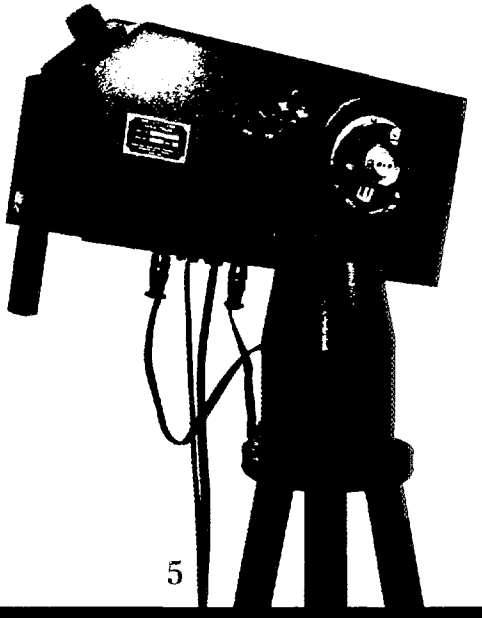


## ABSOLUTE INDUCTOSYN POSITION TRANSDUCERS

provide immediate, precise position information without resetting or passing through home position after power outages and other disruptions. They are supplied in several forms, one speed and multispeed, and N/N-1 speed. Incremental transducers can also be supplied with an index or once per revolution marker output via a separate scale element or embedded Hall effect devices.




Dual tracking INDUCTOSYN analog to digital converters develop separate outputs from concentric 128 and 127 cycle per revolution scale patterns. Digital subtraction converts the difference between the tracks (1 cycle per revolution) to absolute digital angle output. Similar techniques can be applied to absolute linear transducers and to tape INDUCTOSYN transducers wrapped around dual diameters.



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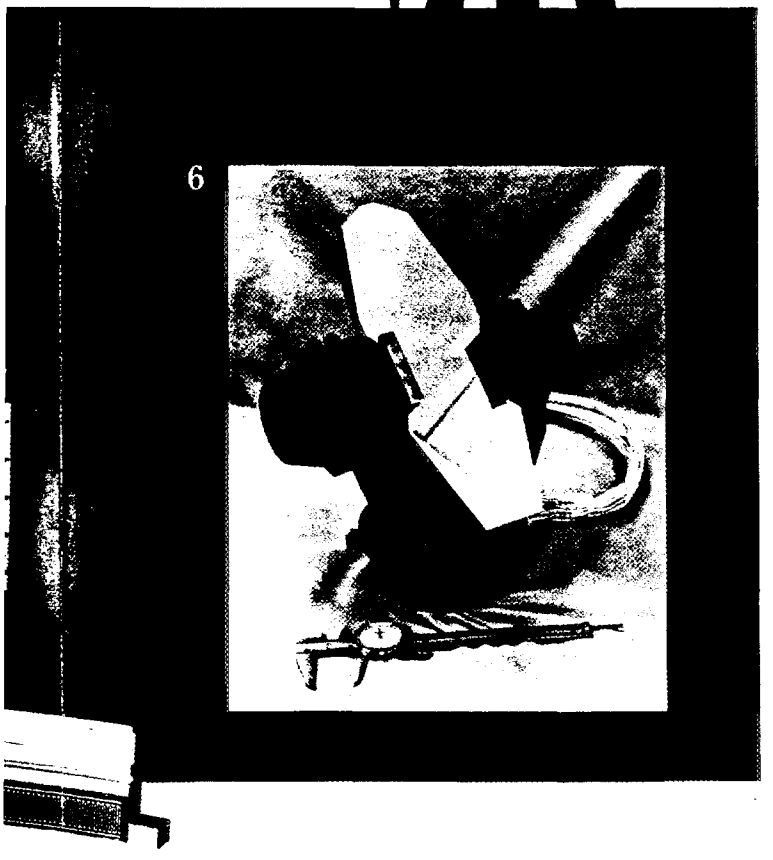
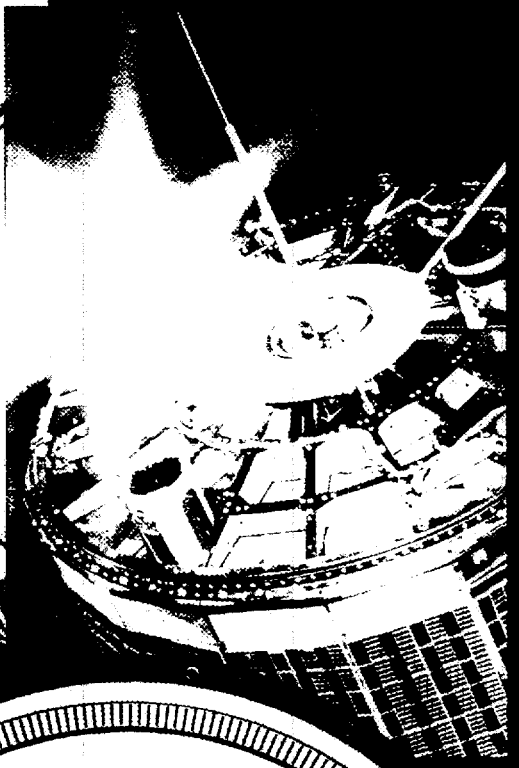
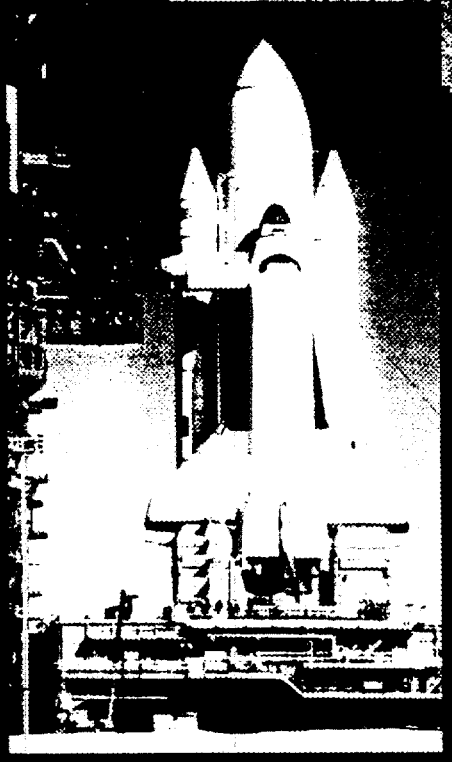
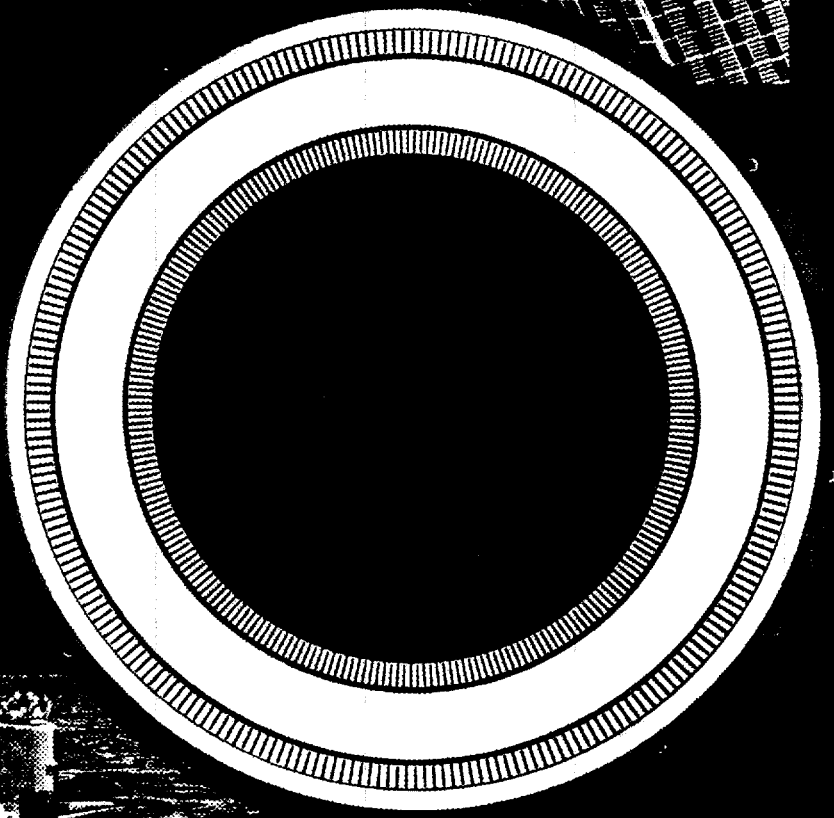


6

1. This yoke frame tracking mount contains two direct drive motors and INDUCTOSYN rotary transducers for precision azimuth and elevation drive.
   Type 459, built by Rademec Defense Systems, Ltd., Chertsey, Surrey, England
2. The Rapier Laserfire low level air defense system uses INDUCTOSYN transducers to transmit target tracking and missile launch angles.
   Built by British Aerospace Dynamics Group, Stevenage, Herfordshire, England
3. 3″ (75 mm) rotary INDUCTOSYN transducers provide ±4 arc second accuracy for scan mirror drive servos, in the Very High Resolution Radiometer, now operating in orbit aboard the Indian National Satellite (INSAT).
   Built by ITT Aerospace/Optical Division
4. Unique application of flexible tape to concave surface for measurement of turret angle. 25° span. Integral coupling transformer eliminates flexible wires or slip rings to turret.
5. 3″ (75 mm) rotary INDUCTOSYN transducers to transmit bearing and elevation information from laser range finder trainer to fire control simulator.
   Built by INVERTRON SIMULATED SYSTEMS Ltd., Burgess Hill, West Sussex, England RH 9TN
6. INDUCTOSYN rotary transducers transmit pointing angles in this gimballed mirror mount, a typical application in space or on the earth.
   Built by Ball Aerospace, Aerospace Systems Division, Boulder, Colorado







Typical applications for
Rotary INDUCTOSYN® transducers.

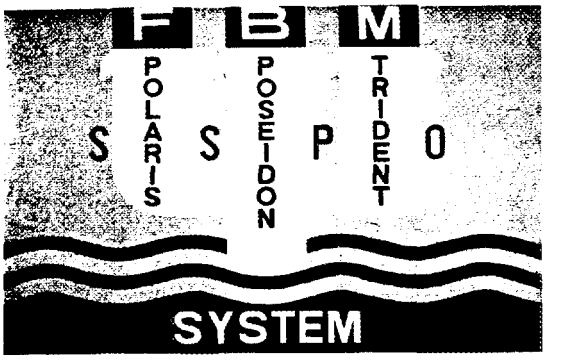
## DESIGNS TO MEET SPECIFIC REQUIREMENTS

INDUCTOSYN transducers can be designed to provide any combination of accuracy and operating features and to withstand virtually any environment. Single speed and multispeed rotary transducers can be provided for both absolute and incremental systems. Linear transducers can be provided with any inch, metric, or arbitrary scale calibration.

Many special features can be provided. These include auxiliary output signals such as end-of-travel, hall effect devices embedded in the substrate for once-per-revolution markers, and complete hybrid preamplifiers embedded in the substrate. Complete rotary assemblies can be provided, including precision bearings.

Substrates may be virtually any metal or engineering material, including steel, stainless steel, aluminum, titanium, beryllium, glass, and fiberglass laminate. Linear transducer patterns may be bonded to flexible spring steel, aluminum, or fiberglass tapes that can be supported in tension or wrapped around cylindrical parts. Subject to practical size and configuration limitations and material compatibility, scale patterns may be bonded directly to user parts.

Last, but not least, one of our standard models may satisfy your needs, as they have for thousands of other users.




This flag was presented to Farrand Controls for outstanding achievements in the Fleet Ballistic Missile program.

### Excerpt from letter presenting POLARIS - POSEIDON - TRIDENT flag to Farrand Controls

"...you made significant contributions in providing INDUCTOSYN® posiiton transducers for inertial navigation equipment, thereby contributing materially to the success of the Fleet Ballistic Missile Weapon System development and production program....."

Sincerely yours,

GLENWOOD CLARK
Rear Admiral, U.S. Navy
Director, Strategic Systems Projects

## INTERFACE TO YOUR EQUIPMENT

The analog output signals of INDUCTOSYN transducers are converted to digital form for many applications. Hybrid electronic conversion packages designed for military service conditions are available from several sources.

Typical INDUCTOSYN analog to digital converters provide all excitation signals, and divide each scale increment (e.g. 0.5°, 0.1", 1 mm, etc.) by 1000, 2000, or other convenient factor. Digital output resolution can thus be 0.0005 degree per bit, for example, taking full advantage of the inherent transducer accuracy. Some converters also provide electronically switchable data conversions such as inch/metric, binary/decimal, and decimal degree/arc seconds.

## FOR MORE INFORMATION

**Call (914) 761-2600 to discuss your needs with our sales applications engineers. They can draw on more than thirty years of experience to recommend the most practical approach to your problem, and help you evaluate tradeoffs among accuracy, environmental constraints, cost, and manufacturing methods.**


**FARRAND CONTROLS**

**FARRAND CONTROLS**
DIVISION OF RUHLE COMPANIES, INC.
99 WALL STREET • VALHALLA, NY 10595-1447
TEL: (914) 761-2600 • TELEX 646640 • FAX: (914) 761-0405

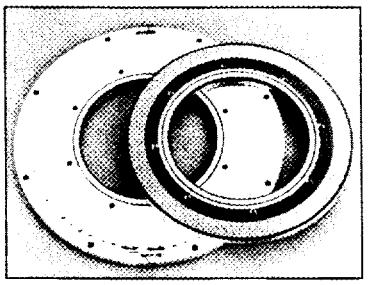


PRINTED IN USA
TMD/1012

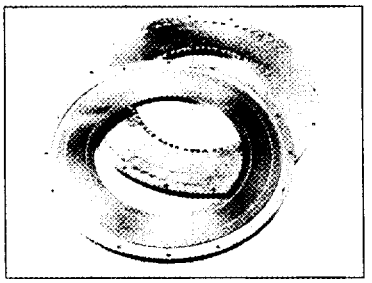
# Inductosyn® Position Transducers

**Inductosyn transducers provide absolute and incremental positioning information accurate to ±40 microinches, ±0.5 arc second, or better.**

## Rotary Inductosyn Transducers

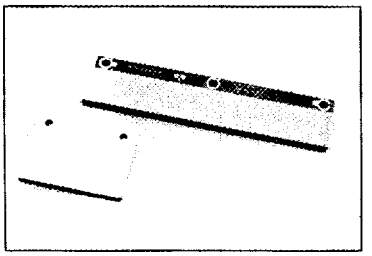


**Incremental**



**Absolute**

## Linear Inductosyn Transducer



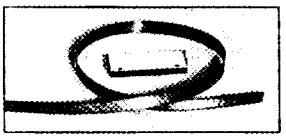
**Scale and Slider**

Inductosyn transducers consist of two noncontacting, inductively coupled elements which can be directly attached to the fixed and moveable sections of the user's equipment. They provide positioning information to digital readout displays, CNC or other controllers, or provide servo feedback signals.

Rugged and reliable, our position transducers operate anywhere, even under extreme conditions—vibration, temperature from 10°K to 160°C, shock, high pressure, vacuum, and dust or oil films. Choose off-the-shelf or custom designs to solve absolute and incremental positioning requirements.

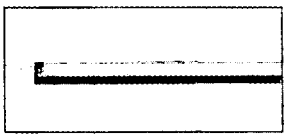
## Additional Standard Linear Inductosyns

### Tape Scales



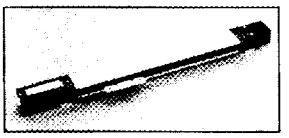
Tape scales provide economical, easily installed one piece scales. Lengths to 120 ft (36M) or more can be supplied. They can be mounted horizontally or vertically. Obtain information on hard to measure travel lengths in long bed metal cutting.

### Adjustable Scales



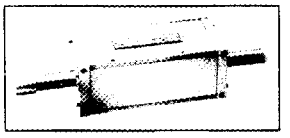
Adjustable scales are one piece bars that can be adjusted after installation to virtually eliminate errors over their full length, limited only by the accuracy of the user's measurement equipment. Lengths to 72 inches (1828 mm) are supplied. Two lengths can be used to provide a total length of 144 inches (3656 mm).

### Tape Spars



Tape Spars are completely enclosed scale assemblies installed directly as a component in the user's machine. Spar slider mounts extend through flexible sealing lips for direct attachment to moveable machine parts.

### Cassettes



Fully enclosed cassette units are used in extreme environments such as hot rolling mills. Many options are available, including cyclic pitch, travel, and spring return. These units can be pressurized through a purge fitting to help prevent contamination from external sources.

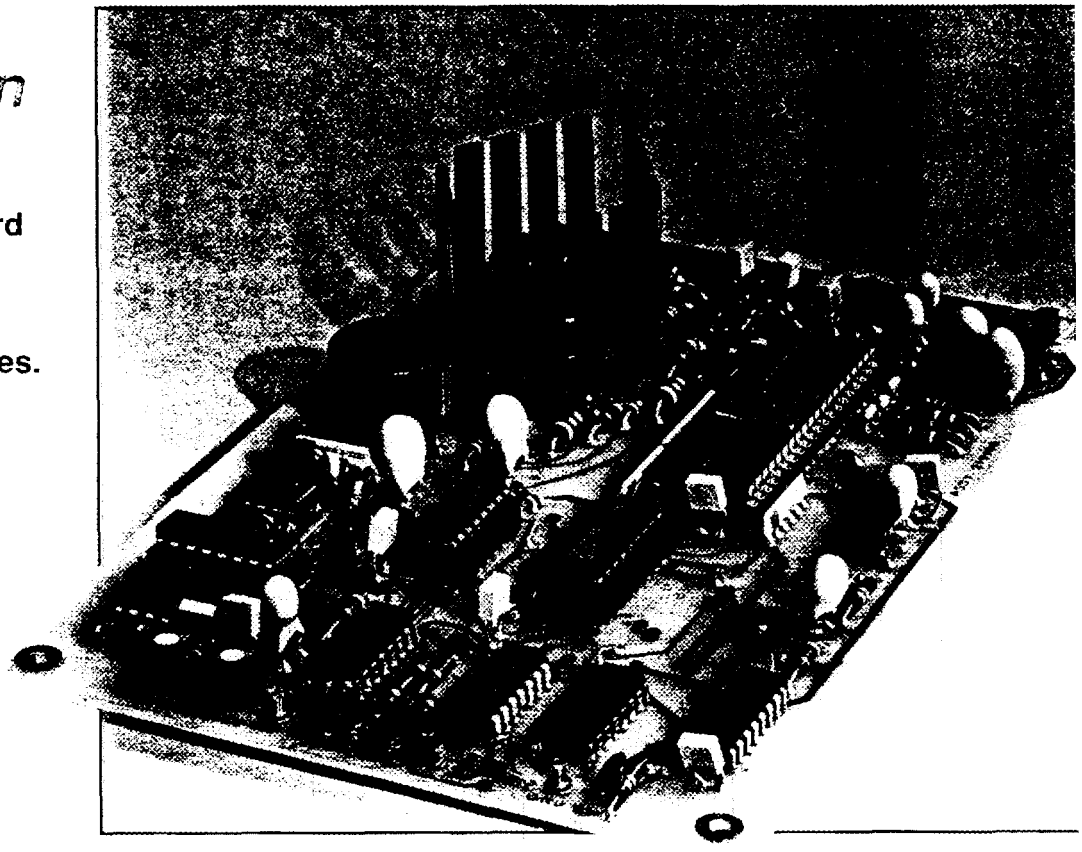

**FARRAND CONTROLS**
**DIVISION OF RUHLE COMPANIES, INC.**
99 Wall Street, Valhalla, NY 10595 • Tel: 914/761-2600 Fax: 914/761-0405


**For literature or applications assistance call 914/761-2600 or fax 914/761-0405.**

# INDUCTOSYN® Analog to Digital I/D Quad Converter Board

## Achieve high resolution position data.

- Interfaces to all standard machine tool controls.
- Resolution up to 0.5 arc sec. or 10 μinches.
- Field tested noise immunity, mounts in standard card rack.
- Many standard cycle divisions available.



Farrand's new I/D (INDUCTOSYN® to digital) Quad Converter Board converts INDUCTOSYN or resolver format analog signals to high resolution digital signals in A quad B and other serial data formats. The unit provides digital position information to control systems which do not have built-in INDUCTOSYN or resolver conversion capabilities.

Many cycle divisions are available as listed under specifications on the reverse side. Typical resolutions are 10 μinches with a 0.1 inch pitch linear INDUCTOSYN transducer or 0.0001 degrees with a 720 pole rotary INDUCTOSYN transducer.

The I/D Quad Converter Board mounts in a standard card rack. Features include field tested noise immunity and LED operation indicators and test points.

Quad Converter input signals are in sine/cosine format from an INDUCTOSYN transducer with suitable preamplifier. The Quad Converter can also be used with a resolver. Quad Converter outputs are from differential drivers, up to 40 mA into a 100 ohm differential load at TTL or RS-422-A levels.

FARRAND CONTROLS

# Specifications

**STANDARD MODULES:**

| Part Number | A Quad B Cycles per INDUCTOSYN® CYCLE | Cycles Division | Transducer | Resolution* | Speed |
|---|---|---|---|---|---|
| 219100-21 | 250 | 1.000 | 0.2 in<br>0.1 in<br>2 mm<br>720 pole | 200 µin<br>100 µin<br>2 µm<br>0.001° | 3000 in/min<br>1500 in/min<br>30 m/min<br>40 rpm |
| 219100-22 | 500 | 2.000 | 0.2 in<br>0.1 in<br>2 mm<br>360 pole | 100 µin<br>50 µin<br>1 µm<br>0.001° | 3000 in/min<br>1500 in/min<br>30 m/min<br>80 rpm |
| 219100-32 | 1000 | 4.000 | 0.2 in<br>0.1 in<br>2 mm | 50 µin<br>25 µin<br>0.5 µm | 750 in/min<br>375 in/min<br>7.5 m/min |
| 219100-31 | 2500 | 10.000 | 0.2 in<br>0.1 in<br>2 mm<br>720 pole | 20 µin<br>10 µin<br>0.2 µm<br>0.0001° | 750 in/mi<br>375 in/min<br>7.5 m/min<br>10 rpm |
| 219100-33 | 900 | 3.600 | 720 pole | 1 arc sec | 10 rpm |
| 219100-34 | 1800 | 7.200 | 360 pole<br>720 pole | 1 arc sec<br>0.5 arc sec | 20 rpm<br>10 rpm |

* **NOTE:** In the quadrature output format the resolution shown above is with the quadrature detection in the "X4" mode. In the "X2" mode, the resolution is twice the value shown and in the "X1" mode, it is four times the value shown.

**INPUT:** Use with an INDUCTOSYN® transducer and Farrand preamplifier. Can also be used with a suitable resolver.

**OUTPUT:** Outputs are from differential drivers, up to 40 mA into a 100 ohm differential load at TTL or RS-422-A levels.

**A. Count Pulses** in any one of the following three formats:

1. Quadrature. (A and $\overline{A}$; B and $\overline{B}$)
2. Count pulse and up/down level: pulse width, 300 nsec ±100 nsec separation; 200 nsec min; setup of U/D: 75 nsec min.
3. *Count up and count down pulse* (width and separation same as in 2 above).

**B. Marker Pulse:** C and $\overline{C}$. Marker is high once per INDUCTOSYN® transducer cycle. In quadrature mode, marker occurs when A and B are both high.

**C. Resolution:** Finer output pulse resolution available.

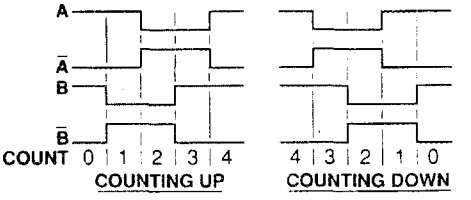
**D.** 10 KHz excitation for INDUCTOSYN® transducers. Matching transformer included.

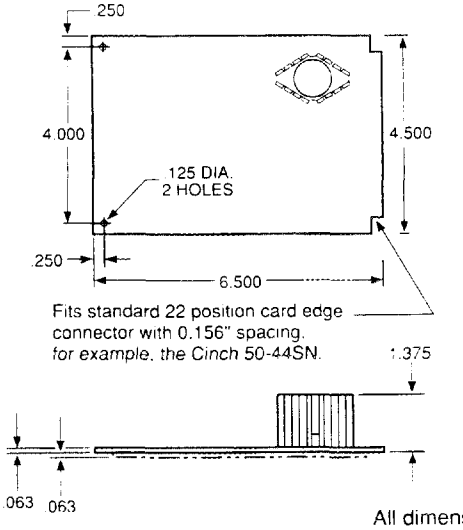
**POWER REQUIRED:** (outputs loaded with 75 ohm each.)
+5V ±0.25 Vdc, 1.0A
+15V ±0.25 Vdc, 250 mA
-15V ±0.25 Vdc, 250 mA
The Quad Converter Board provides ±12 Vdc, 50 mA to power the preamp.

**OPTIONAL EQUIPMENT:**

| | |
|---|---|
| 219215 | Interconnect Board |
| 219208-1 | Connector |
| 219200 | Preamplifier |

**QUADRATURE OUTPUT FORMAT:**




All dimensions in inches.


FARRAND CONTROLS
Division of Ruhle Companies, Inc.
99 Wall Street, Valhalla, NY 10595-1447
TEL: 914/761-2600 FAX: 914/761-0405

**Outside United States of America:**
INDUCTOSYN INTERNATIONAL
Division of Ruhle Companies, Inc.
99 Wall Street, Valhalla, NY 10595-1447 USA
TEL: 914/761-2600 FAX: 914/761-0405



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Astrosystems, Inc.
6 Nevada Drive, Lake Success, New York 11042 (516) 328-1600

# FACSIMILE TRANSMITTAL

DATE: 12-7-93

TO: David Holcomb

COMPANY NAME: Oak Ridge Natl. Lab.

ADDRESS:

TELEFAX NUMBER: 615- 574- 4058

FROM: Mike Goldstein

TELEFAX NUMBER: (516) 328-1658

REFERENCE:

PAGES: 5 (INCLUDING THIS COVER PAGE)

COMMENTS: As per your request, here is some preliminary data. more will follow by mail. Let me know if you have any questions

Best regards
Michael

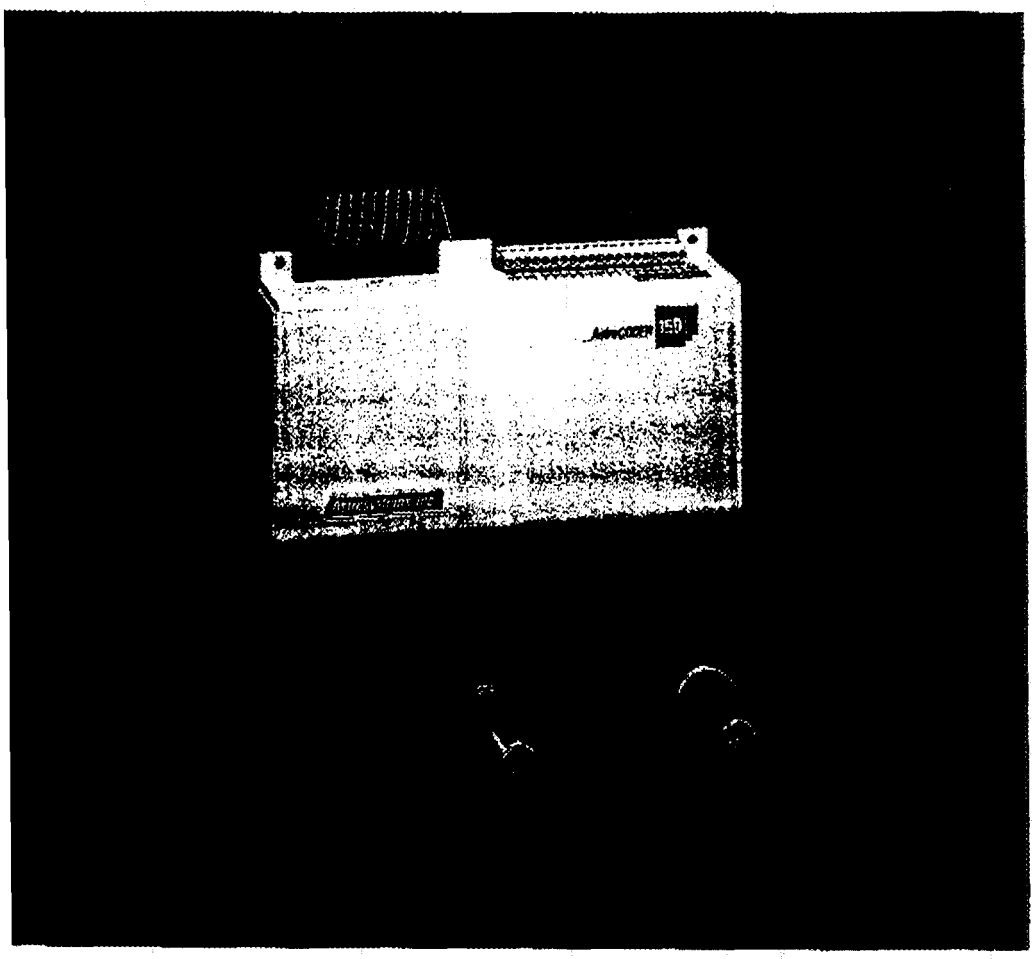
PLEASE NOTE: IF YOU HAVE ANY PROBLEMS WITH THIS TRANSMISSION, PLEASE CALL US IMMEDIATELY AT (516) 328-1600.

WE ARE SENDING FROM AN AUTOMATIC TELECOPIER WHICH IS GROUP 1, 2, AND 3 COMPATIBLE.

*Fully field configurable–*
*Set it **your** way*

# AstroCODER 150

## Absolute Position Encoder...Plus!



**Multi-shaft resolver encoder you customize to any application... with these standard features:**

- Two-axis input
  Two single turn or one multiturn rugged resolver transducer
- Four simultaneous data outputs
  1. 12 or 16 bit parallel: binary, BCD or gray code; TTL, source or sink
  2. DC voltage: select shaft position, shaft speed, or differential position between shafts
  3. Serial data to PC or PLC: RS422
  4. HI/LO speed alarm on each axis
- Two-axis synchronization capability
- Scalable for readout in user units
- Built-in offset and power supply
- Remote registration and reset
- Data freeze input
- Display option
- Priced for cost-sensitive applications

***AstroCODER/150...***
***Breaking new ground***
***in encoder technology***

**Astrosystems, Inc.**

# AstroCODER 150

### *The Absolute Encoder...Plus!*

Astrosystems AstroCODER/150 begins with accurate, reliable, resolver-based technology to measure absolute shaft position for automation control unaffected by power disruptions, electrical noise or hostile environment. From there, it goes on to offer unmatched capabilities.

It outputs position data in **three** separate forms simultaneously:

- serial digital
- parallel digital
- DC analog voltages

For each of these outputs, the user can select and set the form of signal best suited to the application.

In addition, AstroCODER/150 outputs speed information and alarms.

### *Digital outputs*

Parallel digital data, PLC compatible, is available as 12 or 16 bit TTL, current source, or current sink output in binary, BCD or gray code format. Both the logic type and code type are field settable. Digital filtering assures noise immunity. It also supports RS422 communication.

### *Setup*

The serial link is used to select all set-up and configuration parameters. Software is provided for use with IBM PC. Alternatively, settings can be factory programmed or set via optional keyboard and display.

### *Speed output and alarm*

AstroCODER/150 continuously computes shaft speed and compares it to programmed high and low limit settings. An alarm is signaled when speed falls outside of the programmed window.

### *Analog output*

The dual DC output voltages (0 to 10V, and -10 to +10V) can be assigned to read either the position or the speed of a single encoder, or alternatively, the position difference between the two encoders.

### *Two-axis synchronization*

In this latter mode, the DC output may be used as a control signal to drive one shaft into perfect position synchronization with the other, utilizing a low cost motor and controller.

### *Offset; remote reset*

Offset on each channel is entered via a remote logic switch input.

### *Scale factor*

For output in user units, the scale factor can be set between 16 and 4096.

### *PLC data latch*

A data freeze is actuated and released by a signal from a PLC, to accommodate any scan rate.

### *Transducers*

The electronics accept inputs from one or two single turn resolvers or a geared precision dual-resolver transducer. For multiturn applications, the resolution is selectable so that the full 16 bits (65,536 parts) can be applied to either 16, 32 or 64 turns. NEMA 4X or environment-proof housings are available for all industrial applications.

***AstroCODER/150...***
***Rugged, accurate reliability in a budget package***

### Specifications

**Transducer:**
Model #HST21-[0]
Quantity: 1 or 2
Housing: NEMA 4X
Operating temperature: -20° to +85°C
Diameter: 2.1 in.
Length: 4.75 in.
Shaft diameter: 0.626 in.
Side load: 400 lbs.
Cable: 4 wire, 1000 ft. maximum
Model #AP75-[10, 25, 50, ft.]
(consult factory for other transducers)

**Controller:**
Model #AC30-[output type]-[option]
[1] sink [2] source [3] TTL
Resolution/repeatability: 12 or 16 bit
Update: 688 µs per encoder
Busy pulse during update
Analog out: 0 to 10V and -10 to +10V
Inputs: Remote registration for reset
Data freeze
Field selectable parameters:
Channel select: 1 or 2
Scale: 16 to 4096
Offset: 0 to (scale - 1)
Hi/Lo speeds: 0 to 3000 RPM
Output code: Binary, BCD, gray
DC assignment:
Position 1 or 2
Speed 1 or 2
Differential position
Direction of rotation: CW or CCW
Dimensions: 6 x 10 x 2 in.
Input power: 120/240V, 50/60 Hz, 5W
Operating temperature: 0 to 70°C

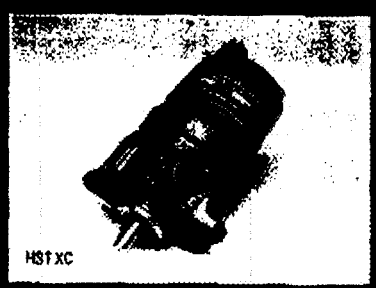
**Options:**
[24V] 11 to 30 VDC @ 750 ma, fused
[AC92] drop-in NEMA 4X front panel keyboard and LCD display
[B] bright display

*Industrial Automation Division*
*6 Nevada Drive, Lake Success, NY 11042*
*(516) 328.1600 Fax (516) 328.1658*

*Rugged, accurate position sensors*

# Transducers

# *Ultra-Reliable Precision Resolvers*




**Operate with all Astrosystems converter electronics.**

All Astrosystems shaft position transducers utilize resolvers as the sensing element. They are absolute, with correct position output available the instant power is applied. Unlike incremental encoders, they have no electronics on the moving shaft, do not count pulses, and are unaffected by electrical noise or power disruptions.

***Rugged, reliable***

Mechanically, resolvers are identical to small AC motors. They are housed in enclosures designed to protect them against shock, vibration, heat, humidity, and a variety of hostile environments... corrosive, volatile or radioactive.

The electronic converter can be located in a benign environment up to 1000 feet away.

***Principle of operation***

A resolver is a type of rotary transformer... a passive element that receives a signal from the electronics, modifies it slightly, then sends it back. The modification is directly related to the shaft angle.

The change is measured precisely within the electronics, which outputs it in digital or analog form. When digital, it serves as an encoder. When analog, it acts as a potentiometer.

**Astrosystems, Inc.**

# Transducers

### *Single turn, multiturn*

Resolvers are bi-directional, continuous rotation devices that measure full 360° rotation. Many applications require more than one turn to drive the element being monitored, e.g. lead screw, rack and pinion, pulley, or belt driven conveyor.

To determine absolute position without counting turns, Astrosystems offers multiturn transducers. They contain two geared resolvers using instrument class precision gears in one of four ratios: 1:10, 36, 64 or 100.

As the input shaft makes a full turn, the second shaft and resolver make a fraction of a turn. The successive positions of this "coarse" resolver define the number of turns completed; the "fine" resolver records the angle within the current turn. Combined, the readings output a single, unique position the instant power is applied, with accuracy of up to 1 part in 100,000.

### *Geared single turn*

For multiturn applications where the required resolution over the total travel is 12 bits or less, a transducer containing a single resolver with built in gear reducer is often sufficient.

### *Interface*

These transducers work in conjunction with any Astrosystems electronic converter. All are temperature compensated to correct for variations.

### *Housing*

Transducer size refers to diameter, expressed in tenths of an inch. All Astrosystems transducers contain size 11 stainless steel resolvers.

### *Nomenclature, sizing*

Single turn (ST)
- NEMA 1: size 11, ST 11
- NEMA 12: heavy duty, size 26, HST 26
- NEMA 13: spray-proof, size 26, HST 26U
- NEMA 4X: washdown, size 21, HST 21U

Multiturn (MT), *turns
- NEMA 1: size 23, MT 23–1/*
- NEMA 12: size 34, HMT 34–1/*
- NEMA 13: size 34, HMT 34–1/*–U

Geared single turn:
- NEMA 1: ST 23–1/**
- NEMA 12: HST 34–1/*
- NEMA 13: HST 34–1/*–U

(Suffixes A, C, E, K, W, etc. will refer to minor differences in wiring or output.)

XC, NRR designate hostile environment transducers.

### *Explosion-proof* – XC

Astrosystems explosion-proof transducers comply with the following standards:

| | |
|---|---|
| NEC | CL I, Group D |
| | CL II, Group E, F, G |
| ULSTD | 886 CL II |
| CSASTD | C22.2 No.30 (1970) |

### *Radiation resistant* – NRR

Radiation resistant transducers for nuclear applications are designed to withstand $10^9$ rads total dosage (gamma equivalent approximately 2 x $10^{18}$ gamma photons/cm$^2$). Applications include fuel-rod positioning, manipulator control, waste handling, valve monitoring, gamma scanners and x-ray welding.

Comprehensive programs to evaluate constituent materials...insulation, lubricants, coatings, etc...have been coordinated with client nuclear installations and component manufacturers. Due to wide variation in operating environments, Astrosystems cannot guarantee specific operating life in nuclear service.

The size 23 transducers have built-in gear ratios of 1:1, 10, 36, 64, 100, for multiturn or geared single turn applications.

| Specifications | ST 11 | HST 26 | MT 23–1/ ST 23–1/** | HMT 34–1/ HST 34–1/* | HST 26U | HST 21U |
|---|---|---|---|---|---|---|
| Starting torque, maximum (oz in) | .07 | 1.0 | .07 | 1.0 | 5.0 | 1.0 |
| Moment of inertia (gm cm²) | 3 | 15 | 5 | 15 | 35 | 60 |
| Shaft load, maximum: axial (lbs) | .3 | 35 | 5 | 35 | 100 | 300 |
| radial (lbs) | .7 | 75 | 8 | 75 | 500 | 1200 |
| Weight (lbs) | .25 | .5 | .12 | 2.75 | .5 | 2.75 |
| Maximum slew speed (RPM) | 3000 | 3000 | 3000 | 3000 | 2000 | 3000 |
| Vibration (g's to 2000 cps) | 15 | 15 | 15 | 15 | 15 | 15 |
| Shock (g's for 11 msec) | 50 | 50 | 50 | 50 | 25 | 50 |
| Accuracy | 0.088° | 0.088° | 0.088° | 0.088° | 0.088° | 0.33° |
| Radiation (rads) | $10^7$ | $10^7$ | $10^7$ | $10^7$ | $10^7$ | $10^7$ |
| Operating temperature (°C) | -20 to +85 | -20 to +85 | -20 to +85 | -20 to +85 | -20 to +85 | -20 to +85 |

‡U NEMA 13 housing: 2.0 oz. in.
† Multiturn transducers available
* 10, 36, 64, 100 turns
** 10, 36, 100 turns

*Industrial Automation Division*
*6 Nevada Drive, Lake Success, NY 11042*
*(516) 328.1600 Fax (516) 328.1658*

# APPENDIX E
# RADFETs

# Sandia National Laboratories FAX

**for Dr. David Holcomb FAX# (615)574-4058**
**from Daniel J. Moreno TEL# (505)844-6860**
**2 pages on Dec.13,1993**

Dr. Holcomb,

As you requested, I have attacted the fact sheet for our dual dielectric RADFET. For information on single dielectric RADFETs you may contact Andrew Holmes-Siedle at the following address:

REM
64a Acre End St.
Eynsham, Oxford OX8 IPD, England

Please feel free to call me with any questions or comments at (505)844-6860.

Sincerely,

Daniel J. Moreno

SENT BY:SANDIA NATIONAL LABS :12-13-93 :10:01AM : 2231/2234/2235/2251- 615 574 4058:# 1/ 2

# SANDIA DUAL-DIELECTRIC RADFET

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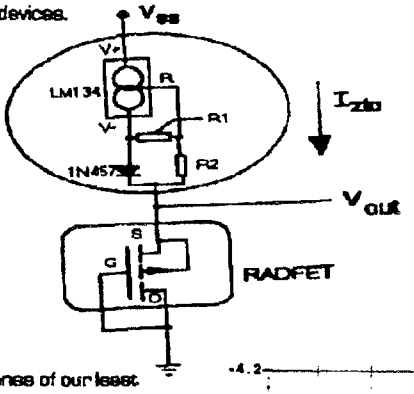
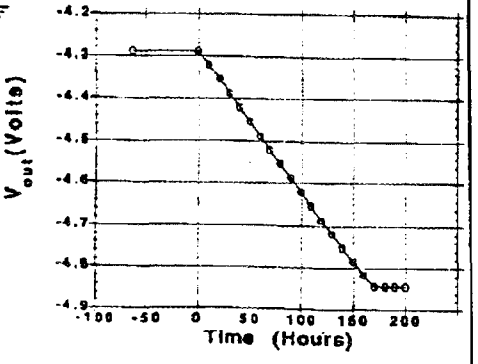
The Sandia dual dielectric RADiation sensing Field Effect Transistor (RADFET) is a simple, rugged, inexpensive, and low power microsensor that can be designed to achieve many ionizing radiation detection needs. The RADFET's dosimetric parameter is a permanent change in its electrical characteristics (threshold voltage) when exposed to ionizing radiation. We have developed RADFETs with sensitivities from 90microvolts/rad to 28millivolts/rad. These devices have exceptional post-irradiation stability and their total dose response is independent of the source's dose rate and of neutron dose. The RADFET's excellent stability allows it to maintain its radiation induced threshold voltage shift indefinitely, with minimal drift. Its dose retention capability can be viewed as a built-in memory that simplifies its operating circuitry. The RADFET can be read with an isothermal current that eliminates errors caused by temperature variations during measurement of its dosimetric parameter. The RADFET occupies less than 1mm² of silicon chip space and can be read with currents as low as 10microamps. Even though single X-ray photons cannot be detected, the RADFET is an accurate and simple means for total dose detection of a wide variety of ionizing radiation particles ($\alpha$, $\beta$, $\gamma$-rays). The following circuits illustrate the simplicity of its operation and how it can be configured to satisfy your application.

## TRACKING GATE CONFIGURATION

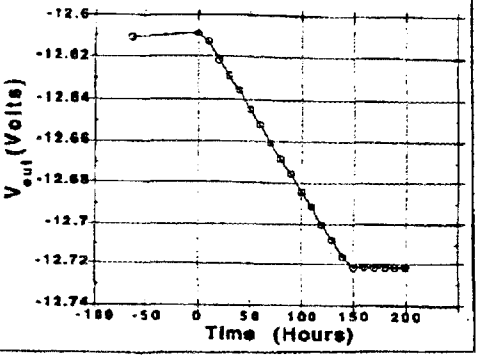
This configuration is illustrated in the following circuit and is great for real time total dose detection. In this circuit, a baseline $V_{out}$ is established by the virgin RADFET. Any increase in $V_{out}$ is induced by ionizing radiation since the zero temperature coefficient current ($I_{ztc}$) minimizes its temperature dependence. The radiation induced shift in $V_{out}$ translates into a total dose value which is easily computed with the known RADFET sensitivity. Total doses up to ~500krad(Si) can be detected with existing devices.




This plot shows the response of our least sensitive RADFET which has a 0.08um oxide thickness, a 0.15um nitride thickness, an $I_{ztc}$=-4.45mA, and a sensitivity of 0.1mV/rad. It was irradiated between t=0 and t=170 hours with a Cs-137 source. The irradiation's dose rate of 33rad/hr and its total dose of 5.6krad are easily computed from the RADFET response slope of -3.3mV/hr.

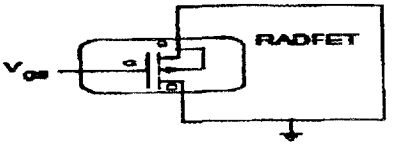



This plot shows the response of our most sensitive RADFET which has a 2.0um oxide thickness, a 0.3um nitride thickness, an $I_{ztc}$=-3.8mA, and a sensitivity of 23mV/rad. This device is great for low dose monitoring. This is evident from its linear and detectable response to a 9.0 microrad/sec Cs-137 irradiation up to a total dose of 4.8rad.

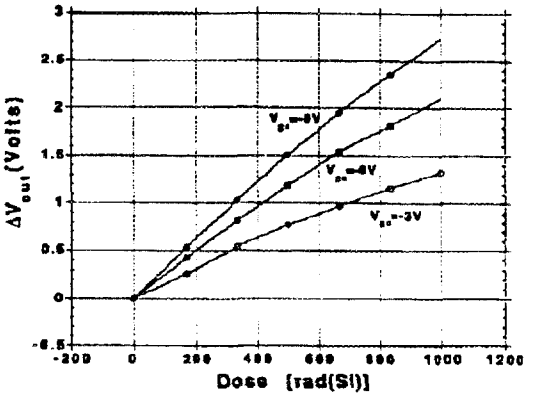



## CONSTANT GATE CONFIGURATION

The irradiation circuit for this configuration is illustrated below. A tracking gate, "read" mode, must be provided for measuring the RADFET's radiation induced threshold voltage shifts. This can be accomplished by pulling the RADFET from the radiation environment and putting it into a "reader" or by designing a circuit that periodically switches to a "read" configuration. Since the "read" mode needs to be engaged only a fraction of the time, the power consumed by your operating circuitry can be minimized. In this configuration the RADFET's sensitivity and its linear response region are proportional to its gate bias ($V_{gs}$) during irradiation. This permits tuning of an application's requirements.

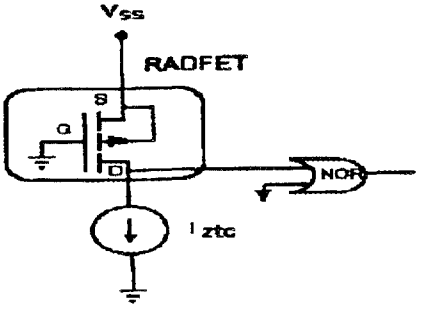



This plot illustrates the response of a RADFET with a 0.45um oxide thickness and a 0.15um nitride thickness. Each curve corresponds to a fresh device which was irradiated with the indicated gate biasing voltage in 250rad increments up to 1000rad. Notice that the RADFET has a good radiation response at Vgs=0 volts and that its sensitivity increases with increasing $V_{gs}$ during irradiation.




## TOTAL DOSE SWITCH

In this configuration, the RADFET acts as an alarm that triggers when it accumulates the designed total dose. This circuit is not for real time monitoring since its output is either "off" for any total dose below or "on" for any total dose exceeding the designed switch dose. A RADFET with the appropriate radiation sensitivity can be selected to achieve almost any switch dose.

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# APPENDIX F
# PROXIMITY DETECTORS

# Automation Components: A Reference Guide for Designers

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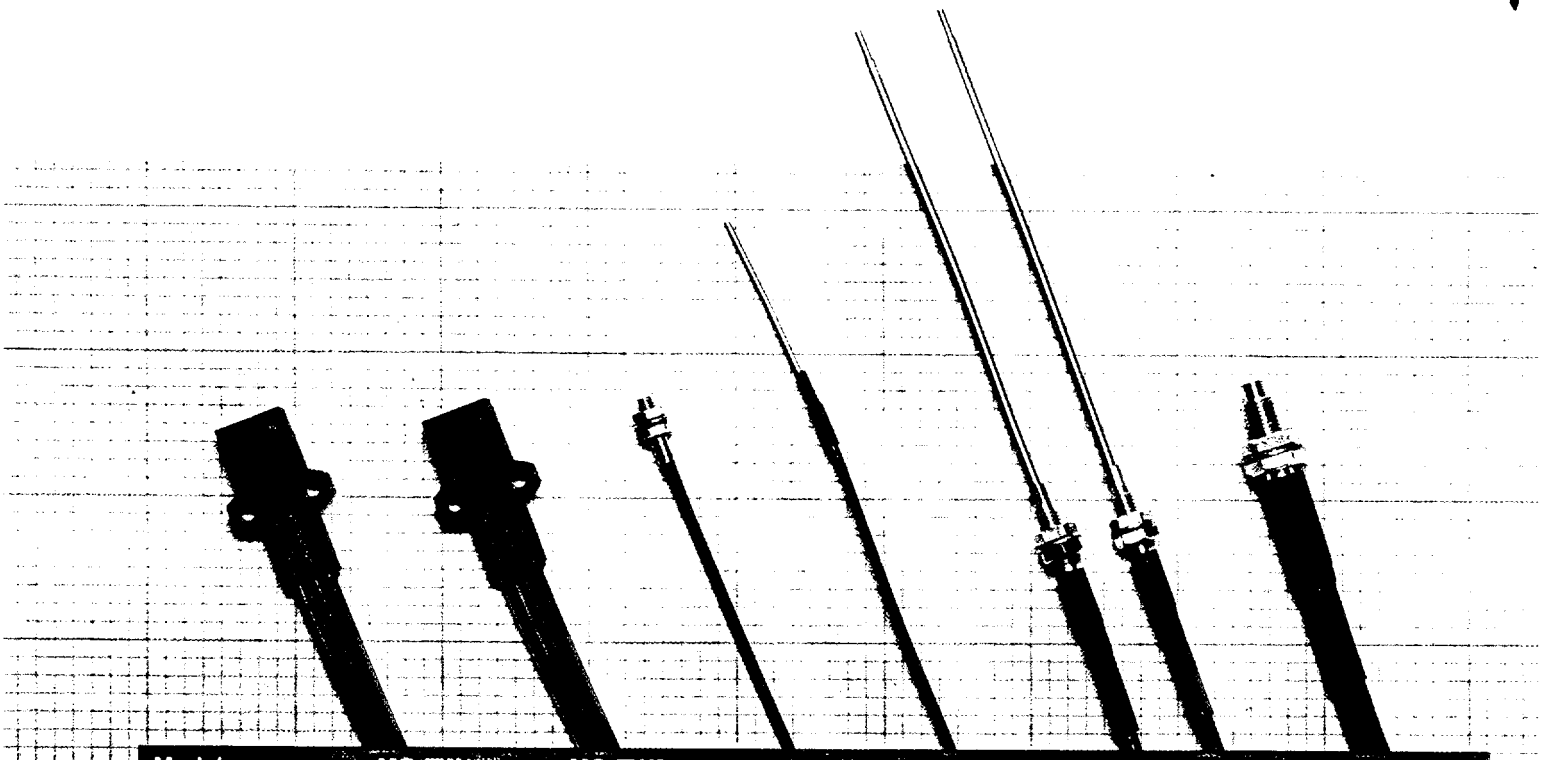
Matsushita Group

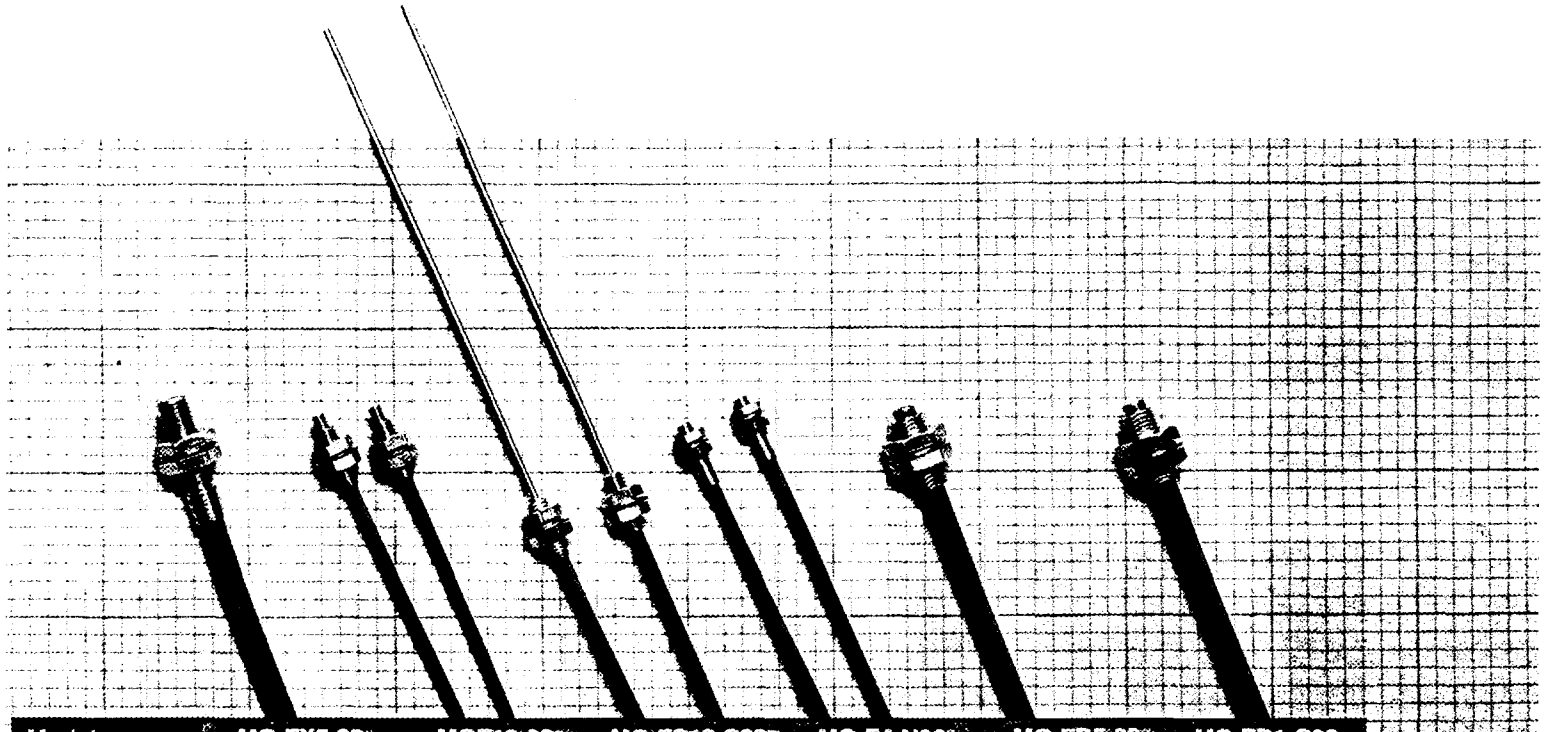
# MQ-F Fiber Photoelectric Switches

- Quick disconnects on both electrical and fiber sides
- DIN rail mounted amplifier
- Right angle and 5X lens attachments
- Glass type rated to 200 C (328 F)



| Model | | MQ-FW1 | MQ-FW2 | MQ-FD1-N02 fine diameter fiber | MQ-F3SD1-K01 ultra-fine diameter fiber | MQ-FHS12-02 glass fiber unit | MQ-FHD5-02 glass fiber unit |
|---|---|---|---|---|---|---|---|
| Length | Fiber | 50 cm, 1 m (19.685", 3.3') | 50 cm, 1 m (19.685", 3.3') | 2 m, (6.6') | 1 m (3.3') | 2 m (6.6') | 2 m (6.6') |
| | Sleeve | — | — | 9 cm, (3.543") | 3 cm, 1 m (1.181") | 9 cm, 1 m (3.543") | 9 cm, (3.543") |
| Detection method | | Triple-beam area reflective type | | Diffuse reflective type | Diffuse reflective type | Thru-beam type | Diffuse reflective type |
| Sensing Distance cm (inches) | 15 cm 5.906" | | | | | | |
| | 10 cm 3.937" | | | | | 12 cm (4.724") | |
| | 5 cm 1.969 | | 2.5 cm (.984") | | | | |
| | | 1.5 cm (.591") | | 1.5 cm (.591") | 1.5 cm (.591") | | 1.5 cm (.591") |
| Detection Speed | | 500 times per sec. | | 1,000 times per sec. | | | |
| Protective Structure | | Fiber tip: Splash-proof type (equivalent to IEC IP64) Amplifier: Dust-protected type plastic cover (equivalent to IEC IP50) | | Fiber tip: Immersion-protected type (equivalent to IEC IP67) Amplifier: Dust-protected type plastic cover (equivalent to IEC IP50) | | | |
| Mount Pitch (mm) | | 12, 2-3.3 dia. | | M3 (P=0.5), M3 (P=0.5), 1.2 dia. | 1.0 dia., 10.0, 1.0 dia. | M2.6 (P=0.45), M4 (P=0.7), 1.8 dia. | 4 dia., M6 (P=0.75), 2.4 dia. |
| Amplifier | | MQ-FWAR amplifier unit (red LED) | | MQ-FAR (red LED) | | MQ-FA (infrared LED) | |
| Amplifier Dimensions (mm) | | May be DIN rail mounted (DIN EN 5022) | | | | | |

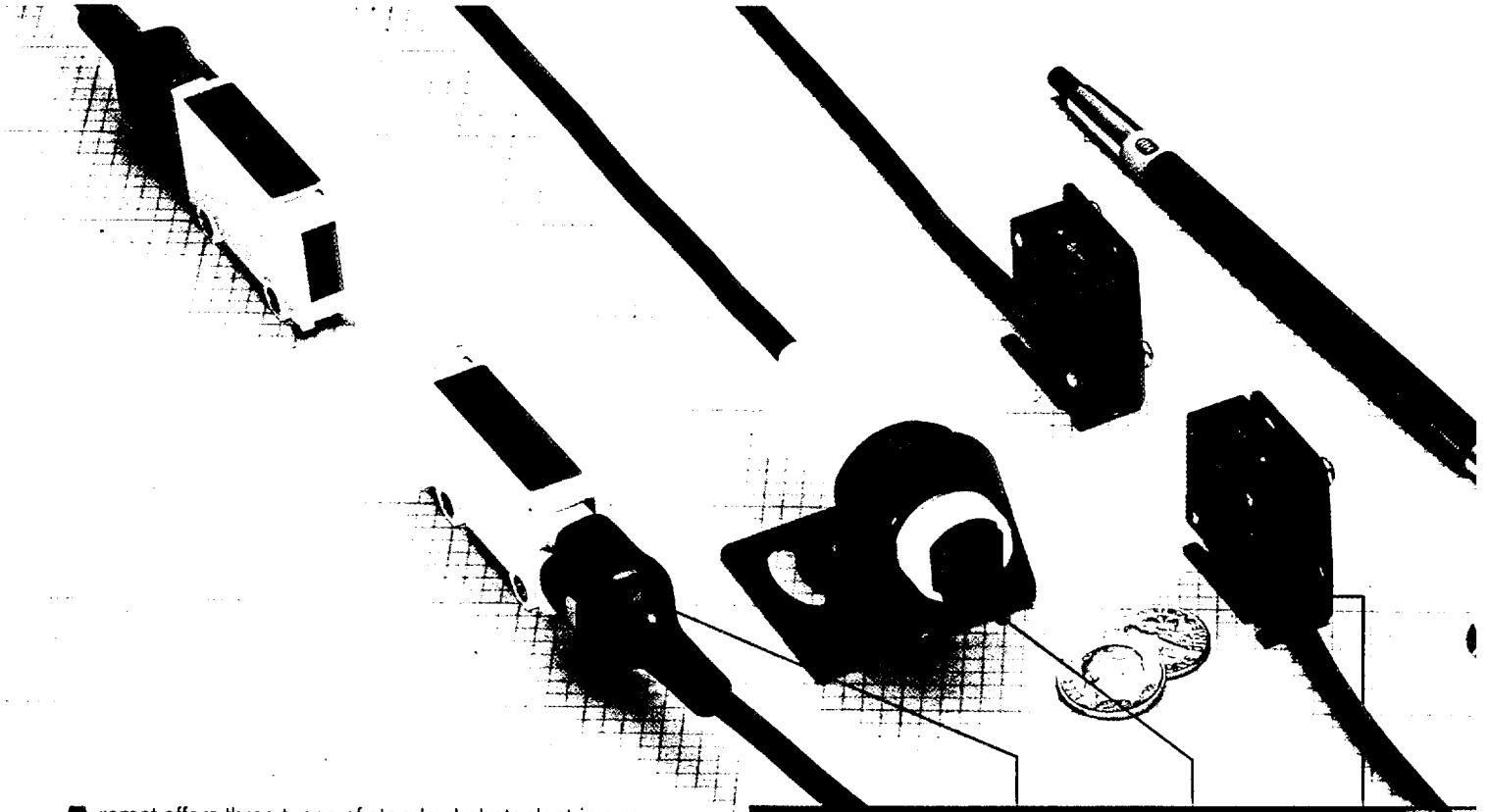
Need a limit switch? See page 30.



| Model | | MQ-FX5-02 free-cut fiber unit | MQF12-02 free-cut fiber unit | MQ-FS10-C02 free-cut fiber unit | MQ-F4-N02 free-cut fiber unit | MQ-FD5-02 free-cut fiber unit | MQ-FD1-C02 free-cut fiber unit |
|---|---|---|---|---|---|---|---|
| Length | Fiber | 2 m (6.6') | 2 m (6.6') | 2 m, (6.6') | 2 m (6.6') | 2 m (6.6') | 2 m (6.6') |
| | Sleeve | — | — | 9 cm, (3.543") | 9 cm, 1 m (3.543") | 9 cm, 1 m (3.543") | 9 cm, (3.543") |
| Detection method | | Diffuse reflective | Thru-beam | | | Diffuse reflective | |
| Sensing Distance (cm (inches)) *Green LED | 15 cm 5.906" / 10 cm 3.937" / 5 cm 1.969" | 5 cm (1.969") | 12 cm (4.724") / *1.5 cm (.591") | 10 cm (3.937") | 3.5 cm (1.378") | 5 cm (1.969") | 1.5 cm (.591") |
| Detection Speed | | 1,000 times per sec. | 1,000 times per sec.(green LED type: 500 times per sec.) | | | | |
| Protective Structure | | Fiber tip: Immersion-protected (equivalent to IEC IP67)<br>Amplifier: Dust-protected type plastic cover (equivalent to IEC IP50) | | | | | |
| Mount Pitch (mm) | | M6 (P=0.75) | M2.6 (P=0.45) M4 (P=0.7) | M4 (P=0.7) 1.2 dia. | M3 (P=0.5) M3 (P=0.5) 0.9 dia. | M6 (P=0.75) | M6 (P=0.75) 2.5 dia. |
| Amplifier | | MQ-FAR (red LED) | MQ-FAR amplifier (red LED): MQ-FAG amplifier (green LED) for MQ-F12-02, MQ-FS12-02, MQ-FD5-02,MQ-FSD5-02 | | | | |
| Amplifier Dimensions (mm) | | May be DIN rail mounted (DIN EN 5022) | | | | | |

# Aromat Standard Photoelectric Sensors

- Inexpensive
- Rugged and reliable
- Complete line to meet any requirement



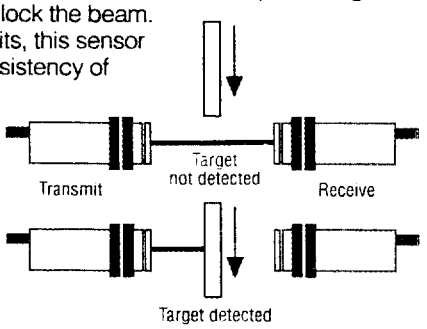
Aromat offers three types of standard photoelectric sensors: Thru-Beam, Retro-Reflective and Diffuse Reflective. They are inexpensive, rugged and reliable for basic detection of the presence or absence of an object.

A performance comparison of these and Aromat's unique Triple Beam™ and Mark Sensor types appears in chart form on page eleven.

**Thru-Beam**

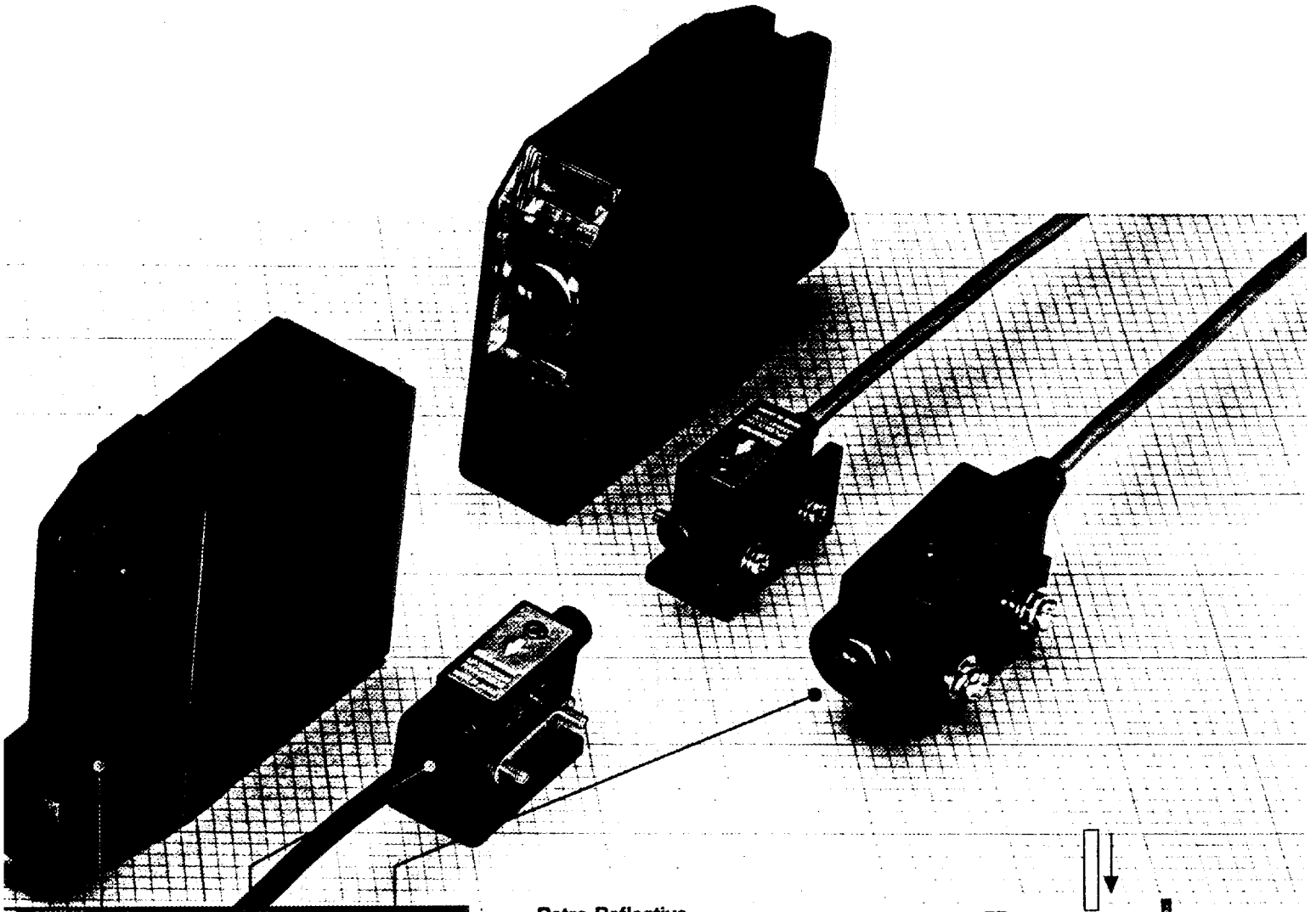
The emitter sends a light beam to a separate receiving module. In DARK ON mode the receiver output changes when an object blocks the beam. In LIGHT ON mode, output changes when an object *does not* block the beam.

When the process permits, this sensor type offers unexcelled consistency of performance.




| | ME | MF18 | MQ |
|---|---|---|---|
| Max Range | 300 CM (10 ft.) | 300 CM (10 ft.) | 300 CM (10 ft.) |
| Environmental Resistance | IP50 NEMA 1 | IP67 NEMA 4X | IP67 |
| Response Time | 1MS | 20 MS | 1 MS |
| Operating Power | DC | AC/DC | DC |
| Output Types Available | NPN Transistor | NPN/PNP, Relay | NPN Transistor |
| Timer | No | No | No |
| Size mm WxHxD (inches) | 11.6x28.2x50.5 (.457x1.111x1.989) | 18mm (0.709") dia. 80.6mm (3.173") L | 18.6x52x52 (.732x2.047x2.047) |
| Comments | Quick disconnect, precise locating | Excellent vibration & water resistance | Tiny, watertight |

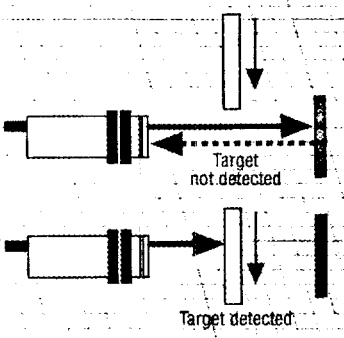
***Need a counter? See page 29.***



| MP-LARGE | MP-SUB | MP-MINI |
|---|---|---|
| 1000 CM (33 ft.) | 50 CM (20 in.) | 300 CM (10 ft.) |
| IP66 NEMA 4 | IP64 NEMA 4 | IP66 NEMA 4X |
| 20 MS | 5 MS | 5 MS |
| AC/DC | DC | DC |
| 1 Form C Relay | NPN Transistor | NPN Transistor |
| Yes | No | No |
| 25.6x81x95 (1.008x3.189x3.74) | 13.8x21x46 (.543x.827x1.811) | 20.4x26.2x70.3 (.803x1.032x2.768) |
| Long range relay output | Small Size | Alignment LED |

**Retro-Reflective**

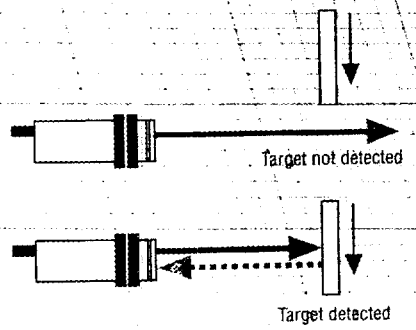
This type of sensor combines the emitter unit and receiving unit in the same housing. The light beam is now bounced off a reflector. As in the Thru-Beam, an interruption of the beam changes the output of the receiver. (DARK ON or LIGHT ON)




**Diffuse Reflective**

The emitter and receiver are in the same housing, as in the Retro-Reflective type, but now the object to be detected is the reflector. DARK ON, LIGHT ON functions are reversed.

Installation of this type detector is easiest and least expensive.




*Need a relay? See page 22.*

NAiS™

# Advanced Photoelectric Sensors

Components for advanced technology

Aromat Corporation™

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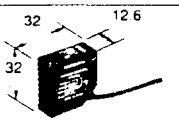
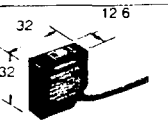
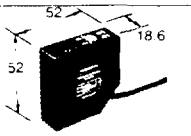
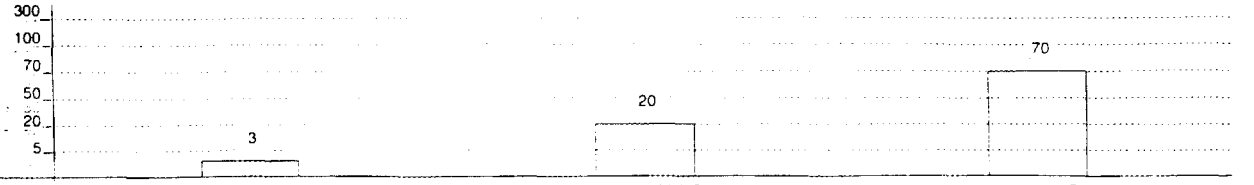
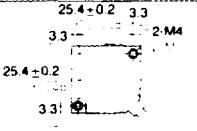
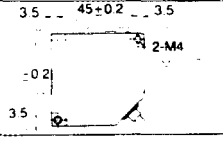
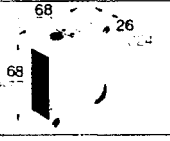
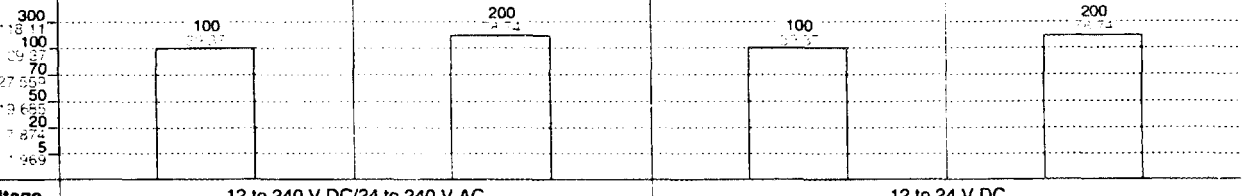
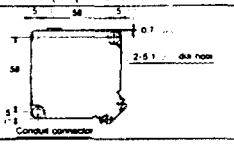
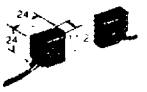
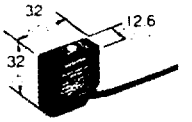
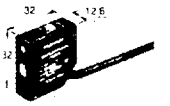
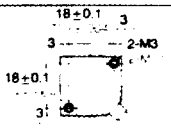
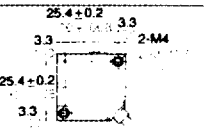
# Triangulation Range Verification Series

| | | | |
|---|---|---|---|
| **Detection principle** | Triangulation Range Verification Method | | |
| **Product name** | MQ-W Area Reflective Photoelectric Sensors | | |
| **Type** | Amplifier Selfcontained-DC | | |
| | MQ-W3 | MQ-W20 | MQ-W70 |
| **Appearance** (mm inch) |  |  |  |
| **Features** | No influence from color of detectable object; Sharp background suppression; Covers all of the applications of diffuse reflection type | | |
| **Sensing method** | Area Reflective Triple Beam™ | | |
| **Light source** | Infrared LED/Red LED | | Infrared LED |
| **Maximum sensing distance** (cm inch) |  | | |
| **Rated operating voltage** | 12 to 24 V DC | 12 to 24 V DC | 12 to 24 V DC |
| **Rated current consumption** | Max. 30 mA (excluding load) | Max. 30 mA (excluding load) | Max. 30 mA (excluding load) |
| **Output capacity** | Max. 100 mA | Max. 100 mA | Max. 100 mA |
| **Standard target** | White drawing paper (1 cm×1 cm) | White drawing paper (2 cm×2 cm) | White drawing paper (7.5 cm×7.5 cm) |
| **Detectable target** | Translucent, opaque | Translucent, opaque | Translucent, opaque |
| **Sensing speed** | 250 times/s | 250 times/s | 250 times/s |
| **Protective construction** | Immersion-protected (Equivalent to IEC IP67) | | |
| **Mounting pitch** (mm inch) |  | |  |

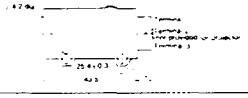
| | | | | |
|---|---|---|---|---|
| **Detection principle** | Triangulation Range Verification Method | | | |
| **Product name** | MR3 Long Distance Area Reflective Photoelectric Sensors | | | |
| **Type** | Amplifier Selfcontained-AC/DC | | Amplifier Selfcontained-DC | |
| | MR3-M100P(T) | MR3-M200P(T) | MR3-M100A(T) | MR3-M200A(T) |
| **Appearance** (mm inch) |  | | | |
| **Features** | Long distance range measurement sensors; 3-mode (ON-delay, OFF-delay, One-shot) timer function is built-in; Accurately detects targets over a broad range of colors, materials and shapes; Unaffected by backgrounnd objects | | | |
| **Sensing method** | Area Reflective Triple Beam™ | | | |
| **Light source** | Infrared LED | | | |
| **Maximum sensing distance** (cm inch) |  | | | |
| **Rated operating voltage** | 12 to 240 V DC/24 to 240 V AC | | 12 to 24 V DC | |
| **Rated current consumption** | DC: Max. 3W/AC: Max. 4 VA [Timer type; DC: Max. 4W/AC: Max. 5 VA] | | Max. 55 mA (excluding load) [Timer type: Max. 60 mA (excluding load)] | |
| **Output capacity** | 3 A 250 V AC (resistive) | | Max. 100 mA (NPN side), Max. 100 mA (PNP side) | |
| **Standard target** | White drawing paper (20 cm×20 cm) | White drawing paper (20 cm×20 cm) | White drawing paper (20 cm×20 cm) | White drawing paper (20 cm×20 cm) |
| **Detectable target** | Translucent/Opaque | Translucent/Opaque | Translucent/Opaque | Translucent/Opaque |
| **Sensing speed** | 25 times/s | | 500 times/s | |
| **Protective construction** | Water-protected (Equivalent to IEC IP66) | | | |
| **Mounting pitch** (mm inch) |  | | | |

# Reflective Light Intensity Series

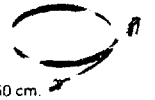
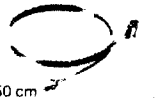
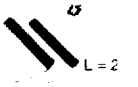
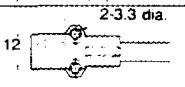
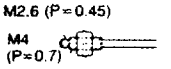
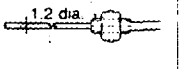
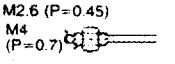
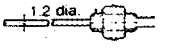
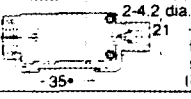
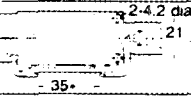
| | | | | |
|---|---|---|---|---|
| **Detection principle** | Reflection Light Intensity Detection Method | | | |
| **Product name** | MQ Photoelectric Sensors | | | MQ Mark Sensor |
| **Type** | Amplifier Selfcontained-DC | | | Amplifier Selfcontained-DC |
| | MQ-300A(B) | MQ-D30A(B) | MQ-D70A(B) | MQ-VD2AR |
| **Appearance** (mm inch) |  | |  |  |
| **Features** | Durable with diecast zinc construction<br>With adjustment indicator LED. light axis matching is simple | Subminiature size with built in amplifier<br>Excellent environmental resistance | Durable with diecast zinc construction<br>With adjustment indicator LED. detection stability can be confirmed | High speed detection of 1,000 times/ achieved<br>Detecting of 0.5 mm wide marks possible<br>Mounting freedom with subminiature size built in amplifier |
| **Sensing method** | Thru-Beam | Diffuse Reflective | | Diffuse Reflective |
| **Light source** | Infrared LED | | | Red LED |
| **Maximum sensing distance (cm inch)** | 300 | 30 | 70 | 2 |
| **Rated operating voltage** | 12 to 24 V DC | | | |
| **Rated current consumption** | Max. 45 mA (excluding load) | Max. 25 mA (excluding load) | Max. 35 mA (excluding load) | Max. 35 mA |
| **Output capacity** | Max. 100 mA | Max. 100 mA | Max. 100 mA | Max.100 mA (excluding load) |
| **Standard target** | 10 mm dia. metal plate (Dull black finish) | White drawing paper (10 cm×10 cm) | White drawing paper (20 cm×20 cm) | 2.0 mm black mark on white fields |
| **Detectable target** | Opaque | Translucent/Opaque | Translucent/Opaque | — |
| **Sensing speed** | 500 times/s | | | 1,000 times/s |
| **Protective construction** | Immersion-protected (Equivalent to IEC IP67) | | | |
| **Mounting pitch** (mm inch) |  |  | | |

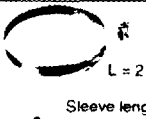
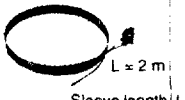
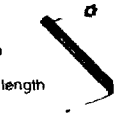
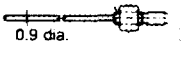
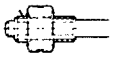
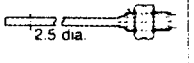
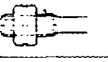
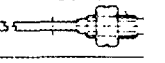
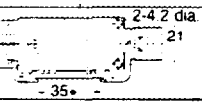
# Photoelectric Sensors Selector Chart

| | | | | | | |
|---|---|---|---|---|---|---|
| **Detection principle** | Reflection Light Intensity Detection Method | | | | | |
| **Product name** | MF18 Photoelectric Sensors | | | | | |
| **Type** | Amplifier Selfcontained-DC | | | Amplifier Selfcontained-AC/DC | | |
| | MF18-300A(B)/C(B) | MF18-R200A(B)/C(B) | MF18-D10A(B)/C(B) | MF18-300P(B) | MF18-R200P(B) | MF18-D10P(B) |
| **Appearance** (mm) | | | | | | |
| **Features** | Popular 18 mm<br>Wide operating voltage range<br>Includes an output protection circuit<br>Excellent vibration and water resistance | | | Popular 18 mm<br>Wide operating voltage range<br>Includes an output protection circuit<br>Excellent vibration and water resistance | | |
| ***Sensing method*** | Thru-Beam | Retroreflective | Diffuse Reflective | Thru-Beam | Retroreflective | Diffuse Reflective |
| **Light source** | Infrared LED | | | Infrared LED | | |
| **Max. sensing distance** (cm inch) | 300 | 200 | 10 | 300 | 200 | 10 |
| **Rated operating voltage** | 5 to 24 V DC | | | 12 to 24 V DC | | |
| **Rated current (power) consumption** | Max. 30 mA (excluding load) | Max. 20 mA (excluding load) | Max. 20 mA (excluding load) | DC: 3.5 W/AC: Max. 3.5 VA (excluding load) | | |
| **Output capacity** | Max. 100 mA | Max. 100 mA | Max. 100 mA | Max. 100 mA | Max. 100 mA | Max. 100 mA |
| **Standard target** | 20 mm dia. metal plate (Dull black finish) | 75 mm dia. metal plate (Dull black finish) | White drawing paper (5 cm×5 cm) | 20 mm dia. metal plate (Dull black finish) | 75 mm dia. metal plate (Dull black finish) | White drawing paper (5 cm×5 cm) |
| **Detectable target** | Opaque | Translucent/Opaque | Transparent/Opaque | Opaque | Translucent/Opaque | Transparent/Opaque |
| **Sensing speed** | 333 times/s | | | 25 times/s | | |
| **Protective construction** | Equivalent to IEC IP67 | | | Equivalent to IEC IP67 | | |
| **Mounting pitch** | — | | | — | | |

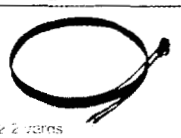
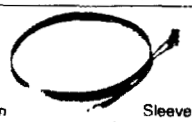
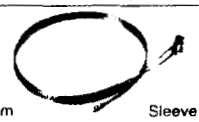
| | | | |
|---|---|---|---|
| **Detection principle** | Reflection Light Intensity Detection Method | | |
| **Product name** | ME Photoelectric Sensors | | |
| **Type** | Amplifier Selfcontained-DC | | |
| | ME-300A(B) | ME-200ZA(B) | ME-D30A(B) |
| **Appearance** (mm inch) | | | |
| **Features** | Connector connection type with serviceability in mind<br>Three-turn adjuster with ratchet mechanism (Indicator provided)<br>Thru-beam type. ME-200ZA which detects even a translucent object<br>High speed detection of 1 ms | | |
| **Sensing method** | Thru-Beam | | Diffuse Reflective |
| **Light source** | Infrared LED | | |
| **Max. sensing distance** (cm inch) | 300 | 200 | 30 |
| **Rated operating voltage** | 12 to 24 V DC | | |
| **Rated current consumption** | Max. 45 mA (excluding load) | Max. 45 mA (excluding load) | Max. 25 mA (excluding load) |
| **Output capacity** | Max. 100 mA | Max. 100 mA | Max. 100 mA |
| **Standard target** | 10 mm dia. metal plate (Dull black finish) | 10 mm dia. metal plate (Dull black finish) | White drawing paper (10 cm×10 cm) |
| **Detectable target** | Opaque | Translucent/Opaque | Transparent/Opaque |
| **Sensing speed** | 500 times/s | | |
| ***Protective construction*** | Equivalent to IEC IP50 | | |
| **Mounting pitch** (mm inch) |  | | |

# Fiber Series

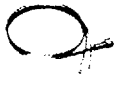
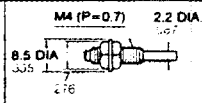
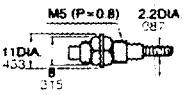
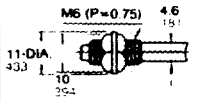
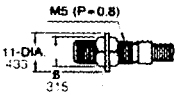
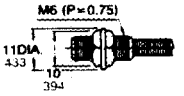
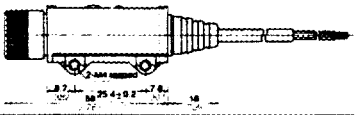
| | | | | | | |
|---|---|---|---|---|---|---|
| **Detection principle** | Fiber Triangulation Range Verification Method | | Fiber Reflection Light Intensity Detection Method | | | |
| **Product name** | MQ-FW Fiber Area Reflective Photoelectric Sensors | | MQ-F Fiber Photoelectric Sensors (Free-cut fiber) | | | |
| **Type** | Amplifier Selfcontained-DC | | Amplifier Selfcontained-DC | | | |
| | MQ-FW1 | MQ-FW2 | MQ-F12-02 | MQ-FS12-02 | MQ-F10-C02 | MQ-FS10-C02 |
| **Appearance** |  |  | | | |  |
| **L = Fiber length** | L = 50 cm. 1 m | L = 50 cm 1 m | L = 2 m | L = 2 m<br>Sleeve length 9 cm | L = 2 m | L = 2<br>Sleeve len 9 cm |
| **Applications** | Detection of multicolored, black, or varying coloured parts | | Check of passage on part feeder and chip part detection | | Movable areas of machine tools and robots | |
| **Sensing method** | Fiber type Area Reflective Triple Beam™ | | Fiber type Thru-Beam | | | |
| **Light source** | Red LED | | Red LED, green LED (for detection of red/white marks) | | Red LED | |
| **Maximum sensing distance (cm )**<br>**( ) indicates use of green LED.** | 1.5 | 2.5 | 12 (1.5) | 12 (1.5) | 10 | 10 |
| **Rated operating voltage** | 12 to 24 V DC | | 12 to 24 V DC | | | |
| **Rated current consumption** | Max. 35 mA (excluding load) | | Max. 35 mA (excluding load) | | | |
| **Output capacity** | Max. 100 mA | | Max. 100 mA | | | |
| **Detectable target** | Translucent/Opaque | | Opaque, 1 mm diameter or more | | | |
| **Sensing speed** | 500 times/s | | 1,000 times/s (green LED type: 500 times/s) | | | |
| **Protective construction** | Fiber tip: Splash-protected (equivalent to IEC 64)<br>Amplifier: Dust-protected (equivalent to IEC IP50) | | Fiber tip: Immersion-protected (equivalent to IEC IP50)<br>Amplifier: Dust-protected (equivalent to IEC IP50) | | | |
| **Mounting pitch (mm )** |  2-3.3 dia. 12 | | M2.6 (P=0.45) M4 (P=0.7)  | M4 (P=0.7) 1.2 dia.  | M2.6 (P=0.45) M4 (P=0.7)  | M4 (P=0.7) 1.2 dia.  |
| **Applicable amplifier** | MQ-FWAR Amplifier unit (red LED)  2-4.2 dia. 21 35 ※ Applicable for DIN standard rail (DIN EN50022) | | MQ-FAR amplifier unit (red LED)<br>MQ-FAG amplifier unit (green LED)  2-4.2 dia. 21 35 ※ Applicable for DIN standard rail (DIN EN5022) | | | |

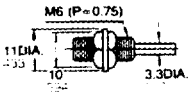
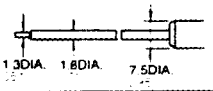
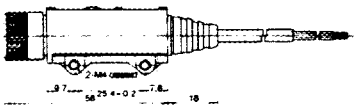
| | | | | | | |
|---|---|---|---|---|---|---|
| **Detection principle** | Fiber Reflection Light Intensity Detection Method | | | | | |
| **Product name** | MQ-F Fiber Photoelectric Sensors (Free-cut fiber) | | | | | |
| **Type** | Amplifier Selfcontained-DC | | | | | |
| | MQ-F4-N02 | MQ-FS4-N02 | MQ-FD5-02 | MQ-FSD5-02 | MQ-FD1-C02 | MQ-FSD1-C02 |
| **Appearance** | |  | |  | |  |
| **L = Fiber length** | L = 2 m | L = 2 m<br>Sleeve length 9 cm | L = 2 m | L = 2 m<br>Sleeve length 9 cm | L = 2 m | L = 2 m<br>Sleeve length 9 cm |
| **Applications** | Precise positioning<br>Lead frame positioning | | Direction discrimination of parts<br>Circuit printed board positioning | | Movable areas of machine tools and robots | |
| **Sensing method** | Fiber type Thru-Beam | | Fiber type Diffuse Reflective | | | |
| **Light source** | Red LED | | Red LED, green LED (for detection of red/white marks) | | Red LED | |
| **Maximum sensing distance (cm )**<br>**( ) indicates use of green LED.** | 3.5 | 3.5 | 5 (0.6) | 5 (0.6) | 1.5 | 1.5 |
| **Rated operating voltage** | 12 to 24 V DC | | | | | |
| **Rated current consumption** | Max. 35 mA (excluding load) | | | | | |
| **Output capacity** | Max. 100 mA | | | | | |
| **Detectable target** | Opaque, 0.5 mm diameter or more | | Transparent/Opaque (copper element wire) 0.1 mm diameter or more | | | |
| **Sensing speed** | 1,000 times/s (green LED type: 500 times/s) | | | | | |
| **Protective construction** | Fiber tip: Immersion-protected (equivalent to IEC IP67), Amplifier: Dust-protected (eqivalent to IEC IP50) | | | | | |
| **Mounting pitch (mm )** | M3 (P=0.5) | M3 (P=0.5) 0.9 dia.  | M6 (P=0.75)  | M6 (P=0.75) 2.5 dia.  | M6 (P=0.75)  | M6 (P=0.75) 2.5 dia.  |
| **Applicable amplifier** | MQ-FAR amplifier unit (red LED)<br>MQ-FAG amplifier unit (green LED)  2-4.2 dia. 21 35 ※ Applicable for DIN standard rail (DIN EN5022) | | | | | |

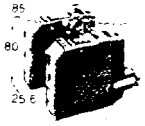
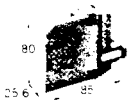
| | | | | | |
|---|---|---|---|---|---|
| **Detection principle** | Fiber Reflection Light Intensity Detection Method | | | | |
| **Product name** | MQ-F Fiber Photoelectric Switches (Free-cut fiber) | MQ-F Fiber Photoelectric Switches (Fine diameter fiber) | | MQ-F Fiber Photoelectric Switches (Ultra-fine diameter fiber) | |
| **Type** | Amplifier Selfcontained-DC | | | | |
| | MQ-FX5-02 | MQ-FD1-N02 | MQ-FSD1-N02 | MQ-F3SD1-K01 | MQ-F3SD1-KR01 |
| **Appearance** | | | | | |
| **L = Fiber length** | L = 2 m | L = 2 m | L = 2 m<br>Sleeve length 9 cm | L = 1 m<br>Sleeve length 3 cm | L = 1 m<br>Sleeve length 3 cm |
| **Applications** | Cutting of printed materials, cloths, etc., positioning and check of passage on part feeder | Precise positioning<br>Label position detection | | Precise positioning<br>Part detection in metal press moulding | |
| **Sensing method** | Fiber type<br>Diffuse Reflective | Fiber type Diffuse Reflective | | Fiber type Diffuse Reflective | |
| **Light source** | Red LED | Red LED | | | |
| **Maximum sensing distance (cm inch)** | 5 | 1.5 | 1.5 | 1.5 | 1.5 |
| **Rated operating voltage** | 12 to 24 V DC | | | | |
| **Rated current consumption** | Max. 35 mA (excluding load) | | | | |
| **Output capacity** | Max. 100 mA | | | | |
| **Detectable target** | Transparent/Translucent (copper element wire) 0.1 mm diameter or more | Transparent/Translucent (copper element wire) 0.05 mm diameter or more | | | |
| **Sensing speed** | 1,000 time/s | | | | |
| **Protective construction** | Fiber tip: Immersion-protected (equivalent to IEC IP67), Amplifier: Dust-protected (equivalent to IEC IP50) | | | | |
| **Mounting pitch (mm inch)** | M6 (P=0.75) | M3 (P=0.5) | M3 (P=0.5)<br>1.2 dia. | 1.0 dia. | 10.0<br>1.0 dia. |
| **Applicable amplifier** | MQ-FAR amplifier unit (red LED) | | 2-4.2 dia.<br>21<br>35<br>※ Applicable for DIN standard rail (DIN EN5022) | | |

| | | | | |
|---|---|---|---|---|
| **Detection principle** | Fiber Reflection Light Intensity Detection Method | | | |
| **Product name** | MQ-F Fiber Photoelectric Sensors (Glass fiber) | | | |
| **Type** | Amplifier Selfcontained-DC | | | |
| | MQ-FH12-02 | MQ-FHS12-02 | MQ-FHD5-02 | MQ-FHSD5-02 |
| **Appearance** |  |  | |  |
| **L = Fiber length** | L = 2 m | L = 2 m<br>Sleeve length 9 cm | L = 2 m | L = 2 m<br>Sleeve length 9 cm |
| **Applications** | Detection of food container passage just after heat treatment, detection of cakes just after oven, detection of parts on P/C board just after passage through soldering bath and detection of moulding chips | | | |
| **Sensing method** | Fiber type Thru-Beam | | Fiber type Diffuse Reflective | |
| **Light source** | Infrared LED | | | |
| **Maximum sensing distance (cm inch)** | 12 | 12 | 5 | 5 |
| **Rated operating voltage** | 12 to 24 V DC | | | |
| **Rated current consumption** | Max. 35 mA (excluding load) | | | |
| **Output capacity** | Max. 100 mA | | | |
| **Detectable target** | Opaque, 1 mm diameter or more | | Transparent/Opaque (copper element wire) 0.1 mm diameter or more | |
| **Sensing speed** | 1,000 times/s | | | |
| **Protective construction** | Fiber tip: Immersion-protected (equivalent to IEC IP67), Amplifier: Dust-protected (equivalent to IEC IP50) | | | |
| **Mounting pitch (mm inch)** | M4 (P=0.7)<br>M2.6 (P=0.45) | M4 (P=0.7)<br>1.8 dia. | M6 (P=0.75)<br>4 dia. | M6 (P=0.75)<br>2.4 dia. |
| **Applicable amplifier** | MQ-FA amplifier unit (Infrared LED) | 2-4.2 dia.<br>21<br>35<br>※ Applicable for DIN standard rail (DIN EN5022) | | |

# Photoelectric Sensors Selector Chart

| | | | | | |
|---|---|---|---|---|---|
| **Detection principle** | Fiber Reflection Light Intensity Detection Method | | | | |
| **Product name** | MP-F Photoelectric Sensor (Plastic fiber) | | | MP-F Fiber Photoelectric Sensor (Glass fiber) | |
| **Type** | Amplifier Selfcontained-DC | | | | |
| | MP-F5 | MP-F25 | MP-FD1 | MP-FH5 | MP-FHD1 |
| **Appearance** |  | | | | |
| **L = Fiber length** | L = 50 cm, 1 m, 2 m, 3 m<br>.55 yard, 1.1 yards, 2.2 yards, 3.3 yards | L = 50 cm, 1 m, 2 m, 3 m<br>.55 yard, 1.1 yards, 2.2 yards, 3.3 yards | L = 50 cm, 1 m, 2 m, 3 m<br>.55 yard, 1.1 yards, 2.2 yards, 3.3 yards | L = 2 m 2.2 yards | L = 2 m 2.2 yards |
| **Features** | Easy adjustment with visible red LED<br>High environmental resistance | | | High temperature resistance<br>High environmental resistance | |
| **Sensing method** | Thru-Beam | | Diffuse Reflective | Thru-Beam | Diffuse Reflective |
| **Light source** | Red LED | | | Red LED | |
| **Max. sensing distance (cm inch)** | 30 / 11.811<br>20 / 7.874<br>10 / 3.937<br>5 / 1.969 | 25 / 9.843 | 1 / .394 | 5 / 1.969 | 1 / .394 |
| **Rated operating voltage** | 12 to 24 V DC | | | | |
| **Rated current consumption** | Max. 40 mA (excluding load) | | | | |
| **Output capacity** | Max. 80 mA | | | | |
| **Standard target** | 2 mm dia. metal plate (Dull black finish) | 6 mm dia. metal plate (Dull black finish) | White drawing paper (1 cm×1 cm) | 2 mm dia. metal plate (Dull black finish) | White drawing paper (1 cm×1 cm) |
| **Detectable target** | Opaque | | Transparent/Opaque | Opaque | Transparent/Opaque |
| **Sensing speed** | 100 time/s | | | | |
| **Protective construction** | Fiber tip: Equivalent to IEC IP66 | | | | |
| **Mounting pitch (mm inch)** |   |   |   |   |   |
| **Applicable amplifier** | Light ON: MP-F1A-DC12/24V<br>Dark ON: MP-F2A-DC12/24V |  | | | |

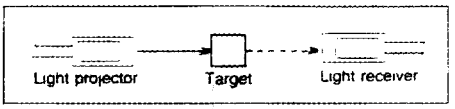
| | | |
|---|---|---|
| **Detection principle** | Fiber Reflection Light Intensity Detection Method | |
| **Product name** | MP-F Photoelectric Sensors (Coaxial fiber) | MP-F Photoelectric Sensor (Metal tube) |
| **Type** | Amplifier Selfcontained-DC | |
| | MP-FX1 | MP-FSD1 |
| **Appearance** | | |
| **L = Fiber length** | L = 50 cm, 1 m .55 yard, 1.1 yards | L = 7 cm .77 yard |
| **Features** | Ideal for tiny target detection | Easy setting<br>High temperature resistance |
| **Sensing method** | Diffuse Reflective | Diffuse Reflective |
| **Light source** | Red LED | Red LED |
| **Max. sensing distance (cm inch)** | 1.5 / .591<br>1.0 / .394<br>0.5 / .197<br>1 / .394 | 1 / .394 |
| **Rated operating voltage** | 12 to 24 V DC | |
| **Rated current consumption** | Max. 40 mA (excluding load) | |
| **Output capacity** | Max. 80 mA | |
| **Standard target** | White drawing paper (1 cm×1 cm) | |
| **Detectable target** | Transparent/Opaque | Transparent/Opaque |
| **Sensing speed** | 100 times/s | |
| **Protective construction** | Fiber tip: Equivalent to IEC IP66 | |
| **Mounting pitch (mm inch)** |   |   |
| **Applicable amplifier** | Light ON: MP-F1A-DC12/24V<br>Dark ON: MP-F2A-DC12/24V |  |

| | | | |
|---|---|---|---|
| **Detection principle** | Reflection Light Intensity Detection Method | | |
| **Product name** | MP Amplifier Selfcontained-AC/DC Photoelectric Sensors | | |
| **Type** | Amplifier Selfcontained-AC/DC | | |
| | MP-1KP(T) | MP-R500P(T) | MP-D70P(T) |
| **Appearance** (mm [illegible]) |   | |   |
| **Features** | Operation with either AC or DC power source<br>Built-in timer type also available | Relay output 3 A 250 V AC<br>No misoperation of output during power on or off condition | |
| **Sensing method** | Thru-Beam | Retroreflective | Diffuse Reflective |
| **Light source** | Infrared LED | | |
| **Max. sensing distance** (cm [illegible]) | 1,000 | 500 | 70 |
| **Rated operating voltage** | 12 to 24 V AC/DC, 100 to 240 V AC/DC | | |
| **Rated power consumption** | DC: Max. 3 W, AC: Max. 3 VA | DC: Max. 2.5 W; AC: Max. 2.5 VA | DC: Max. 2.5 W; AC: Max. 2.5 VA |
| **Output capacity** | 3 A 250 V AC (resistive) | | |
| **Standard target** | 30 mm dia. metal plate (Dull black finish) | 70 mm dia. metal plate (Dull black finish) | White drawing paper (20 cm×20 cm) |
| **Detectable target** | Opaque | Translucent/Opaque | Transparent/Opaque |
| **Sensing speed** | 25 times/s [T type: 20 times/s] | | |
| **Protective construction** | Equivalent to IEC IP66 | | |
| **Mounting pitch** (mm [illegible]) | [illegible] | [illegible] | [illegible] |

# TERMINOLOGY

## ■ Thru-beam type

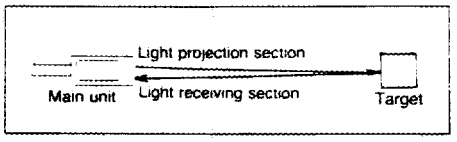
This refers to the method of detection in which the light receiver and the light project are positioned opposite each other, and due to a target passing between the two, the received light level is caused to change.




## ■ Diffuse reflective type

In this method of detection, the light projection section and light receiving section are set either coaxially or with their axes closely adjacent.

When an object passes in front of the detector or approaches sufficiently close to cause a change in the reflected light level, detection occurs.




## ■ Sensing distance

This is the distance range over which the object can be detected by the photoelectric sensor. For the thru-beam type and retroreflective type, this refers to the maximum distance which can be set for stable operation. For the diffuse reflective type, it refers to the maximum distance for stable operation with a standard detectable target.

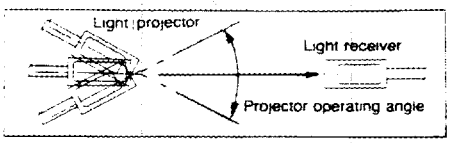
## ■ Standard target

Basically this refers to a detectable object that can be used as a standard for measuring performance characteristics by defining form, dimension, and material.

## ■ Operating angle

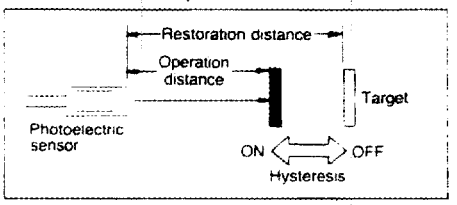
This refers to the angle through which the light projector, light receiver, and reflecting panel can operate in the horizontal and/or vertical direction based on the designated conditions (standard test conditions).

When it is too narrow, adjustment of the light axis at the time of setting is difficult, and when it is too wide, due to adjacently positioned photoelectric sensors, interference easily occurs.




## ■ Hysteresis

In the diffuse reflective type photoelectric sensor, this refers to the difference in distance between operation and restoration.




## ■ Operation with light intercepted

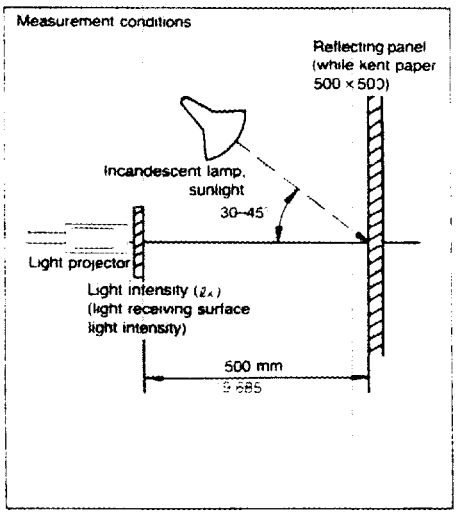
This refers to the manner of operation in which light beam entering the light receiver (section) is intercepted or reduced sufficiently to cause operation. It is called "Dark-ON".

## ■ Operation with light entry

This refers to the manner of operation in which an increase in the level of the light beam entering the photoelectric sensor causes operation to occur. It is called "Light-ON".

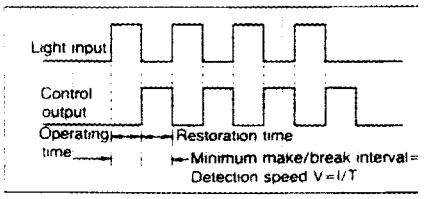
## ■ Permissible ambient light

The maximum light level from external sources, measured in lux, which will not cause more than a 20% variation in the received light signal level.




## ■ Detection speed

The minimum interval of switching of t output section is designated as greate than that determined by the number o times of operation in one second. This represents the total of make and brea time.




## ■ Response time

Normally with regard to the operating time and restoration time, for the photo electric sensor these times are essent the same.

## ■ IEC IP code

The IEC (International Electrotechnica Commission) has established standar and within these standards, to indicate the level of protection, a characteristic code designated as IP with 2 digits is used to indicate the environmental co ditions to which there must be confor

IP □□

Second characteristics di

First characteristics digit

First characteristics digit

| 1st digit | Protection level |
|---|---|
| 0 | No protection |
| 1 | Protected from a solid body greater than 50 m |
| 2 | Protected from a solid body greater than 12 m |
| 3 | Protected from a solid body greater than 2.5 m |
| 4 | Protected from a solid body greater than 1.0 m |
| 5 | Preventative formation |
| 6 | Resistance formation |

Second characteristics digit

| 2st digit | Protection level |
|---|---|
| 0 | No protection |
| 1 | At designed conditions, protected against water drip |
| 2 | At designated conditions, protected against wate dripping when inclined at an angle of 15° |
| 3 | At designated conditions, protected against spraying water |
| 4 | At designated conditions, protected against water splashing |
| 5 | At designated conditions, protected against a water |
| 6 | At designated conditions, when exposed to a wa jet, water does not enter the inside section |
| 7 | At designated conditions, protected so that unde water immersion conditions, there is no influence |
| 8 | Protected against water soaking condition |

# OPERATING PRINCIPLES

## Detection principle of new Triple Beam™ area reflective series

### ■ Optical triangulation distance measurement method

The light beam emitted by the LED, passing through the condensing lens of the light projector, is applied to the surface of the target to be detected. One part of the diffused reflected light rays passes through the light receiver lens producing a spot at a position on the detection element. When the detectable target is at a position A that is at a comparatively near distance as shown in Fig. 1, a spot is produced at (a). When the target is at a position B that is far, a spot is produced at (b). Accordingly, if any spot position on the position detecting element is detected, the distance to the target can be determined. This is the principle of optical triangulation range measurement.

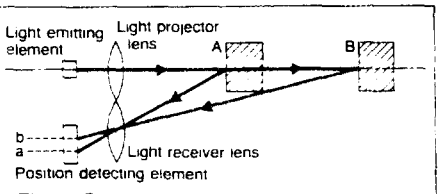



Fig. 1 Optical triangulation range measurement method
Other examples of this method are the automatic focusing and camera range measurement systems.

### ■ Triple Beam type range measurement principle

The MQ photoelectric sensor area reflective type has adapted this optical triangulation range measurement principle, but in order to improve the reliability of the detection of the sensor, a more elaborate method has been devised. First, light receivers are positioned symmetrically on either side of the axis of the light projector, composing a triple beam arrangement. As shown in Fig. 2, when the moving detectable target is at the edge of the projected light beam, the spot reflected from the target is at a location different from the point where the spot is produced when the beam is completely intercepted, generating a range measurement difference of $+\Delta X$, but with the triple beam composition, the symmetrically arranged position detection element (2) has a spot produced conversely at a $-\Delta X$ difference position, and by means of averaging both range measurement signals, the correct range measurement can be made. This results in significantly improved repeatability and background suppression.

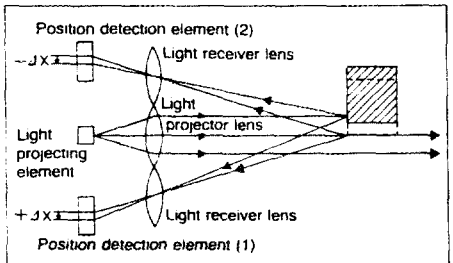



Fig. 2 Beam range measurement method
By averaging the range measurement signals of the 2 light receiving systems, the range measurement difference is cancelled.

### ■ Optical system of the Triple Beam photoelectric sensor

In the MQ photoelectric sensor area reflective type, it is necessary to give special consideration to the lens. In order to improve the precision, an aspherical lens, having limited spherical and coma aberration, is used.
In addition, as shown in Fig. 4, a photo diode having 2 output terminals is used. By comparing the output currents from the 2 elements, there is no relationship to the level of the incident light. Thus, the ratio of reflection from the detectable target exerts no influence and the range measurement and detection can be interpreted accuracy.

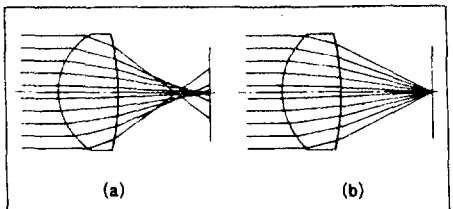



Fig. 3 Light beam trace of the lens
(a) is a spherical lens, and (b) is the aspherical lens. Because there is no aberration in (b), range measurement precision is high.

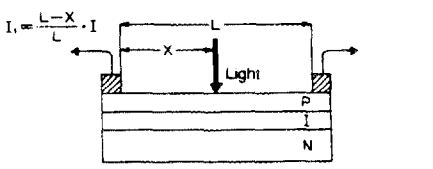



Fig. 4 PSD (position detection element) construction
By making a calculation of the ratio of $I_1$ and $I_2$, the light spot position can be detected.

### ■ Operating principle of area reflective method

The operation of the MQ photoelectric sensor area reflective type is explained in Fig. 5. After the output from the 2 PSD elements is added, the I/V value is converted and the logarithm determined. By subtraction, the distance signal in ($I_1/I_2$) is obtained. This can be optionally set, and with the distance adjustment control, comparison with the produced value can be made to sense whether the target is or is not within the sensing distance.

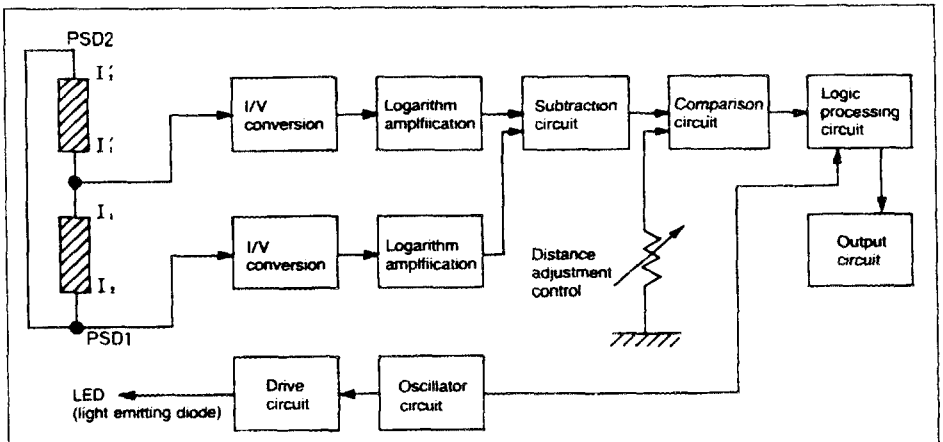


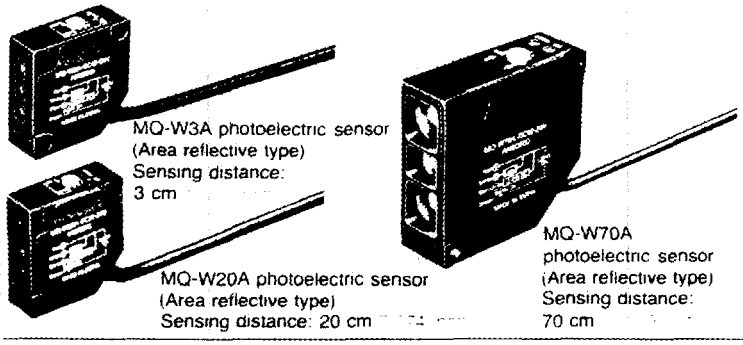

Fig. 5 Signal processing circuit block diagram

Aromat

# TRIPLE BEAM™ RANGE MEASUREMENT PHOTOELECTRIC SENSOR

Components for advanced technology

# MQ-W Area Reflective Photoelectric Sensors




- **Ignores variations in colors, materials and target shape — Reliably detects clear, black, multi-colored objects.**
- **Very accurate beam light detection with no miss-operation, ignoring walls, machinery, or other objects beyond the set sensing distances**
- **Stable position detection even with soiled lens surface**
- **High speed detection: 250 times/second**
- **Enviropnmental resistance (IEC IP 67)**
- **Light ON or OFF output detection is selectable**
- **Wide-range operation 12 to 24 V DC**

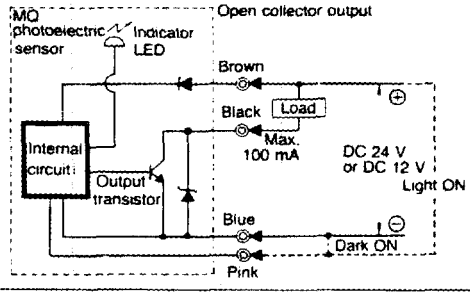
## PRODUCT TYPE

cm

| Detection method | Product name | Part No. | Operation | Max. sensing distance | Packing Inner | Packing External |
|---|---|---|---|---|---|---|
| Area reflective type | MQ-W3A photoelectric sensor | MQ-W3A-DC12-24 V* ** | Light-ON/Dark-ON selectable | 3 | 1 pc | 10 pcs |
| | MQ-W20A photoelectric sensor | MQ-W20A-DC12–24 V* ** | Light-ON/Dark-ON selectable | 20 | | |
| | MQ-W70A photoelectric sensor | MQ-W70A-DC12–24 V* | Light-ON/Dark-ON selectable | 70 | | |

## OUTPUT CIRCUIT DIAGRAM

*PNP output type available. Substitute "C" for the "A" in the part number.
**Red LED type available. Add "R" after the "A" in the part number.

| Detection method | Circuit diagram | Type | Output transistor operating condition | Operation indicator LED | Load operation condition |
|---|---|---|---|---|---|
| Area reflective type |  | MQ-W3A | (When red and green are connected.) When light enters ON (Light-ON) (When black and green are connected) When light is blocked ON (Dark-ON) | When light inters ON | (When red and green are connected.) Operates when light enters (When black and green are connected.) Operates when light is blocked |
| | | MQ-W20A | | | |
| | | MQ-W70A | | | |



## SPECIFICATIONS

1. Ratings

| Item | | Description |
|---|---|---|
| Operating side | Rated operating voltage | 12 to 24 V DC |
| | Rated current consumption | Max. 30 mA (excluding load) |
| Load side | Output current capacity | Max. 100 mA |

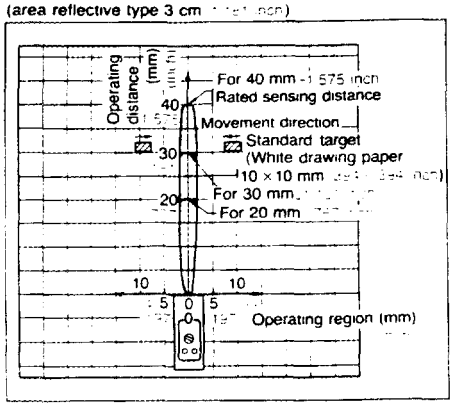
2. Performance outline

| Type | MQ-W3A | MQ-W20A | MQ-W70W |
|---|---|---|---|
| Standard target | White drawing paper 1×1 cm | White drawing paper 2×2 cm | White drawing paper 7.5×7.5 cm |
| Detectable target | Translucent and opaque target | | |
| Operating voltage range | 9.6 to 30 V DC ripple (P-P) included | | |
| Max. sensing distance | 3 cm | 20 cm | 70 cm 27 |
| Possible distance range | 2 to 3 cm .787 to 1.181 inch | 4 to 20 cm | 20 to 70 cm |
| Hysteresis | Max. 10% of max. sensing distance | Max. 20% of max. sensing distance | |
| Initial insulation resistance | Min. 20 MΩ (at 500 V DC): Between a lead wire and external housing | | |
| Initial dielectric strength | 500 Vrms for 1 min: Between a lead wire and external housing | | |
| Detection speed | 2 ms (250 times/s) | | |
| Vibration resistance | 10 to 55 Hz: 1 cycle/min double amplitude of 1.5 mm (2 hours on 3 axes) | | |
| Shock resistance | 100 G (6 times on 3 axes) | | |
| Protective construction | Diecast case immersion protected (equivalent to IEC IP67) | | |
| Usable ambient light level: Incandescent lamp | Max. 10.000 lux | | |
| Usable ambient light level: Sunlight | Max. 30.000 lux | | |
| Ambient temperature | −25° to +55°C | | |
| Ambient humidity | Max. 85% RH | | |
| Indicator | Operation indicator LED: Red ON with light entry: Adjustment indicator LED: Red ON with sufficient intensity of lights | | |
| Light source | Infrared LED | | |

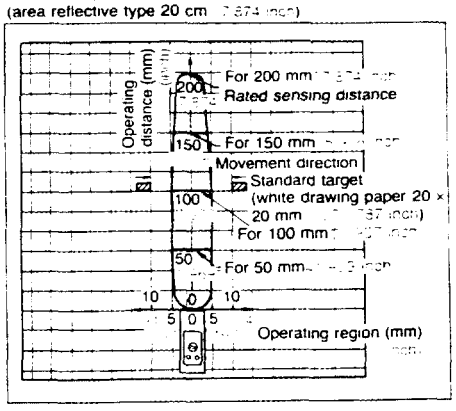
Note: Undesignated measurement conditions are assumed to be rated operating voltage, storage battery power source, ambient temperature 20°C, standard target, and light intensity at light receiving surface less than 200 lux.

# DATA

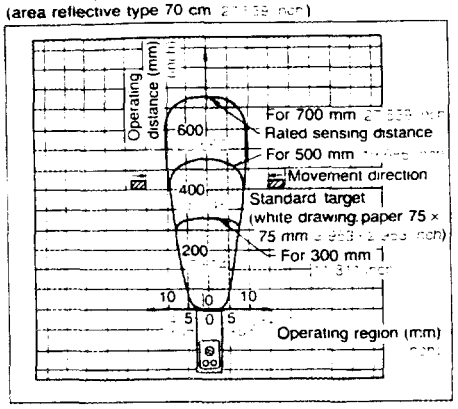
MQ-W3A photoelectric sensor
(area reflective type 3 cm)




MQ-W20A photoelectric sensor
(area reflective type 20 cm)

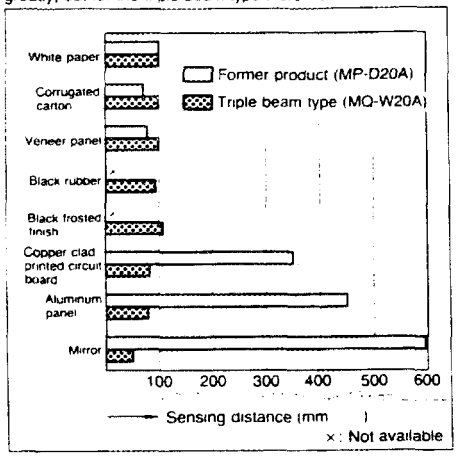



MQ-W70A photoelectric sensor
(area reflective type 70 cm)

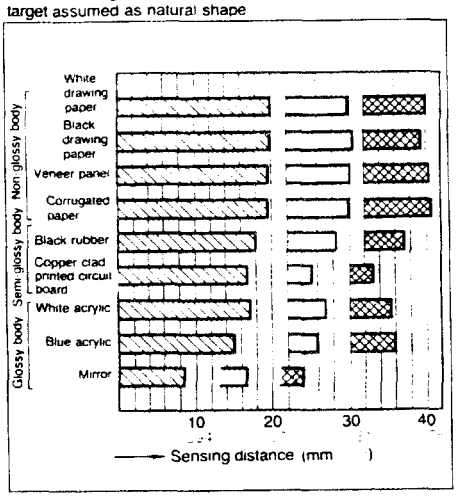



## 2. Material characteristics

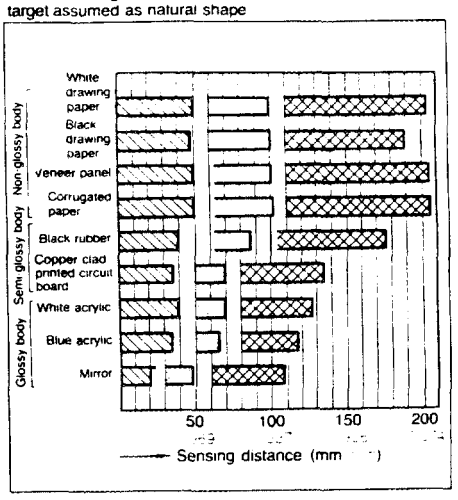
Comparison between MQ-W20A and former product
Condition: Target (40×60 mm)
target assumed as natural shape
For the former product (diffuse reflective type), depending upon the object material, the operating region varied greatly, but for the triple beam type there was no variation.




MQ-W3A photoelectric sensor
(area reflective type 3 cm)
Condition: Target (40×60 mm)
target assumed as natural shape

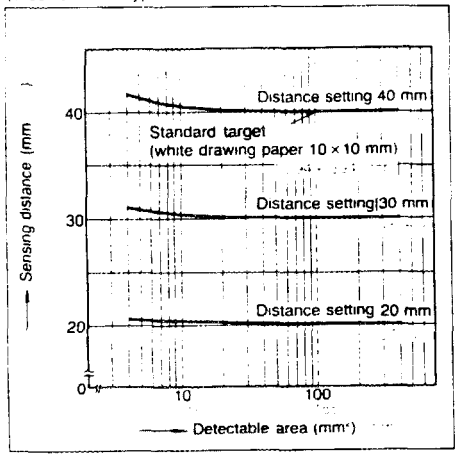



MQ-W20A photoelectric sensor
(area reflective type 20 cm)
Condition: Target (40×60 mm)
target assumed as natural shape

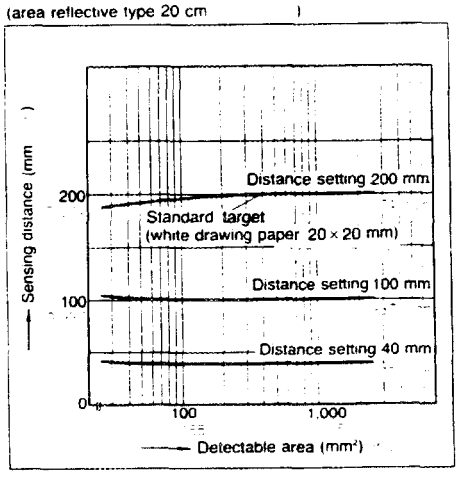



## 3. Sensing distance vs. surface area characteristic

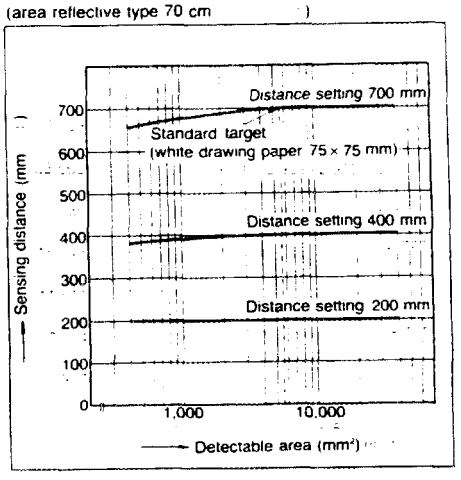
MQ-W3A photoelectric sensor
(area reflective type 3 cm)




MQ-W20A photoelectric sensor
(area reflective type 20 cm)

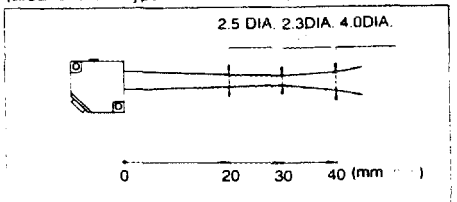



MQ-W70A photoelectric sensor
(area reflective type 70 cm)



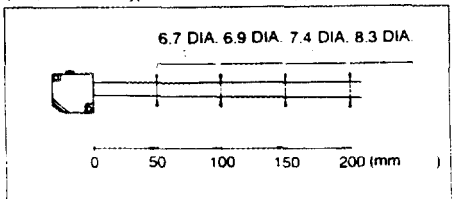

## 4. Light projector beam diameter characteristic

MQ-W3A photoelectric sensor
(area reflective type 3 cm)



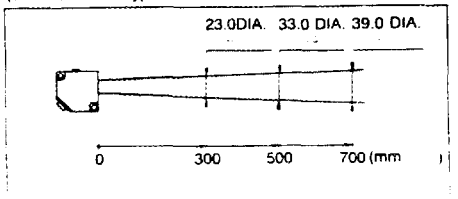

Light beam diameter is determined as the region where the amount of light is decreased to $1/e^2$ ($e \fallingdotseq 2.72$) when the largest amount of light is assumed as 1.

MQ-W20A photoelectric sensor
(area reflective type 20 cm)




Light beam diameter is determined as the region where the amount of light is decreased to $1/e^2$ ($e \fallingdotseq 2.72$) when the largest amount of light is assumed as 1.

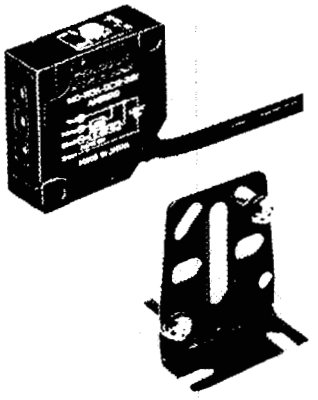
MQ-W70A photoelectric sensor
(area reflective type 70 cm)



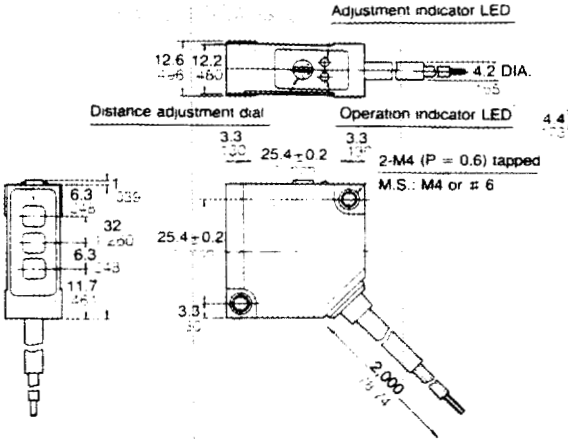

Light beam diameter is determined as the region where the amount of light is decreased to $1/e^2$ ($e \fallingdotseq 2.72$) when the largest amount of light is assumed as 1.

# DIMENSIONS mm inch

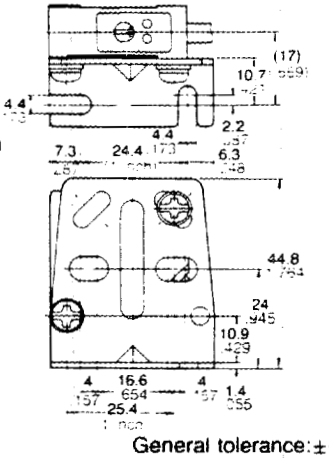
1. MQ-W3A (area reflective type)



External form dimensional drawing

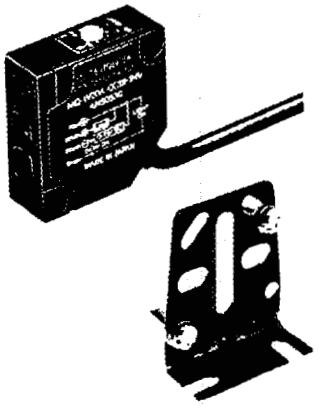



Photoelectric sensor with a bracket on

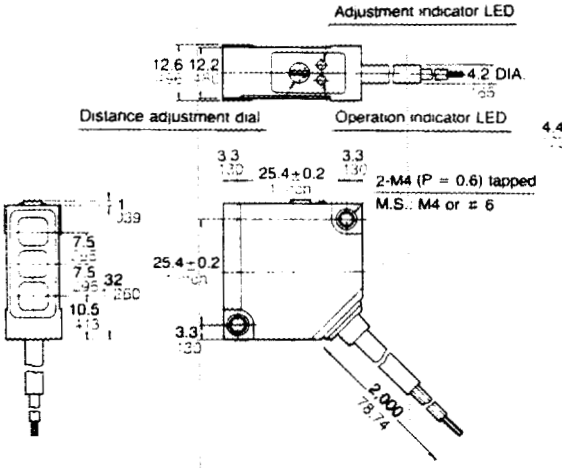



General tolerance: ±0.5 ±.020

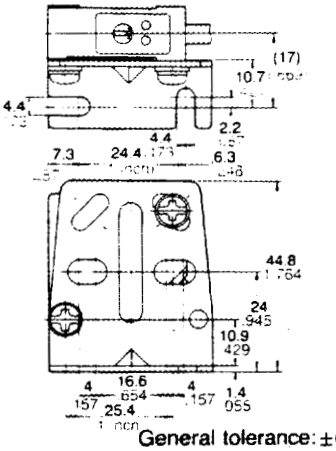
2. MQ-W20A (area reflective type)



External form dimensional drawing

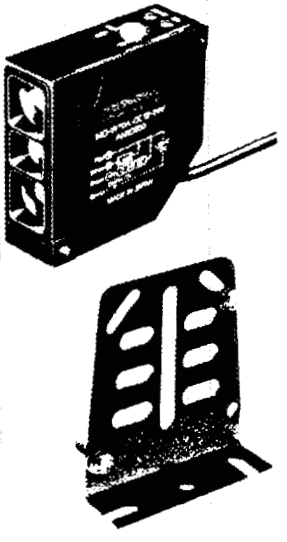



Photoelectric sensor with a bracket on

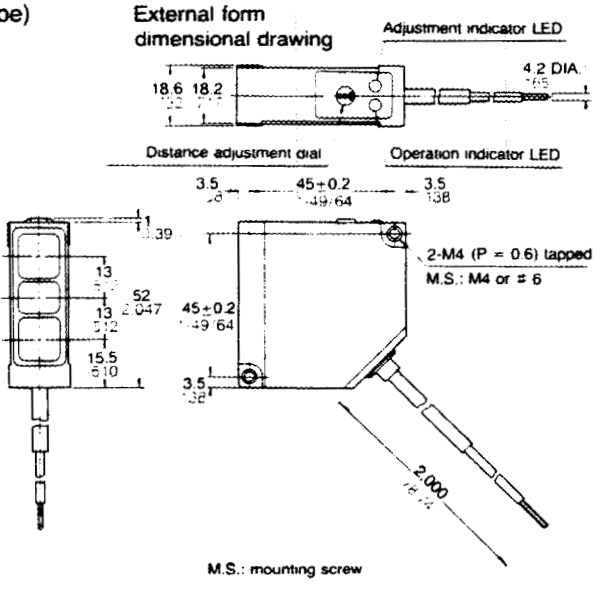



General tolerance: ±0.5 ±.020

3. MQ-W70A (area reflective type)

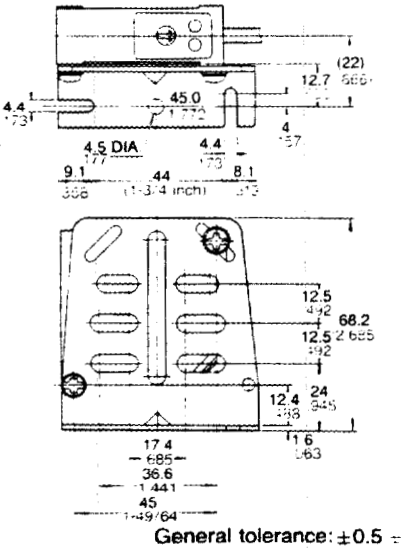


External form dimensional drawing



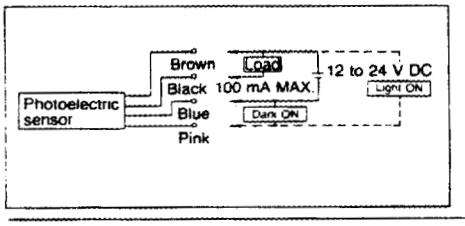

M.S.: mounting screw

Photoelectric sensor with a bracket on




General tolerance: ±0.5 ±.020

# CONNECTING DIAGRAM




Make connection to ⊕ side with pink wire for Light ON

Make connection to ⊖ side with pink wire for Dark ON

Note: When switching a power source, make ground connection to the frame ground terminal or to the ground terminal. This will assure more stable operation.

| | Operating condition | |
|---|---|---|
| Output transistor | With light intercepted ON<br>With light entering ON | Common use |
| Operation indicator LED | Lights with light entering | |

# CAUTIONS

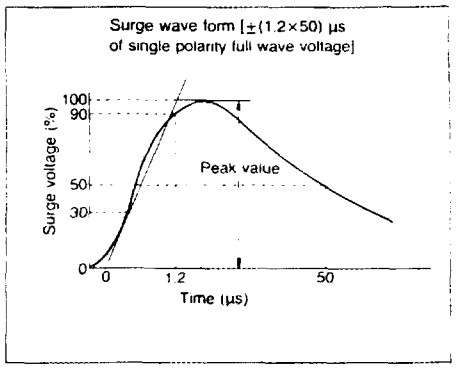
**1. Ambient environment**

1) Use within the range of ambient temperature of −25°C to +55°C (−13°F to +131°F).

2) Use within a range of 9.6 V to 30 V DC (ripple P-P included) for operating voltage.

3) Use with an ambient light level at the light receiving surface of less than 10,000 lux for incandescent lamp and less than 30,000 lux for sunlight.

4) Because a surge voltage exceeding 500 V [±(1.2×50) μs of single polarity full wave voltage] may cause damage to the internal circuit, a surge absorbing element should be used.




5) Avoid using in a location where there is excessive steam, dust, or corrosive gas.

6) The sensor is of immersion protected type, but this does not mean that it can be used in water or where there is direct impingement of rain for detecting objects.

**2. Connections**

1) Because the internal circuit can be damaged due to incorrect connections, before power is applied, the wiring should be thoroughly checked.

2) Load relays having a rated operating voltage of 12 V or 24 V DC as the load should be used. Care should be taken to allow for the voltage drop (1.2 V) from the operating voltage of the internal circuit as applied to the load relay.

3) If a load greater than 100 mA is connected, the output section will be damaged, so sufficient care should be taken.

4) If the wiring to the photoelectric sensors run parallel to high voltage or power lines, due to inductive noise, misoperation or damage can occur. Wiring should be run in separate conduits.

5) Use cable of 0.3 mm² AWG22 or larger for extensions, and the length should be less than 100 meters (328 ft).

6) If the unit is struck by a hammer or other heavy tool, the function can be impaired. Sufficient care should be taken.

7) The changeover from Light-ON (light entry ON) to Dark-ON (light intercepted OFF) can be carried out with the pink lead wire. For Light-ON, connect the pink wire to the ⊕ side, and for Dark-ON, connect the pink wire to the ⊖ side.

**3. Distance adjustment**

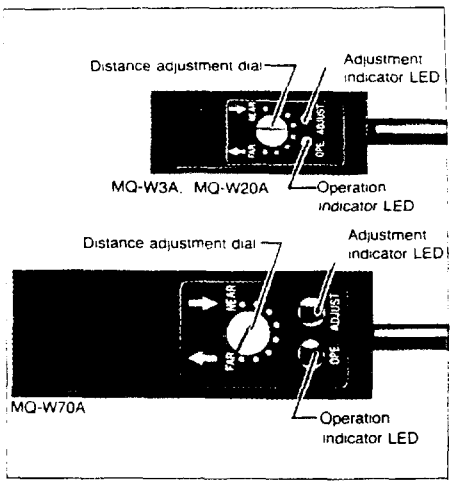
1) Set the detecting surface of the photoelectric sensor in the detecting direction and temporarily fasten it.

2) While no target is in the detection region, set the distance adjustment dial to maximum (FAR) and slowly turn it counterclockwise.
Continue turning the control counterclockwise until the operation indicator LED (OPE.) is extinguished. This is the adjustment position. If the indicator LED is extinguished at the maximum position, that is the adjustment position.

3) With target in the detection area, set the dial in the minimum position (NEAR) and turn the control clockwise to locate the position where the indicator LED turns ON. If the indicator LED goes ON at the minumum position, then NEAR is the adjustment position.

4) Set the control to a point midway between the locations found in step 2) and step 3) above.

5) Securely fasten the photoelectric sensor. When fastening, the sensor should be sufficiently secure so that it will not shift under vibration or shock.




Notes:

1. If the adjustment indicator LED does not light in the adjustment of step 3) as prescribed, or if the position between step 2) and step 3) is less than 2 graduations, change the position of the detection surface and repeat the procedure of step 1) to step 4), or try to determine the source of external factors such as variation in ambient temperature, variation in target position, etc., that is creating the problem.

2. The difference in detection distance due to the colors of the target is virtually non-existent, but if the actual target is one where the reflectivity is extremely low (targets which have a frosted finish produced by black rubber), or where the reflectivity is extremely high (mirror, glass, or truly reflecting target), confirmation should be done with the actual target.

**4. Sensing section**

1) If an excessive amount of dust or dirt adheres to the detection surface, despite the fact that the detection method is not greatly affected by such a condition, the detection distance may be reduced, and it is advisable to keep the detection surface clean.

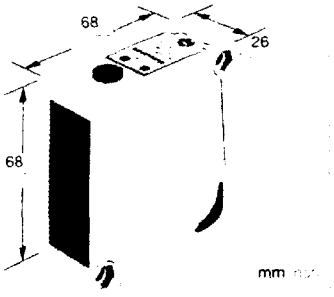
2. The front surface of the lens is polycarbonate. This material is resistant to water, dilute acids and alkalis, aliphatic hydrocarbons, oils, etc., but it is not resistant to ketones, esters, halogenated hydrocarbons, or aromatic hydrocarbons.

Aromat

# AREA REFLECTIVE AMPLIFIER SELFCONTAINED -DC TYPE -AC/DC TYPE

Components for advanced technology

# MR3/MR3-T Photoelectric Sensors




**1. Long distance range measurement sensors.**
The first long distance detection photoelectric sensors for 1m and 2m applications. Suitable for detection of passing targets and positioning.

**2. New added type with timer functions.**
The 3-mode (ON-delay, OFF-delay, One-shot) timer function is built-in the MR3-T type, to prevent detection errors and make it easier to send a high speed signal through a PC etc. The control time range is from 0.1 to 5 sec.

**3. AC or DC power**
The DC type operates on 12 to 24V DC and the AC/DC type on 12 to 240V DC or 24 to 240V AC power supply. This allows for operation voltages world wide.

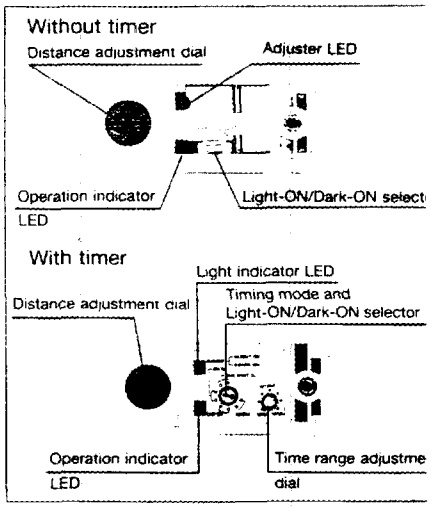
**4. Accurately detects objects, regardless of colors, materials and shapes.**
Area reflective type sensor permits the detection of white and black targets at the same distance. Also targets with mixed colors, difficult to detect with standard diffuse reflective type sensors, can be detected.

**5. Unaffected by background objects.**
Area reflective type sensors do not detect objects beyond the set point. False detection, caused by movement beyond detectable objects, does not occur.

**6. Tolerates dirty lens with consistent position detection.**
There is virtually no variation in the operation even if the lens surface becomes dirty. Position detection of targets approaching from the front is always constant.

**7. Various outputs selectable**
Two outputs are provided for the DC type, one NPN and one PNP output, so that a single photoelectric sensor can match the polarity of the power supply wiring. The output section of the AC/DC type contains compact yet 1 Form A contact rated 3A, 250V AC (resistive).

**8. Designed for easy installation and adjustment.**
- Screw terminals for easy wiring.
- One-touch switch for mode selection




**9. An output protection circuit is built-in the DC type.**

**10. Water-protected construction (equivalent to IEC IP66).**

## APPLICATIONS

Detection of medium to large targets. Large product assembly lines, automat vertical warehouses, personnel detection, etc.

## PRODUCT TYPE

**1. MR3-M100 area reflective types** (Max. sensing distance: 100 cm 1.1 yards)

| Type | | Name | Part No. | Specifications |
|---|---|---|---|---|
| DC type (NPN and PNP) | Without timer | MR3-M100A photoelectric sensor | MR3-M100A-DC12-24V | Light-ON / Dark-ON changeover |
| | With timer: Normal ON-delay, OFF-delay One-shot (Selectable with the switch) | MR3-M100AT photoelectric sensor | MR3-M100AT-DC12-24V | |
| AC/DC type | Without timer | MR3-M100P photoelectric sensor | MR3-M100P-12-240V | |
| | With timer: Normal ON-delay, OFF-delay One-shot (Selectable with the switch) | MR3-M100PT photoelectric sensor | MR3-M100PT-12-240V | |

**2. MR3-M200 area reflective types** (Max. sensing distance: 200 cm 2.2 yards)

| Type | | Name | Part No. | Specifications |
|---|---|---|---|---|
| DC type (NPN and PNP) | Without timer | MR3-M200A photoelectric sensor | MR3-M200A-DC12-24V | Light-ON / Dark-ON changeover |
| | With timer: Normal ON-delay, OFF-delay One-shot (Selectable with the switch) | MR3-M200AT photoelectric sensor | MR3-M200AT-DC12-24V | |
| AC/DC type | Without timer | MR3-M200P photoelectric sensor | MR3-M200P-12-240V | |
| | With timer: Normal ON-delay, OFF-delay One-shot (Selectable with the switch) | MR3-M200PT photoelectric sensor | MR3-M200PT-12-240V | |

# SPECIFICATIONS

## 1. DC type

### 1-1) Ratings

| | | Types without timer, MR3 | Types with timer, MR3-T |
|---|---|---|---|
| Operating side | Rated operating voltage | 12 to 24V DC | |
| | Rated current consumption | Max. 55mA (excluding load) | Max. 60mA (excluding load) |
| Load side | Output current capacity | Max. 100mA (NPN side), Max. 100mA (PNP side) | |

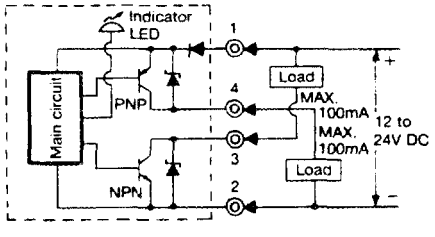
### 1-2) Performance

| | | Types without timer, MR3 | | Types with timer, MR3-T | |
|---|---|---|---|---|---|
| | | MR3-M100A | MR3-M200A | MR3-M100AT | MR3-M200AT |
| Standard target | | White drawing paper: 20×20cm | | | |
| Detectable target | | Translucent and opaque material | | | |
| Operating voltage range | | 9.6 to 30V DC ripple (P-P) included | | | |
| Max. sensing distance | | 1m | 2m | 1m | 2m |
| Possible distance range | | 0.2 to 1m | 0.5 to 2m | 0.2 to 1m | 0.5 to 2m |
| Hysteresis | | 10% or less of max. sensing distance | | | |
| Initial insulation resistance | | Min. 20MΩ (at 500V DC) Between input/output terminal and external housing | | | |
| Initial breakdown voltage | | Between input/output terminal and external housing: 500Vrms for 1 min | | | |
| Detection speed | | 1ms (500 times/s) | | | |
| Vibration resistance | Functional | 10 to 55Hz (1 cycle/min), double amplitude 1.5mm (10min on 3 axes) | | | |
| | Destructive | 10 to 55Hz (1 cycle/min), double amplitude 1.5mm (2h on 3 axes) | | | |
| Shock resistance | Functional | 10G (6 times on 3 axes) | | | |
| | Destructive | 100G (6 times on 3 axes) | | | |
| Protective construction | | Plastic case, water-protected (equivalent to IEC IP66) | | | |
| Usable ambient light level | Incandescent lamp | Max. 3,000 lux | | | |
| | Sunlight | Max. 10,000 lux | | | |
| Ambient temperature | | −25°C to 55°C | | | |
| Ambient humidity | | Max. 85%RH | | | |
| Storage temperature | | −30°C to 70°C | | | |
| Indicator | | Operation indicator LED (Light incident), Adjuster LED | | Light indicator LED (Light incident), Operation indicator LED | |
| Light source | | Infrared LED | | | |
| Timing functions | Time range | — | | 0.1 to 5s | |
| | Timer mode | — | | Normal, ON-delay, OFF-delay, One-shot | |

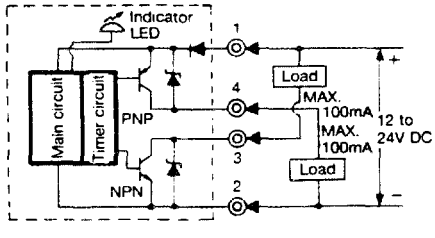
Unless otherwise specified, the measurement conditions comprise rated operating voltage, power supply by battery, 20°C ambient temperature, standard target and 200 lux or less illuminance on the receiver surface.

### 1-3) Output circuit diagram

Types without timer, MR3

| Circuit diagram | Type |
|---|---|
|   | MR3-M100A<br>Detection ON<br>Detection OFF<br><br>MR3-M200A<br>Detection ON<br>Detection OFF |

Types with timer, MR3-T

| Circuit diagram | Type |
|---|---|
|   | MR3-M100AT<br>Detection ON<br>Detection OFF<br><br>MR3-M200AT<br>Detection ON<br>Detection OFF |

## 2. AC/DC type

### 2-1) Ratings

| | | Types without timer, MR3 | Types with timer, MR3-T |
|---|---|---|---|
| Operating side | Rated operating voltage | 12 to 240V DC/24 to 240V AC | |
| | Rated power consumption | DC: Max. 3W AC: Max. 4VA | DC: Max. 4W AC: Max. 5VA |
| Load side | Output capacity | 3A 250V AC (resistive) | |

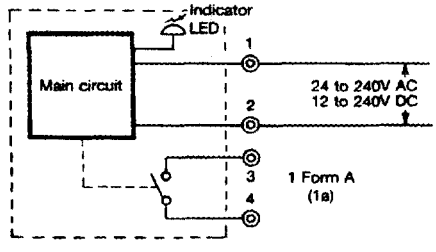
### 2-2) Performance

| | | Types without timer, MR3 | | Types with timer, MR3-T | |
|---|---|---|---|---|---|
| | | MR3-M100P | MR3-M200P | MR3-M100PT | MR3-M200PT |
| Standard target | | White drawing paper: 20×20cm 7.874×7.874 inches | | | |
| Detectable target | | Translucent and opaque material | | | |
| Operating voltage range | | 10.8 to 264V DC/21.6 to 264V AC | | | |
| Max. sensing distance | | 1m 1.1 yards | 2m 2.2 yards | 1m 1.1 yards | 2m 2.2 yards |
| Possible distance range | | 0.2 to 1m .22 to 1.1 yards | 0.5 to 2m .55 to 2.2 yards | 0.2 to 1m .22 to 1.1 yards | 0.5 to 2m .55 to 2.2 yards |
| Hysteresis | | 10% or less of max. sensing distance | | | |
| Initial insulation resistance | | Min. 100MΩ (at 500V DC) Between live terminal and dead metal parts; Between live terminal and contact; Between contact and dead metal parts; Between open contacts: | | | |
| Initial breakdown voltage | | Between live terminal and dead metal parts: 2,000Vrms for 1 min<br>Between live terminal and contact: 2,000Vrms for 1 min<br>Between contact and dead metal parts: 2,000Vrms for 1 min<br>Between open contacts: 1,000Vrms for 1 min | | | |
| Detection speed | | 20ms (25 times/s) | | | |
| Vibration resistance | Functional | 10 to 55Hz (1 cycle/min), double amplitude 1.5mm .059 inch (10min on 3 axes) | | | |
| | Destructive | 10 to 55Hz (1 cycle/min), double amplitude 1.5mm .059 inch (2h on 3 axes) | | | |
| Shock resistance | Functional | 10G (3 times on 3 axes) | | | |
| | Destructive | 100G (3 times on 3 axes) | | | |
| Protective construction | | Plastic case, water-protected (equivalent to IEC IP66) | | | |
| Usable ambient light level | Incandescent lamp | Max. 3,000 lux | | | |
| | Sunlight | Max. 10,000 lux | | | |
| Usable ambient temperature | | −25°C to 55°C −13°F to 131°F | | | |
| Usable ambient humidity | | Max. 85%RH | | | |
| Storage temperature | | −30°C to 70°C −22°F to 158°F | | | |
| Indicator | | Operation indicator LED (Light incident), Adjuster LED | | Light indicator LED (Light incident), Operation indicator LED | |
| Light source | | Infrared LED | | | |
| Timing functions | Time range | — | | 0.1 to 5s | |
| | Timer mode | — | | Normal, ON-delay, OFF-delay, One-shot | |
| Output | Contact arrangement | 1 Form A | | | |
| | Initial contact resistance (By voltage drop 6V DC 1A) | Max. 100mΩ | | | |
| | Contact material | Gold flash over silver alloy | | | |
| | Expected life (max.) | Electrical: $10^5$ times (20 cpm at rated load) Mechanical: $5\times10^7$ times (20 cpm) | | | |

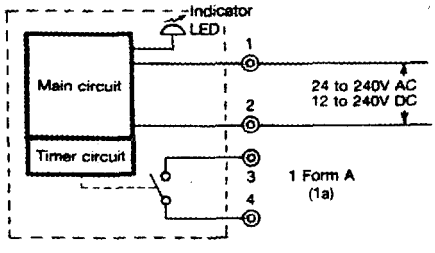
Unless otherwise specified, the measurement conditions comprise rated operating voltage, 20°C 68°F ambient temperature, standard target and 200 lux or less illuminance on the receiver surface.

### 2-3) Output circuit diagram

Types without timer, MR3

| Circuit diagram | Type |
|---|---|
|   | MR3-M100P<br>Detection ON<br>Detection OFF |
| | MR3-M200P<br>Detection ON<br>Detection OFF |

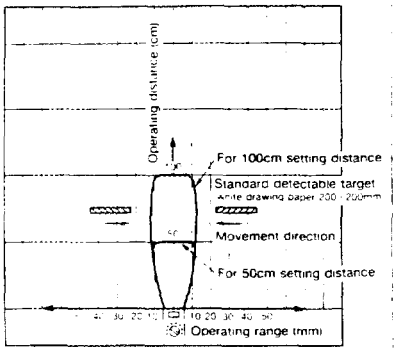
Types with timer, MR3-T

| Circuit diagram | Type |
|---|---|
|   | MR3-M100PT<br>Detection ON<br>Detection OFF |
| | MR3-M200PT<br>Detection ON<br>Detection OFF |

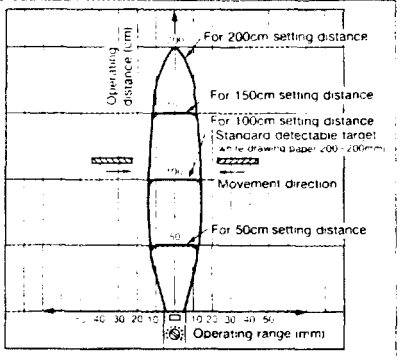
# DATA

## 1. Operation range characteristics

① MR3-M100 types
(Area reflective type 100cm )

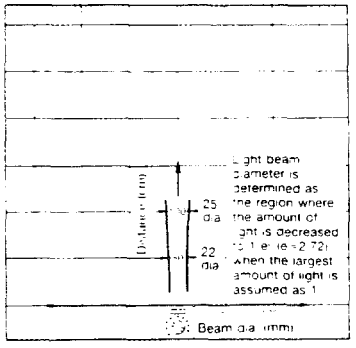



② MR3-M200 types
(Area reflective type 200cm )

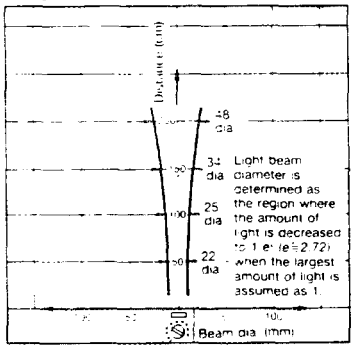



## 2. Projector beam dia. characteristics

① MR3-M100 types
(Area reflective type 100cm )

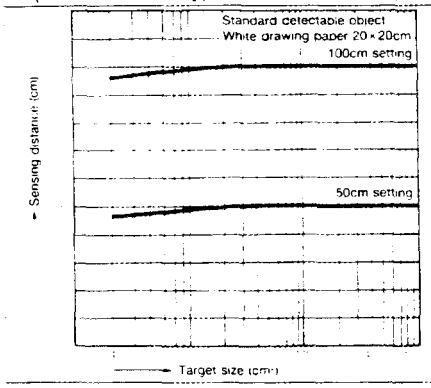



② MR3-M200 types
(Area reflective type 200cm )

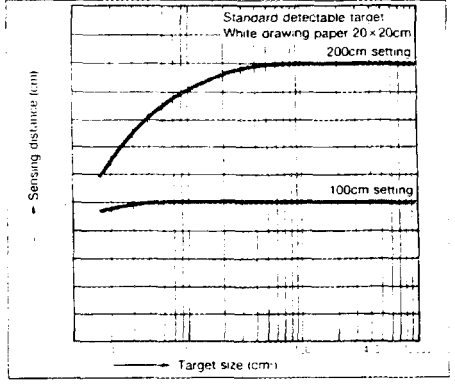



## 3. Detectable target characteristics

① MR3-M100 types
(Area reflective type 100cm )



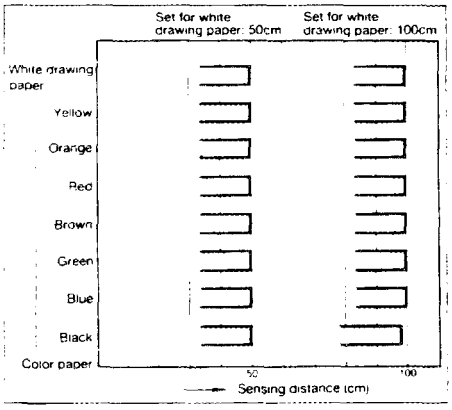

② MR3-M200 types
(Area reflective type 200cm )




## 4. Material characteristics

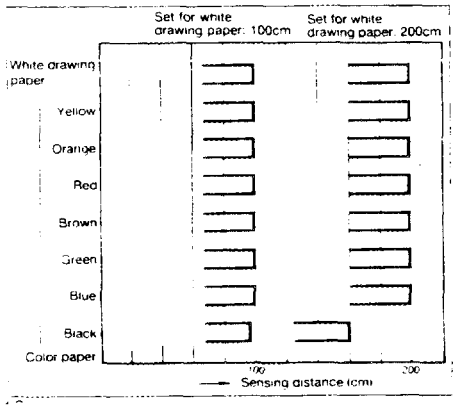
① MR3-M100 types
(Area reflective type 100cm )

Condition: Target: 15 × 15(cm) natural shape




② MR3-M200 types
(Area reflective type 200cm )

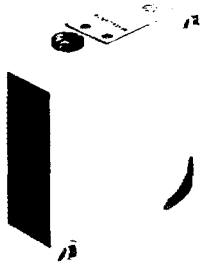
Condition: Target: 15 × 15(cm) natural shape



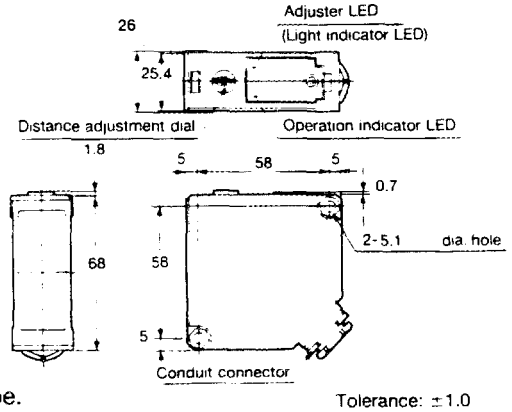

# DIMENSIONS

mm

MR3/MR3-T Photoelectric sensor



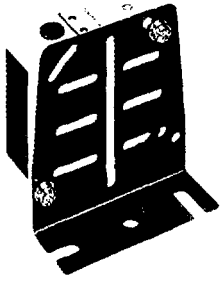
Outline dimensions

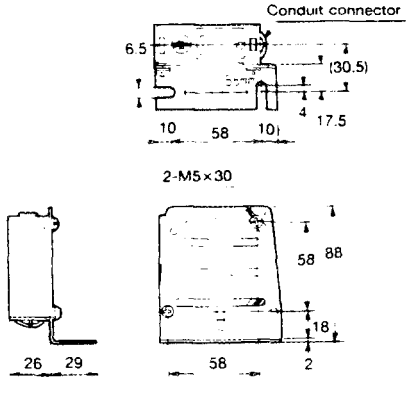



( ) denotes MR3-T timer type.

Tolerance: ±1.0

Dimensions with the mounting bracket attached.



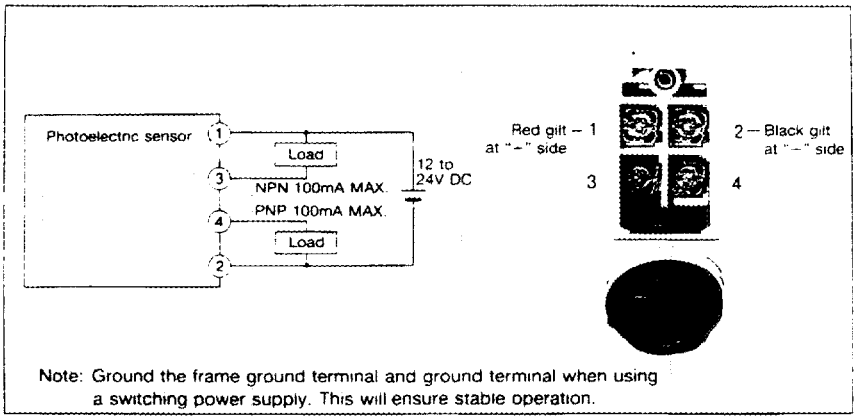



Note: The mounting bracket is enclosed in the inner carton.

Tolerance: ±1.0

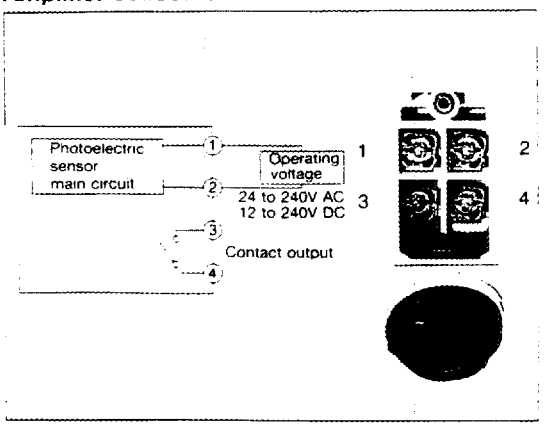
# SCHEMATIC

**Amplifier selfcontained-DC**



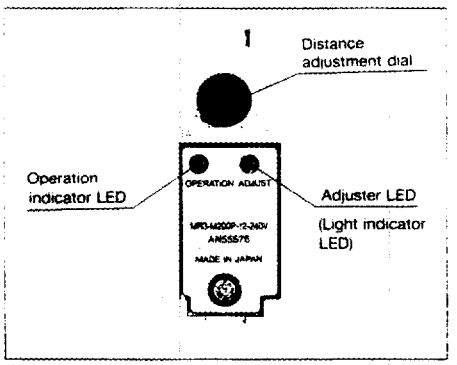

Note: Ground the frame ground terminal and ground terminal when using a switching power supply. This will ensure stable operation.

**Amplifier selfcontained-AC/DC**




# DISTANCE ADJUSTMENT

1) Point the detection surface of the photoelectric sensor in the direction to detect and temporarily fasten.
2) Set the distance adjustment dial to its maximum setting FAR. Slowly turn it counterclockwise without an object present and note the position where the operation (light) indicator LED turns OFF. The maximum position at which the LED turns off is the FAR position.
3) Place a target at the detection position and set the distance adjustment dial to its minimum setting NEAR. Slowly turn it clockwise and note the operation (light) indicator LED turns ON. The minimum position at which the LED turns ON is the NEAR position.
4) Set the distance adjustment dial to the middle of the two positions found in step 2) and step 3) before.
5) Fasten the photoelectric sensor. Mount securely so that the photoelectric sensor is not shifted from alignment by vibrations or impact.




**For the MR3-T timer type, see the words in the ( ).**

**Notes:**
1. If the adjuster LED does not turn on in step 4) (note that there is no adjuster LED for the MR3-T timer type), or if the position of the distance adjustment dial in step 2) or step 3) is less than 2 graduations, either change the position of the detection surface and repeat step 1) to step 4), or adjust external factors such as ambient temperature variations, position of detection target, etc.
2. The detection distance varies only slightly with the color of the target. However, if the target has an extremely low reflection factor (dull black rubber), detection may not be possible, or if the target has an extremely high reflection factor (mirrors, glass, glossy paper and other specular reflection target), adjustment of the detection distance may not be possible. Use the actual target to check operation.
3. Excessive force should not be applied to the distance adjustment dial, otherwise it may be damaged.

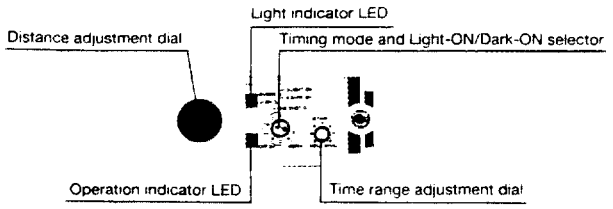
# TIMING FUNCTIONS FOR MR3-T TIMER TYPE

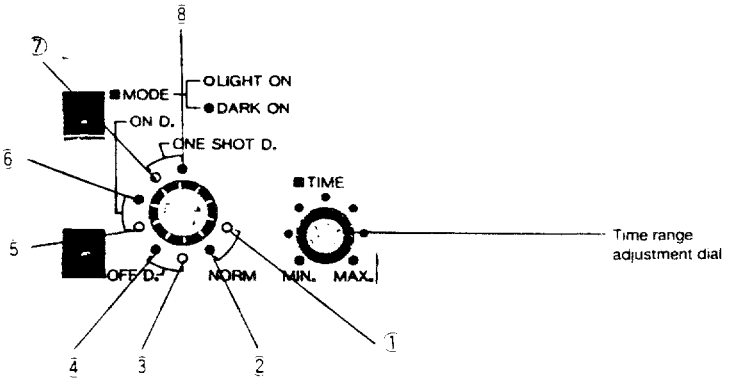
**1) Timing operation**

| Control output mode | Timing mode (Timing mode selector *1) | Detection state | Timing functions |
|---|---|---|---|
| | | Light entry / Light blocked | |
| Light-ON mode | Normal mode ① | ON / OFF | — |
| | ON-delay mode ⑤ | ON / OFF (T) | Inhibits control output for the set time (Ts) |
| | OFF-delay mode ③ | ON / OFF (T) | The control output stays ON for the set time (Ts) after detection is over. |
| | One-shot mode ⑦ | ON / OFF (T) | The control output is ON for the set time (Ts) after detection. |
| Dark-ON mode | Normal mode ② | ON / OFF | — |
| | ON-delay mode ⑥ | ON / OFF (T) | The control output is inhibited OFF for the set time after detection is over. |
| | OFF-delay mode ④ | ON / OFF (T) | The control output stays OFF for the set time (Ts) after detection. |
| | One-shot mode ⑧ | ON / OFF (T) | The control output is ON for the set time (Ts) after detection is over. |

*1: See "Timing mode and Light-ON/Dark-ON selector" below.
Notes: 1) Timing range: T 0.1s to 5s
2) During the normal mode, the time range adjustment dial should be set to MIN position.

**2) Timing mode and Light-ON/Dark-ON selector**




① Light-ON/Normal mode
② Dark-ON/Normal mode
③ Light-ON/OFF-delay mode
④ Dark-ON/OFF-delay mode
⑤ Light-ON/ON-delay mode
⑥ Dark-ON/ON-delay mode
⑦ Light-ON/One-shot mode
⑧ Dark-ON/One-shot mode

# CAUTIONS

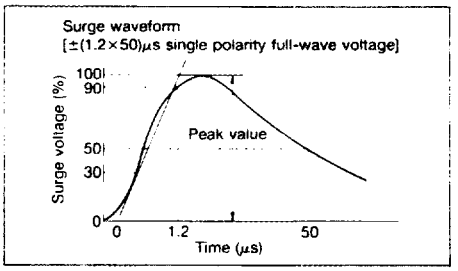
**1. Operating Environment**

1) The sensor should be used in an ambient temperature range of −25°C to +55°C −13°F to +131°F.

2) Use an operating voltage in the range of 9.6V to 30V DC (includes peak to peak ripple) for the DC types and 21.6V to 264V AC or 10.8V to 264V DC for the AC/DC types.

3) The light intensity on the receiver surface should be less than 3,000 lux for an incandescent light source and less than 10,000 lux for sunlight.

4) Use a surge absorber as the internal circuit may be damaged if external surge voltages exceed 500V (for DC type)/4,000V (for AC/DC type) [±(1.2×50)μs single polarity full-wave voltage].




5) Avoid use in locations with high concentrations of steam, dust, corrosive gases, etc.

6) Use a load relay with a rated operating voltage of 12V DC or 24V DC for the DC types. The voltage applied to the load relay is the operating voltage of the photoelectric sensor minus the internal voltage drop (maximum 1.2V NPN side, 2V PNP side). Voltage fluctuations should be taken into account.

7) The output circuit of the DC type contains a short-circuit protection circuit. When controlling loads with a large inrush current, such as capacitive loads, be sure the inrush current does not exceed the maximum output current capacity. If the short-circuit protection circuit is activated, it can be reset either by turning the power off and then turning it back on, or by ON/OFF operation.

**2. Wiring**

1) Check all wiring before applying power since incorrect wiring may damage the internal circuit.
Also, carefully tighten the terminal screws so that the wires of adjacent terminals do not touch.

2) Although any cable can be used, a round cable with a smooth surface and an outside diameter of 9 to 11mm .354 to .433 inch should be used and the cable connector (supplied) shall be tightened correctly to maintain water-tight performance. Use a tightening torque of 15 to 20kg·cm 13.02 to 17.35lb·in.

3) The conduit inlet accepts PF1/2 threads.

4) If crimp terminals are used, crimp the terminals and then secure with the terminal (M3.5) screws.

5) Tighten the terminal screws with a maximum torque of 5kg·cm [illegible]lb·in.

6) Ground the frame ground (FG) terminal and ground (G) terminal when using a commercially available switching regulator. If a ground is not connected, switching noise from the power supply may result in faulty operation.

7) Wire 0.3mm² AWG22 or larger should be used for wiring up to a length of 100m [illegible]ft.

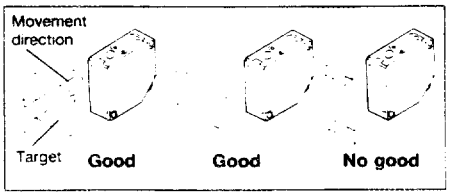
**3. Detector**

1) Keep the detector surface clean as excessive dust or dirt on the detector surface will decrease the margin of the sensing distance.

2) The front surface of the lens and case are made of polycarbonate resin. Although it withstands water, weak acids and alkalines, aliphatic hydrocarbons, and oils and fats, it is not resistant to ketones, esters, halogenated hydrocarbons and aromatic hydrocarbons.

**4. Movement Direction of the Target**

Take care with the mounting direction of the photoelectric sensor with respect to the movement direction of the target.

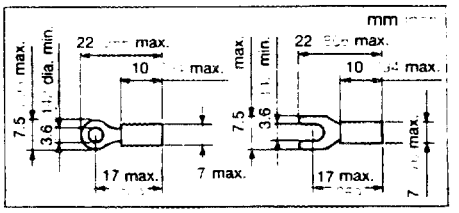



**5. Other cautions**

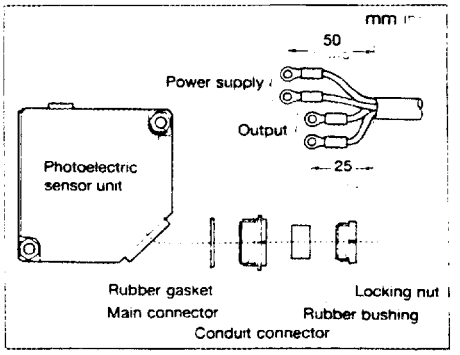
1) When using the supplied mounting bracket, tighten the mounting screws with a maximum torque of 8kg·cm 6.94lb·in. If the supplied mounting bracket is not used, mount the sensor on a flat surface.

2) Using a torque of 3 to 5kg·cm 2.60 to 4.34lb·in. tighten the terminal cover and display cover screws to maintain watertight performance.

# USABLE CRIMP TERMINAL DIMENSIONS



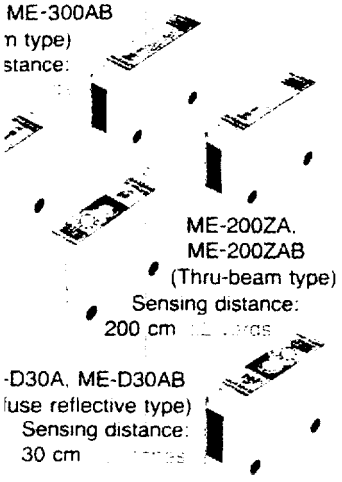

# CABLE CONNECTOR CONSTRUCTION AND CABLE PREPARATION



# EASY INSTALLATION AND MAINTENANCE

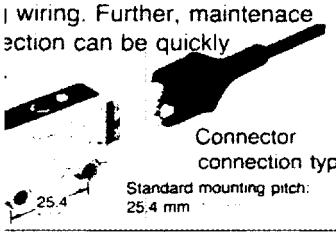
Components for advanced technology

# ME Photoelectric Sensors




**ector connection type with bility in mind**

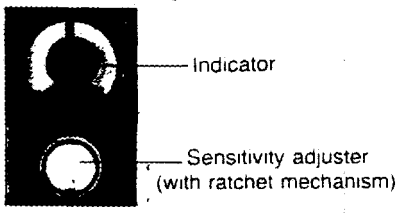
nection type allows separation of iting job and the wiring job, thus l wiring. Further, maintenace ection can be quickly




**2. Three-turn adjuster with ratchet mechanism (Indicator provided)**

For detection adjustment, the three-turn adjuster corresponds to the fine detection conditions.

Further, the ratchet mechanism prevents the adjuster from breakage caused by excessive turning during adjustment. The indicators which are visible at a glance faciliate setting when a number of the switches are arranged in line.

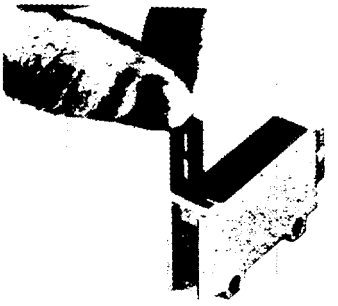



**3. Thru-beam type, ME-200ZA which detects even a translucent object**

The ME-200ZA and ME-200ZAB are provided with the three-turn adjuster. Accordingly, a translucent object which has been hard to detect in the existing thru-beam type can be detected.

**4. Silt filter attachable**

To detect a tiny object or to improve the positioning accuracy, the effective slit filter can be attached. (Separately available)



**5. High speed detection of 1 msec.**

Detection is possible at a rate of 500 times per sec., thus corresponding to high speed machines such as electronic part insertion machines.

**6. Common use for 12-24V DC operational voltage**

The sensor can be used over a wide range from 9.6V to 30V DC.

## APPLICATIONS

Electronic equipment production lines for electric appliances and measuring instruments (under optimum environmental conditions)

## )UCT TYPE

nplifier Selfcontained-DC Photoelectric Sensor

| tion d | Product name | Operation state | Max. sensing distance | Part No. (with connector) | Part No. (with cabled connector) |
|---|---|---|---|---|---|
| | ME-300A photoelectric sensor with projector and receiver in a set | Dark-ON | 300 cm 3.3 yards | ME-300A1-DC12-24V | ME-300A2-DC12-24V |
| eam | ME-300AB photoelectric sensor with projector and receiver in a set | Light-ON | 300 cm 3.3 yards | ME-300AB1-DC12-24V | ME-300AB2-DC12-24V |
| | ME-200ZA photoelectric sensor with projector and receiver in a set | Dark-ON | 200 cm 2.2 yards | ME-200ZA1-DC12-24V | ME-200ZA2-DC12-24V |
| | ME-200ZAB photoelectric sensor with projector and in a set | Light-ON | 200 cm 2.2 yards | ME-200ZAB1-DC12-24V | ME-200ZAB2-DC12-24V |
| e tive | ME-D30A photoelectric sensor | Light-ON | 30 cm [illegible] | ME-D30A1-DC12-24V | ME-D30A2-DC12-24V |
| | ME-D30AB photoelectric sensor | Dark-ON | 30 cm [illegible] | ME-D30AB1-DC12-24V | ME-D30AB2-DC12-24V |

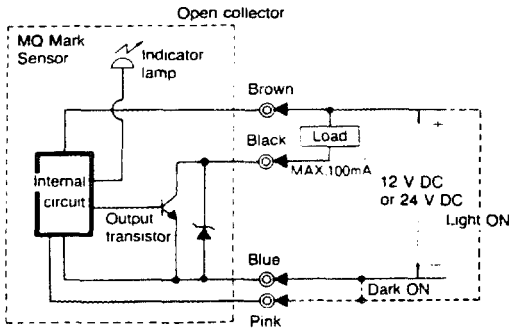
unting hardware are provided.

ssories

| duct name | Specifications | Application | Part No. |
|---|---|---|---|
| plate set | Round, vertical and horizontal holed plates are available in a set two per each. | ME photoelectric sensor | ANA1804 |
| nnector terminal type) | Dust protective cover provided | MQ-F amplifier unit and ME photoelectric sensor | AN53810 |
| nnector rminal type) | Dust protective cover provided | Projector of ME photoelectric sensor | AN53811 |
| bled connector ore type) | 2 m long cable and dust protective cover provided | Projector of ME photoelectric sensor | AN53812 |
| bled connector core type) | 2 m long cable and dust protective cover provided | MQ-F amplifier unit and ME photoelectric sensor | AN53813 |

ite: The connector or cabled connector is attached to the main body of the photoelectric sensor.

## OUTPUT CIRCUIT DIAGRAM

| Detection method | Circuit diagram | Type | Output transistor operating condition | Operation indicator lamp | Load operating condition |
|---|---|---|---|---|---|
| Diffused reflection |   | MQ-VD2AR | When red and green are connected together, with light input circuit goes ON (Light ON)<br><br>When black and green are connected together, with light cut off circuit goes ON (Dark ON) | Lights with light input | When red and green are connected together, operates with light input<br><br>When black and green are connected together, operates with light cut off |

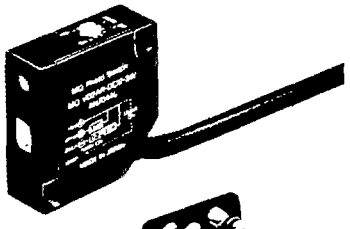
## DIMENSIONAL DRAWING

MD-VD2AR (MARK SENSOR)

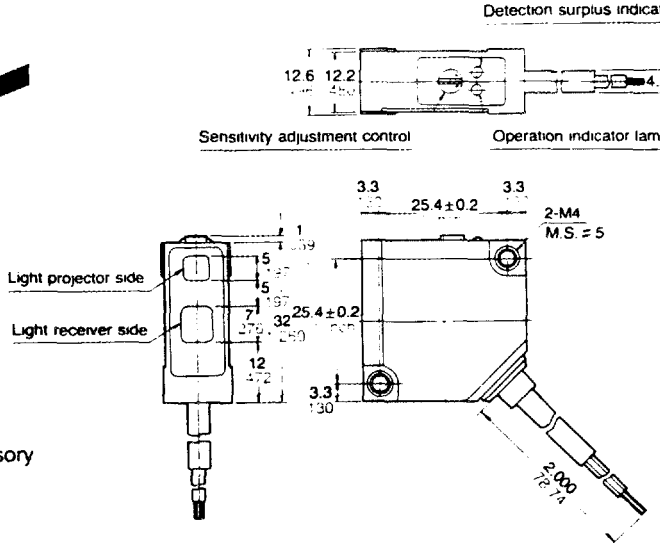
mm inch

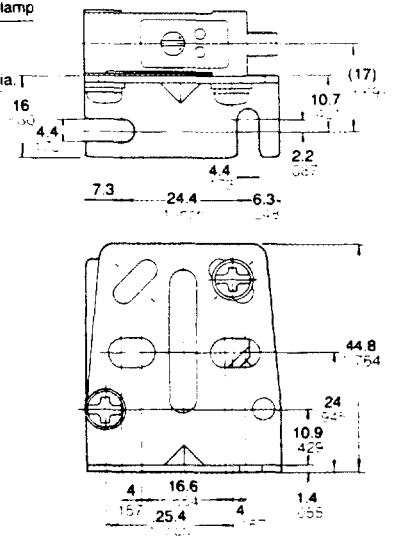
External form drawing

Mounting bracket mounting condition drawing



Mounting bracket accessory

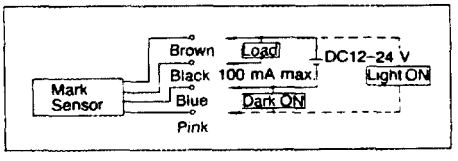



M.S.: Mounting screw

General tolerance: ±0.5 ±.020

## WIRING




For light ON, connect pink to + side; for dark ON connect pink to – side.
Note: When used for power source switching, ground both the frame ground and ground terminal. This provides more positive safety.

| | Operating condition | |
|---|---|---|
| Output transistor | Light cut off ON<br>Light input ON | common use |
| Operation indicator lamp | Light with light input | |

## REGISTER MARK DETECTION ADAPTATION

| Base color \ Register mark color | Black | Red | Orange | Yellow | Green | Blue | White |
|---|---|---|---|---|---|---|---|
| Black | | ○ | ○ | ○ | | | ○ |
| Red | ○ | | | | ○ | ○ | |
| Orange | ○ | | | | ○ | ○ | |
| Yellow | ○ | | | | ○ | ○ | |
| Green | | | ○ | ○ | | | ○ |
| Blue | | ○ | | ○ | | | ○ |
| White | | | | | ○ | ○ | |

This table shows the criteria for selection when the sensor is used for register mark detection applications.

The "○" indicates suitability for use.

# CAUTIONS

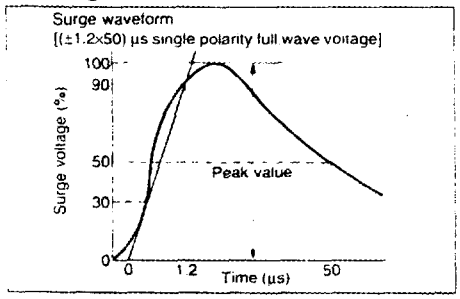
**1. Regarding ambient environment**

1) Use in the ambient temperature range of −25°C to +55°C (−13°F to +131°F).

2) Use in the operating voltage range of 9.6 V DC to 30 V DC (ripple P-P included).

3) The ambient light intensity at the light receiving surface should be less than 3,000 lux for incandescent light and less than 10,000 lux for sunlight.

4) If an external surge voltage exceeding 500 V [(±1.2×50) μs single polarity full wave voltage] is impressed, the internal circuit will be damaged, and a surge suppressing element should be used.




5) Avoid use in locations where there is excessive steam, dust, or corrosive gases.

6) This sensor is an immersion proof type, but this does not imply that the sensor can be used immersed in water or for detection of objects in rain.

**2. Regarding wiring connections**

1) Because of the possibility of damaging the internal circuit due to incorrect wiring, before applying power, confirm the correctness of the wiring.

2) For the load relay, use relays of rated operating voltage of 12 V or 24 V DC. Because there is a voltage drop internally in the Mark Sensor of a maximum of 1.2 V, this should be considered as a factor in the operating voltage variation for the load relay.

3) For an extension cable, less than 100 m (110 yards) in length, use wire of at least 0.3 mm² AWG22.

4) When mounting the Mark Sensor, do not use a hammer or other tool for striking the device, since such tools can impair the function of the device.

5) The changeover from ON with light input to ON with light cut off is accomplished with the connection of the pink lead wire. For ON with light input (light ON) connect the pink lead wire to the + side; for ON with light cut off (dark ON), connect the pink lead wire to the − side

**3. Regarding the detection object**

The detection object should be a mark with a mark background in a different color system: (white, yellow, orange, and red systems) combined with (black, blue, and green systems). Combinations of the same colors indicated in the parentheses will produce low sensitivity and are not suitable.

**4. Regarding sensitivity adjustment**

For a black background with a white mark:

1) Aim the detection surface of the Mark Sensor in the sensing direction and temporarily fasten it.

2) Place the mark in the detection position, and adjust the control slowly from the minimum (L) position until the position is found where the operation indicator lamp lights. If the light remains lit even when the control is reduced to the minimum position (L), then that is the detection sensitivity position.

3) With the condition of no mark present, adjust the sensitivity starting from the maximum (H) position of the control and turn counterclockwise until the operation indicator lamp goes out. If the lamp goes out even in the H position, that is the setting for no mark present.

4) The final setting should be midway between the settings found in step 2) and step 3) above.

5) Fasten the Mark Sensor. Be sure to fasten the unit securely so that it will not shift due to shock or vibration.

**Note:**
In setting the adjustment in step 4) for detecting the mark, if the detection surplus indicator lamp does not light, or if the adjustment positions in step 2) and step 3) are less than 2 graduations, change the detection surface position, or change the angle between the sensor and the detection object, and repeat the procedure from step 1) to step 4). The primary causes of variation of the position of detection the mark, such as the ambient temperature variations, or other external variables should be suppressed.

For a white background with a black mark

1) Aim the detection surface of the Mark Sensor in the sensing direction and temporarily fasten it.

2) Place the mark in the detecting position, and adjust the control slowly from the maximum (H) position counterclockwise until the position is found where the operation indicator lamp goes out. If the light is out even when the control is in the H position, then that is the detection sensitivity position.

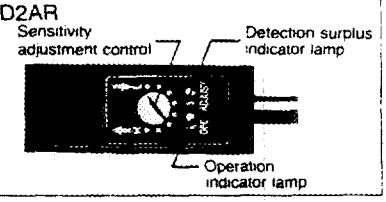
3) With the condition of no mark present, slowly adjust the sensitivity starting from the minimum (L) position and turn clockwise slowly until the operation indicator lamp lights. If the lamp lights even with the control in the minimum position, that is the setting for no mark present.

4) The final setting should be midway between the settings found in step 2) and step 3) above.

5) Fasten the Mark Sensor. Be sure to fasten the unit securely so that it will not shift due to shock or vibration.

**Note:**
In setting the adjustment in step 4) for detecting the mark, if the detection surplus indicator lamp does not light, or if the adjustment positions in step 2) and step 3) are less than 2 graduations, change the detection surface position, or change the angle between the sensor and the detection object, and repeat the procedure from step 1) to step 4). The primary causes of variation of the position ofdetecting the mark, such as the ambient temperature variations, or other external variables should be suppressed.

Diffused reflection type (Mark Sensor)
MQ-VD2AR




**5. Regarding the detection section**

1) If dust, dirt, or other foreign matter adhere to the detection surface, the margin of detection distance will be reduced. The detection surface should be kept clean at all times.

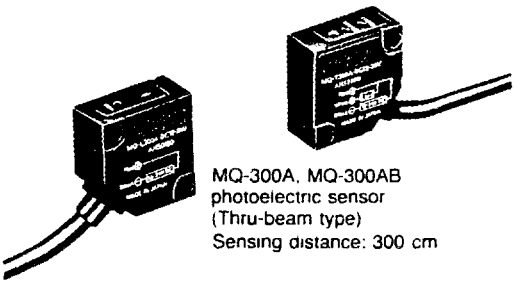
2) The front surface of the lens is made of polycarbonate. This material is resistant to warer, dilute acids and alkalis, aliphatic hydrocarbons, fats, and oils, but it is not resistant to ketones, esters, halogenated hydrocarbons, or aromatic hydrocarbons.

Aromat

# ULTRA MINIATURE TYPE PHOTOELECTRIC SENSOR

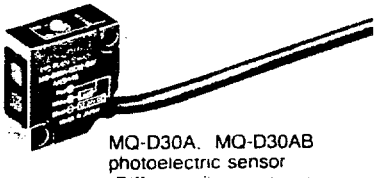
Components for advanced technology

# MQ Photoelectric Sensors

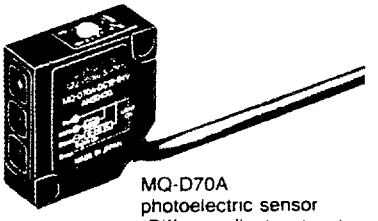


MQ-300A, MQ-300AB
photoelectric sensor
(Thru-beam type)
Sensing distance: 300 cm

- **Ultra minature with built-in amplifier**
- **High speed detection: 500 times/second**
- **Free-mounting, either vertical or horizontal**
- **Environmental resistance (IEC IP 67)**
- **Wide-range operation 12 to 24 V DC**



MQ-D30A, MQ-D30AB
photoelectric sensor
(Diffuse reflective type)
Sensing distance: 30 cm



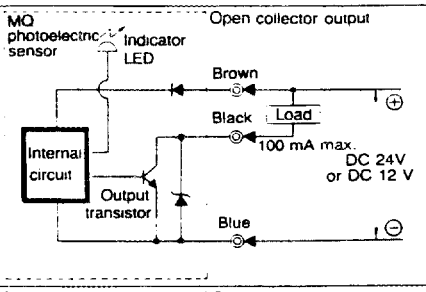
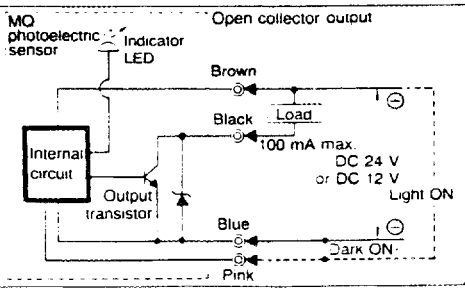
MQ-D70A
photoelectric sensor
(Diffuse reflective type)
Sensing distance: 70 cm

## PRODUCT TYPE

cm

| Detection method | Product name | | Part No. | Operation | Max. sensing distance | Packing Inner | Packing Exturnal |
|---|---|---|---|---|---|---|---|
| Thru-beam type | MQ-300A photoelectric sensor | Projector and receiver | MQ-300A-DC12–24 V | Dark-ON | 300 | 1 pc | 10 pcs |
| | | Projector | MQ-L300A-DC12–24 V | — | — | | |
| | | Receiver | MQ-T300A-DC12–24V | — | — | | |
| | MQ-300AB photoelectric sensor | Projector and receiver | MQ-300AB-DC12–24 V | Light-ON | 300 | 1 pc | 10 pcs |
| | | Projector | MQ-L300A-DC12–24 V | — | — | | |
| | | Receiver | MQ-T300AB-DC12–24 V | — | — | | |
| Diffuse reflective type | MQ-D30A photoelectric sensor | | MQ-D30A-DC12–24 V | Light-ON | 30 | 1 pc | 10 pcs |
| | MQ-D30AB photoelectric sensor | | MQ-D30AB-DC12–24 V | Dark-ON | 30 | | |
| | MQ-D70A photoelectric sensor | | MQ-D70A-DC12–24 V | Light-ON Dark-ON changeover | 70 | | |

## OUTPUT CIRCUIT DIAGRAM

| Detection method | Circuit diagram | Type | Output transistor operating condition | Operation indicator LED | Load operation |
|---|---|---|---|---|---|
| Thru-beam type |   | MQ-300A (Detection ON) | When light is blocked ON | When light enters ON | Operates when light is blocked |
| | | MQ-300AB (Detection OFF) | When light enters ON | | Operates when light enters |
| Diffuse reflective type | | MP-D30A (Detection ON) | When light enters ON | | Operates when light enters |
| | | MP-D30AB (Detection OFF) | When light is blocked ON | | Operates when light is blocked |
| Diffuse reflective type |   | MQ-D70A | [Connect red with green] When light enters ON (Light-ON) [Connect black with green] When light is blocked ON (Dark-ON) | | [Connect red with green] When light enters Operates [Connect black with green] When light is blocked Operates |

# SPECIFICATIONS

1. Ratings

| Item \ Type | | Thru-beam type (MQ-300A, MQ-300AB) | Diffuse reflective type (MQ-D30A, MQ-D30AB, MQ-D70A) |
|---|---|---|---|
| Operating side | Rated operating voltage | 12 to 24 V DC | 12 to 24 V DC |
| | Rated current consumption | Max. 45 mA<br>Light projector: Max. 25 mA<br>Light receiver: Max. 20 mA (excluding load) | Max. 25 mA for MQ-D30A, MQ-D30AB<br>Max. 35 mA for MQ-D70A (excluding load) |
| Load side | Output current capacity | Max. 100 mA | Max. 100 mA |

2. Performance outline

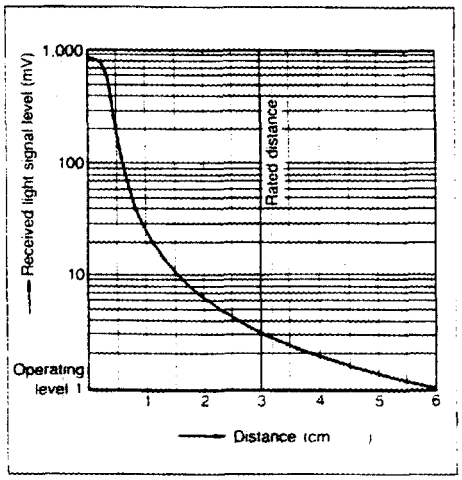
| Type | | Thru-beam type | Diffuse reflective type | |
|---|---|---|---|---|
| | | MQ-300A, MQ-300AB | MQ-D30A, MQ-D30AB | MQ-D70AB |
| Standard target | | 10 mm [illegible] inch diameter metal plate (black frosting) | White drawing paper 10×10 cm 3.937×3.937 inch | White drawing paper 20×20 cm [illegible] |
| Detectable target | | Opaque material of 5 mm dia. or more | Translucent and opaque target | |
| Operating voltage range | | 9.6 to 30 V DC ripple (P-P) included | | |
| *Max. sensing distance | | 3 m 9.42 ft | 30 cm 11.181 inch | 70 cm 29.559 inch |
| Hysteresis | | — | Max. 20% of max. sensing distance | |
| Operation angle | | Min. 5° for for both projector and receiver | — | |
| Initial insulation resistance | | Min. 20 MΩ (at 500 V DC): Between lead wire and external housing | | |
| Initial dielectric strength | | 500 Vrms for 1 min: Between a lead wire and external housing | | |
| Detection speed | | 1 ms (500 times/s) | | |
| Vibration resistance | | 10 to 55 Hz: 1 cycle/min double amplitude of 1.5 mm (2 h on 3 axes) | | |
| Shock resistance | | 100 G (6 times on 3 axes) | | |
| Protective construction | | Diecast case immersion protected (equivalent to IEC IP67) | | |
| Usable ambient light level | Incandescent lamp | Max. 10,000 lux | | |
| | Sunlight | Max. 30,000 lux | | |
| Usable ambient temperature | | −25° to +35°C −13° to +131°F | | |
| Usable ambient humidity | | Max. 85% RH | | |
| Indicator | | Projector: Power indicator LED (red)<br>Receiver: Operation indicator LED (red)<br>Adjustment indicator LED (red) | Operation indicator LED (red)<br>Adjustment indicator LED (red) MQ-D70 type only | |
| Light source | | Infrared LED | | |

Note: Undesignated measurement conditions are assumed to be rated operating voltage, storage battery power source, ambient temperature 20°C 68°F, standard target, and light intensity at light receiving surface less than 200 lux.

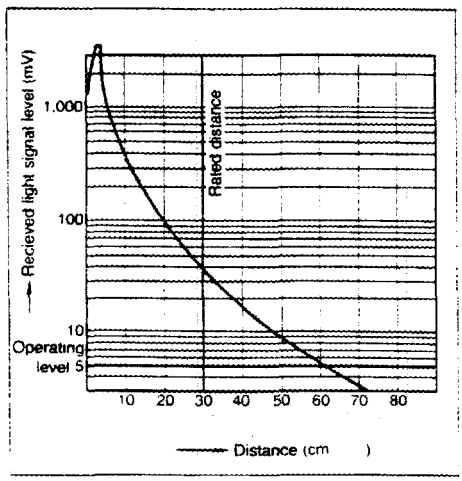
# DATA

1. Received light signal level vs. distance characteristics

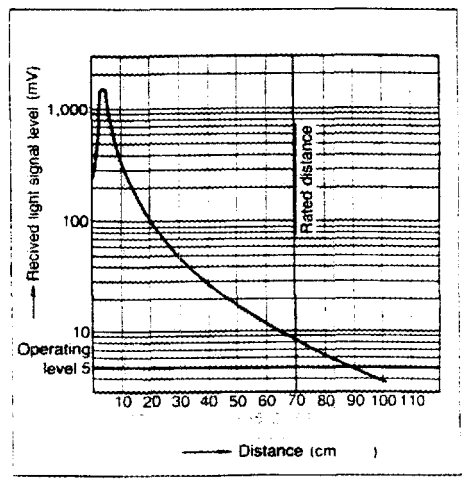
MQ-300A, MQ-300AB photoelectric sensor
(Thru-beam type 300 cm 118.11 inch)




MQ-D30A, MQ-D30AB photoelectric sensor
(Diffuse reflective type 30 cm 11.181 inch)
Condition: At maximum (H) sensitivity control position
Target: 10×10 cm 3.937×3.937 inch white drawing paper

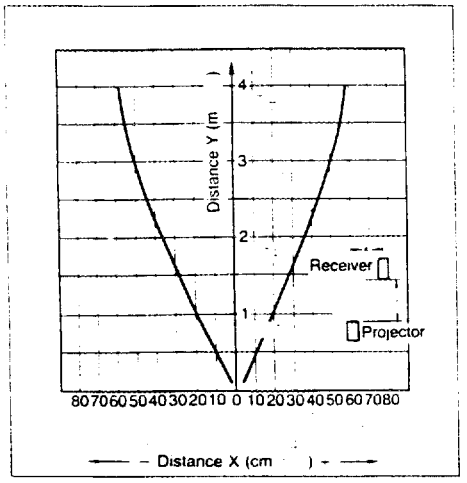



MQ-D70A photoelectric sensor
(Diffuse reflective type 70 cm 27.559 inch)
Condition: At maximum (H) sensitivity control position
Target: 20×20 cm [illegible] inch white drawing paper

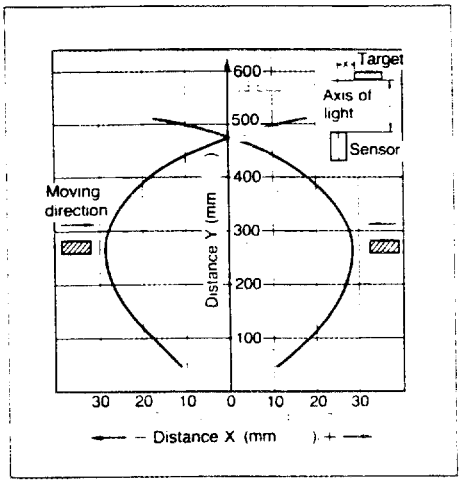


## 2. Operating region characteristics

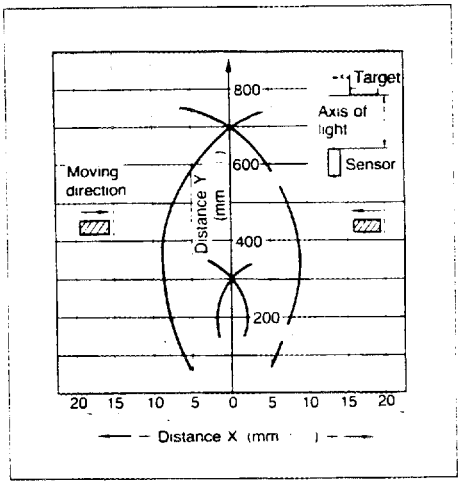
MQ-300A, MQ-300AB photoelectric sensor
(Thru-beam type 300 cm [illegible])




MQ-D30A, MQ-D30AB photoelectric sensor
(Diffuse reflective type 30 cm [illegible])
Condition: At maximum (H) sensitivity control position
Target: 10×10 cm [illegible] white drawing paper

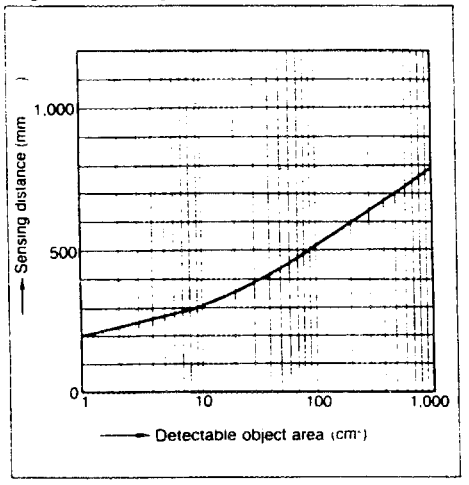



MQ-D70A photoelectric sensor
(Diffuse reflective type 70 cm [illegible])
Condition: At maximum (H) sensitivity control position
Target: 20×20 cm [illegible] white drawing paper

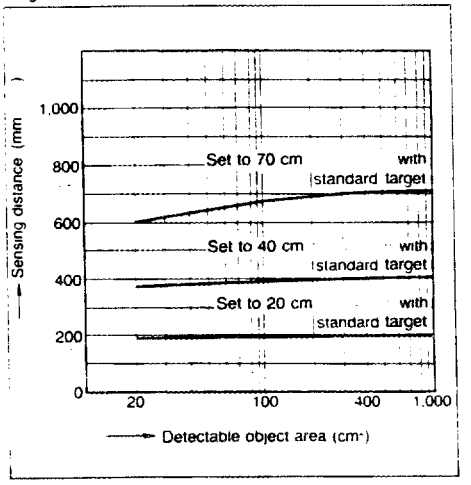



## 3. Sensing distance vs. surface area characteristics

MQ-D30A, MQ-D30AB photoelectric sensor
(Diffuse reflective type 30 cm )
Condition: At maximum (H) sensitivity control position
Target: White drawing paper

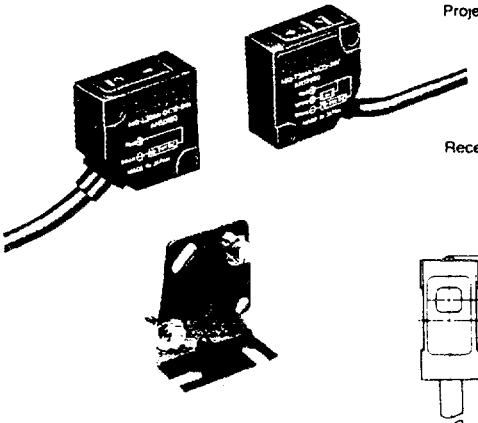



MQ-D70A photoelectric sensor
(Diffuse reflective type 70 cm )
Condition: At maximum (H) sensitivity control position
Target: White drawing paper

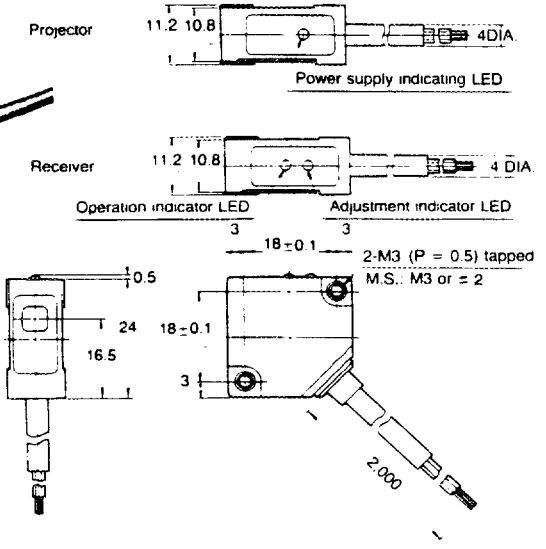



# DIMENSIONS mm

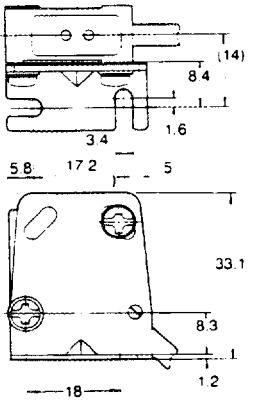
## 1. MQ-300A, MQ-300AB (Thru-beam type)



External form dimensional drawing




Photoelectric sensor with a bracket on



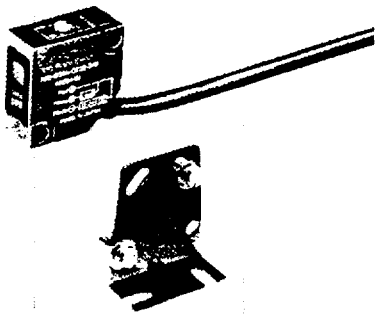

General tolerance: ±0.5

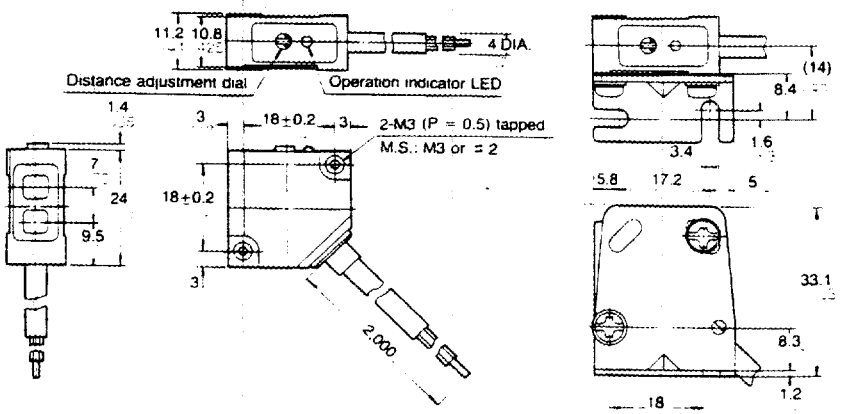
## 2. MQ-D30A, MQ-D30AB
(Diffuse reflective type)

mm inch

External form dimensional drawing

Photoelectric sensor with a bracket on



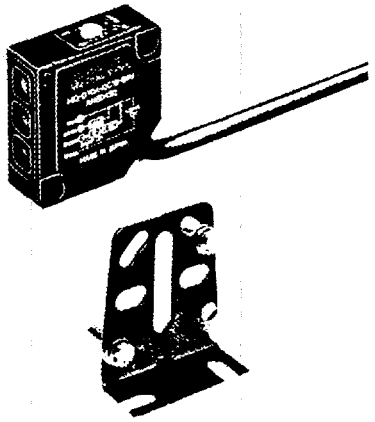


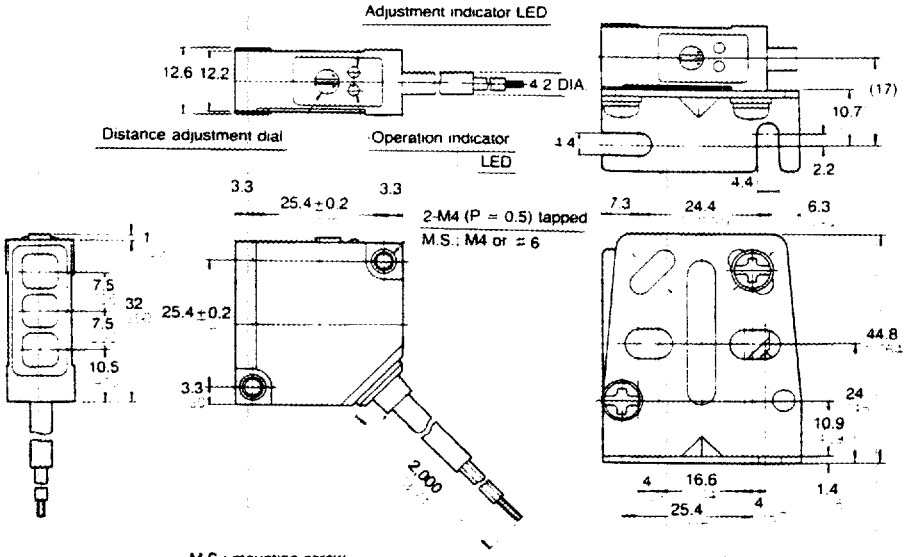

Geneal tolerance ±0.5

## 3. MQ-D70A
(Diffuse reflective type)

Extenel form dimensional drawing

Photoelectric sensor with a bracket on



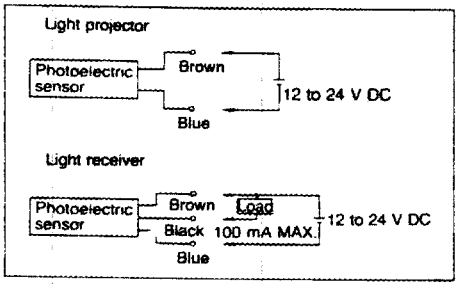



M.S.: mounting screw

General tolerance ±0.5

# CONNECTING DIAGRAM

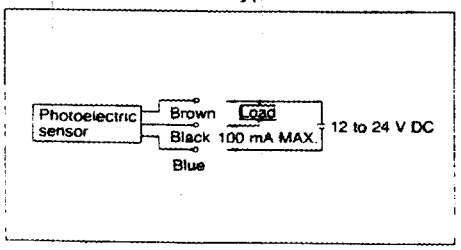
## 1. Thru-beam type




| | Operating condition |
|---|---|
| Output transistor | Light entry ON<br>MQ-300AB-DC12-24V<br>Light intercepted ON<br>MQ-300A-DC12-24V |
| Operation indicator LED | Lights with light entry |

Note: When switching power source, make ground connection to the frame ground or to the ground terminal. This will assure more stable operation.

## 2. Diffuse reflective type




| | Operating condition | |
|---|---|---|
| Output transistor | Light entry ON<br>MQ-D30A-DC12-24V<br>Light intercepted ON<br>MQ-D30AB-DC12-24V | |
| | Light entry ON<br>Light intercepted ON | Common use<br>MQ-D70A-DC12-24V |
| Operation indicator LED | Lights with light entry | |

Note: When switching power source, make ground connection to the frame ground or to the ground terminal. This will assure more stable operation.

# CAUTIONS

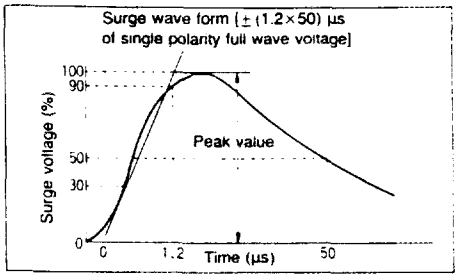
**1. Ambient environment**

1) Use within the range of ambient temperature of −25°C to +55°C [illegible] F to [illegible] F.

2) Use within a range of 9.6 V to 30 V DC *(ripple P-P included) for operating voltage.*

3) Use with an ambient light level at the light receiving surface of less than 10,000 lux for incandescent lamp and less than 30,000 lux for sunlight.

4) Because a surge voltage exceeding 500 V [±(1.2×50) μs of single polarity full wave voltage] may cause damage to the internal circuit, a surge absorbing element should be used.




5) Avoid using in a location where there *is excessive steam, dust, or corrosive gas.*

6) The sensor is of immersion protected type, but this does not mean that it can be used in water or where there is direct impingement of rain.

**2. Connections**

1) Because the internal circuit can be damaged due to incorrect connections, before power is applied, the wiring should be thoroughly checked.

2) Load relays having a rated operating voltage of 12 V or 24 V DC as the load should be used. Care should be taken to allow for the voltage drop (1.2 V) from the operating voltage of the internal circuit as applied to the load relay.

3) If a load greater than 100 mA is connected, the output section will be damaged, so sufficient care should be taken.

4) If the wiring to the sensor is run parallel to high voltage or power lines, due to inductive noise, misoperation or damage can occur. Wiring should be run in separate conduits.

5) Use cable of 0.3 mm² [illegible] or greater for extensions, and the length should be less than 100 meters 328 ft.

6) If the unit is struck by a hammer or other heavy tool, the function can be impaired. Sufficient care should be taken.

7) For the MQ-D70A-DC12-24V (diffuse reflective type 70 cm), the changeover from light entering ON (Light ON) to light intercepted ON (Dark ON) can be carried out with the pink lead wire. For Light ON, connect the pink wire to the ⊕ side, and for Dark ON, connect the pink wire to the ⊖ side.

8) When attaching to a terminal board or similar terminal facility using machine type 0.15 mm² [illegible] lead wire, use either soldering or wrapping around the screw of screw type terminals.

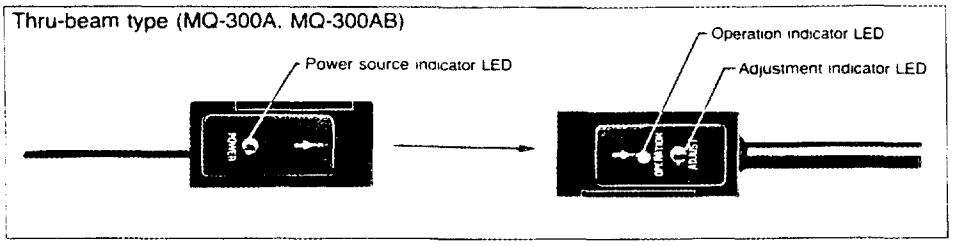
**3. Light axis adjustment for the Thru-beam type**

1) Temporarily fasten the light projector and the light receiver, and make a rough adjustment of the opposing direction. In the operating condition, the operation indicator LED (OPE.) will light.

2) Swing the light projector to left and right, and up and down, with the adjustment indicator LED (ADJUST) of the light receiver set so that at the midpoint of the range the LED lights, then fasten the unit.

3) Next swing the light receiver to left and right, and up and down, with the adjustment indicator LED (ADJUST) of the light receiver set so that at the midpoint of the range the LED lights, then fasten the receiver.

4) When fastening the units, fasten them securely so that there will be no shift of the light axis due to vibration or shock.




**4. Sensitivity adjustment of the diffuse reflective type**

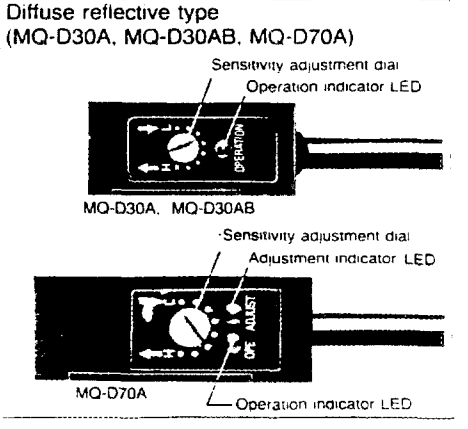
1) Point the detection surface of the photoelectric sensor in the detecting direction and temporarily fasten the unit.

2) With no target in position, slowly turn the sensitivity adjustment dial from the maximum position (H side) counterclockwise to locate the point where the operation indicator LED (for the MQ-D70A-DC12–24V, the adjustment indicator LED) goes out. Even if the location of that point is at the H position, that will be the set point.

3) Place a target in the detection position, turn the control again to the left until the operation indicator LED (for the MQ-D70A-DC12–24V, the Adjustment indicator LED) is extinguished.

4) Set the dial at a position midway between the point found in step 2) and step 3) above.

5) Firmly fasten the photoelectric sensor. When fastening, securely fasten the unit so that the position will not shift due to vibration or shock.




Notes:

1. If the position set between step 2) and step 3) above is less than 2 graduations, change the position of the detection surface and repeat the procedure of step 1) to step 4), or try to determine the source of external factors such as variation in ambient temperature, variation in detectable object position, etc., that is creating the problem.

2. Because there is a difference in the sensing distance due to the material, color, size, form, and direction of the target, and to ambient conditions, confirmation should be made using the actual object that is to be detected.

**5. Regarding the sensing section**

1) If an excessive amount of dust or dirt adheres to the detection surface the detection diatance will be reduced, and it is advisable to keep the detection surface clean at all times.

2) The front surface of the lens is polycarbonate. This material is resistant to water, dilute acids, and alkalis, carbonate. This material is resistant to water, dilute acids, and alkalis, aliphatic hydrocarbons, oils, etc., but it is not resistant to ketones, esters, halogenated hydrocabons, or aromatic hydrocarbons.

Aromat

# CYLINDRICAL AMPLIFIER SELFCONTAINED-DC TYPE SELFCONTAINED-AC/DC TYPE

Components for advanced technology

# MF18 Photoelectric Sensors

- **Popular 18mm size**
MF18 series of photoelectric sensors conforms to the 18mm size popular in Europe. (CENELEC standard)

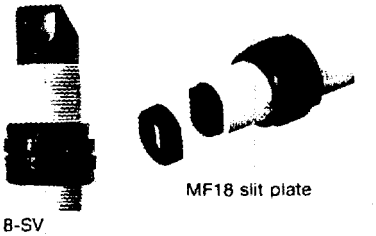
- **Wide operating voltage range**
The selfcontained-DC type sensor operates over a voltage range of 5 to 24V DC, and the selfcontained-AC/DC type sensor on 24 to 240V AC/DC power supply.

- **100mA output**
NPN and PNP output types are available in the selfcontained-DC type. These provide a chatter-free, high speed alternative to a relay output.

- **Includes an output protection circuit**
An output protection circuit is built-in and limits output damage due to incorrect wiring.

- **Excellent vibration and water resistance**
The case interior is filled with resin to prevent broken leads, cracks, etc. . . . due to vibration.
Furthermore, the simple construction achieves protection against immersion (equivalent to IEC IP67) for excellent environmental resistance.

- **Optional lenses**
A side view attachment which bends the light axis 90° and a slit plate for small target detection are available.



MF18 slit plate

MF18-SV
side view attachment

## APPLICATIONS

General plant facilities such as food processing equipment, packing equipment, conveyors, automated equipment, assembly lines, etc.

## PRODUCT TYPE

**1. Thru-beam type** (Max. sensing distance: 300 cm )

| Types | | Name | Part No. | Replacement for projector and receiver sold separately | Specifications |
|---|---|---|---|---|---|
| Amplifier selfcontained-DC | NPN output | MF18-300A photoelectric sensor | MF18-300A-DC5-24V | Projector: MF18-L300A-DC5-24V<br>Receiver: MF18-T300A-DC5-24V | Dark-ON |
| | | MF18-300AB photoelectric sensor | MF18-300AB-DC5-24V | Projector: MF18-L300A-DC5-24V<br>Receiver: MF18-T300AB-DC5-24V | Light-ON |
| | PNP output | MF18-300C photoelectric sensor | MF18-300C-DC5-24V | Projector: MF18-L300A-DC5-24V<br>Receiver: MF18-T300C-DC5-24V | Dark-ON |
| | | MF18-300CB photoelectric sensor | MF18-300CB-DC5-24V | Projector: MF18-L300A-DC5-24V<br>Receiver: MF18-T300CB-DC5-24V | Light-ON |
| Amplifier selfcontained-AC/DC | | MF18-300P photoelectric sensor | MF18-300P-24-240V | Projector: MF18-L300P-24-240V<br>Receiver: MF18-T300P-24-240V | Dark-ON |
| | | MF18-300PB photoelectric sensor | MF18-300PB-24-240V | Projector: MF18-L300P-24-240V<br>Receiver: MF18-T300PB-24-240V | Light-ON |

**2. Retroreflective type** (Max. sensing distance: 200 cm )

| Types | | Name | Part No. | Specifications |
|---|---|---|---|---|
| Amplifier selfcontained-DC | NPN output | MF18-R200A photoelectric sensor | MF18-R200A-DC5-24V | Dark-ON |
| | | MF18-R200AB photoelectric sensor | MF18-R200AB-DC5-24V | Light-ON |
| | PNP output | MF18-R200C photoelectric sensor | MF18-R200C-DC5-24V | Dark-ON |
| | | MF18-R200CB photoelectric sensor | MF18-R200CB-DC5-24V | Light-ON |
| Amplifier selfcontained-AC/DC | | MF18-R200P photoelectric sensor | MF18-R200P-24-240V | Dark-ON |
| | | MF18-R200PB photoelectric sensor | MF18-R200PB-24-240V | Light-ON |

**3. Diffuse reflective type** (Max. sensing distance: 10 cm )

| Types | | Name | Part No. | Specifications |
|---|---|---|---|---|
| Amplifier selfcontained-DC | NPN output | MF18-D10A photoelectric sensor | MF18-D10A-DC5-24V | Light-ON |
| | | MF18-D10AB photoelectric sensor | MF18-D10AB-DC5-24V | Dark-ON |
| | PNP output | MF18-D10C photoelectric sensor | MF18-D10C-DC5-24V | Light-ON |
| | | MF18-D10CB photoelectric sensor | MF18-D10CB-DC5-24V | Dark-ON |
| Amplifier selfcontained-AC/DC | | MF18-D10P photoelectric sensor | MF18-D10P-24-240V | Light-ON |
| | | MF18-D10PB photoelectric sensor | MF18-D10PB-24-240V | Dark-ON |

# SPECIFICATIONS

## 1. Amplifier selfcontained-DC type

### 1-1) Ratings

| Type | | Thru-beam type | Retroreflective type | Diffuse reflective type |
|---|---|---|---|---|
| | | MF18-300A, MF18-300AB<br>MF18-300C, MF18-300CB | MF18-R200A, MF18-R200AB<br>MF18-R200C, MF18-R200CB | MF18-D10A, MF18-D10AB<br>MF18-D10C, MF18-D10CB |
| Operating side | Rated operating voltage | 5 to 24V DC | | |
| | Rated current consumption (Excluding load) | Max. 30mA<br>Projector: Max. 15mA<br>Receiver: Max. 15mA | Max. 20mA | Max. 20mA |
| Load side | Output current capacity | Max. 100mA | | |

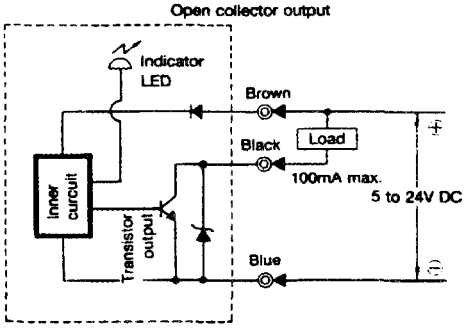
### 1-2) Performance outline

| Type | | Thru-beam type | Retroreflective type | Diffuse reflective type |
|---|---|---|---|---|
| | | MF-18-300A, MF18-300AB<br>MF18-300C, MF18-300CB | MF18-R200A, MF18-R200AB<br>MF18-R200C, MF18-R200CB | MF18-D10A, MF18-D10AB<br>MF18-D10C, MF18-D10CB |
| Standard target | | 20mm .073 inch diameter metal plate (dull black finish) | 75mm 2.953 inches diameter metal plate (dull black finish) | White drawing paper 5×5cm 1.969×1.969 inches |
| Detectable target | | Opaque material 10mm .394 inch or more in diameter | Translucent and opaque material | Transparent and opaque material |
| Operating voltage range | | 4.75 to 30V DC (include ripple factor) | | |
| Max. sensing distance | | 3m 3.3 yards | 0.1 to 2m .6 to 2.2 yards (with included reflector) | 10cm 3.937 inches |
| Hysteresis | | — | — | Max. 20% |
| Operation angle | | 3° to 10° | 2° to 10° | — |
| Initial insulation resistance | | Between lead wire and external housing 20MΩ (at 500V DC) | | |
| Initial dielectric strength | | Between lead wire and external housing 500Vrms for 1 min | | |
| Detection speed | | 1.5ms (333 times/s) | | |
| Vibration resistance | Functional | 10 to 55Hz (1 cycle/min), double amplitude 1.5mm (2h on 3 axes) | | |
| | Destructive | 10 to 55Hz (1 cycle/min), double amplitude 1.5mm (2h on 3 axes) | | |
| Shock resistance | Functional | 100G (6 times on 3 axes) | | |
| | Destructive | 100G (6 times on 3 axes) | | |
| Protective construction | | Plastic case, immersion-protected (equivalent to IEC IP67) | | |
| Usable ambient light level | Incandescent lamp | Max. 3,000 lux | | |
| | Sunlight | Max. 10,000 lux | | |
| Ambient temperature | | −25°C to 55°C −13°F to 131°F | | |
| Ambient humidity | | Max. 85%RH | | |
| Storage temperature | | −30°C to 70°C −22°F to 158°F | | |
| Indicator | | Projector: Power indicator LED (Red)<br>Receiver: Light indicator LED (Red on, when light is entering) | Light indicator LED (Red on, when light is entering) | |

Notes: 1. Unless otherwise specified, the measurement conditions are; the rated operating voltage, battery power, 20°C 68°F ambient temperature, standard target and receiver surface luminance of 200 lux or less.
2. The rated distance and response difference distance of the diffuse reflective type are distances when using a standard target. The sensing distance may differ depending on the target's material, color and size.

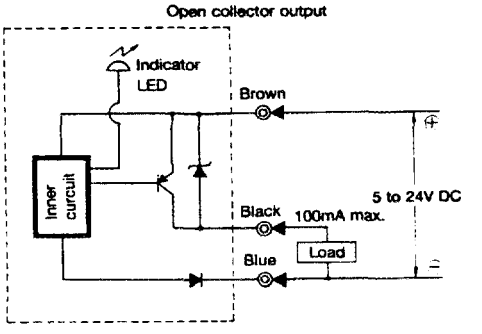
### 1-3) Output circuit diagram

NPN output type

| Circuit diagram | Type |
|---|---|
|  | MF18-300A (Detection ON) |
| | MF18-300AB (Detection OFF) |
| | MF18-R200A (Detection ON) |
| | MF18-R200AB (Detection OFF) |
| | MF18-D10A (Detection ON) |
| | MF18-D10AB (Detection OFF) |



PNP output type

| Circuit diagram | Type |
|---|---|
|  | MF18-300C (Detection ON) |
| | MF18-300CB (Detection OFF) |
| | MF18-R200C (Detection ON) |
| | MF18-R200CB (Detection OFF) |
| | MF18-D10C (Detection ON) |
| | MF18-D10CB (Detection OFF) |

## 2. Amplifier selfcontained-AC/DC type

### 2-1) Ratings

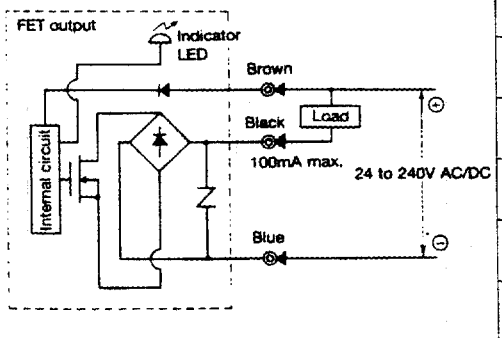
| Type | | Thru-beam type | Retroreflective type | Diffuse reflective type |
|---|---|---|---|---|
| | | MF18-300P, MF18-300PB | MF18-R200P, MF18-R200PB | MF18-D10P, MF18-D10PB |
| Operating side | Rated operating voltage | 24 to 240V AC/DC | | |
| | Rated power consumption (Excluding load) | DC: Max. 3.5W AC: Max. 3.5VA<br>Projector: Max. 1.5W Max. 1.5VA<br>Receiver: Max. 2W Max. 2VA | DC: Max. 2W<br>AC: Max. 2VA | DC: Max. 2W<br>AC: Max. 2VA |
| Load side | Output current capacity | Max. 100mA | | |

### 2-2) Performance

| Type | | Thru-beam type | Retroreflective type | Diffuse reflective type |
|---|---|---|---|---|
| | | MF18-300P, MF18-300PB | MF18-R200P, MF18-R200PB | MF18-D10P, MF18-D10PB |
| Standard target | | 20mm .78 inch diameter metal plate (dull black finish) | 75mm 2.953 inches diameter metal plate (dull black finish) | White drawing paper 5×5cm 1.969×1.969 inches |
| Detectable target | | Opaque material 10mm .394 inch or more in diameter | Translucent and opaque material | Transparent and opaque material |
| Operating voltage range | | 21.6 to 264V AC/DC (50 to 60Hz) | | |
| Max. sensing distance | | 3m 3.3 yards | 0.1 to 2m .6 to 2.2 yards (with included reflector) | 10cm 3.937 inches |
| Hysteresis | | — | — | Max. 20% |
| Operation angle | | 3° to 10° | 2° to 10° | — |
| Initial insulation resistance | | Between lead wire and external housing 20MΩ (at 500V DC) | | |
| Initial dielectric strength | | Between lead wire and external housing 1,500Vrms for 1 min | | |
| Detection speed | | 20ms (25 times/s) | | |
| Vibration resistance | Functional | 10 to 55Hz (1 cycle/min), double amplitude 1.5mm (2h on 3 axes) | | |
| | Destructive | 10 to 55Hz (1 cycle/min), double amplitude 1.5mm (2h on 3 axes) | | |
| Shock resistance | Functional | 100G (6 times on 3 axes) | | |
| | Destructive | 100G (6 times on 3 axes) | | |
| Protective construction | | Plastic case, immersion-protected (equivalent to IEC IP67) | | |
| Usable ambient light level | Incandescent lamp | Max. 3,000 lux | | |
| | Sunlight | Max. 10,000 lux | | |
| Ambient temperature | | −25°C to 55°C −13°F to 131°F | | |
| Ambient humidity | | Max. 85%RH | | |
| Storage temperature | | −30°C to 70°C −22°F to 158°F | | |
| Indicator | | Projector: Power indicator LED (Red)<br>Receiver: Light indicator LED (Red on, when light is entering) | Light indicator LED (Red on, when light is entering) | |

Notes: 1. Unless otherwise specified, the measurement conditions are; the rated operating voltage, 20°C 68°F ambient temperature, standard target and receiver surface luminance of 200 lux or less.
2. The rated distance and response difference distance of the diffuse reflective type are distances when using a standard target. The sensing distance may differ depending on the target's material, color and size.

### 2-3) Output circuit diagram

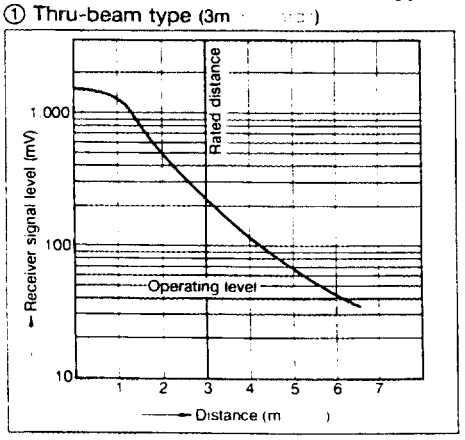
| Circuit diagram | Type |
|---|---|
|  | MF18-300P (Detection ON) |
| | MF18-300PB (Detection OFF) |
| | MF18-R200P (Detection ON) |
| | MF18-R200PB (Detection OFF) |
| | MF18-D10P (Detection ON) |
| | MF18-D10PB (Detection OFF) |

# DATA

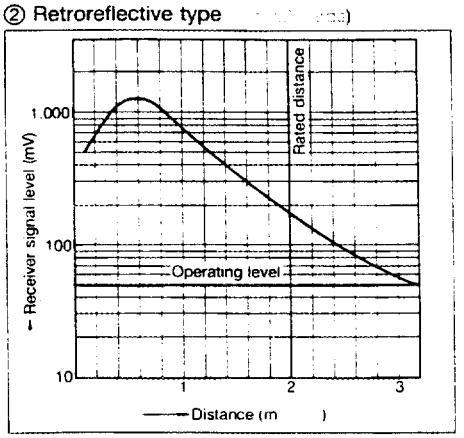
## 1. Receiver signal level and distance characteristics

### 1-1) Amplifier selfcontained-DC type

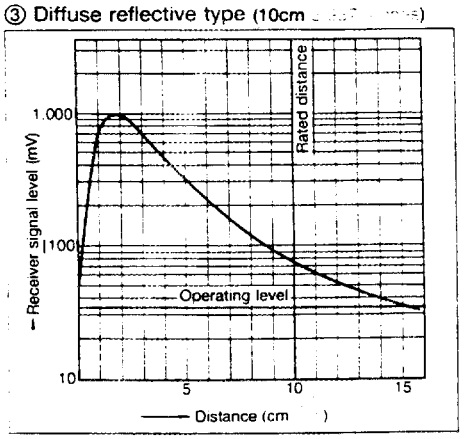
① Thru-beam type (3m )




② Retroreflective type )

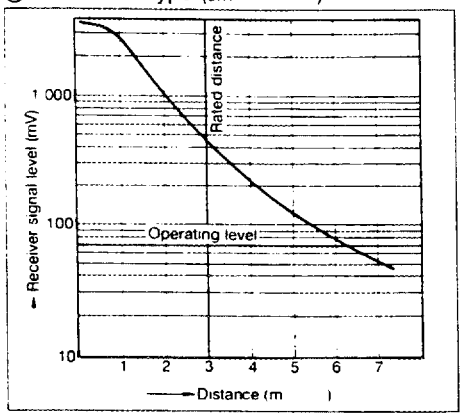



③ Diffuse reflective type (10cm )

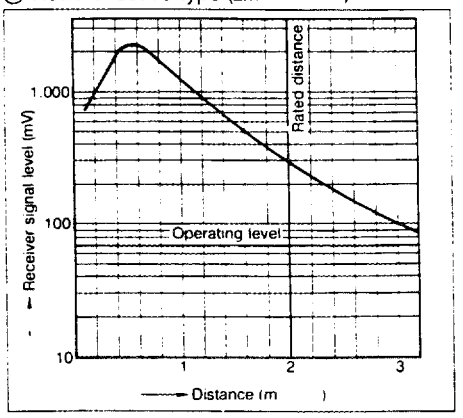



### 1-2) Amplifier selfcontained-AC/DC type

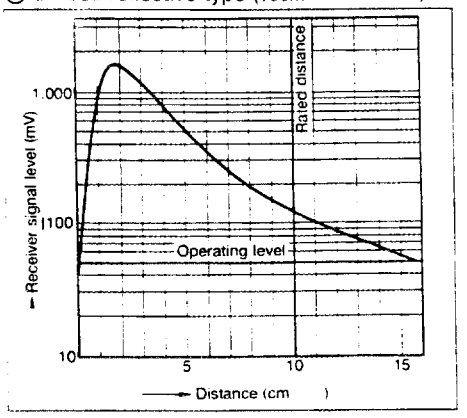
① Thru-beam type (3m )




② Retroreflective type (2m )



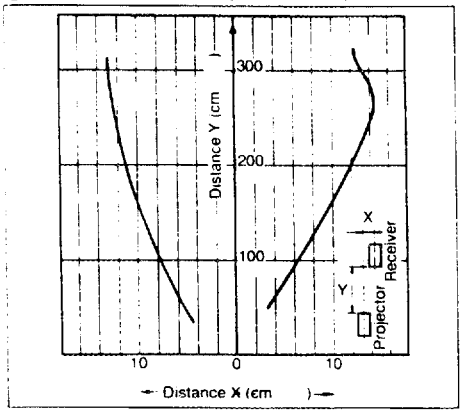

③ Diffuse reflective type (10cm )



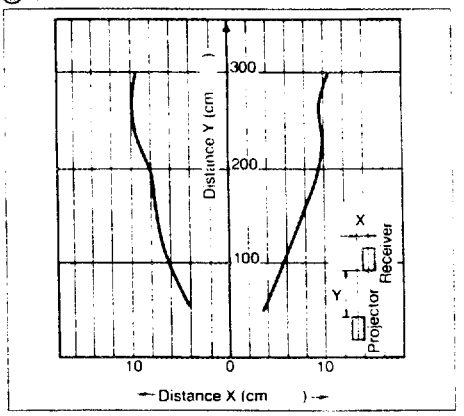

## 2. Operating region characteristics

### 2-1) Thru-beam type

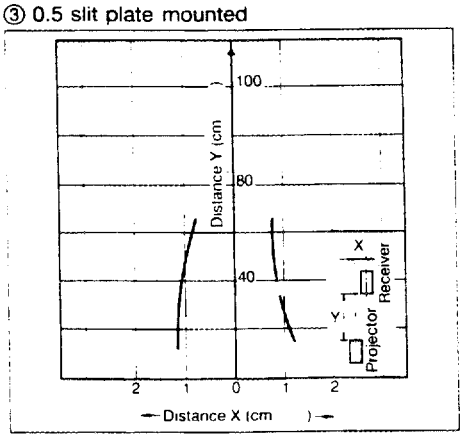
① Standard condition (3m )



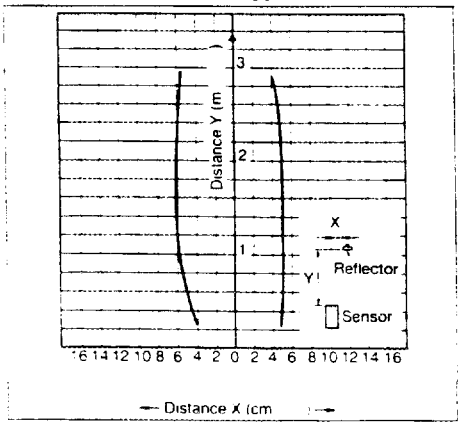

② Side view mounted



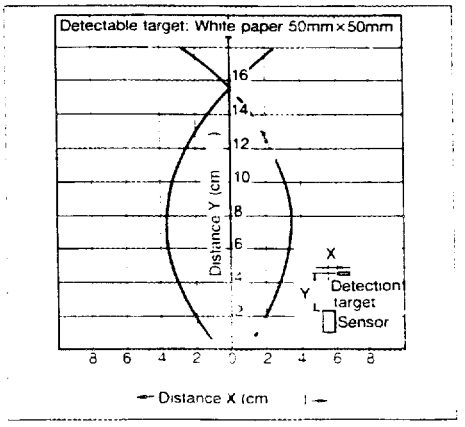

③ 0.5 slit plate mounted




### 2-2) Retroreflective type (2m )



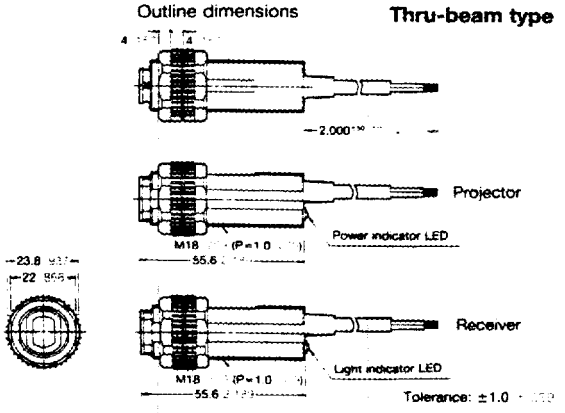

### 2-3) Diffuse reflective type (10cm )

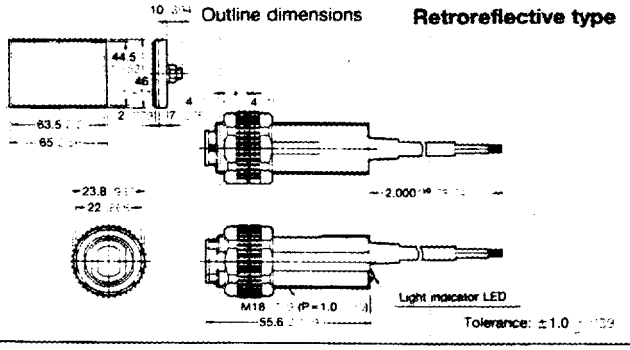


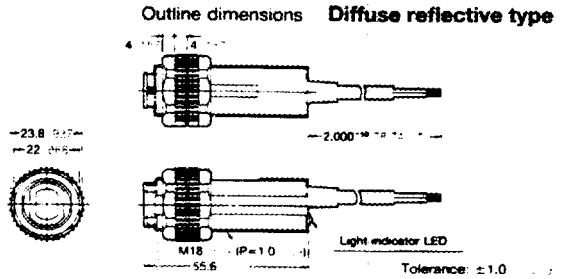
# DIMENSIONS

mm (inch)

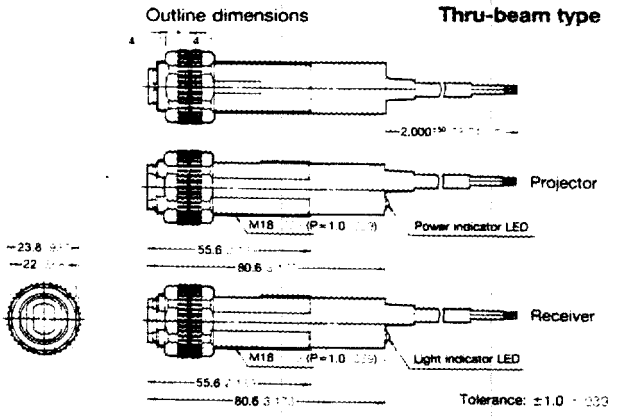
## Amplifier selfcontained-DC

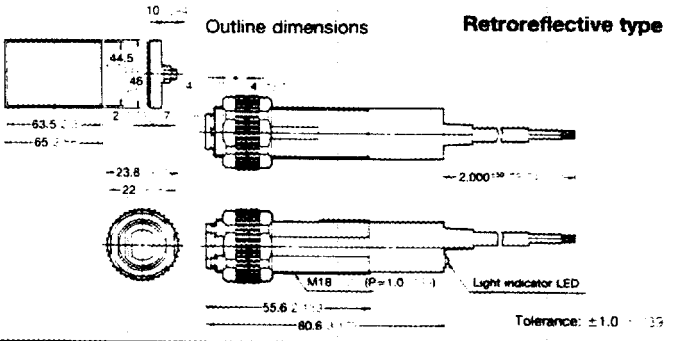


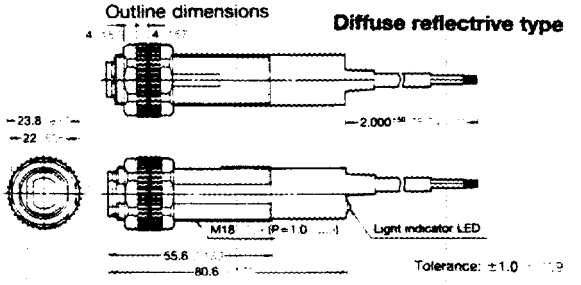




## Amplifier selfcontained-AC/DC



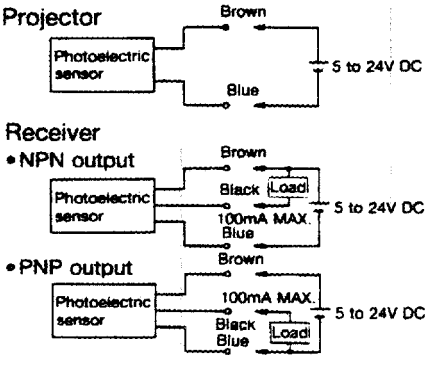




# SCHEMATIC

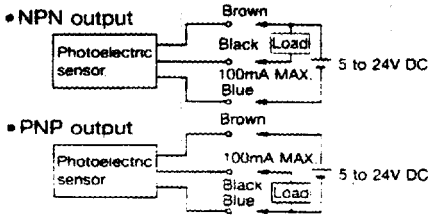
## Amplifier selfcontained-DC type

### 1. Thru-beam type




Note: Ground the frame ground terminal and ground terminal when using a switching power supply. This will ensure stable operation.

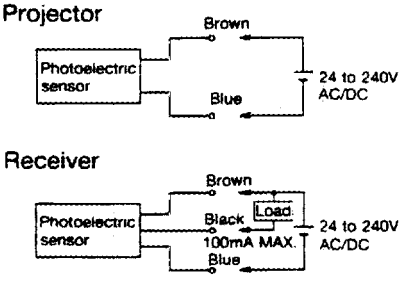
### 2. Retroreflective, Diffuse reflective type



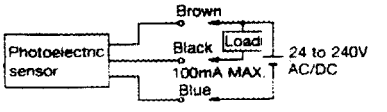

Note: Ground the frame ground terminal and ground terminal when using a switching power supply. This will ensure stable operation.

## Amplifier selfcontained-AC/DC type

### 1. Thru-beam type




### 2. Retroreflective, Diffuse reflective type



# CAUTIONS

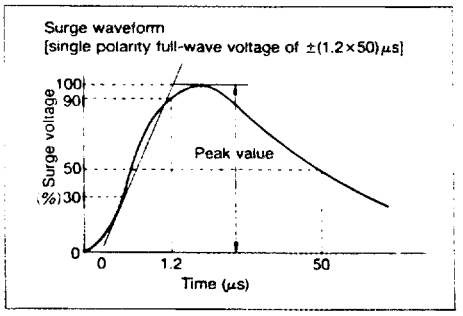
**1. Operating Environment**

1) The sensor should be used in an ambient temperature range of −25°C to +55°C.

2) Use an operating voltage in the range of 4.75 to 30V DC (includes peak-to-peak ripple) for the self-contained-DC type or in the range of 21.6 to 264V AC/DC for the self-contained-AC/DC type.

3) The light intensity on the receiver surface should be less than 3,000 lux for an incandescent light source and less than 10,000 lux for sunlight.

4) Use a surge absorber as the internal circuitry may be damaged if external surge voltages exceed 500V [single polarity full-wave voltage of ±(1.2×50)μs].




5) Avoid use in locations with high concentrations of steam, dust, corrosive gases, etc.

6) Although the sensor is immersion-protected, this does not mean that object detection is possible underwater or in rain.

7) Mount the sensor with the supplied nut and tighten with a torque of 20kg-cm or less.

**2. Wiring**

1) Check all wiring before applying power since incorrect wiring can damage the internal circuitry.

2) The voltage applied to the load relay is the operating voltage of the photoelectric sensor minus the internal voltage drop (max. 1.2V for self-contained-DC type/max. 3V for self-contained-AC/DC type). Voltage fluctuations should be taken into account.

3) The output is short-circuit protected. When controlling loads with a large inrush current, such as lamps or motors, be sure the inrush current does not exceed the maximum output current capacity. If the short-circuit protection is activated, the output can be reset by either cycling the power off and on, or by causing the sensor to go through a Light/Dark cycle.

4) Note that running the wiring for the photoelectric sensor parallel to high voltage lines or power lines may result in faulty operation or damage due to induced noise.

5) The leads may be extended up to 100m with a wire 0.3mm² (32AWG) or larger.

**3. Detector**

1) Keep the detector surface clean since dust or dirt on the detector surface will decrease the detection distance.

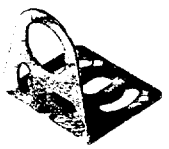
2) The front surface of the lens is made of polycarbonate resin. Although it withstands water, weak acids and alkalines, aliphatic hydrocarbons, oils and fats, it is not resistant to ketones, esters, halogenated hydrocarbons and aromatic hydrocarbons.

# ACCESSORY

MF18 reflector
(Provided with the photoelectric sensor.)

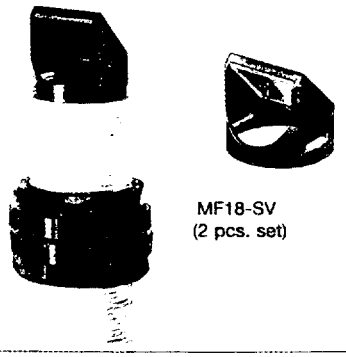
MF18-M

MF18 mounting bracket



ANF68002

MF18-SV side view attachment
(for thru-beam type)
Bends the light axis to a right angle.



MF18-SV
(2 pcs. set)

MF18 slit plate set
(for thru-beam type)

Slit plate

ANF68010
(Includes two each of three different slit plates and slit holder.)

Slit plate holder

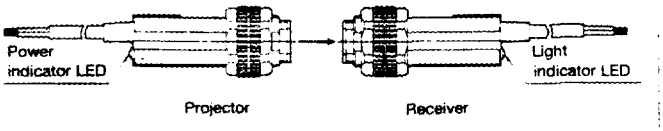
| Product name | Part No. | Applicable types | Specifications |
|---|---|---|---|
| MF18 reflector | MF18-M | MF18 retroreflective types | Included with the photoelectric sensor (replacement part) |
| MF18-SV side view attachment | MF18-SV | MF18 thru-beam types | Bends the light axis in a right angle (2 items as a set) |
| MF18 slit plate | ANF68010 | MF18 thru-beam types | Set (includes 6 plates, 2 slit plate holders) |
| MF18 mounting bracket | ANF68002 | MF18 photoelectric sensors | For fixing MF18 photoelectric sensor |

# LIGHT AXIS ADJUSTMENT AND SENSITIVITY ADJUSTMENT

**1. Light axis adjustment for the thru-beam type**

1) Temporarily fasten the projector and receiver so that they are roughly facing each other. During operation, the operation indicator LED turns on.
2) Move the projector to the left, right, up and down and secure it when it is centered within the range in which the operation indicator LED on the receiver is on.
3) Next move the receiver to the left, right, up and down and fasten it when it is centered within the range in which the operation indicator LED on the receiver is on.
4) Mount the projector and receiver securely so that the light beam is not shifted out of alignment by vibrations or impact.

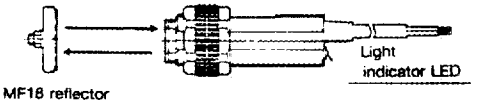
Thru-beam type
[MF18-300A(AB), MF18-300C(CB), MF18-300P(PB)]




**2. Light axis adjustment for the retroreflective type**

1) Visually align the reflector and photoelectric sensor and temporarily secure them.
2) Move the photoelectric sensor left, right, up and down and fasten it when it is centered within the range in which the operation indicator LED is on.
3) Check that the photoelectric sensor operates when a target is moved into the detection path.
4) Fasten the reflector and photoelectric sensor. Mount them securely so that the photoelectric sensor is not shifted out of alignment by vibrations or impact.

Retroreflective type
[MF18-R200A(AB), MF18-R200C(CB), MF18-R200P(PB)]

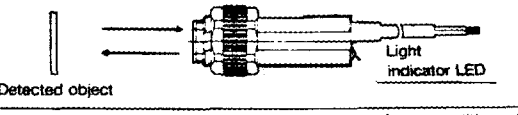



Note: Targets are usually opaque or translucent. However, shiny targets (cans, mirrors, plated metals, etc.) have a high reflection factor, if the reflected light from a shiny target enters the photoelectric sensor, the blocking of the reflector may not be detected. Detection is possible for these kinds of targets by mounting the photoelectric sensor at an angle.

**3. Light axis adjustment for the diffuse reflective type**

1) Point the detection surface of the photoelectric sensor in the detection direction and temporarily secure.
2) Adjust the photoelectric sensor so that the operation indicator LED turns on when a target is placed in the detection area and turns off when the target is removed.
3) Fasten the photoelectric sensor. Mount securely so that the photoelectric sensor is not shifted out of alignment by vibrations or impact.

Diffuse reflective type
[MF18-D10A(AB), MF18-D10C(CB), MF18-D10P(PB)]

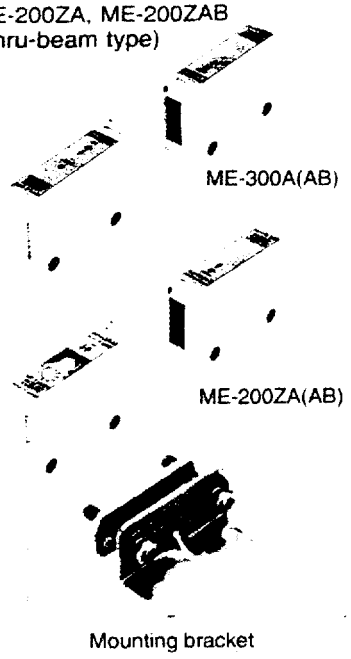


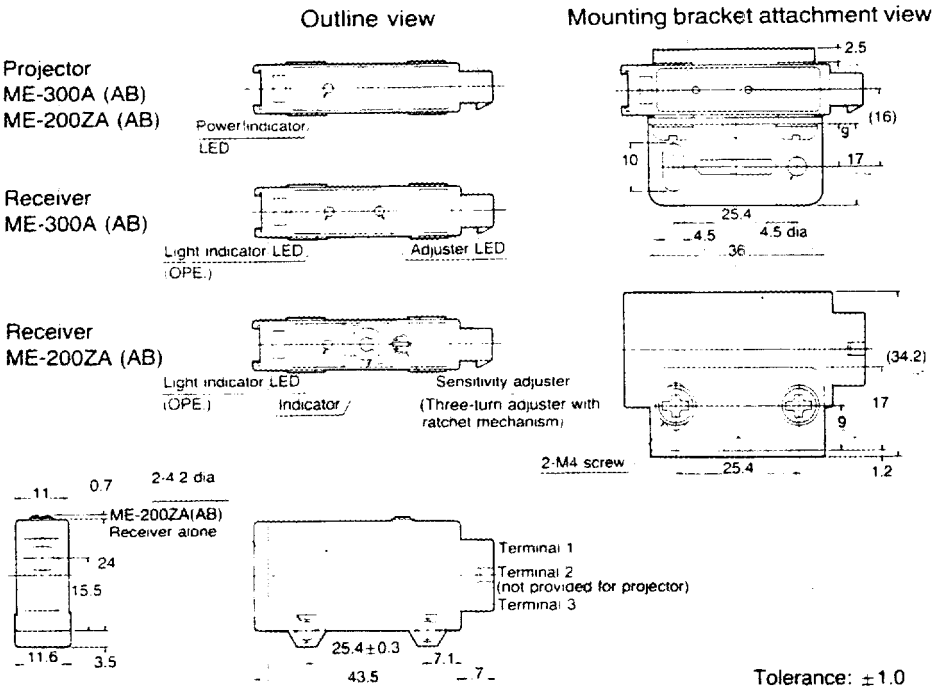

Note: The max. sensing distance may vary with the surface condition of that. Since this sensor is not equipped with a sensitivity adjusting volume, the light beam should be adjusted to a stable operation by changing the distance, the angle and the substance at background.

## DIMENSIONS (excluding the connector)

mm

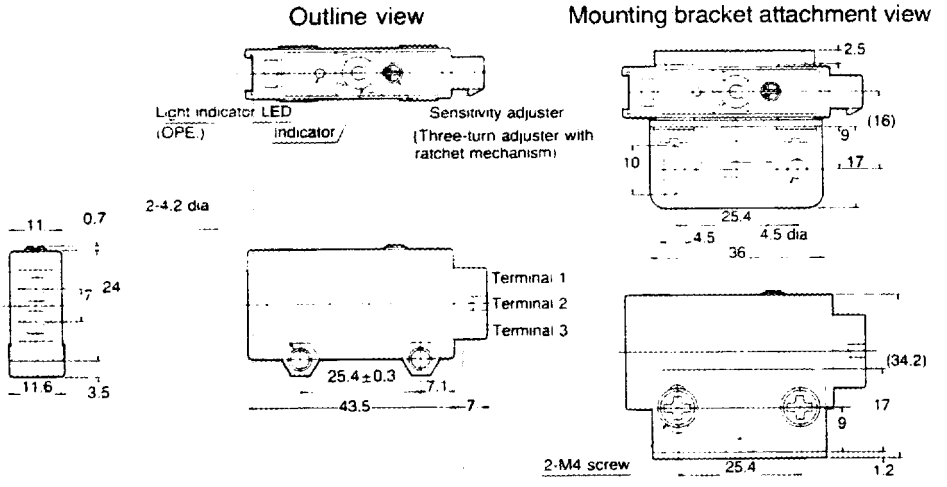
1. ME-300A, ME-300AB, ME-200ZA, ME-200ZAB (Thru-beam type)




Tolerance: ±1.0

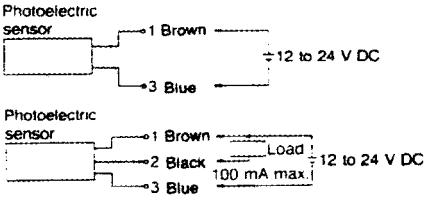
2. ME-D30A, ME-D30AB (Diffuse refelective type)



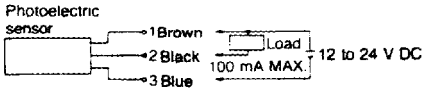

Tolerance: ±1.0

## CONNECTIONS

1. Thru-beam type




2. Diffuse reflective type

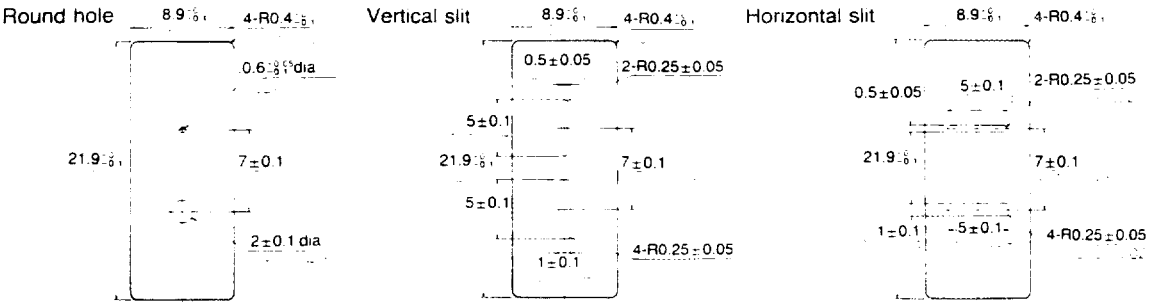



Note: The colors are applicable for a set with cabled connector.

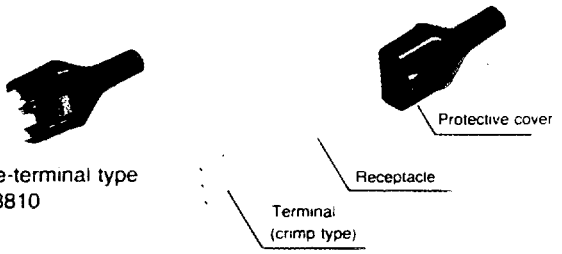
# ACCESSORIES

mm inch

1. ME slit plate

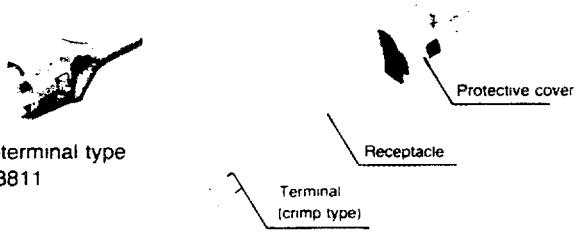



2. MC connector




Three-terminal type
AN53810

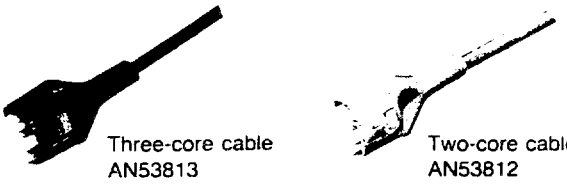
| Terminal No. (code) | Content |
|---|---|
| 1 (——) | + terminal |
| 2 (═══) | ⊖ terminal |
| 3 (≡≡≡) | − terminal |




Two-terminal type
AN53811

| Terminal No. (code) | Content |
|---|---|
| 1 (——) | + terminal |
| 3 (≡≡≡) | terminal |

3. MC cabled connector (2 m 2.0 , arc long cable)



Three-core cable
AN53813

Two-core cable
AN53812

| Terminal No. (code) | Content |
|---|---|
| 1 (Brown) | + terminal |
| 2 (Black) | ⊖ terminal |
| 3 (Blue) | − terminal |

Note: The connector or the cabled connector is attached to the main body of the photoelectric sensor.

# CAUTIONS

**1. Operational conditions**

1) The ambient temperature should be kept within a range from −25°C to +55°C (−13°F to +131°F).

2) The operating voltage should be kept within a range from 9.6 V DC to 30 V DC (including ripple P-P).

3) The ambient illuminance should be 10,000 lux or less at the receiver under an incandescent lamp, and 30,000 lux or less at the receiver under sunlight.

4) Since the internal circuit may be broken when the external surge voltage exceeds 500 V [single polarity full wave voltage of ±(1.2×50) μs], the surge absorbing element should be used.

5) Avoid using the sensor at the site where much steam, dust or corrosive gas is suspended, water or oil splashes directly over the unit, or organic solvent adheres to the unit.

**2. Wiring**

1) Since improper wiring results in breakage of the internal circuit, check the wiring before turning on the power supply.

2) The load relays rated at 12 V DC or 24 V DC should be used. Since the voltage applied to the load relay is determined by substracting the internal voltage drop (max. 1.2 V) from the photoelectric sensor operating voltage, care should be taken for the voltage fluctuation.

3) Keep in mind that the output area is broken if a load of 100 mA or more is connected.

4) Keep in mind that the inductive noises cause mulfunction and breakage if the wiring to the photoelectric sensor runs with the high voltage cables and the power cable.

5) When extending the cable, use a cable of 0.3 mm² or more and limit its length within 100 m.

6) When using an attached mounting hardware, the tightening torque for the mounting screws should be 15 kg-cm or less. When the attached mounting hardware is not used, the unit should be mounted on the flat surface. Use M4 screws with plain washers and apply a torque of 10 kg-cm or less.

7) When the photoelectric sensor is mounted with the lock mechanism side of the connector closely contacted on the flat surface, use the attached mounting plate as a spacer or put a 2.5 mm [illegible] or more thick spacer between the photoelectric sensor main body and the flat surface.

8) When crimping the terminals, it is recommended to use the following tool made by Molex.

| Crimping | Insertion | Pulling-out |
|---|---|---|
| JHTR1719C | J5800-001 | J5800-002 |

Here, the terminal is 5005TL made by Molex and the receptacle is 5025-03R1.

**3. Optic axis adjustment for the thru-beam type**

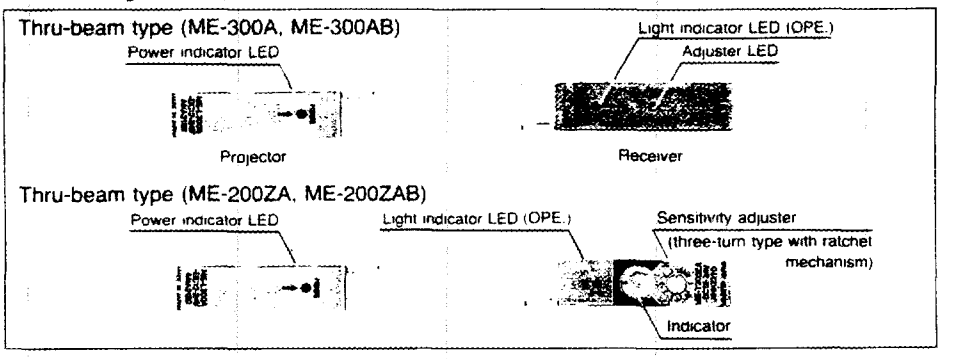
1) Temporarily fasten the projector and the receiver, and roughly position them to face each other. If positioned in the operational state, the light indicator LED (OPE.) will come on.

2) Finely reposition the projector by swinging it to left and right, and up and down so as to turn on its adjuster LED (ADJUST) at the center in the lighting range. Then, secure the projector.

3) Next, reposition the receiver by swinging it to left and right, and up and down so as to turn on its adjuster LED at the center in the lighting range. Then, secure the receiver.

4) Securely fasten the units to prevent displacement of the optic axes when vibration or shock is applied.

5) Since the sensitivity adjuster is provided on the ME-200ZA(AB), adjust the sensitivity particularly for detection of translucent target such as acrylic resins.




**4. Sensitivity adjustment for diffuse reflective type**

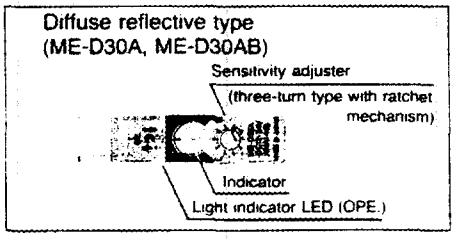
1) Facing the detector in the detection direction, temporarily fasten the photoelectric sensor.

2) Under the condition that no detectable target exists, gradually turn the sensitivity adjuster counterclockwise from the maximum (H side) to find the position where the Light indicator LED (OPE.) goes out. When the LED goes out even if the adjuster is in the max. position, select the H position.

3) Place a detectable target in the detection position, and gradually turn the sensitivity adjuster clockwise from the minimum position (L side) to find the position where the light indicator LED (OPE.) comes on. When the LED comes on even if the adjuster in the min. position, select the L position.

4) Set the adjuster at the middle point between the positions selected in step 2) and step 3).

5) Securely fasten the photoelectric sensor to prevent displacement of the sensor when vibration of shock is applied.




**Notes:**

1. When the positions in step 2) and step 3) indicate the 5th graduation or less, reposition the detector and repeat the procedure from step 1) to step 4), or check external factors such as the fluctuation of the temperature and the deviation of the target position.

2. Since the detectable distance depends on the material, color, size, shape and direction of a target and the environmental conditions, check the distance by using an actual target.

3. Use the sensitivity adjuster within a range between H and L on the nameplate. If used outside the range, the L state is selected.

**5. Sensing area**

1) If dust or dirt excessively adheres to the sensing area, the detectable distance will be reduced. Therefore, the sensing area should be kept clean at all times.

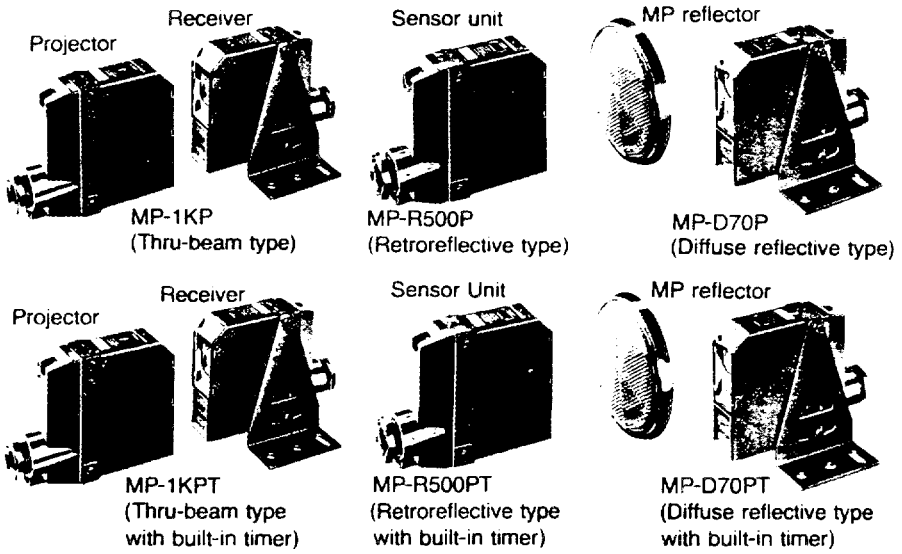
2) The front surface of the lens and the casing are made of polycarbonate. This material is resistant against water, dilute acids, and alkalis, aliphatic hydrocarbons, oils, etc., but not resistant against ketones, esters, halogenated hydrocarbons, or aromatic hydrocarbons.

Aromat

# SLIM TYPE FOR EASY INSTALLATION AND ADJUSTMENT

Components for advanced technology

# MP-Selfcontained-AC/DC Photoelectric Sensors




- **Operation with either AC or DC power source**
- **Built-in timer type also available**
- **Relay output 3 A 250 V AC**
- **No misoperation of output during power on or off condition**
- **Operation and adjustment indication LED**
- **Slim type for easy installation and adjustment**
- **Environmental resistance (IEC IP66)**

## PRODUCT TYPE

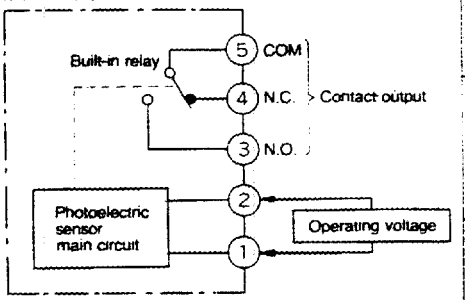
cm

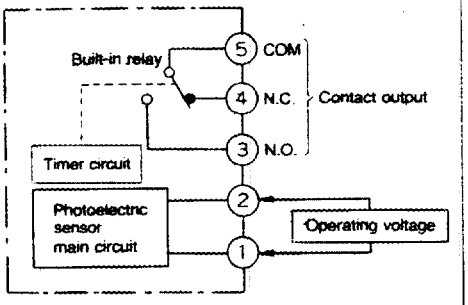
| Type | Part No. | Replacement for projector and receiver sold separately | Specifications |
|---|---|---|---|
| Standard type | MP-1KP-12/24V | Projector MP-L1KP-12/24V | Thru-beam type 1000 |
| | | Receiver MP-T1KP-12/24V | |
| | MP-1KP-100/240V | Projector MP-L1KP-100/240V | Thru-beam type 1000 |
| | | Receiver MP-T1KP-100/240V | |
| | MP-R500P-12/24V | — | Retroreflective type 500 |
| | MP-R500P-100/240V | — | Retroreflective type 500 |
| | MP-D70P-12/24V | — | Diffuse reflective type 70 |
| | MP-D70P-100/240V | — | Diffuse reflective type 70 |
| Timer built-in type | MP-1KPT-12/24V | Projector MP-L1KP-12/24V | Thru-beam type 1000 |
| | | Reciever MP-T1KPT-12/24V | |
| | MP-1KPT-100/240V | Projector MP-L1KP-100/240V | Thru-beam type 1000 |
| | | Receiver MP-T1KPT-100/240V | |
| | MP-R500PT-12/24V | — | Retroreflective type 500 |
| | MP-R500PT-100/240V | — | Retroreflective type 500 |
| | MP-D70PT-12/14V | — | Diffuse reflective type 70 |
| | MP-D70PT-100/240V | — | Diffuse reflective type 70 |
| MP reflector | MP-MP | Reflector for MP-R500P, MP-R500PT | |

Note) MP-MP is provided with MP-R500P and MP-R500PT.

## CIRCUIT DIAGRAM

| Type | Operation | | Circuit diagram | Built-in relay operating condition | Operation indicator (OPERATION) |
|---|---|---|---|---|---|
| Standard type | ON·OFF operation | Thru-beam type MP-1KP | MP-Photoelectric sensor | When light is blocked ON | When light enters ON |
| | | Retroreflective type MP-R500P | | When light is blocked ON | When light enters ON |
| | | Diffuse reflective type MP-D70P | | When light enters ON | When light enters ON |
| Timer built-in type | Timed-out operation | Thru-beam type MP-1KPT | MP-Photoelectric sensor | ON delay OFF delay One-shot (each operation changeable) | When light enters ON |
| | | Retroreflective type MP-R500PT | | | When light enters ON |
| | | Diffuse reflective type MP-D70PT | | | When light enters ON |

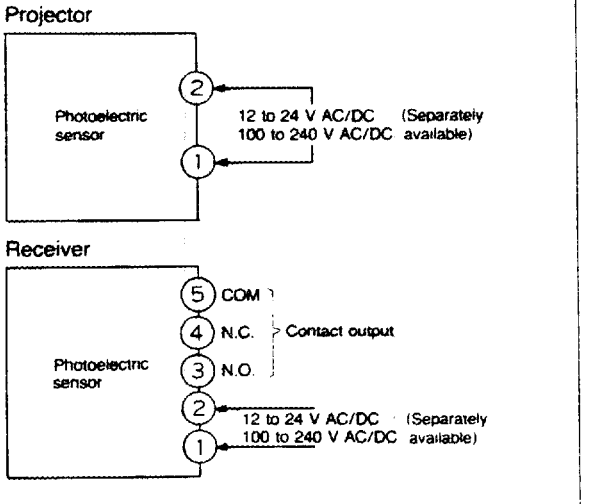


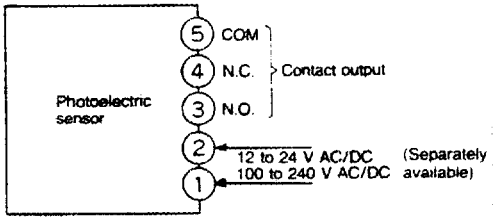

Note: Timer built-in type can be used as a standard type by setting the timing adjustor to the minimum and using the operation mode of ON delay or OFF delay.

## CONNECTION DIAGRAM

MP-1KP, MP-1KPT




MP-R500P, MP-D70P
MP-R500PT, MP-D70PT




Note: No polarity even in the case of using the sensor with DC power source.

# SPECIFICATIONS

| Item \ Type | Thru-beam type | | Retroreflective type | | Diffuse reflective type | |
|---|---|---|---|---|---|---|
| | MP-1KP | MP-1KPT | MP-R500P | MP-R500PT | MP-D70P | MP-D70PT |
| **Rated operating voltage** | 12 to 24 V AC/DC, 100 to 240 V AC/DC (separately available) | | | | | |
| **Rated power consumption** | (AC) Projector: Max. 1.5 VA<br>Receiver: Max. 2.5 VA<br>(DC) Projector: Max. 1.5 W<br>Receiver: Max. 1.5 W | | (AC) Max. 2.5 VA<br>(DC) Max. 2 W | | (AC) Max. 2.5 VA<br>(DC) Max. 2 W | |
| **Rated control capacity (UL rating)** | 3A 250 V AC (resistive load) | | | | | |
| **Standard target** | 30 mm dia. metal plate (dull black finish) | | 70 mm dia. metal plate (dull black finish) | | White drawing paper 20 ×20 cm | |
| **Detectable target** | Opaque target more than 15 mm dia. | | Opaque target more than 70 mm dia. | | Transparent & opaque target | |
| **Operating voltage range** | 10.8 to 26.4 V AC/DC (50/60 Hz), 80 to 264 V AC/DC (50/60 Hz) (Separately available) | | | | | |
| **Max. sensing distance** | 10 m | | 5 m (using an included MP reflector) | | 70 cm | |
| **Operating angle** | Above 2° for both projector and receiver | | Above 2° | | — | |
| **Hysteresis** | — | | — | | Below 20% at rated setting distance | |
| **Detection speed** | 25 times/sec. | 20 times/sec. | 25 times/sec. | 20 times/sec. | 25 times/sec. | 20 times/sec. |
| **Operation indicating method** | Projector: Power indicator (Red LED)<br>Receiver: Indicator light ON light input (Red LED)<br>Adjuster (Red LED) | Projector: Power indicator (Red LED)<br>Receiver: Indicator lights ON light input (Red LED)<br>Adjuster (Red LED)<br>Relay operation indicator (Red LED) | Indicator lights ON light input (Red LED)<br>Adjuster (Red LED) | Indicator lights ON light input (Red LED)<br>Relay operation indicator (Red LED) | Indicator lights ON light input (Red LED) | Indicator lights ON light input (Red LED)<br>Relay operation indicator (Red LED) |
| **Time setting interval** | — | 0.1 to 1 s, 0.5 to 10 s (changeable) | — | 0.1 to 1 s, 0.5 to 10 s (changeable) | — | 0.1 to 1 s, 0.5 to 10 s: (changeable) |
| **Timer operation** | — | ON-delay<br>OFF-delay<br>One-shot<br>(changeable) | — | ON-delay<br>OFF-delay<br>One-shot<br>(changeable) | | ON-delay<br>OFF-delay<br>One-shot<br>(changeable) |
| **Connection method** | Screw terminal connection type | | | | | |
| **Contact form** | 1 Form C | | | | | |
| **Contact resistance (initial)** | Below 100 mΩ at 6 V DC 1 A | | | | | |
| **Contact material** | Gold-flash silver alloy | Gold-clad silver alloy | Gold-flash silver alloy | Gold-clad silver alloy | Gold-flash silver alloy | Gold-clad silver alloy |
| **Electrical life min.** | $2\times10^5$ | $10^5$ | $2\times10^5$ | $10^5$ | $2\times10^5$ | $10^5$ |
| **Mechanical life min.** | $2\times10^7$ operations | | | | | |
| **Insulation resistance (initial)** | Above 100 MΩ (using 500 V DC megger) between mutual each portion and contacts of charged terminals, uncharged metal parts and contact output | | | | | |
| **Dielectric strength** | 2000 V AC (1500 V AC with timer type) for one minute between mutual each portion<br>1000 V AC (750 V AC with timer type) for one minute between contacts | | | | | |
| **Vibration resistance** — **Functional** | 10 to 55 Hz (1 cycle/min) double amplitude 1.5 mm (2 h on 3 axes) | | | | | |
| **Vibration resistance** — **Destructive** | 10 to 55 Hz (1 cycle/min) double amplitude 0.5 mm (10 min on 3 axes) | | | | | |
| **Shock resistance** — **Functional** | 100 G (5 times on 3 axes) | | | | | |
| **Shock resistance** — **Destructive** | 10 G (6 times on 3 axes) | | | | | |
| **Amplidier light level** | Incandescent lamp: max. 10,000 lux | | | | | |
| **Ambient temperature** | −10°C to +55°C | | | | | |
| **Ambient humidity** | Max. 85% RH | | | | | |
| **Protective construction** | Molded plastic body (equivalent to IEC IP66) | | | | | |

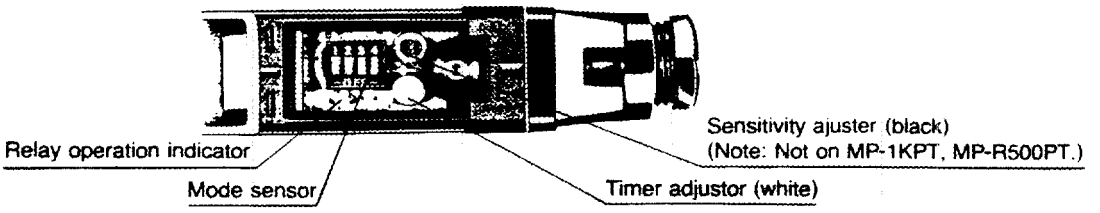
Notes:

1. Unless otherwise specified, the measurement conditions are: rated operating voltage, battery power, an ambient temperature of 20°C the stand ard target and an illuminance of 200 lux on the receiver surface.
2. With the diffuse reflective type, the max. sensing distance and hysteresis are the values for the standard target. The detection distance varies with the material, color and size of the target to be detected.

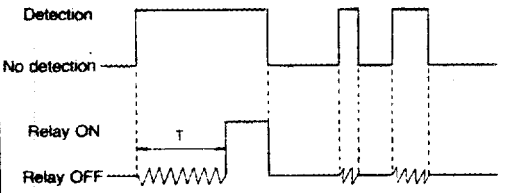
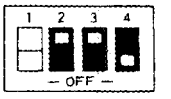
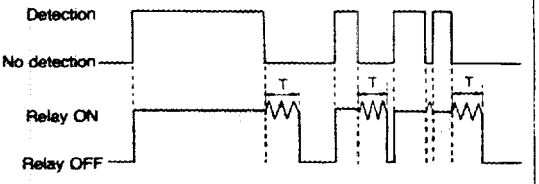
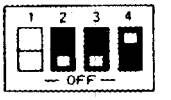
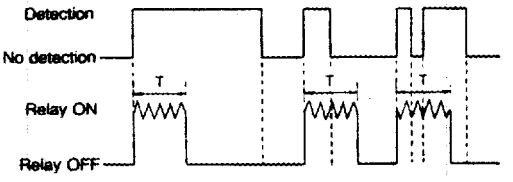
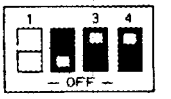
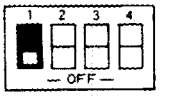
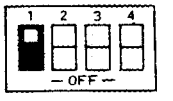
# EXPLANATION OF THE TIMER MECHANISM (MP-1KPT, MP-R500PT, MP-D70PT)

1. Explanation of the control panel

Remove the upper panel cover to expose the control panel. (Photo shows MP-D70PT.)




2. Explanation of operation

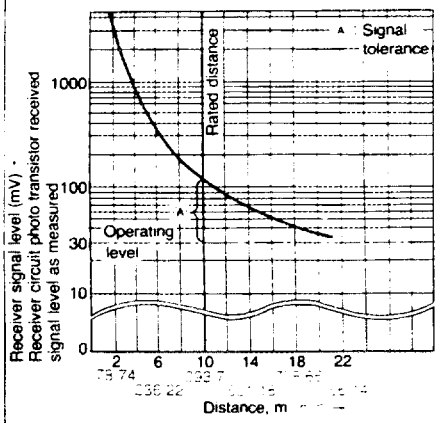
| Operation type | Description | Time chart T = timer interval | Mode sensor □ON ■OFF |
|---|---|---|---|
| ON-delay | Not usable for short-interval detection.<br>Used for long-period detection like checking the stoppage of production lines. |  |  |
| OFF-delay | Lengthens output signal to set time interval.<br>If the response time of the load apparatus is slow, the detection time is lengthened to match it. |  |  |
| One-shot | Emits signal for certain period of time after detection.<br>Used for machinery which always requires a signal of a certain level as input. |  |  |
| Time selection | Timer interval<br>With sensor 1 off, 0.1 to 1 s<br>With sensor 1 on, 0.5 to 10 s<br>Adjust the time interval with the timer adjustor (white). | | 0.1 to 1 second<br>  <br>0.5 to 10 seconds<br>  |

Note: If the timer adjustor is set at the minimum value MIN and the sensor is used in the ON-delay or OFF-delay mode, it can be used as a fundamental operation type.

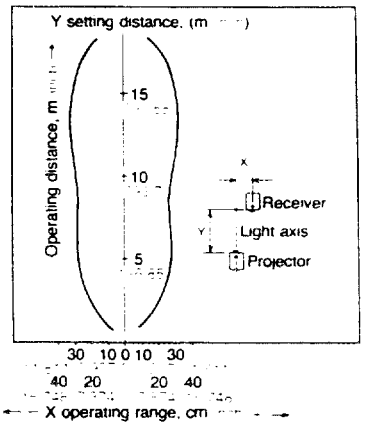
# DATA

## MP-1KP, MP-1KPT (Thru-beam type) characteristic examples

1. Receiver signal level and distance characteristics

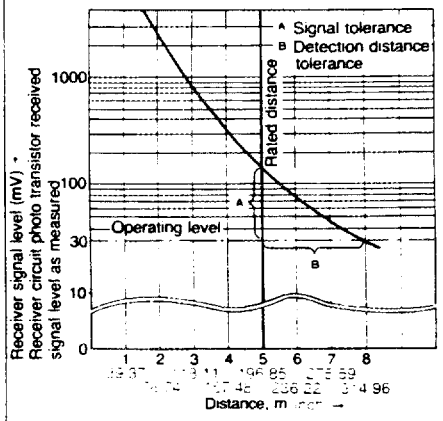



2. Operating level region characteristics

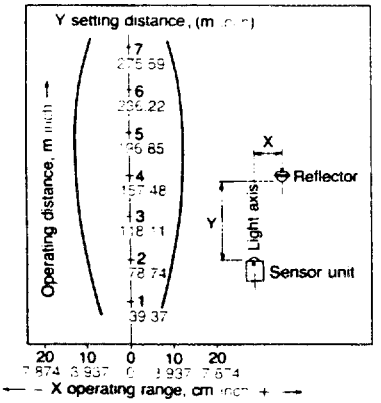



## MP-R500P, MP-R500PT (Retroreflective type) characteristic examples

1. Receiver signal level and distance characteristics



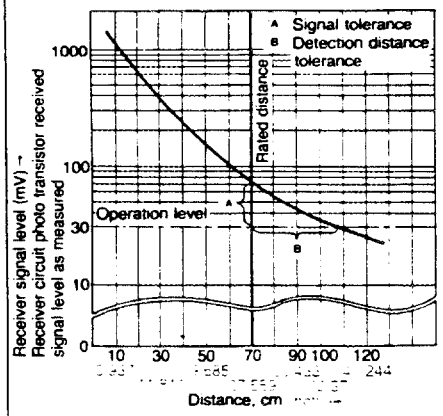

2. Operating level region characteristics




## MP-D70P, MP-D70PT (Diffuse reflective type) characteristic examples

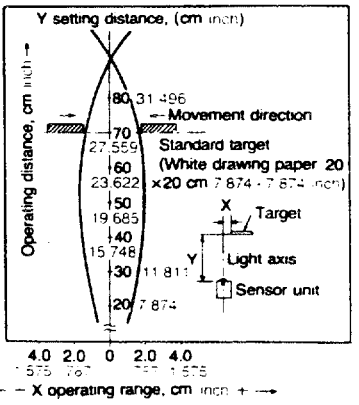
1. Receiver signal level and distance characteristics

Standard target (white drawing paper 20 × 20 cm 7.874 × 7.874 inch) with sensitivity adjustment set at maximum sensitivity



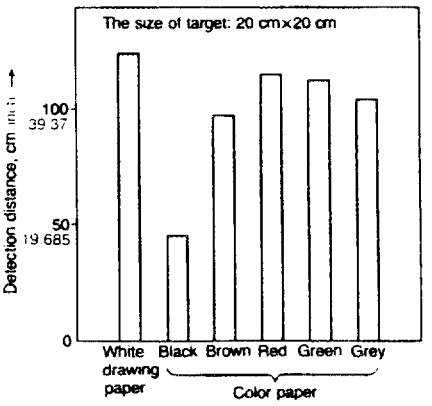

2. Operating level region characteristics

Standard target (white drawing paper 20×20 cm 7.874×7.874 inch) with sensitivity adjustment set at maximum sensitivity




3. Detection distance—color characteristics

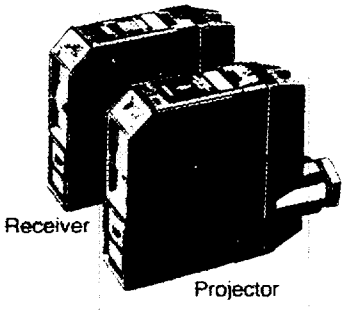
Standard target (white drawing paper 20×20 cm 7.874 × 7.874 inch) with sensitivity adjustment set at maximum sensitivity

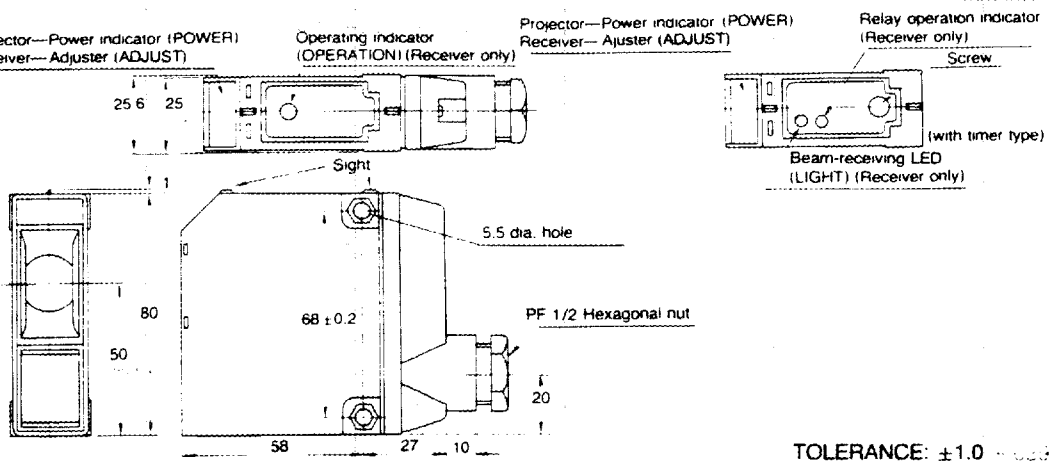


# DIMENSIONS

mm inch

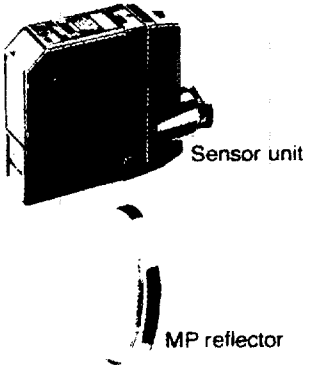
Thru-beam type
MP-1KP, MP-1KPT

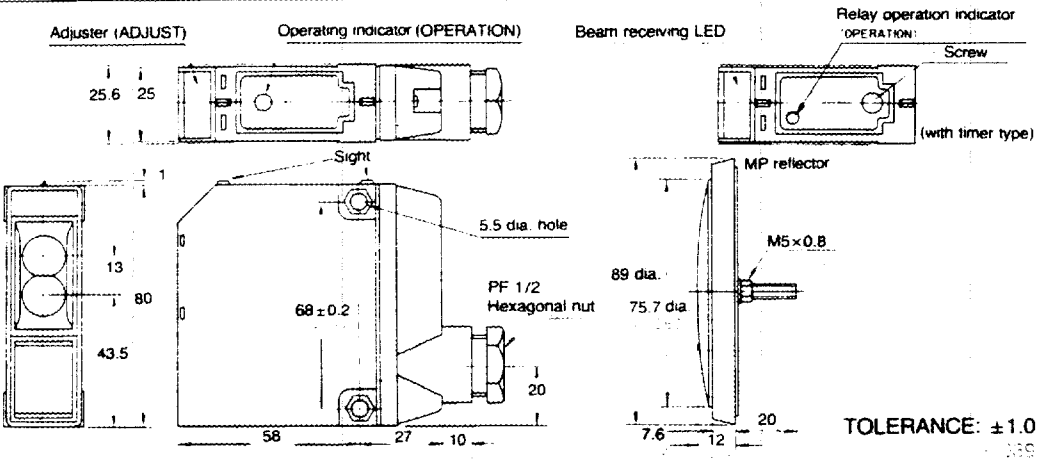



TOLERANCE: ±1.0

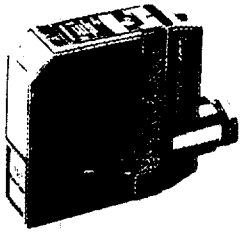
Retroreflective type
MP-R500P, MP-R500PT

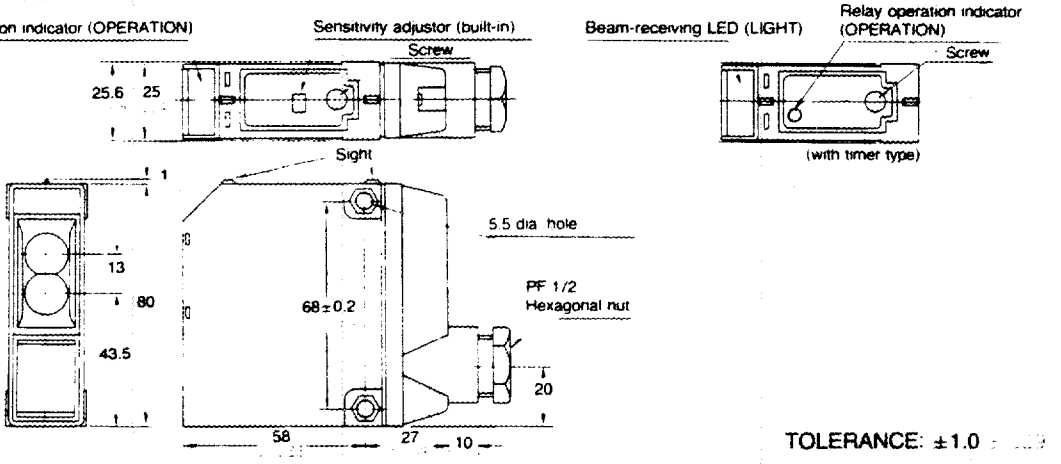



TOLERANCE: ±1.0

Diffuse reflective type
MP-D70P, MP-D70PT



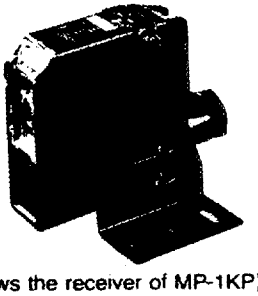



TOLERANCE: ±1.0

# MOUNTING BRACKET ATTACHMENT VIEW

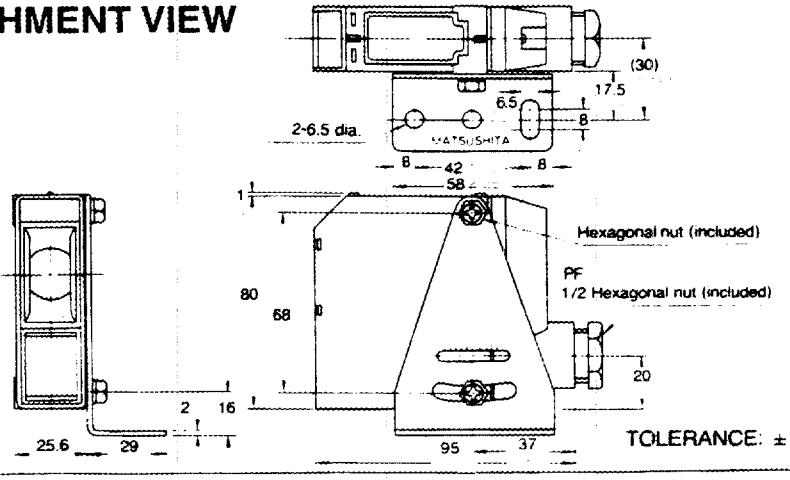
mm inch

MP-1KP, MP-R-500P, MP-D70P
MP-1KPT, MP-R500PT, MP-D70PT



(Photo shows the receiver of MP-1KP)

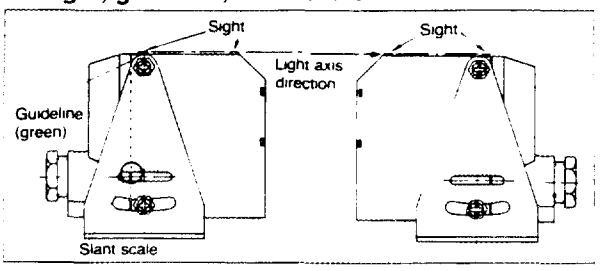
*Accessories are enclosed in each carton box.




TOLERANCE: ±1.0

# REGARDING LIGHT AXIS AND SENSITIVITY ADJUSTMENT

**1. Sight, guideline, slant scale**




Light beam axis adjustment is simple with the sights on the top of the housing. Guide-lines (green) are also on the sensor unit and using the mounting accessory, the unit can be slanted according to the scale (1 graduation per about 2°).

**2. Light beam adjustment with the thru-beam type**

1) Temporarily mount the projector and the receiver. With the light beam being received, the OPERATION LED or the beam-receiving LED (LIGHT) will go on.
2) Move the projector left and right, up and down to a position in the center of the range indicated by the ADJUST LED.
3) Next, move the receiver right and left, up and down to a position in the center of the range indicated by the ADJUST LED.
4) Be careful that vibration or impact during the installation does not cause misalignment of the light beam axis.

**3. Light beam adjustment of the retroreflective type**

1) Temporarily mount photoelectric sensor in a straight line by visual alignment.
2) Move the photoelectric sensor left and right, up and down to a position in the center of the range indicated by the lighting up of the ADJUST LED, or in the case of the sensor with a timer, the LIGHT LED.
3) Pass the target in the detection field and check that the photoelectric sensor operates properly.
4) Affix the reflector and the photoelectric sensor in position. Be careful that vibration or impact does not cause misalignment.

Note: The targets which can be detected are listed as opaque or translucent materials. However, shiny materials (like cans, mirrors, plated metals) reflect too well and may not be detected by the sensor. In such a case, the detection angle should be changed to allow proper detection.

**4. Sensitivity adjustment for the diffuse reflective type**

1) Temporarily mount the photoelectric sensor facing the direction of detection.
2) Without any target in the field, gradually turn the sensitivity adjustor from its maximum position, toward the left until the operation LED goes off. If LED is off even when the setting is at the maximum position leave the setting at the maximum.
3) Place the target in the field and continue turning the adjustor toward the left until the operation LED goes off.
4) Set the volume at the center between the settings found in steps 2) and 3).
5) Affix the photoelectric sensor in position. Be careful that vibration or impact does not cause misalignment.

Note: The detection distance varies with the material, color, size, shape and direction of the target as well as the environmental conditions. The actual target should be used to make the proper adjustments.

# CAUTIONS

1. Use within the ambient temperature range of −10° to +55°C

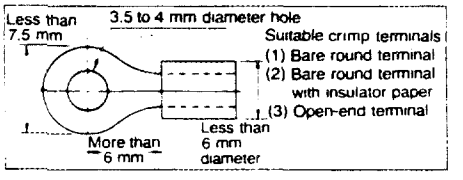
2. If the external surge voltage exceeds the following values, the internal circuit may be damaged; a surge absorber should be used.

| | |
|---|---|
| 12 to 24 V AC/DC type | 500 V |
| 100 to 240 V AC/DC type | 4,000 V |

Surge waveform: ±(1×40) μs of single polarity full-wave voltage.

3. Do not use where there is much steam, dust or corrosive gas or where organic solvents can adhere to the device.
4. Mistake wiring can damage the internal circuit. Re-check the connections before turning on the power.
5. To maintain water protection, the cord should have an outer diameter of 9 to 11 mm with a smooth covering material that allow the sealing rubber and hexagonal nut accessories to be securely tightened.
6. Wiring and circuit construction

1) Make the connections as shown in the wiring diagram.
2) If crimp terminals are to be used, affix the connected pressure terminals to a UP terminal (M3.5 screw).



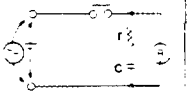
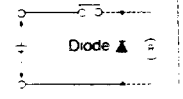
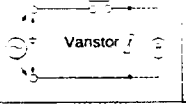

3) Output from the built-in relay IC contact is sent to the output terminal. For switching an inductive load, a contact protection circuit should be included.

7. Detection section

1) Durtiness or soiling of the detector surface can lower the detection distance allowance. Keep the detector surface clean. The lens cover can easily be removed for the cleaning. (The lens cover is not of water-protected construction.)
2) The lens is of acryl and the lens cover is of polycarbonate. They can withstand water, dilute acid or alkali, aliphatic hydrocarbons, and oils. They cannot withstand ketones, esters, halogen hydrocarbons, and aromatic hydrocarbons.

8. Remove the panel cover on the top of the photoelectric sensor to adjust the sensitivity, set the time interval, set the sensor. After the adjustments have been made, replace the packing and securely tighten the screws of the panel cover to preserve the water-protection.

# PROTECTIVE CIRCUIT

| Circuit example | Conditions |
|---|---|
| Built-in relay contact | (1) r must be more than several tens of ohms. (2) AC voltage is used when i) The impedance of R is large. ii) The impedance of R is c and sufficiently low in comparison to the impedance c and r. |
| Built-in relay contact  | Can be used for both AC and DC. r = R c = 0.1 μF |
| Built-in relay contact  | (1) For DC only (2) Not for AC |
| Built-in relay contact  | Can be used for both AC and DC. |

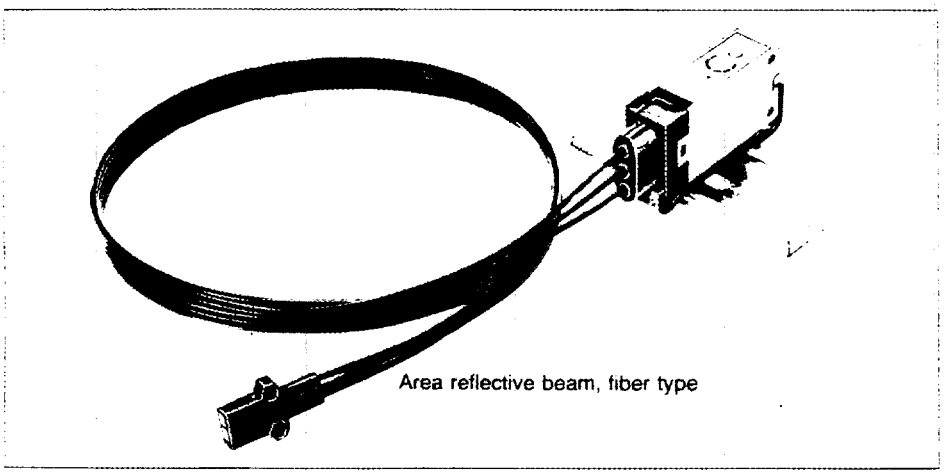
Note: The R in the circuits represents inductive load.

Aromat

# RELIABLE DETECTION OF SMALL TARGETS WITH NEW AREA REFLECTIVE TECHNOLOGY

Components for advanced technology

# MQ-FW Area Reflective Type Fiber



Area reflective beam, fiber type

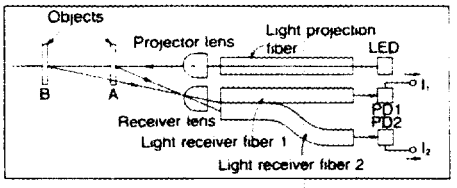
**1. Area reflective beam, fiber type, secures detection of any object**

- Detection little influenced by the color, material and surface conditions of objects is secured.
- The tip of the fiber is resistant against dirt.
- Little influenced by the background beyond the detectable distance.

Detection is possible under adverse conditions.

**Detection principles.**

The detection is determined by comparing the light intensities input into the diodes PD1 and PD2.

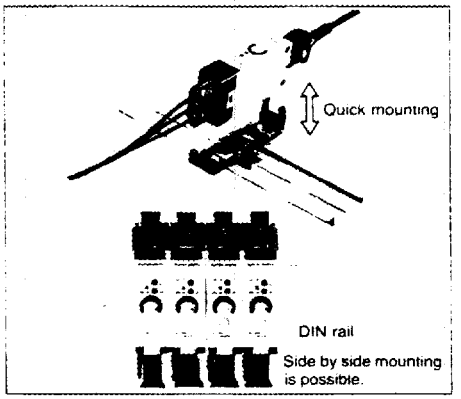



Since the differences between tight intensity levels of two photo diodes decide the detection through the triangulation range verification system, detection under slight variation of the distance is secured.

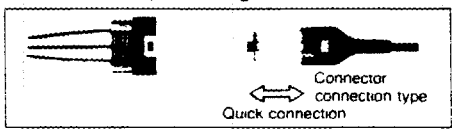
**2. Detection position may be checked at a glance because of the visible red spot.**

**3. High serviceability**

- Mountable on the DIN rail. Side by side mounting with labor-saving is possible.

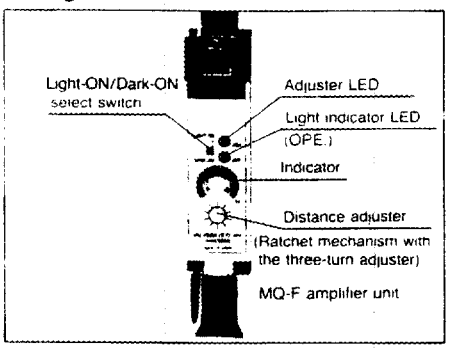



- The connector terminal structure facilitates simple wiring.




**4. Ratchet mechanism with the three-turn adjuster** (equipped with the indicator)

- The three-turn adjuster allows fine adjustment of the detectable distance.
- The ratchet mechanism prevents the adjuster from breakage caused by excessive turning.
- Equipped with an indicator which is visible at a glance. Temporary setting of the detectable distance is possible.
- The adjuster LED equipped facilitates setting of the detectable distance.




**5. The Light-ON and Dark-ON modes are quickly switched.**

(equipped with the switch)

**6. High speed detection at 1 ms**

The detection is possible to 500 times per sec., thus being applicable for high speed devices.

**7. Common use for operating voltages of 12 to 24 V DC**

Widely applicable over a range of 9.6 V to 30 V DC.

## APPLICATIONS

Position detection of silicon wafers, detection of packing on the cap and check of leg pins on electronic parts

## COMBINATION CHART

• Since the components are separately available, they may be combined as desired.

| Detection method | Shapes | Fiber unit Part No. | | Max. sensing distance (cm inch) 1.5 3.5 5 10 12 | Cable length 2 m 2.2 yards Combination Amplifier unit (Light-ON/Dark-ON switchable) |
|---|---|---|---|---|---|
| Area reflective type | Standard | MQ-FW1 | Fiber length 50 cm 1.5 yards | 1.5 cm | MQ-FWAR1-DC12-24V (equipped with connector) MQ-FWAR2-DC12-24V (with cabled connector) |
| | | MQ-FW1-01 | Fiber length 1 m 1 yards | 1.5 cm | |
| | | MQ-FW2 | Fiber length 50 cm | 2.5 cm | |
| | | MQ-FW2-01 | Fiber length 1 m 1 yards | 2.5 cm | (Red LED) Mountable on DIN rail |

# PRODUCT TYPE

1. MQ-FW Amplifier unit

| Applicable fiber | Projector element | Operation type | Assembly with connector | Assembly with cabled connector (2 m) |
|---|---|---|---|---|
| | | | Part No. | Part No. |
| Area reflective type fiber | Red LED | Light-ON/Dark-ON common type (Selectable with switch) | MQ-FWAR1-DC12-24V | MQ-FWAR2-DC12-24V |

Note: Equipped with the DIN rail mountable base.

2. MQ-FW Fiber unit

| Detection method | Shape | Max. sensing distance | Fiber length | Part No. |
|---|---|---|---|---|
| Area reflective type | Standard | 1.5 cm | 50 cm | MQ-FW1 |
| | | 1.5 cm | 1 m | MQ-FW1-01 |
| | | 2.5 cm | 50 cm | MQ-FW2 |
| | | 2.5 cm | 1 m | MQ-FW2-01 |

Note: Equipped with fiber plug.

3. Accessories

| Product name | Specifications | Application | Part No. |
|---|---|---|---|
| MC connector (Tri-terminal type) | With dust protective cover | MQ-FW amplifier unit<br>ME photoelectric sensor | AN53810 |
| Connector with MC cable (Tri-cord type) | Cable length (2 m)<br>with dust protective cover | MQ-FW amplifier unit<br>ME photoelectric sensor | AN53813 |

Note: The amplifier main body is equipped with the connector or the cabled connector.

# SPECIFICATIONS

1. Ratings

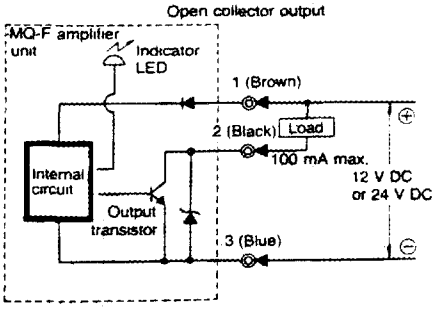
| Item | | Description |
|---|---|---|
| Operation side | Rated operational voltage | 12 to 24 V DC |
| | Rated current consumption | Max. 35 mA (excluding the load) |
| Load side | Output current capacity | Max. 100 mA |

2. Performance outline

| | | | |
|---|---|---|---|
| **Detection method** | | Area reflective type | |
| **Fiber unit** | | MQ-FW1, MQ-FW1-01 | MQ-FW2, MQ-FW2-01 |
| **Amplifier unit** | | MQ-FWAR1-DC12-24V (with connector), MQ-FWAR2-DC12-24V (with cabled connector) | |
| **Projector element** | | Red LED | |
| **Operation mode** | | Light-ON/Dark-ON (selectable with the main body switch) | |
| **Standard target** | | White paper 2×2 cm | |
| **Detectable target** | | Opaque or translucent materials | |
| **Operating voltage range** | | 9.6 to 30 V DC (including the ripple P-P) | |
| **Max. sensing distance** | | 15 mm | 25 mm |
| **Possible distance range** | | 10 to 15 mm | 20 to 25 mm |
| **Hysteresis** | | Max. 5% (at the max. sensing distance) | |
| **Detection speed** | | 1 ms (500 times/s) | |
| **Indicator** | | Light indicator LED (OPE.) (red), Adjuster LED (red) | |
| **Initial insulation resistance** | | Min. 20 MΩ between input/output terminal and external (at 500 V DC) | |
| **Initial breakdown voltage** | | 500 V AC for 1 min between input/output terminal and external | |
| **Vibration resistance** | | 10 to 55 Hz (1 cycle/min), double amplitude 1.5 mm (2 h on 3 axes) | |
| **Shock resistance** | | 100 G (6 times on 3 axes) | |
| **Ambient light level** | | Incandescent lamp: Max. 3,000 lux; sunlight: Max. 10,000 lux | |
| **Ambient temperature** | **Amplifier** | −25°C to +55°C | |
| | **Fiber** | −40°C to +70°C | |
| **Ambient humidity** | | Max. 85% RH | |
| **Protective construction** | | Amplifier: Plastic case, dust-protected construction (equivalent to IEC IP50)<br>Fiber tip: Splash-protected type (equivalent to IEC IP64) | |
| **Fiber material** | | Urethane-chloroethylene copolymerization shiethed, plastic fiber | |
| **Bending allowance of fiber unit** | | 25 mm | |

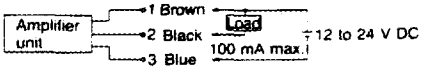
Note: Unless otherwise specified, the measurement conditions comprise rated operating voltage, power supply by battery, 20°C ambient temperature, standard detectable object and 200 lux or less illuminance on the receiver surface.

# OUTPUT CIRCUIT DIAGRAM (Light-ON/Dark-ON switchable)

| Detection method | Circuit diagram | Light-ON/Dark-ON select switch | Operation state of output transistor | Light indicator LED (OPE.) | Operation check of load |
|---|---|---|---|---|---|
| Area reflective type |   Colors are applicable for the cabled type. | Light-ON side | ON when light received (Light-ON) | Lit when light received | Activated when light received |
| | | Dark-ON side | ON when light not received (Dark-ON) | | Activated when light not received |

# WIRING DIAGRAM

MQ-F amplifier unit

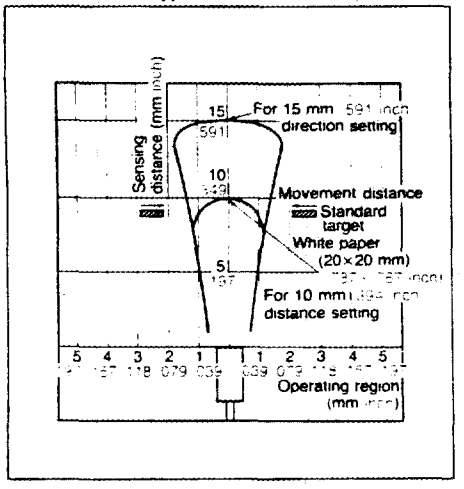



Note: The colors are applicable for the set with cable connector.

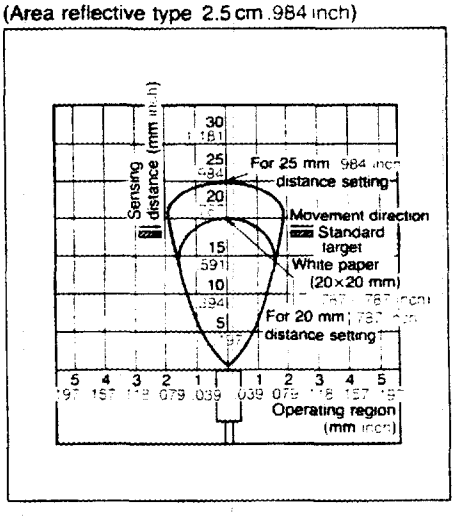
# DATA

## 1. Operation range characteristics

MQ-FWAR amplifier unit
MQ-FW1 fiber unit
(Area reflective type 1.5 cm .591 inch)

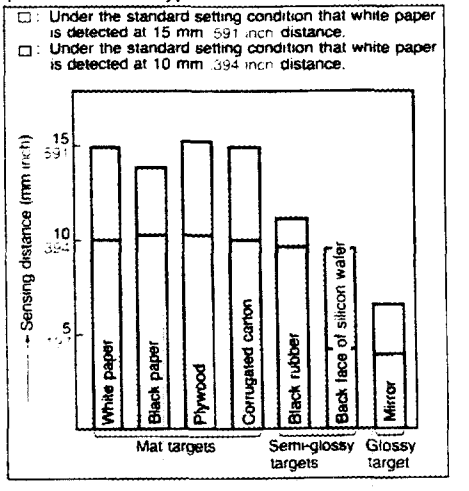



MQ-FWAR amplifier unit
MQ-FW2 fiber unit
(Area reflective type 2.5 cm .984 inch)

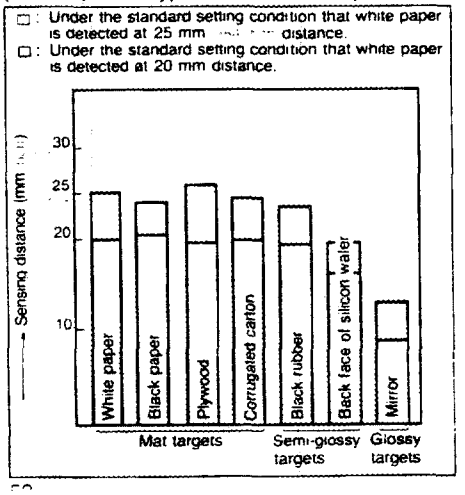



## 2. Material characteristics

MQ-FWAR amplifier unit
MQ-FW1 fiber unit
(Area reflective type 1.5 cm .591 inch)

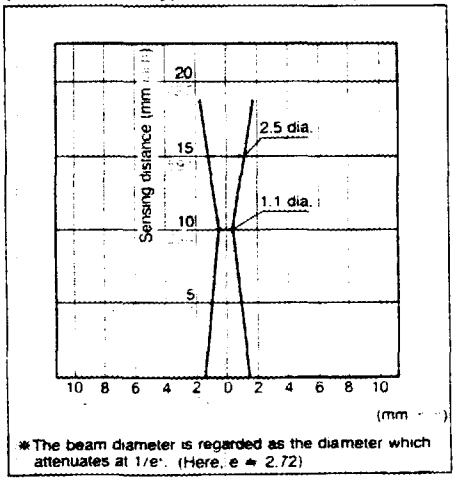



MQ-FWAR amplifier unit
MQ-FW2 fiber unit
(Area reflective type 2.5 cm .984 inch)

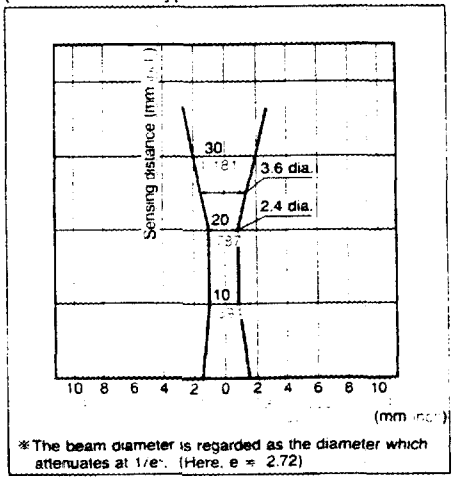



## 3. Projector beam dia. characteristics

MQ-FWAR amplifier unit
MQ-FW1 fiber unit
(Area reflective type 1.5 cm .591 inch)

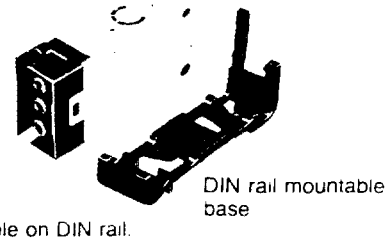


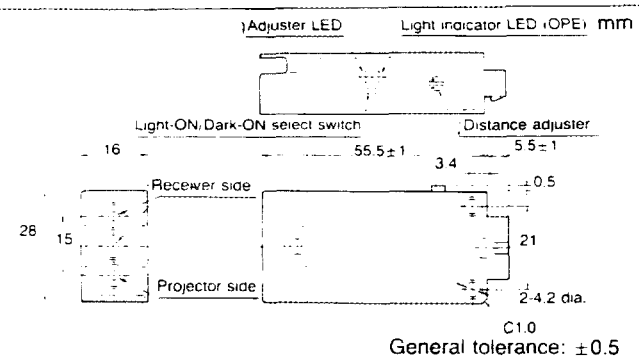

MQ-FWAR amplifier unit
MQ-FW2 fiber unit
(Area reflective type 2.5 cm .984 inch)



## AMPLIFIER UNIT DIMENSIONS

MQ-FWAR amplifier unit



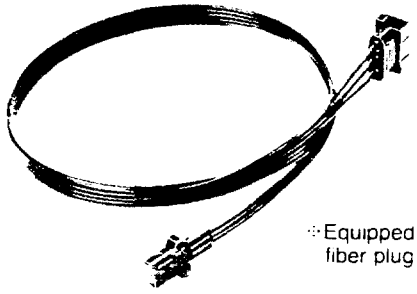



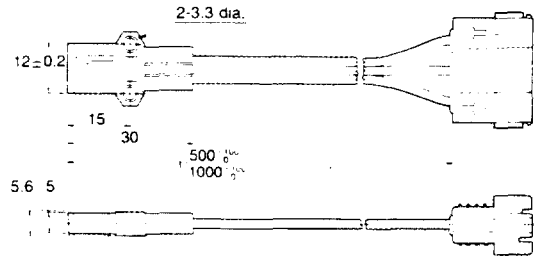

General tolerance: ±0.5

※ Equipped with the base mountable on DIN rail.

## AREA REFLECTIVE TYPE FIBER DIMENSIONS

MQ-FW1 fiber unit
(Area reflective type)

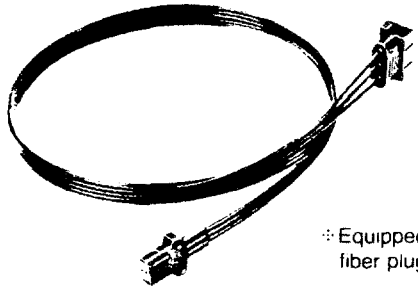


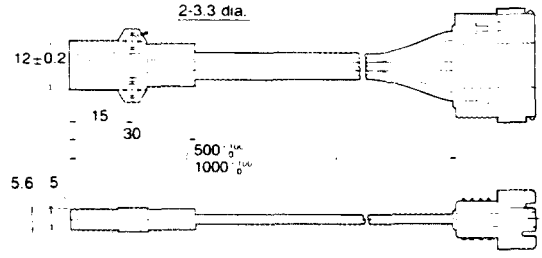




※ Equipped with fiber plug

General tolerance: ±0.5

MQ-FW2 fiber unit
(Area reflective type)




※ Equipped with fiber plug

General tolerance: ±0.5

## CAUTIONS

**1. Distance adjustment for the area reflective type**

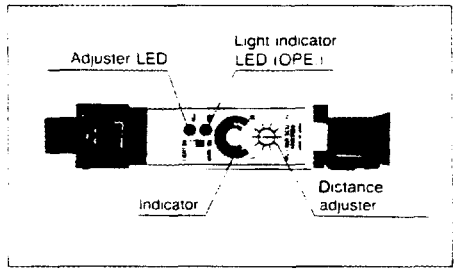
1) Facing the fiber unit in the detection direction, temporarily fasten it.

2) Under the condition that no detectable object exists, gradually turn the distance adjuster counterclockwise from the maximum position (H) to find the position where the light indicator LED (OPE.) goes out. When the LED goes out even if the adjuster is in the max. position (H), select the H position.

3) Place a detectable target in the detection position, and gradually turn the distance adjuster clockwise from the minimum position (L) to find the position where the light indicator LED (OPE.) comes on.
When the LED turns on the even if the adjuster is in the min. position (L), select the L position.

4) Set the adjuster at the middle point between the positions selected in step 2) and step 3).

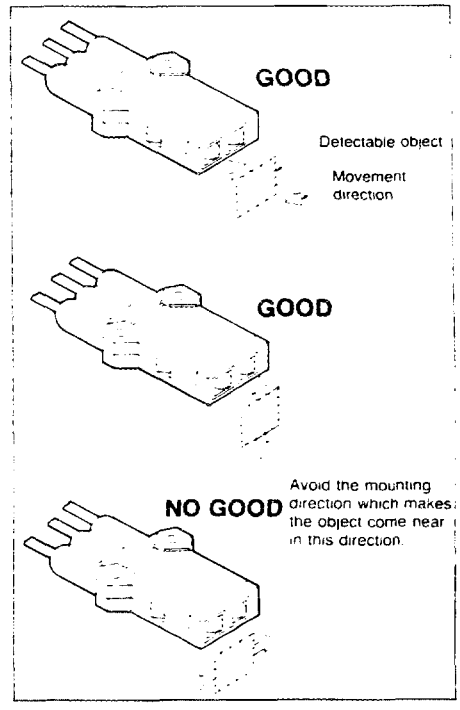
5) Securely fasten the head of the fiber unit.
During fastening, take care to secure it to an extent that it is not displayed when vibration or shock is applied.




Note: Though the sensing distance is little influenced by the colors of objects, the detectable distance may vary for considerably reflective objects such as mirrors, glass and other mirror reflective objects.

**2. Movement direction of detectable target**

Take care for the mounting direction of the fiber unit according to the movement direction of an object.



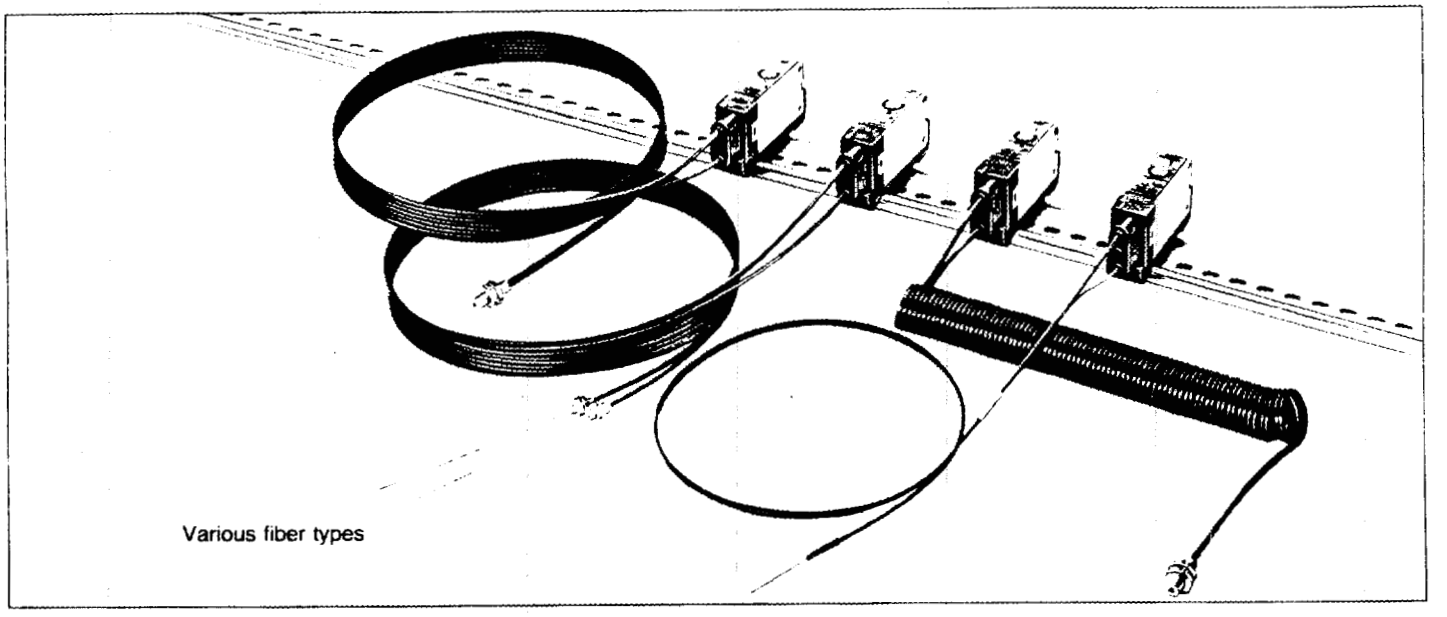

For the ambient conditions, wiring and operation of the fiber unit, refer to the cautions for operation (page 43).

Aromat

# FOR WIDE AND EXTENDED APPLICATIONS

Components for advanced technology

# MQ-F Free-Cut/Fine Diameter/Ultra-Fine Diameter Fibers



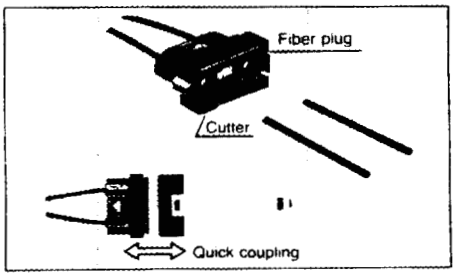
Various fiber types

**1. Free-cut, fine diameter, ultra-fine diameter fibers**

• Free-cut fiber

The fiber can be cut to a desired length at the site according to the equipment, thus improving the serviceability.

**Cutter contained in the fiber plug**

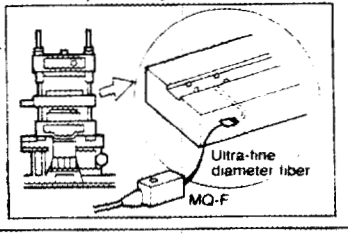



• Fine diameter fiber

[Tip outside diameter: 1.2 mm .047 inch (diffuse reflective type), fiber diameter: 0.5 mm .020 inch] This is most suitable particularly for label positioning and other applications which require detection accuracies.

• Ultra-fine diameter fiber

[Tip outside diameter: 1.0 mm [illegible] fiber diameter: 0.25 mm×7 [illegible] fibers] Applicable for metallic press moulding which requires accuracies during assembly. The superiority is shown in check of the pressing staple and detection of residual burring.

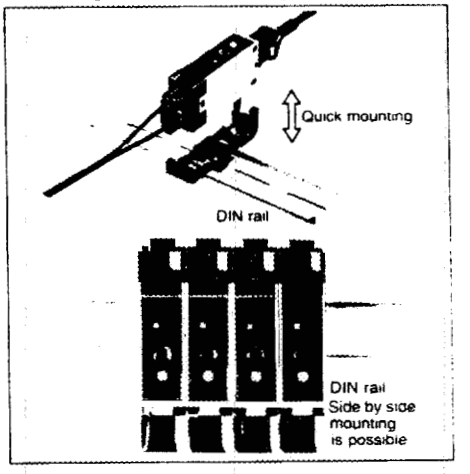



**2. Red and green LED lights on the amplifier unit**

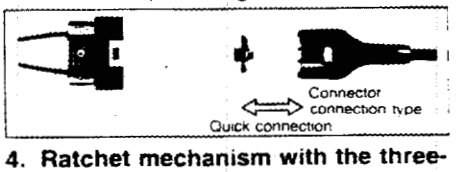
In addition to the standard red LED type, the green type is also available to facilitate detection of red marks on white backgrounds.

**3. Structure with serviciability taken into account**

• Mountable on the DIN rail. Side by side mounting with labor-saving is possible.




• The connector terminal structure facilitates simple wiring.



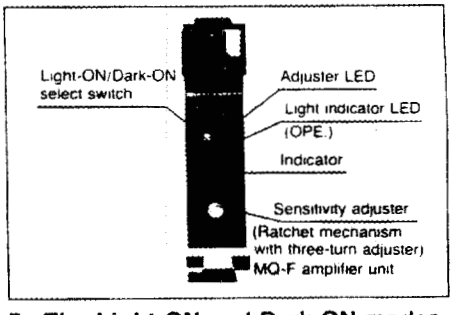

**4. Ratchet mechanism with the three-turn adjuster** (equipped with the indicator)

• The three-turn adjuster allows fine adjustment of the sensing distance.

• The ratchet mechanism prevents the adjuster from breakage caused by excessive turning.

• Equipped with the indicator which is visible at a glance. Temporary setting of the sensing distance is possible.

• The adjuster LED equipped facilitates setting of the detectable distance.




**5. The Light-ON and Dark-ON modes are quickly switched.**

(equipped with the switch)

**6. High speed detection at 0.5 ms**

(Red LED type)

The detection is possible to 1,000 times per second. In addition, the green LED type detects 500 times per second for high speed devices.

**7. Common use for operating voltages of 12 to 24 V DC**

Widely applicable over a range of 9.6 V to 30 V DC.

## APPLICATIONS

Detection of chip parts, detection of label position and positioning of lead frame

# COMBINATION CHART

1. MQ-F Fiber unit and MQ-F Amplifier unit • These units are available as a separate unit and shall be combined as desired.

| Type | Detection method | Appearance | Fiber unit Part No. | Stainless sleeve provided No. in ( ) represents sleeve length | Max. sensing distance (cm inch) No. in ( ) for green LED 1.5 3.5 5 10 12 | Cable length: 2 m 2.2 yards Combination Amplifier unit (Light-ON/Dark-ON switchable) |
|---|---|---|---|---|---|---|
| Free-cut fiber | Thru-beam type | Standard | MQ-F12-02 Fiber length: 2 m (Applicable for attachment) | MQ-FS12-02 Fiber length: 2 m (9 cm) | (1.5 cm) 12 cm | MQ-FAR1-DC12-24V (with connector) MQ-FAR2-DC12-24V (with cabled connector) |
| | | Curled | MQ-F10-C02 Fiber length: 2 m (Applicable for attachment) | MQ-FS10-C02 Fiber length: 2 m (9 cm) | 10 cm | |
| | | Fine dia. (Fiber dia.: 0.5 mm .020 inch) | MQ-F4-N02 Fiber length: 2 m | MQ-FS4-N02 Fiber length: 2 m (9 cm) | 3.5 cm | (Red LED light) With base mountable on DIN rail |
| | Diffuse reflective type | Standard | MQ-FD5-02 Fiber length: 2 m | MQ-FSD5-02 Fiber length: 2 m (9 cm) | (0.6 cm) .236 inch 5 cm 1.969 inches | MQ-FAG1-DC12-24V (with connector) for MQ-F(S)12-02 and MQ-F(S)D5-02 types MQ-FAG2-DC12-24V (with cabled connector) for MQ-F(S)12-02 and MQ-F(S)D5-02 types |
| | | Coaxial | MQ-FX5-02 Fiber length: 2 m | — | 5 cm 1.969 inches | |
| | | Curled | MQ-FD1-C02 Fiber length: 2 m | MQ-FSD1-C02 Fiber length: 2 m (9 cm) | 1.5 cm .591 inch | |
| Fine diameter fiber | Diffuse reflective type | Fine dia. (Fiber dia. 0.5 mm .020 inch) | MQ-FD1-N02 Fiber length: 2 m | MQ-FSD1-N02 Fiber length: 2 m (9 cm) | 1.5 cm | (Green LED light) (For detection of white/red mark) With base mountable on DIN rail |
| Ultra-fine diameter fiber | Diffuse reflective type | Standard | — | MQ-F3SD1-K01 Fiber length: 1 m (3 cm) | 1.5 cm .591 inch | |
| | | Bent tip | — | MQ-F3SD1-KR01 Fiber length: 1 m (3 cm) | 1.5 cm .591 inch | |

2. MQ-F Fiber attachment

| Product name | Part No. | Description | Applicable fiber |
|---|---|---|---|
| MQ-FLE Lens attachment | MQ-FLE (2 pcs as a set) | • The detectable distance is extended to 5 times. (When two pcs. are used.) | MQ-F12-02 MQ-F10-C02 MQ-FH12-02 |
| MQ-FSV Side view attachment | MQ-FSV (2 pcs as a set) | • Space saving—Fibers are used in the parallel state. (When two pcs. are used.) | |

# PRODUCT TYPE

1. MQ-F Amplifier unit

| Applicable fiber | Projector element | Operation type | Assembly with connector Part No. | Assembly with cabled connector (2 m 2.2 yards) Part No. |
|---|---|---|---|---|
| Free-cut, fine diameter, ultra-fine diameter fibers | Red LED | Light-ON/Dark-ON common type (Selectable with switch) | MQ-FAR1-DC12-24V | MQ-FAR2-DC12-24V |
| Free-cut fiber (partial) (for detection of red/white mark) | Green LED | | MQ-FAG1-DC12-24V | MQ-FAG2-DC12-24V |

Note: The base mountable on DIN rail is attached.

2. MQ-F Fiber unit

| Type | Detection method | Appearance | Max. sensing distance No. in ( ) for green LED | Fiber length No. in ( ) represents sleeve length. | Part No. |
|---|---|---|---|---|---|
| Free-cut fiber (plastic) | Thru-beam type | Standard | 12 cm (1.5 cm) 4.724 inches (.591 inch) | 2 m 2.2 yards | MQ-F12-02 |
| | | Standard (with sleeve) | 12 cm (1.5 cm) 4.724 inches (.591 inch) | 2 m (9 cm) 2.2 yards (3.543 inches) | MQ-FS12-02 |
| | | Curled | 10 cm 3.937 inches | 2 m 2.2 yards | MQ-F10-C02 |
| | | Curled (with sleeve) | 10 cm 3.937 inches | 2 m (9 cm) 2.2 yards (3.543 inches) | MQ-FS10-C02 |
| | | Fine diameter (0.5 mm .020 inch dia. fiber) | 3.5 cm 1.378 inches | 2 m 2.2 yards | MQ-F4-N02 |
| | | Fine diameter (with sleeve) | 3.5 cm 1.378 inches | 2 m (9 cm) 2.2 yards (3.543 inches) | MQ-FS4-N02 |
| | Diffuse reflective type | Standard | 5 cm (0.6 cm) 1.969 inches (.236 inch) | 2 m 2.2 yards | MQ-FD5-02 |
| | | Standard (with sleeve) | 5 cm (0.6 cm) 1.969 inches (.236 inch) | 2 m (9 cm) 2.2 yards (3.543 inches) | MQ-FSD5-02 |
| | | Coaxial | 5 cm 1.969 inches | 2 m 2.2 yards | MQ-FX5-02 |
| | | Curled | 1.5 cm .591 inch | 2 m 2.2 yards | MQ-FD1-C02 |
| | | Curled (with sleeve) | 1.5 cm .591 inch | 2 m (9 cm) 2.2 yards (3.543 inches) | MQ-FSD1-C02 |
| Fine diameter fiber (plastic) | Diffuse reflective type | Fine diameter (0.5 mm .020 inch dia. fiber) | 1.5 cm .591 inch | 2 m 2.2 yards | MQ-FD1-N02 |
| | | Fine diameter (with sleeve) | 1.5 cm .591 inch | 2 m (9 cm) 2.2 yards (3.543 inches) | MQ-FSD1-N02 |
| Ultra-fine diameter fiber (plastic) | Diffuse reflective type | Standard (with sleeve) | 1.5 cm .591 inch | 1 m (3 cm) 1.1 yards (1.181 inches) | MQ-F3SD1-K01 |
| | | Bent tip (with sleeve) | 1.5 cm .591 inch | 1 m (3 cm) 1.1 yards (1.181 inches) | MQ-F3SD1-KR01 |

Note: Attached with fiber plug.

### 3. Accessories

| Product name | Specifications | Application | Part No. |
|---|---|---|---|
| MC connector (three terminals) | With dust-protective cover | MQ-F amplifier unit, ME photoelectric sensor | AN53810 |
| MC cabled connector (3-color cord) | Cable length: 2 m [illegible] axes, with dust-protective cover | MQ-F amplifier unit, ME photoelectric sensor | AN53813 |

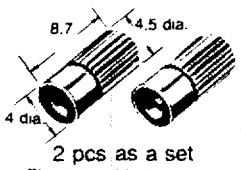
Note: Connector or cabled connector is attached on the amplifier unit.

# MQ-F FIBER ATTACHMENTS

### 1. Appearance

mm

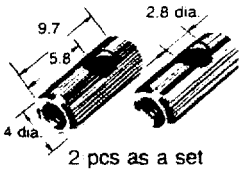
MQ-FLE Lens Attachment




2 pcs as a set

*The detectable distance is multiplied to about 5 times*

MQ-FSV Side View Attachment




2 pcs as a set

*The optical axis is turned at a right angle*

### 2. Performance

| Attachment | MQ-FLE Lens Attachment | | MQ-FSV Side View Attachment | |
|---|---|---|---|---|
| Applicable fiber unit | MQ-F12-02 | MQ-F10-C02 | MQ-F12-02 | MQ-F10-C02 |
| Rated sensing distance<br>No. in ( ) for green LED | 1 m (9 cm) | 60 cm [illegible] | 12 cm (1.5 cm) | 10 cm [illegible] |
| Detectable object | Opaque 4 mm [illegible] or more | | Opaque 3 mm [illegible] or more | |
| Operational angle | 5° to 40° | | 20° to 60° | |

Note: Unless otherwise specified, the measurement conditions comprize rated operational voltage, power supply by battery, 20°C [illegible] ambient temperature, standard detectable object and 200 lux or less illuminance on the receiver surface.

# SPECIFICATIONS

### 1. Ratings

| Item | | Description |
|---|---|---|
| Operation side | Rated operational voltage | 12 to 24 V DC |
| | Rated current consumption | Max. 35 mA (excluding the load) |
| Load side | Output current capacity | Max. 100 mA |

### 2. Performance

| **Fiber type** | Free-cut fiber | | | | | | Fine diameter fiber | Ultra-fine diameter fiber |
|---|---|---|---|---|---|---|---|---|
| **Detection method** | Thru-beam type | | | Diffuse reflective type | | | | |
| **Appearance** | Standard | Curled | Fine diameter | Standard | Coaxial | Curled | Fine diameter | Ultra-fine diameter |
| **Fiber unit** | MQ-F12-02<br>MQ-FS12-02<br>(with sleeve) | MQ-F10-C02<br>MQ-FS10-C02<br>(with sleeve) | MQ-F4-N02<br>MQ-FS4-N02<br>(with sleeve) | MQ-FD5-02<br>MQ-FSD5-02<br>(with sleeve) | MQ-FX5-02 | MQ-FD1-C02<br>MQ-FSD1-C02<br>(with sleeve) | MQ-FD1-N02<br>MQ-FSD1-N02<br>(with sleeve) | MQ-F3SD1-K01<br>(with sleeve)<br>MQ-F3SD1-KR01<br>(with sleeve, bent tip) |
| **Amplifier unit** | Red LED light type: MQ-FAR1-DC12-24V (with connector), MQ-FAR2-DC12-24V (with cabled connector)<br>Green LED light type: MQ-FAG1-DC12-24V (with connector), MQ-FAG2-DC12-24V (with cabled connector) | | | | | | | |
| **Projector element** | Red LED<br>green LED | Red LED | | Red LED<br>green LED | Red LED | | | |
| **Operation mode** | Light-ON/Dark-ON (selectable with the main body switch) | | | | | | | |
| **Standard target** | 2 mm<br>metallic mat black color | | 1 mm<br>metallic mat balck color | White paper 3 × 3 cm [illegible] | | | White paper 1.5 × 1.5 cm | |
| **Minimum target** | 1 mm<br>nontransparent object | | 0.5 mm<br>nontransparent object | 0.1 mm copper element wire | | | 0.05 mm<br>copper element wire | |
| **Detectable target** | Opaque material | | | Transulucent or opaque material | | | | |
| **Operating voltage range** | 9.6 to 30 V DC (including the ripple P-P) | | | | | | | |
| **Max. sensing distance**[2]<br>**No. in ( ) for green LED** | 12 cm<br>(1.5 cm) | 10 cm | 3.5 cm | 5 cm<br>(0.6 cm) | 5 cm | 1.5 cm | 1.5 cm | 1.5 cm |
| **Operational angle** | 10° to 90° | | | — | | | | |
| **Hysteresis**[2] | — | | | 1 cm (1.2 mm)<br>or less | | 3 mm [illegible] or less | | |
| **Detection speed** | Red LED type: 1,000 times/s; Green LED type: 500 times/s | | | | | | | |
| **Indicator** | Light indicator LED (OPE.) (red), Adjuster LED (red) | | | | | | | |
| **Initial insulation resistance** | 20 MΩ or more between input/output terminal and external (at 500 V DC) | | | | | | | |
| **Initial breakdown voltage** | 500 V AC for one minute between input/output terminal and external | | | | | | | |
| **Vibration resistance** | 10 to 55 Hz (1 cycle/min), double amplitude 1.5 mm [illegible] (2 h on 3 axes) | | | | | | | |
| **Shock resistance** | 100 G (6 times on 3 axes) | | | | | | | |
| **Ambient light level** | Incandescent lamp: Max. 3,000 lux; sunlight: Max. 10,000 lux | | | | | | | |
| **Ambient temperature** — **Amplifier** | −25°C to +55°C | | | | | | | |
| **Ambient temperature** — **Fiber** | −40°C to +70°C [illegible] | | | | | | | |
| **Ambient humidity** | Max. 85% RH | | | | | | | |
| **Protective construction** | Amplifier: Plastic case, dust-protected construction (IEC50 or equivalent); Fiber tip: Immersion-protected type (IEC IP67 or equivalent) | | | | | | | |
| **Fiber material** | Plastic fiber, polyethylene sheathed Stainless sleeve for the sleeve type | Plastic fiber, urethane-chloro-ethylene copoly-merization sheathed Stainless sleeve for the sleeve type | Plastic fiber, poly-ethylene sheathed Stainless sleeve for the sleeve type | Plastic fiber, poly-ethylene sheathed Stainless sleeve for the sleeve type | Plastic fiber, poly-ethylene sheathed | Plastic fiber, urethane-chloro-ethylene copoly-merization sheathed Stainless sleeve for the sleeve type | Plastic fiber, poly-ethylene sheathed Stainless sleeve for the sleeve type | Plastic fiber, polyethylene tubed Stainless sleeve for the sleeve type |
| **Bending allowance of fiber unit** | 25 mm | | | | | | | |

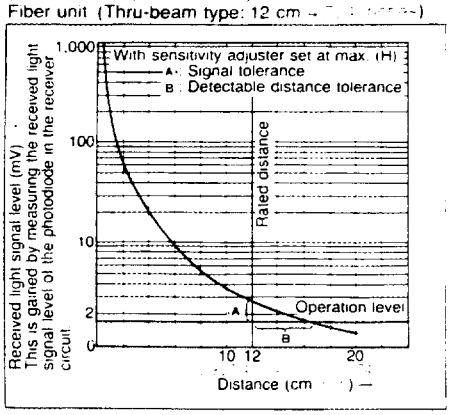
Notes: 1. Unless otherwise specified, the measurement conditions comprise rated operating voltage, power supply by battery, 20 C [illegible] ambient temperature, standard target and 200 lux or less illuminance on the receiver surface.

2. For the diffuse reflective type, the max. sensing distance and hysteresis are based on the standard target, and the detectable distance may vary depending on the material, color and size of a target.

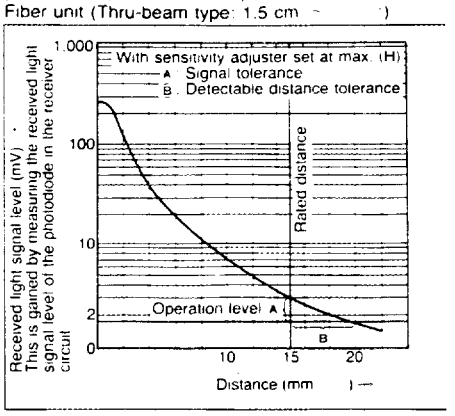
# DATA

## 1. Characteristics of light level received vs distance

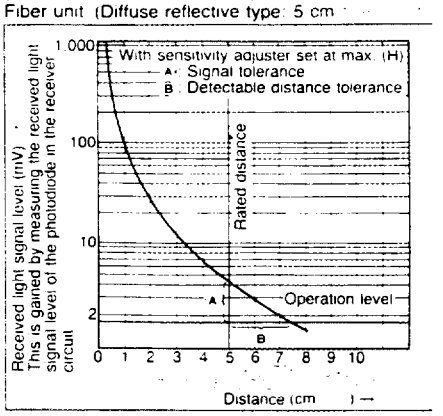
MQ-FAR amplifier unit (red LED)
(MQ-F12-02) (MQ-FS12-02)
Fiber unit (Thru-beam type: 12 cm)



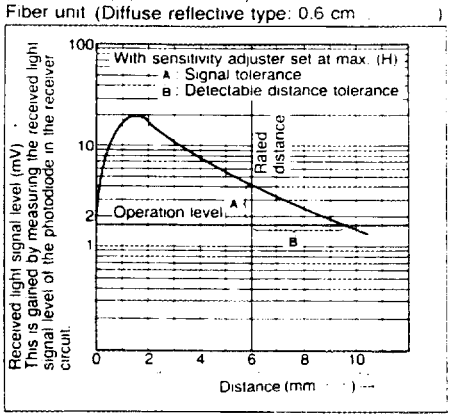

MQ-FAG amplifier unit (green LED)
(MQ-F12-02) (MQ-FS12-02)
Fiber unit (Thru-beam type: 1.5 cm)




MQ-FAR amplifier unit (red LED)
(MQ-FD5-02) (MQ-FSD5-02)
Fiber unit (Diffuse reflective type: 5 cm)

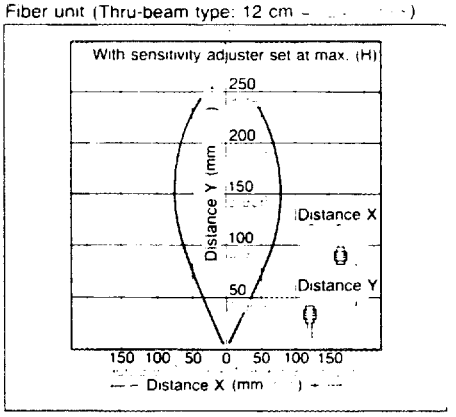



MQ-FAG amplifier unit (green LED)
(MQ-F05-02) (MQ-FS05-02)
Fiber unit (Diffuse reflective type: 0.6 cm)

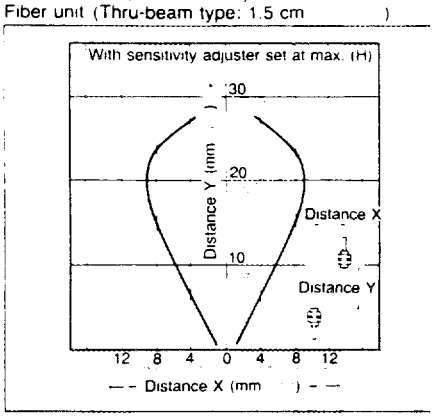



## 2. Operation range characteristics

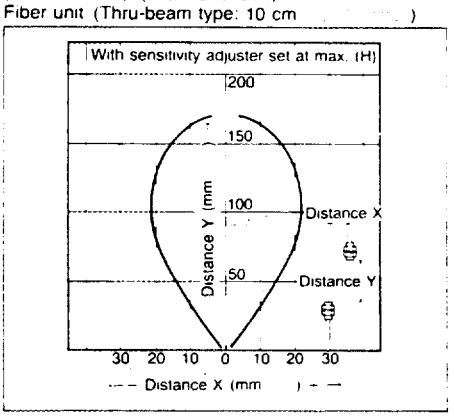
MQ-FAR amplifier unit (red LED)
(MQ-F12-02) (MQ-FS12-02)
Fiber unit (Thru-beam type: 12 cm)



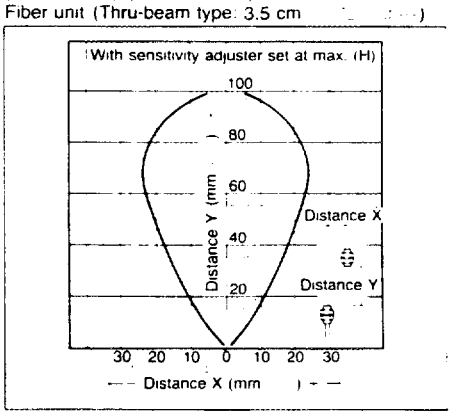

MQ-FAG amplifier unit (green LED)
(MQ-F12-02) (MQ-FS12-02)
Fiber unit (Thru-beam type: 1.5 cm)



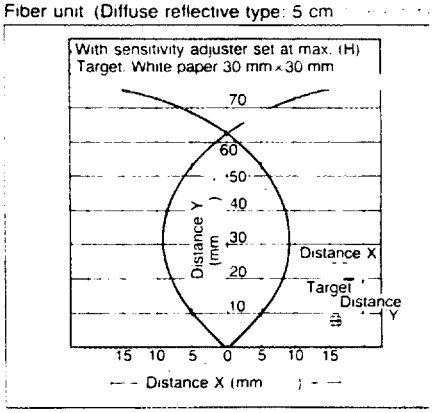

MQ-FAR amplifier unit (red LED)
(MQ-F10-C02) (MQ-FS10-C02)
Fiber unit (Thru-beam type: 10 cm)



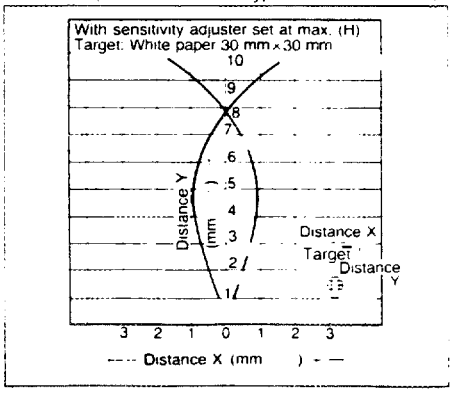

MQ-FAR amplifier unit (red LED)
(MQ-F4-N02) (MQ-FS4-N02)
Fiber unit (Thru-beam type: 3.5 cm)



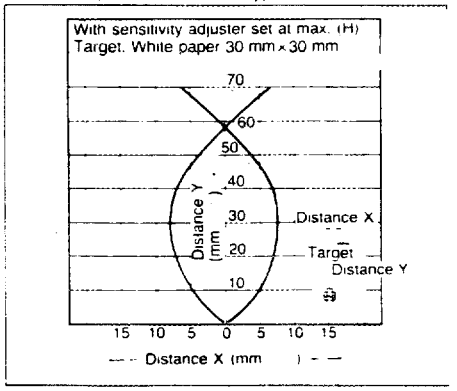

MQ-FAR amplifier unit (red LED)
(MQ-FD5-02) (MQ-FSD5-02)
Fiber unit (Diffuse reflective type: 5 cm)



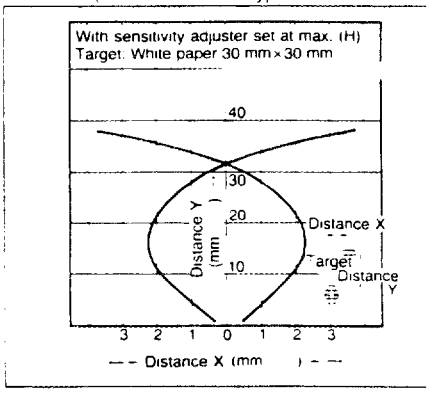

MQ-FAG amplifier unit (green LED)
(MQ-FD5-02) (MQ-FSD5-02)
Fiber unit (Diffuse reflective type: 0.6 cm)



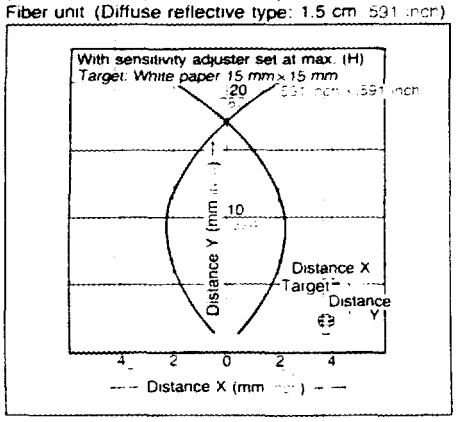

MQ-FAR amplifier unit (red LED)
(MQ-FX5-02)
Fiber unit (Diffuse reflective type: 5 cm)



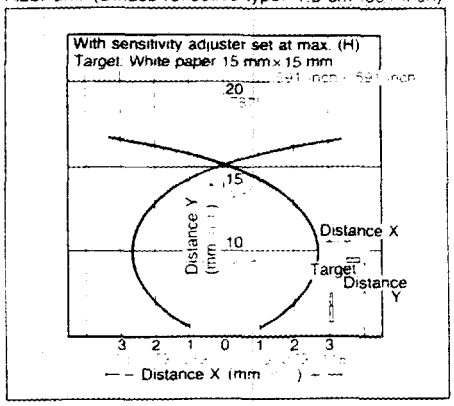

MQ-FAR amplifier unit (red LED)
(MQ-FD1-C02) (MQ-FSD1-C02)
Fiber unit (Diffuse reflective type: 1.5 cm)



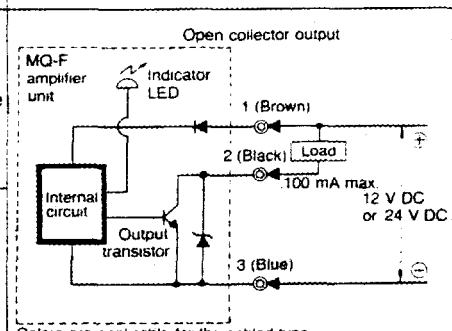
MQ-FAR amplifier unit (red LED)
(MQ-FD1-N02) (MQ-FSD1-N02)
Fiber unit (Diffuse reflective type: 1.5 cm .591 inch)




MQ-FAR amplifier unit (red LED)
(MQ-F3SD1-K01) (MQ-F3SD1-KR01)
Fiber unit (Diffuse reflective type: 1.5 cm .591 inch)

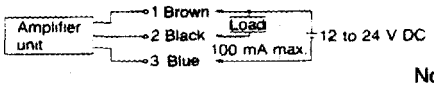



# OUTPUT CIRCUIT DIAGRAM (Light-ON/Dark-ON switchable)

| Detection method | Circuit diagram | Light-ON/Dark-ON select switch | Operation state of output transistor | Light indicator LED (OPE.) | Operation state of load |
|---|---|---|---|---|---|
| Thru-beam type |   Colors are applicable for the cabled type. | Dark-ON side | ON when light interrupted (Dark-ON) (ON when object detected) | Lit when light received | Activated when light interrupted |
| | | Light-ON side | ON when light received (Light-ON) (OFF when object detected) | | Activated when light received |
| Diffuse reflective type | | Light-ON side | ON when light received (Light-ON) (ON when object detected) | | Activated when light received |
| | | Dark-ON side | ON when light not received (Dark-ON) (OFF when object detected) | | Activated when light not received |

# WIRING DIAGRAM

MQ-F amplifier unit

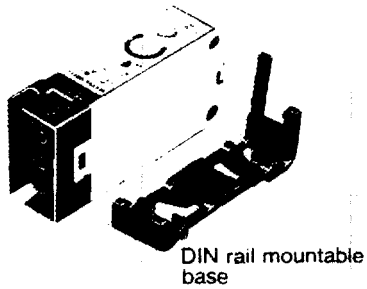


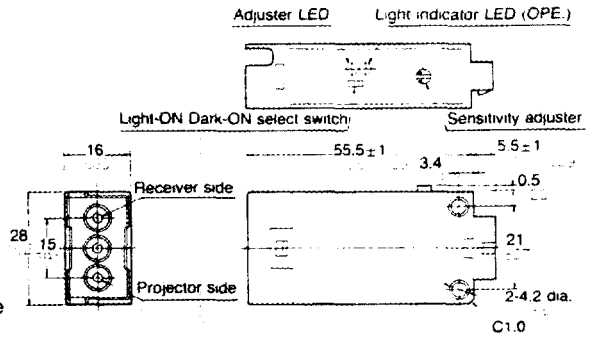

Note: The colors are applicable for the set with cabled connector.

# AMPLIFIER UNIT DIMENSIONS

mm

MQ-FAR Amplifier unit

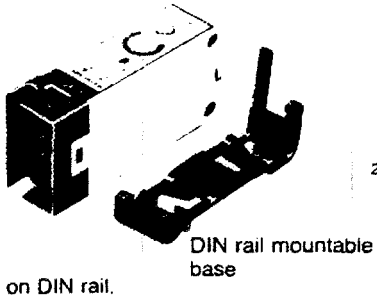


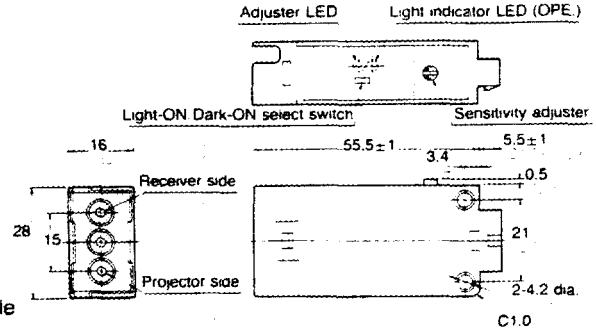




※Equipped with the base mountable on DIN rail.

General tolerance: ±0.5

MQ-FAG Amplifier unit



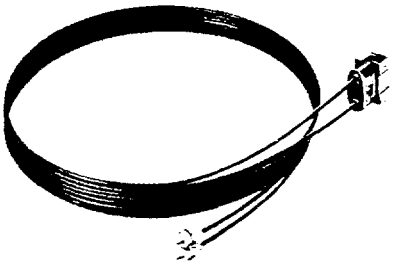

※Equipped with the base mountable on DIN rail.

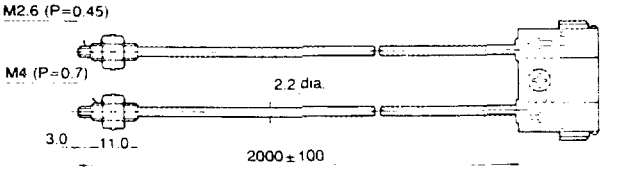
General tolerance: ±0.5

# FREE-CUT FIBER DIMENSIONS

mm

MQ-F12-02 Fiber Unit
(Thru-beam type)

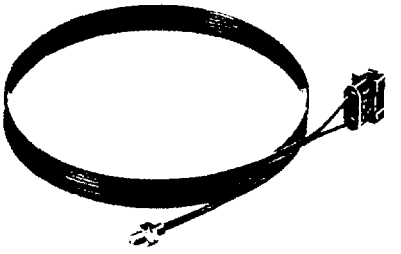


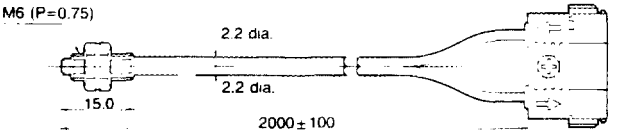



※Equipped with fiber plug

General tolerance: ±0.5

MQ-FD5-02 Fiber Unit
(Diffuse reflective type)

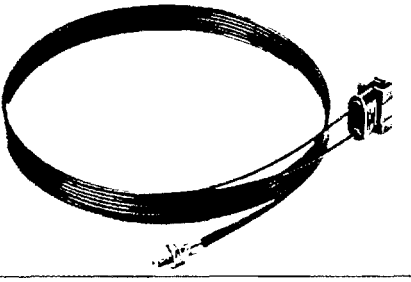


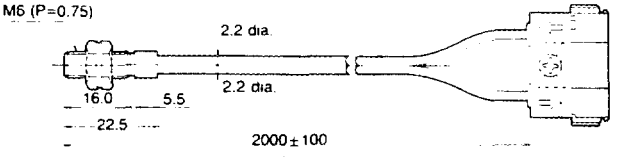



※Equipped with fiber plug

General tolerance: ±0.5

MQ-FX5-02 Fiber Unit
(Coaxial fiber, diffuse reflective type)

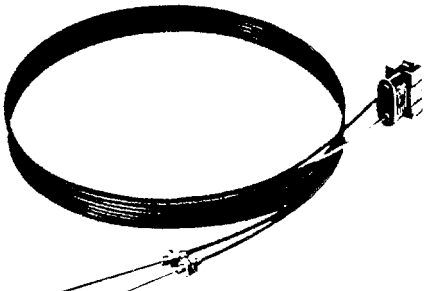


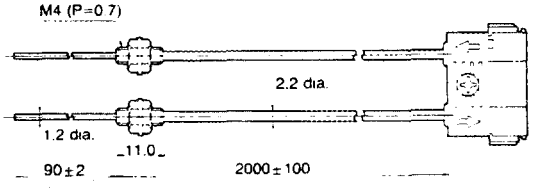



※Equipped with fiber plug

General tolerance: ±0.5

MQ-FS12-02 Fiber Unit
(Thru-beam type with stainless sleeve)

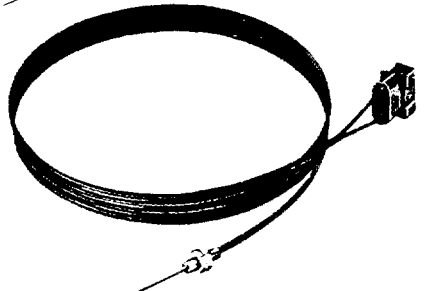


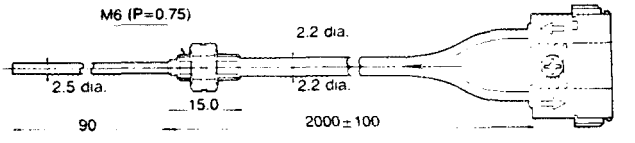



※Equipped with fiber plug

General tolerance: ±0.5

MQ-FSD5-02 Fiber Unit
(Diffuse reflective type with stainless sleeve)

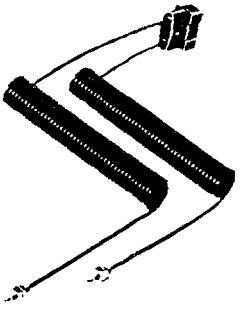


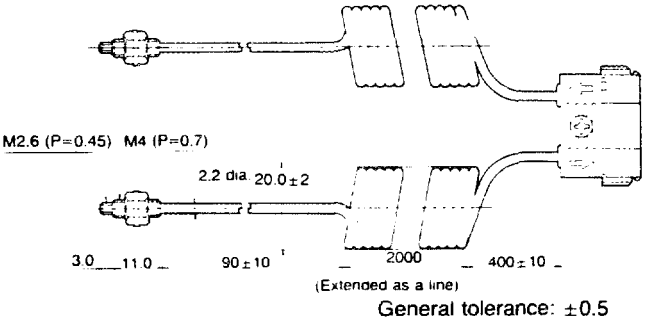



※Equipped with fiber plug

General tolerance: ±0.5

MQ-F10-C02 Fiber Unit
(Curled fiber, Thru-beam type)



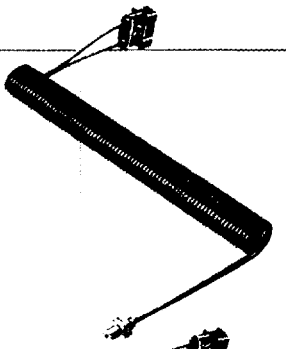


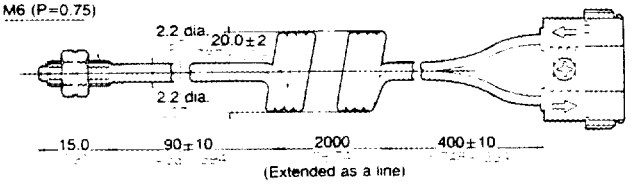

※Equipped with fiber plug

General tolerance: ±0.5

mm inch

MQ-FD1-C02 Fiber Unit
(Curled fiber, diffuse reflective type)

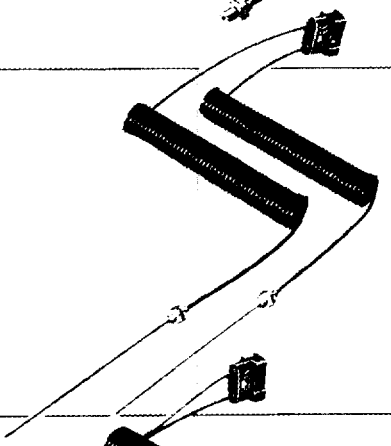


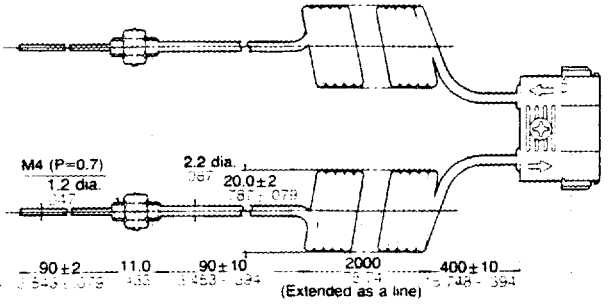



※Equipped with fiber plug

General tolerance: ±0.5

MQ-FS10-C02 Fiber Unit
(Curled fiber, thru-beam type with stainless sleeve)

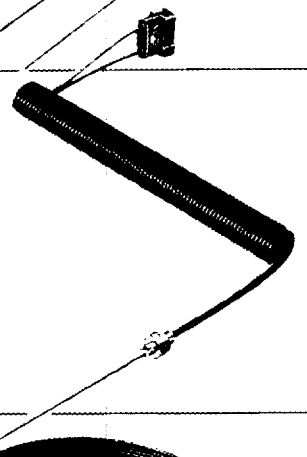


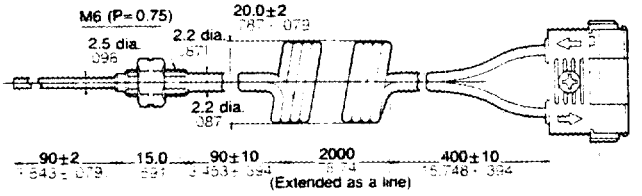



※Equipped with fiber plug

General tolerance: ±0.5

MQ-FSD1-C02 Fiber Unit
(Curled fiber, diffuse reflective type with stainless sleeve)

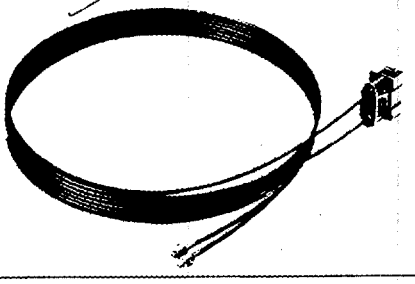


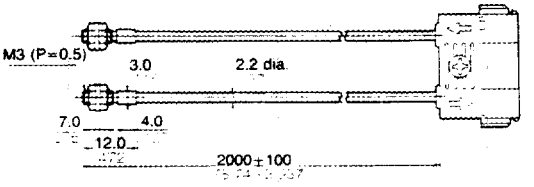



※Equipped with fiber plug

General tolerance: ±0.5

MQ-F4-N02 Fiber Unit
(Fine diameter fiber, thru-beam type)

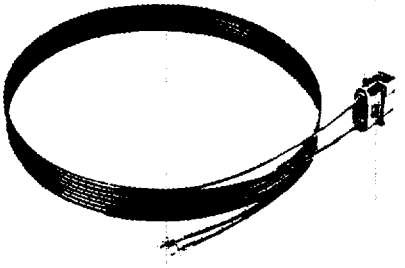


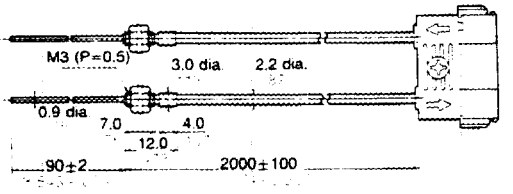



※Equipped with fiber plug

General tolerance: ±0.5

MQ-FS4-N02 Fiber Unit
(Fine diameter fiber, thru-beam type with stainless sleeve)



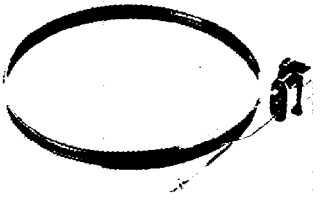


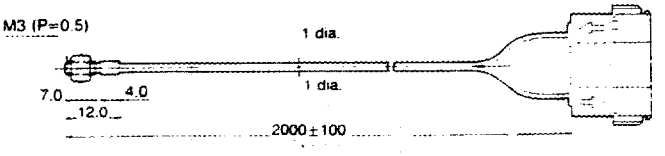

※Equipped with fiber plug

General tolerance: ±0.5

# FINE DIAMETER FIBER DIMENSIONS

MQ-FD1-N02 Fiber Unit
(Diffuse reflective type)

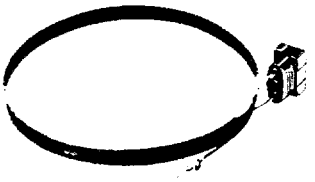




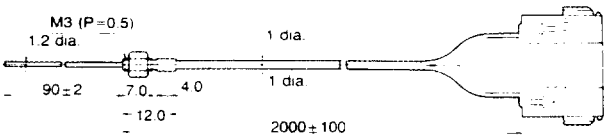

※Equipped with fiber plug

General tolerance: ±0.5

MQ-FSD1-N02 Fiber Unit
(Diffuse reflective type
with stainless sleeve)



mm

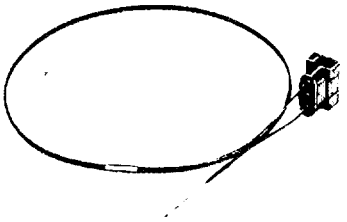


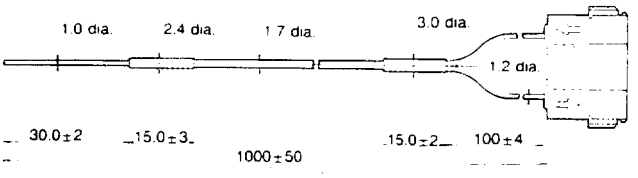

⁘ Equipped with fiber plug

General tolerance: ±0.5

# ULTRA-FINE DIAMETER FIBER DIMENSIONS

MQ-F3SD1-K01 Fiber Unit
(Diffuse reflective type
with stainless sleeve)

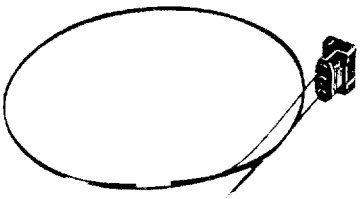


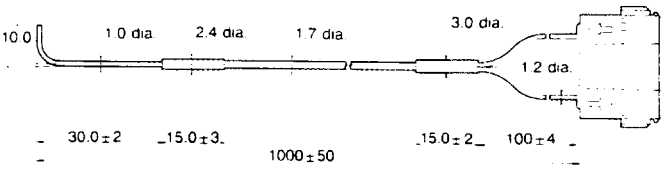



⁘ Equipped with fiber plug

General tolerance: ±0.5

MQ-F3SD1-KR01 Fiber Unit
(Diffuse reflective type
with stainless sleeve)






⁘ Equipped with fiber plug

General tolerance: ±0.5

# CAUTIONS

**1. Sensitivity adjustment for the thru-beam type**

1) Swing the projector and receiver fiber units to left and right, and up and down so as to position the light indicator LED (OPE.) at the center in the lightening range, and then secure them. At this time, confirm that the adjuster LED is lit.

2) Adjusting the sensitivity makes possible detection of translucent and opaque targets. For opaque targets, the adjuster is turned to the maximum position (H) to increase the distance tolerance.

Note: If the adjsuter LED goes out during operation, it is an alarm signal that detection does not work. Readjust and check sensitivity.

**2. Sensitivity adjustment for the diffuse reflective type**

1) Facing the detection face of the fiber unit in the detection direction, temporarily fasten it.

2) Under the condition that no detectable object exists, gradually turn the sensitivity adjuster counterclockwise from the maximum position (H) to find the position where the light indicator LED (OPE.) goes out. When the LED goes out if the adjuster is in the max. position, select the H position.

3) Place a detectable target in the detection position, and further turn the sensitivity adjuster counterclockwise to find the position where the light indicator LED (OPE.) goes out.

4) Set the adjuster at the middle point between the positions selected in step 2) and step 3).

5) Securely fasten the head of the fiber unit.

During fastening, take care to secure it to an extent that it is not displaced when vibration or shock is applied.

Notes:

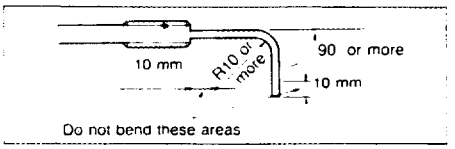
1. Since the sensing distance depends on the material, color, size, shape and direction of targets, and the environmental conditions, check it using an actual target. Since the transmission factor also varies depending on the bending angle of the optical fiber, avoid the operation near the limit of the operation but operate it within two thirds of the limit distance.
2. If the adjuster LED does not come on in step 4), reposition the detection face and repeat the procedure of step 1) to step 4) or isolate an external cause such as variation of the ambient temperature or position variation of an object to detect.

**3. Bending of stainless sleeve**

1) Keep the bending curvature 10 mm radius or more.

2) Smoothly bend the sleeve using a round rod of 20 mm diameter.

3) The sleeve can not be bent within 10 mm from the tip or the root. Moreover, the bending angle shall be within 90 degrees. (MQ-F3SD1-K01 and MQ-F3SD-KR01 can not be bent.)

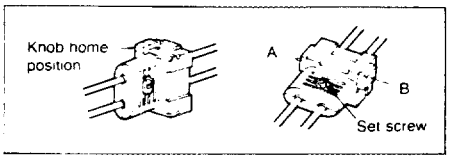



**4. Handling of curled fiber**

The extension of the curled fiber should be kept 5 times or less of its initial length. (If extended as a line, the length is 85 cm , max.)

**5. Cutting of fiber**

(Way to cut fiber)




1) Set the knob in the home position.

2) Loosen the set screw, and set the fiber to a desired length.

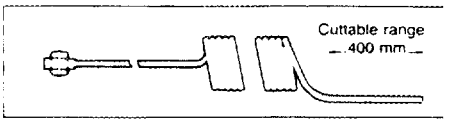
3) Securely tighten the set screw and push down the knob at once. Do not stop on the way.

Push both A and B at the same time.

4) Before inserting into the amplifier unit return the knob to the home position.

Notes:

1. In case of the free-cut type, the sensing distance is 20% reduced.
2. Do not open the blade carelessly because of danger.
3. Cut two fibers at the same time.
4. Do not cut fibers more than three times. Otherwise, the cut surface becomes worse to reduce the detectable distance.
5. The curled fiber can be cut only at the straight range (400 mm ) a shown below. Do not cut the could area.




6. MQ-FD1-N02, MQ-FSD1-N02, MQ-F3SD1-K01 and MQ-F3SD1-KR01 can not be free-cu

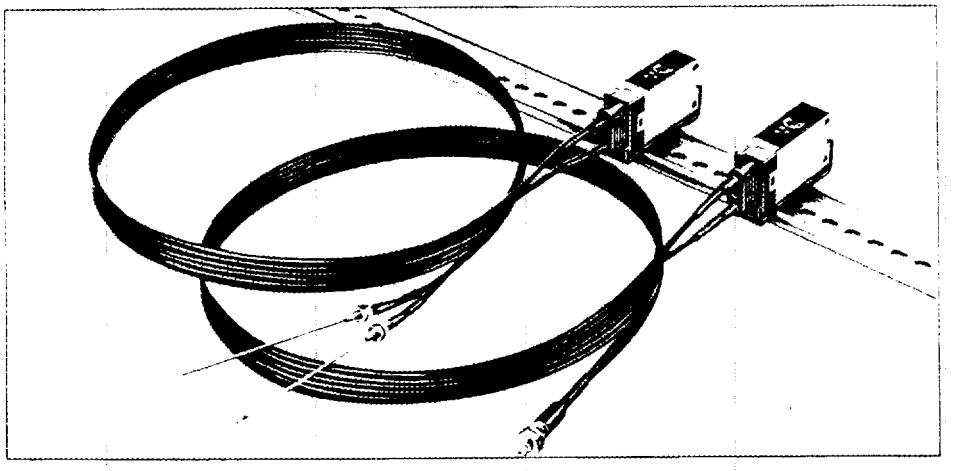
⁘ For the ambient conditions, wiring and operation of the fiber unit, refer to the cautions for operation (page 43).

Aromat

# HEAT RESISTANT GLASS FIBER UP TO 200°C +392°F

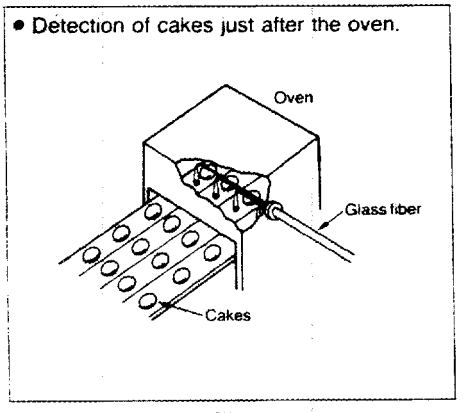
Components for advanced technology

# MQ-F Glass Fibers

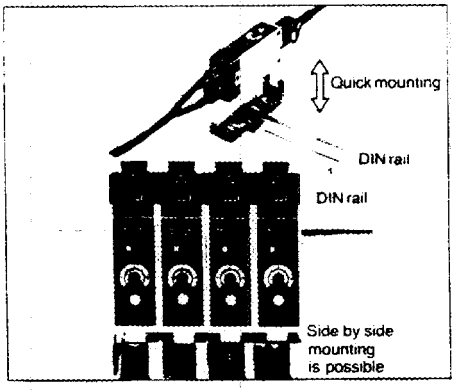


**1. Heat resistant glass fiber**
Heat resistant type with a wide range of −40°C to +200°C −40°F to 392°F. Its superiority will be proven for detection in the heat treatment process in the food industry, the soldering process in the electronics industry and so on.

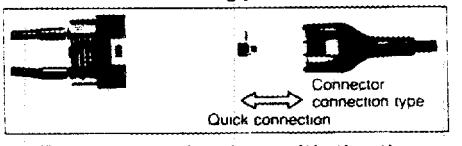
• Detection of cakes just after the oven.



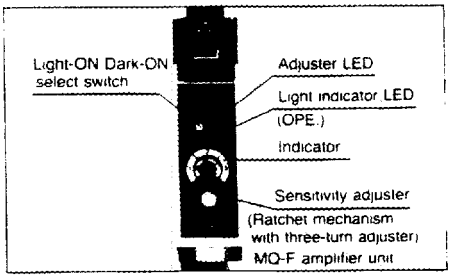

**2. High serviceability**
• Mountable on the DIN rail. Side by side mounting with labor-saving is possible.




• The connector terminal structure facilitates a fast wiring job.




**3. Ratchet mechanism with the three-turn adjuster** (equipped with the indicator)
• The three-turn adjuster allows fine adjustment of the sensing distance.
• The ratchet mechanism prevents the adjuster from breakage caused by excessive turning.
• Equipped with the indicator which is visible at a glance. Temporary setting of the detectable distance is possible.
• The adjuster LED equipped facilitates setting of the sensing distance.




**4. The Light-ON and Dark-ON modes are quickly switched.**
(equipped with the switch)

**5. High speed detection at 0.5 ms**
(Red LED type)
The detection is possible to 1,000 times per s. In addition, the green LED type operates at 500 times per s for high speed devices.

**6. Common use for operational voltages of 12 to 24 V**
Widely applicable over a range of 9.6 V to 30 V DC.

## APPLICATIONS

Detection of passage of food container just after the heat treatment process and cakes just after the oven, detection of parts on the PC board just after passing the soldering bath, and prevention of breakage of the metallic dies in the injection moulding machine (detection of moulding chips).

## COMBINATION LIST

1. MQ-F Fiber Units and MQ-F Amplifier Units • These units are available as separate units and may be combined as desired.

| Type | Detection system | Appearance | Fiber unit Part No. | Stainless sleeve provided (No. in ( ) represents sleeve length) | Max. sensing distance (cm inch) 1.5 3.5 5 10 12 | Cable length: 2 m 2.2 yards Combination Amplifier unit (Light-ON/Dark-ON switchable) |
|---|---|---|---|---|---|---|
| Glass fiber | Thru-beam type | Standard | MQ-FH12-02 Fiber length: 2 m | MQ-FHS12-02 Fiber length 2 m (9 cm) | 12 cm 4.724 inches | MQ-FA1-DC12-24V (with connector) MQ-FA2-DC12-24V (with cabled connector) (Infrared LED) With base mountable on DIN rail |
| | Diffuse reflective type | | MQ-FHD5-02 Fiber length: 2 m | MQ-FHSD5-02 Fiber length: 2 m (9 cm) | 5 cm | |

2. MQ-F Fiber Attachment

| Product name | Part No. | Description | Applicable fiber |
|---|---|---|---|
| MQ-FLE Lens attachment | MQ-FLE (2 pcs as a set) | • The detectable distance is extended to 5 times. (When two pcs. are used.) | MQ-F12-02 MQ-F10-C02 MQ-FH12-02 |
| MQ-FSV Side view attachment | MQ-FSV (2 pcs as a set) | • Space saving—Fibers are used in the parallel state. (When two pcs. are used.) | |

# PRODUCT TYPE

1. MQ-F Amplifier Unit

| Applicable fiber | Projector element | Operation type | Assembly with connector | Assembly with cabled connector (2 m 2.2 yards) |
|---|---|---|---|---|
| | | | Part No. | Part No. |
| Glass fiber | Infrared LED | Light-ON/Dark-ON common type (Selectable with switch) | MQ-FA1-12-24VDC | MQ-FA2-12-24VDC |

Note: The base mountable on DIN rail is attached.

2. MQ-F Fiber Unit

| Type | Detection method | Appearance | Max. sensing distance | Fiber length No. in ( ) represents sleeve length | Part No. |
|---|---|---|---|---|---|
| Glass fiber | Thru-beam type | Standard | 12 cm 4.724 inches | 2 m 2.2 yards | MQ-FH12-02 |
| | | Standard (with sleeve) | 12 cm 4.724 inches | 2 m (9 cm) 2.2 yards (3.543 inches) | MQ-FHS12-02 |
| | Diffuse reflective type | Standard | 5 cm 1.969 inches | 2 m 2.2 yards | MQ-FHD5-02 |
| | | Standard (with sleeve) | 5 cm 1.969 inches | 2 m (9 cm) 2.2 yards (3.543 inches) | MQ-FHSD5-02 |

Note: The fiber plug is attached.

3. Accessories

| Product name | Specifications | Applicable fiber | Part No. |
|---|---|---|---|
| MQ-FLE lens attachment | The detectable distance is multipled to about 5 times (two pcs. used.) | MQ-F12-02<br>MQ-F10-C02<br>MQ-FH12-02 | |
| MQ-FSV side view attachment | The optical axis is turned at a right angle (two pcs. used). | | MQ-FSV |
| MC connector (three terminals) | Dust protective cover | MQ-F amplifier unit, ME photoelectric sensor | AN53810 |
| MC cabled connector (3-core cord) | Cable length: 2 m 7.874 inches, with dust protective cover | MQ-F amplifier unit, ME photoelectric sensor | AN53813 |

Note: Connector or cabled connector is attached on the amplifier unit.

# RATINGS AND PERFORMANCE OUTLINE

1. Ratings

| Item | | Description |
|---|---|---|
| Operation side | Rated operational voltage | 12 to 24 V DC |
| | Rated current consumption | Max. 35 mA (excluding the load) |
| Load side | Output current capacity | Max. 100 mA |

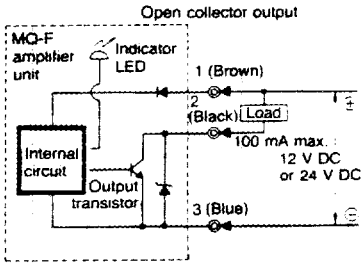
2. Performance

| | | | |
|---|---|---|---|
| **Fiber type** | | Glass fiber | |
| **Detection method** | | Thru-beam type | Diffuse reflectance type |
| **Fiber unit** | | MQ-FH12-02, MQ-FHS12-02 (with sleeve) | MQ-FHD5-02, MQ-FHSD5-02 (with sleeve) |
| **Amplifier unit** | | MQ-FA1-DC12-24V (with connector), MQ-FA2-DC12-24V (with cabled connector) | |
| **Projector element** | | Infrared LED | |
| **Operation mode** | | Light-ON/Dark-ON (selectable with the main body switch) | |
| **Standard target** | | 2 mm .079 inch dia. metallic mat black color | White paper 3×3 cm 1.181 × 1.181 inches |
| **Minimum target** | | 1 mm .039 inch dia. nontransparent object | 0.1 mm .004 inch dia. copper element wire |
| **Detectable target** | | Opaque material | Translucent or opaque material |
| **Operating voltage range** | | 9.6 to 30 V DC (including the ripple P-P) | |
| **Max. sensing distance**[2] | | 12 cm 4.724 inches | 5 cm 1.969 inches |
| **Operational angle** | | 10° to 90° | — |
| **Hysteresis**[2] | | — | 1 cm .394 inch or less (at the rated setting distan |
| **Detection speed** | | 1,000 times/s | |
| **Indicator** | | Light indicator LED (OPE.) (red), Adjuster LED (red) | |
| **Insulation resistance (initial)** | | 20 MΩ or more between input/output terminal and external (at 500 V DC) | |
| **Dielectric strength (initial)** | | 500 V AC for 1 min between input/output terminal and external | |
| **Vibration resistance and malfunction vibration** | | 10 to 55 Hz (1 cycle/min), double amplitude 1.5 mm .059 inch (2 h on 3 axes) | |
| **Shock resistance and malfunction vibration** | | 100 G (6 times on 3 axes) | |
| **Environmental illuminance** | | Incandescent lamp: Max. 3,000 lux; sunlight: Max. 10,000 lux | |
| **Ambient temperature** | **Amplifier** | −25°C to +55°C −13°F to +131°F | |
| | **Fiber** | −40°C to +200°C −40°F to +392°F | |
| **Ambient humidity** | | Max. 85% RH | |
| **Protective construction** | | Amplifier: Plastic case, dust-protective construction (equivalent to IEC IP50)<br>Fiber tip: Immersion-proof type (equivalent to IEC IP67) | |
| **Fiber material** | | Glass fiber, teflon sheathed, with sleeve or stainless tipped sleeve | |
| **Bending allowance of fiber unit** | | 25 mm .984 inch | |

Notes: 1. Unless otherwise specified, the measurement conditions comprise rated operating voltage, power supply by battery, 20°C 68°F ambient temperature, standard target and 200 lux or less illuminance on the receiver surface.

2. For the diffuse reflective type, the max. sensing distance and hysteresis are based on the standard target, and the detectable distance may vary depending on the material, color and size of a target.

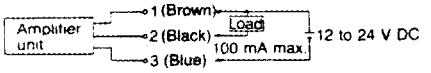
# OUTPUT CIRCUIT DIAGRAM (Light-ON/Dark-ON switchable)

| Detection method | Circuit diagram | Light-ON/Dark-ON select switch | Operation state of output transistor | Light indicator LED (OPE.) | Operation state of load |
|---|---|---|---|---|---|
| Thru-beam type |  | Dark-ON side | ON when light interrupted (Dark-ON) (ON when object detected) | Lit when light received | Activated when light interrupted |
| | | Light-ON side | ON when light received (Light-ON) (OFF when object detected) | | Activated when light received |
| Diffuse reflective type | | Light-ON side | ON when light received (Light-ON) (ON when object detected) | | Activated when light received |
| | | Dark-ON side | ON when light not received (Dark-ON) (OFF when object detected) | | Activated when light not received |



# WIRING DIAGRAM

MQ-F amplifier unit

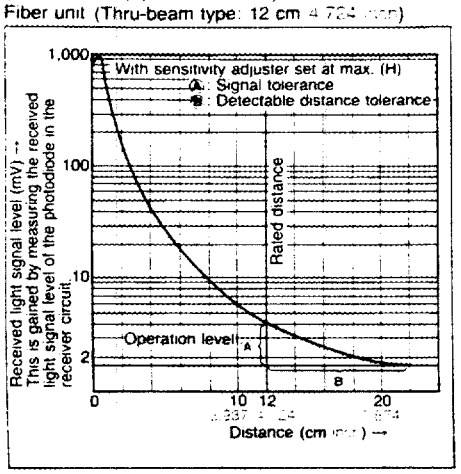



Note: The colors are applicable for the set with cabled connector.

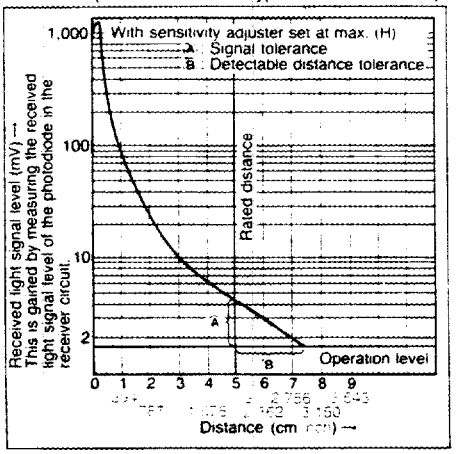
# DATA

## 1. Characteristics of light level received vs distance

MQ-FA amplifier unit
(MQ-FH12-02) (MQ-FHS12-02)
Fiber unit (Thru-beam type: 12 cm 4.724 inch)

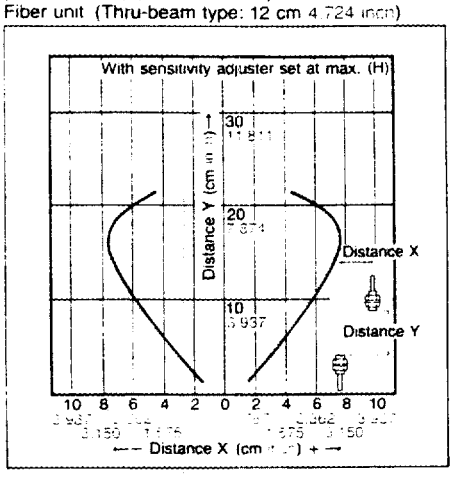



MQ-FAG amplifier unit
(MQ-FHD5-02) (MQ-FHSD5-02)
Fiber unit (Diffuse reflective type: 5 cm 1.969 inch)

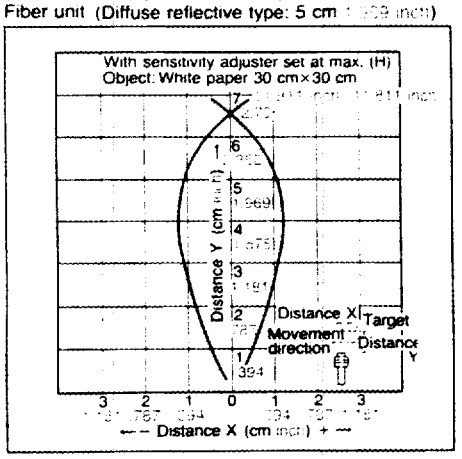



## 2. Operation range characteristics

MQ-FA amplifier unit
(MQ-FH12-02) (MQ-FHS12-02)
Fiber unit (Thru-beam type: 12 cm 4.724 inch)




MQ-FA amplifier unit
(MQ-FHD5-02) (MQ-FHSD5-02)
Fiber unit (Diffuse reflective type: 5 cm 1.969 inch)

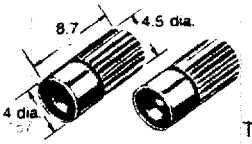



# MQ-F FIBER ATTACHMENTS

## 1. Appearance

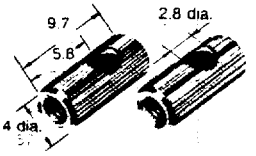
mm inch

MQ-FLE Lens Attachment




Two pcs. as a set

MQ-FSV Side View Attachment



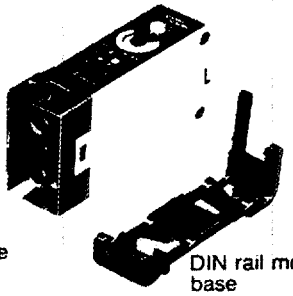

Two pcs. as a set

## 2. Performance

| Attachment | MQ-FLE Lens Attachment | MQ-FSV Side View Attachment |
|---|---|---|
| Applicable fiber unit | MQ-FH12-02 | MQ-FH12-02 |
| Rated setting distance | 1 m 39.37 inches | 12 cm 4.724 inches |
| Detectable object | Opaque: 4 mm 0.157 inch dia. or more | Opaque: 3 mm 0.118 inch dia. or more |
| Operational angle | 5° to 40° | 20° to 60° |
| Ambient temperature | −40°C to +200°C −40°F to +392°F (when combined with glass fiber) | |
| Ambient humidity | Max. 85% RH | |

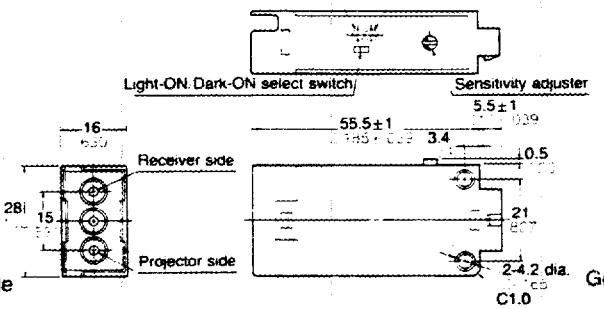
# AMPLIFIER UNIT DIMENSIONS

MQ-FA Amplifier unit



※ Equipped with the base mountable on DIN rail.

DIN rail mountable base



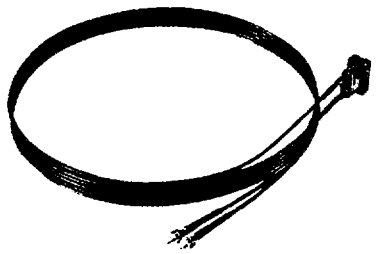

mm inch

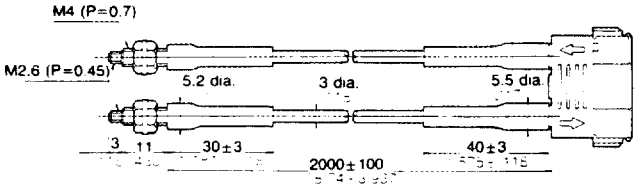
General tolerance: ±0.5

# GLASS FIBER DIMENSIONS

mm inch

MQ-FH12-02 Fiber Unit
(Thur-beam type)

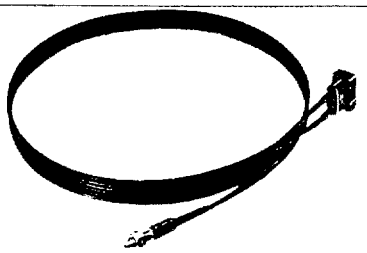


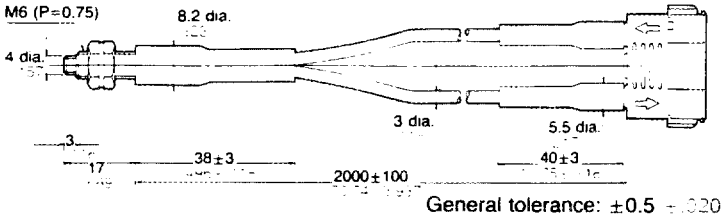



⊕ Equipped with fiber plug

General tolerance: ±0.5

MQ-FHD5-02 Fiber Unit
(Diffuse reflective type)

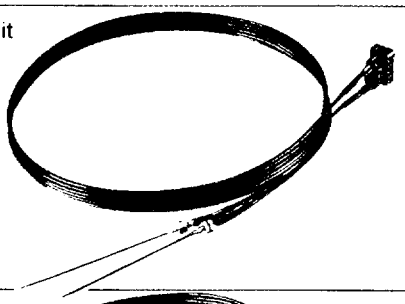


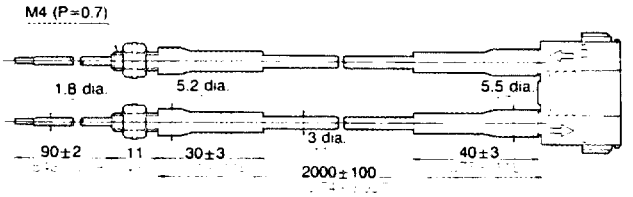



⊕ Equipped with fiber plug

General tolerance: ±0.5

MQ-FHS12-02 Fiber Unit
(Thru-beam type with stainless sleeve)

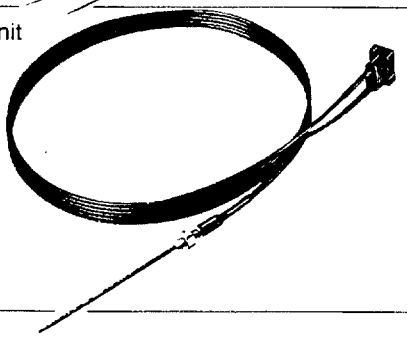


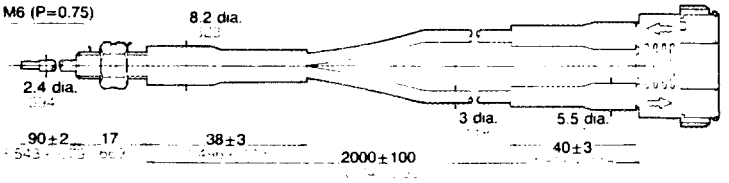



⊕ Equipped with fiber plug

General tolerance: ±0.5

MQ-FHSD5-02 Fiber Unit
(Diffuse reflective type with stainless sleeve)






⊕ Equipped with fiber plug

General tolerance: ±0.5

# CAUTIONS

**1. Sensitivity adjustment for the thru-beam type**

1) Swing the projector and receiver fiber units to left and right, and up and down so as to position the light indicator LED (OPE.) at the center in the lightening range, and then secure them. At this time, confirm that the adjuster LED is lit.

2) Adjusting the sensitivity makes possible detection of translucent and opaque targets. For opaque targets, the adjuster is turned to the maximum position (H), to increase the distance tolerance.

Note: If the adjsuter LED goes out during operation, it is an alarm signal that detection does not work. Readjust and check sensitivity.

**2. Sensitivity adjustment for the diffuse reflective type**

1) Facing the detection face of the fiber unit in the detection direction, temporarily fasten it.

2) Under the condition that no detectable object exists, gradually turn the sensitivity adjuster counterclockwise from the maximum position (H) to find the position where the light indicator LED (OPE.) goes out. When the LED goes out if the adjuster is in the max. position, select the H position.

3) Place a detectable target in the detection position, and further turn the sensitivity adjuster counterclockwise to find the position where the light indicator LED (OPE.) goes out.

4) Set the adjuster at the middle point between the positions selected in steps 2) and 3).

5) Securely fasten the head of the fiber unit.

During fastening, take care to secure it to an extent that it is not displaced when vibration or shock is applied.

Notes:

1. Since the sensing distance depends on the material, color, size, shape and direction of targets, and the environmental conditions, check it using an actual target. Since the transmission factor also varies depending on the bending angle of the optical fiber, avoid the operation near the limit of the operation but operate it within two thirds of the limit distance.

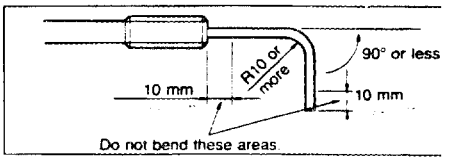
2. If the adjuster LED does not come on in step 4), reposition the detection face and repeat the procedure of step 1) to step 4) or isolate an external cause such as variation of the ambient temperature or position variation of an object to detect.

**3. Bending of stainless sleeve**

1) Keep the bending curvature 10 mm .394 inch radius or more.

2) Smoothly bend the sleeve using a round rod of 20 mm .787 inch diameter.

3) The sleeve can not be bent within 10 mm .394 inch from the tip or the root. Moreover, the bending angle shall be within 90 degrees.




※For the ambient conditions, wiring and operation of the fiber unit, refer to the cautions for operation (page 43).

# MQ-F COMMON ITEMS

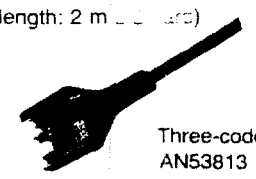
## Accessories

MC connector

Three-terminal type
AN53810

| Terminal No. (code) | Description |
|---|---|
| 1 ( — ) | ⊖ terminal |
| 2 ( = ) | ● terminal |
| 3 ( ≡ ) | ⊖ terminal |

Connector with MC cabled connector
(Cable length: 2 m [illegible])

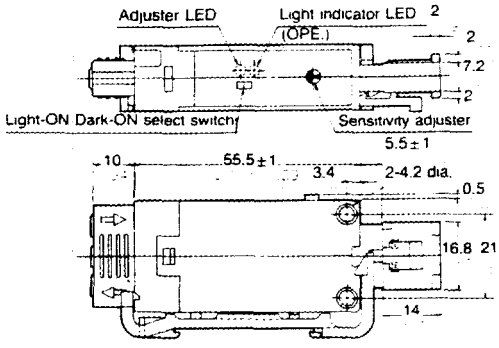


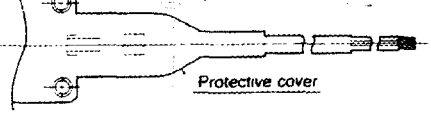
Three-code cable
AN53813

| Terminal No. (Color code) | Description |
|---|---|
| 1 (Brown) | ⊕ terminal |
| 2 (Black) | ● terminal |
| 3 (Blue) | ⊖ terminal |

## Amplifier Mounting

mm [illegible]



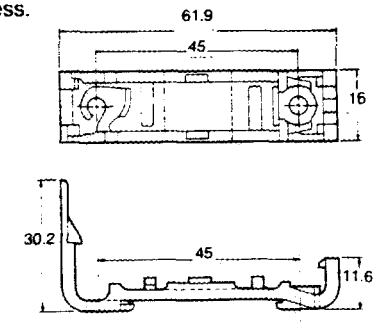

* The DIN rail mountable base and connector are attached on the amplifier unit, and the fiber plug is attached on the fiber unit respectively.

General tolerance: ±1 [illegible]

## Accessory Attached Dimensions

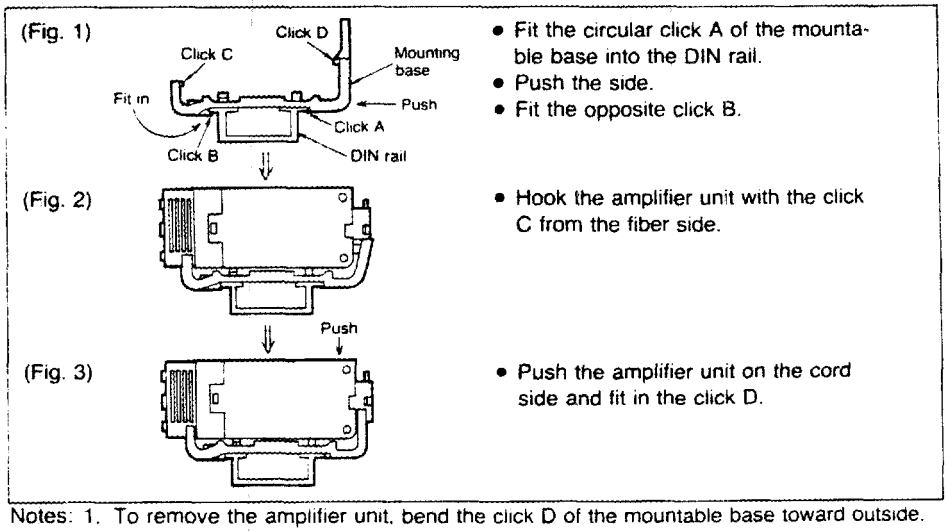
- Direct mounting on the chassis

1) When using the DIN rail mountable base, use two M4 pan head screws. (Keep in mind that the hex. recessed cap bolts can not be used as the mounting fasteners.)
2) For the screw pitch, see the following view. (Pitch: 45 mm [illegible])
3) To fasten the amplifier main body, use M4 screws on the flat surface and combine the screw with the plain or spring washer, and tighten the screw to a torque of 10 kg-cm or less.




- Mounting on the DIN rail

1) Use the 35 mm [illegible] wide DIN rail (DIN EN5002).
2) Mount the unit as shown below.

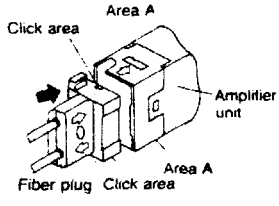



- Fit the circular click A of the mountable base into the DIN rail.
- Push the side.
- Fit the opposite click B.
- Hook the amplifier unit with the click C from the fiber side.
- Push the amplifier unit on the cord side and fit in the click D.

Notes: 1. To remove the amplifier unit, bend the click D of the mountable base toward outside.
2. When vertically mounting the DIN rail, face the fiber side upward.

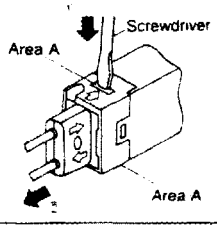
## Attachment and Detachment of Fiber Plug

- To attach the fiber plug on the fiber plug




Push the fiber plug in the arrow direction as far as the upper and lower clicks of the fiber plug are securely engaged on the upper and lower areas A of the amplifier unit.

- To detach the fiber plug from the amplifier unit




Lightly push the upper and lower areas A of the amplifier unit with a screwdriver or similar to disengage the click area of the fiber plug. Then, pull out the fiber plug.
Note: Take care not to excessively push the area A, or the click area of the fiber plug will be sometimes broken.

# CAUTIONS

**1. Environmental conditions**

• Amplifier unit

1) The ambient temperature shall be kept within a range of −25°C to +55°C

2) The operational voltage shall be kept within a range from 9.6 V to 30 V DC (including ripple P-P).

3) Since the internal circuit may be broken when the external surge voltage exceeds 500 V (single polarity full wave voltage of ±(1.20×50) μs), the surge absorbing element should be used.

• Fiber unit

1) The ambient illuminance shall be 3,000 lux or less at the receiver under an incandescent lamp, and 10,000 lux or less at the receiver under sunlight.

2) The unit shall not be used at the site where much steam, dust or corrosive gas is suspended, water or oil splashes directly over the unit, or organic solvent adheres to the unit.

**2. Wiring**

• Amplifier unit

1) Since improper wiring results in breakage of the internal circuit, check the wiring before turning on the power supply.

2) The load relays rated at 12 V DC or 24 V DC shall be used.

Since the voltage applied to the load relay is determined by subtracting the internal voltage drop (max. 1.2 V) from the photoelectric sensor operating voltage, care shall be taken for the voltage fluctuation.

3) Keep in mind that the output area is broken if a load of 100 mA or more is connected.

4) Keep in mind that the induction noises cause malfunction and breakage if the wiring to the photoelectric sensor runs with the high voltage cables and the power cable.

5) When crimping the terminals, use the following tool made by Molex.

| Crimping | Insertion | Pulling-out |
|---|---|---|
| JHTR1719C | J5800-001 | J5800-002 |

Here, the terminal is 5005 TL made by Molex and the receptacle is 5025-03R1.

6) When extending the cable, use a cable of 0.3 mm² or more and limit its length within 100 m.

7) When connecting the receptacle to the plug of the photoelectric sensor, properly connect them and securely push in the plug as far as the lock mechanism is activated. The construction to prevent reverse connection is provided.

To remove the receptacle, release the lock mechanism and pull out the plug with the receptacle held by hand.

8) It is recommended to attach an auxiliary dust protective cover to the receptacle.

9) When the commercially available switching regulator is used, ground FG (frame ground terminal) and G (ground terminal). Otherwise, the switching noise of power supply may sometimes cause malfunction. In this case, care shall be taken.

**3. Handling of the fiber unit.**

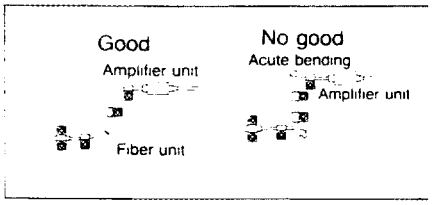
1) The fiber unit shall be securely equipped on the amplifier.

2) Do not tighten with an excessive strength. Apply a torque of 8 kg-cm or less for tightening.

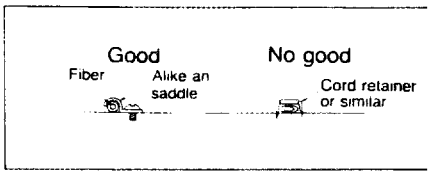
3) Do not apply a pulling force of 3 kg more to the fiber unit.

4) Make the bending curvature of the fiber as large as possible. If the curvature is small, the transmission factor is reduced. So, check this during actual operation. (The curvature shall be R25 mm or more.)

5) Largely bend the fiber and do not bent it at the root.




6) Do not compress the fiber or apply a load to it.



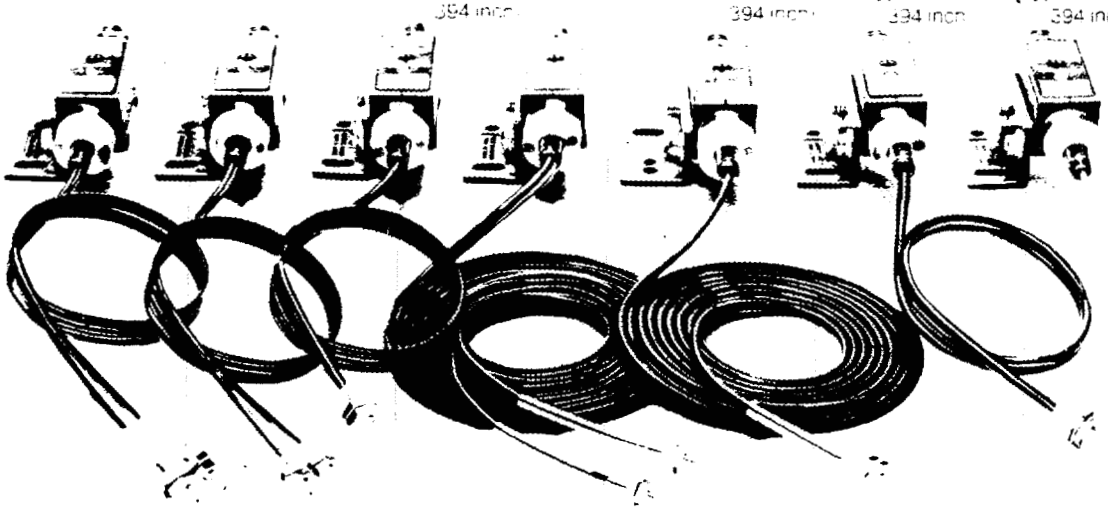
Aromat

# MP-F FIBER SELFCONTAINED-DC TYPE

Components for advanced technology

## MP-F Photoelectric Sensors

| Plastic fiber type | | | Glass fiber type | | Coaxial fiber type | Metal tube type |
|---|---|---|---|---|---|---|
| MP-F25 (Thru-beam type 25 cm [illegible] inch) | MP-F5 (Thru-beam type 5 cm [illegible] inch) | MP-FD1 (Diffuse reflective type 1 cm .394 inch) | MP-FH5-02 (Thru-beam type 5 cm [illegible] inch) | MP-FHD1-02 (Diffuse reflective type 1 cm .394 inch) | MP-FX1 (Diffuse reflective type 1 cm .394 inch) | MP-FSD1-7 (Diffuse reflective type 1 cm .394 inch) |



- **Complete line for easy selection**
  **Plastic fiber as standard**
  **Glass fiber for high temperature condition**
  **Coaxial fiber for accurate detection**
  **Metal tube type for easy setting**
- **Tiny target detection**
- **Enviromental resistance (IEC IP66)**
- **No misoperation of output during power on or off condition**
- **Operation and adjustment indication with LED**

## PRODUCT TYPE

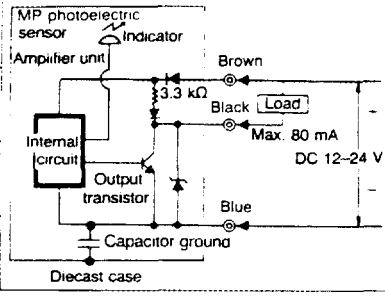
1. MP-F Amplifier unit

| Load operation condition | Part No. | Packing | |
|---|---|---|---|
| | | Inner | External |
| When light enters, output transistor ON | MP-F1A-DC12/24 V | 1 pc | 10 pcs |
| When light is blocked, output transistor ON | MP-F2A-DC12/24 V | 1 pc | 10 pcs |

2. MP-F fiber unit

| Type | Detection method | Max. sensing distance | Fiber length | Part No. | Packing | |
|---|---|---|---|---|---|---|
| | | | | | Inner | External |
| Glass fiber type | Thru-beam type | 5 cm [illegible] | 2 m [illegible] | MP-FH5-02 | 1 pc | 10 pcs |
| | Diffuse reflective type | 1 cm [illegible] | 2 m [illegible] | MP-FHD1-02 | 1 pc | 10 pcs |
| Coaxial fiber type | Diffuse reflective type | 1 cm [illegible] | 50 cm [illegible] | MP-FX1 | 1 pc | 10 pcs |
| | | 1 cm [illegible] | 1 m [illegible] | MP-FX1-01 | 1 pc | 10 pcs |
| Metal tube type | Diffuse reflective type | 1 cm [illegible] | 7 cm [illegible] | MP-FSD1-7 | 1 pc | 10 pcs |
| Plastic fiber type | Thru-beam type | 5 cm [illegible] | 50 cm [illegible] | MP-F5 | 1 pc | 10 pcs |
| | | | 1 m [illegible] | MP-F5-01 | 1 pc | 10 pcs |
| | | | 2 m [illegible] | MP-F5-02 | 1 pc | 10 pcs |
| | | | 3 m [illegible] | MP-F5-03 | 1 pc | 10 pcs |
| | | 25 cm [illegible] | 50 cm [illegible] | MP-F25 | 1 pc | 10 pcs |
| | | | 1 m [illegible] | MP-F25-01 | 1 pc | 10 pcs |
| | | | 2 m [illegible] | MP-F25-02 | 1 pc | 10 pcs |
| | | | 3 m [illegible] | MP-F25-03 | 1 pc | 10 pcs |
| | Diffuse reflective type | 1 cm [illegible] | 50 cm [illegible] | MP-FD1 | 1 pc | 10 pcs |
| | | | 1 m [illegible] | MP-FD1-01 | 1 pc | 10 pcs |
| | | | 2 m [illegible] | MP-FD1-02 | 1 pc | 10 pcs |
| | | | 3 m [illegible] | MP-FD1-03 | 1 pc | 10 pcs |

# COMBINATION OF FIBER UNIT AND AMPLIFIER UNIT OPERATION

| Fiber unit | Amplifier unit | Output circuit diagram | Operating condition of output transistor | | Operation indicator | Operating condition of load: Relay, etc. | Operating condition of load: MP-PC Control Pack |
|---|---|---|---|---|---|---|---|
| Thru-beam type MP-F5 MP-F25 MP-FH5 | Light input ON type (MP-F1A) |  | Light input ON (Light ON) | OFF when object detected (equivalent to a contact) | Lights with light input | Operates with light input | Output relay operates with light input |
| | Light interrupted ON type (MP-F2A) | | Light inter-rupted ON (dark ON) | ON when object detected (equivalent to b contact) | Lights with light input | Operates with light interrupted | Output relay operates with light interrupted |
| Diffuse reflective type MP-FD1 MP-FHD1 MP-FX1 MP-FSD1 | Light input ON type (MP-F1A) | | Light input ON (Light ON) | ON when object detected (equivalent to a contact) | Lights with light input | Operates with light input | Output relay operates with light input |
| | Light interrupted ON type (MP-F2A) | | Light inter-rupted ON (dark ON) | OFF when object detected (equivalent to b contact) | Lights with light input | Operates with light interrupted | Output relay operates with light interrupted |



Notes: In order to improve resistance to noise, because the diecast case is the condenser ground, when installing, use the special bracket provide
When a different mounting bracket is used, insulation should be provided.

# SPECIFICATIONS

## 1. Ratings

| Item | | Type | When used with MP-F1A amplifier unit | When used with MP-F2A amplifier unit |
|---|---|---|---|---|
| Operating side | Rated operating voltage | | DC 12 to 24 V | DC 12 to 24 V |
| | Rated current consumption | | Max. 40 mA (excluding load) | Max. 40 mA (excluding load) |
| Load side | Output current capacity | | Max. 80 mA | Max. 80 mA |
| | Operating method | | With light input, output transistor ON (light ON) | When light interrupted, output transistor ON (dark ON) |

## 2. Performance outline

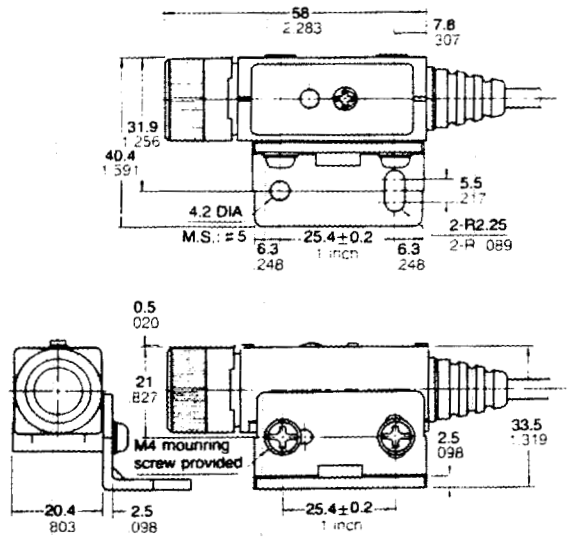
| Fiber type | | Plastic fiber | | | Glass fiber | | Coaxial fiber | Metal tube |
|---|---|---|---|---|---|---|---|---|
| Combination / Item | Detection method | Thru-beam type | | Diffuse reflective type | Thru-beam type | Diffuse reflective type | Diffuse reflective type | Diffuse reflective type |
| | Fiber unit | MP-F5 MP-F5-01 MP-F5-02 MP-F5-03 | MP-F25 MP-F25-01 MP-F25-02 MP-F25-03 | MP-FD1 MP-FD1-01 MP-FD1-02 MP-FD1-03 | MP-FH5-02 | MP-FHD1-02 | MP-FX1 MP-FX1-01 | MP-FSD1-7 |
| | Amplifier unit | MP-F1A-DC12/24V · MP-F2A-DC12/24V | | | | | | |
| Standard target | | 2 mm dia. metal plate (black frosted) | 6 mm dia. metal plate (black frosted) | White drawing paper (1 × 1 cm²) | 2 mm dia. metal plate (black frosted) | White drawing paper (1 × 1 cm²) | | |
| Minimum detectable target | | 1 mm dia. opaque target | 2.5 mm dia. opaque target | 0.1 mm dia. copper wire | 1 mm dia. opaque target | 0.05 mm dia. copper wire | | |
| Detectable target | | Opaque target | | Opaque target transparent target | Opaque target | Opaque target, transparent target | | |
| Operating voltage range | | 10.8 to 26.4 V DC (Including ripple (P-P)) | | | | | | |
| Max. setting distance** | | 5 cm | 25 cm | 1 cm | 5 cm | 1 cm | 1 cm | 1 cm |
| Operating angle | | Above 10° | Above 10° | — | Above 10° | — | — | — |
| Hysteresis** | | — | — | Less than 2 mm (at max. sensing distance) | — | Less than 2 mm (at max. sensing distance) | | |
| Detection speed | | 100 times/s | | | | | | |
| Operation indicating method | | With light input, indicator lights (visible red light) | | | | | | |
| Vibration resistance | Functional | 10 to 55 Hz (1 cycle/min) | | | | | | |
| | Destructive | Oscillation amplitude 1.5 mm (2 h on 3 axes) | | | | | | |
| Shock resistance | Functional / Destructive | 100 G (6 times on 3 axes) | | | | | | |
| Protection construction | | Diecast case (equivalent to IEC IP66) | | | | | | |
| Ambient use conditions | Ambient light level | Incadescent lamp max. 3,000 lux | | | | | | |
| | | Daylight max. 10,000 lux | | | | | | |
| | Ambient use temperature: Amplifier | −25 C–+55 C | | | | | | |
| | Ambient use temperature: Fiber | −40°C–+70°C | | | −40°C–+200°C | | −40°C–+70°C | −40°C–+200°C |
| | Ambient use humidity | Max. 85% RH | | | | | | |
| Amplifier permissible bending radius | | 5 mm | | | 25 mm | | 10 mm | |
| Fiber material | | Plastic fiber, polyethylene covering | | | Glass fiber, teflon covering | | Plastic fiber, polyethylene covering | Glass fiber, annealed stainless tube |
| Fiber length | | 50 cm approx. 20 inches (1 m 2 m, 3 m available) | | | 2 m | | 50 cm approx. 20 inches (1 m available) | 7 cm |

Notes: 1) Unless otherwise specified, the measurement conditions are: the rated operating voltage, battery power, ambient temperature of 20°C standard target, light intensity at receiving surface of less than 200 lux.

**2) In the diffuse reflective type, because the max. sensing distance and hysteresis are the distance with a standard target, the distances will vary due to target's material, color, size, etc.

## DIMENSIONS

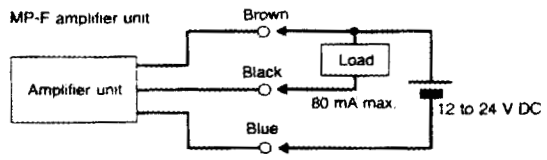
**When special bracket is used for mounting** mm inch




General tolerance: ±1 ±.039

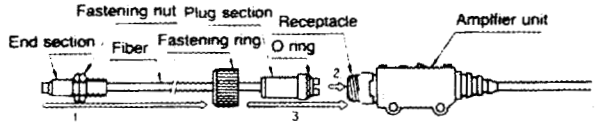
※Accessories provided in box with each sensor.

## WIRING DIAGRAM




## METHOD FOR CONNECTING

**fiber unit to amplifier unit**



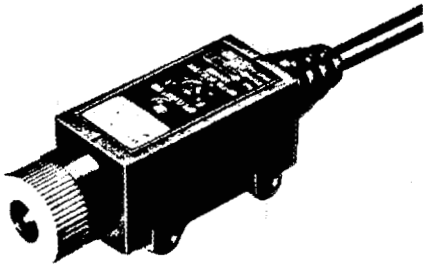

1. Pass the fiber unit through the fastening ring. After passing the fiber unit through the ring, attach the fastening nut.
2. Insert the plug into the receptacle. Be careful to observe the correct direction.
3. Attach the amplifier unit securely using the fastening ring.

※The drawing shows the diffuse reflective type, but it is the same for the thru-beam type.

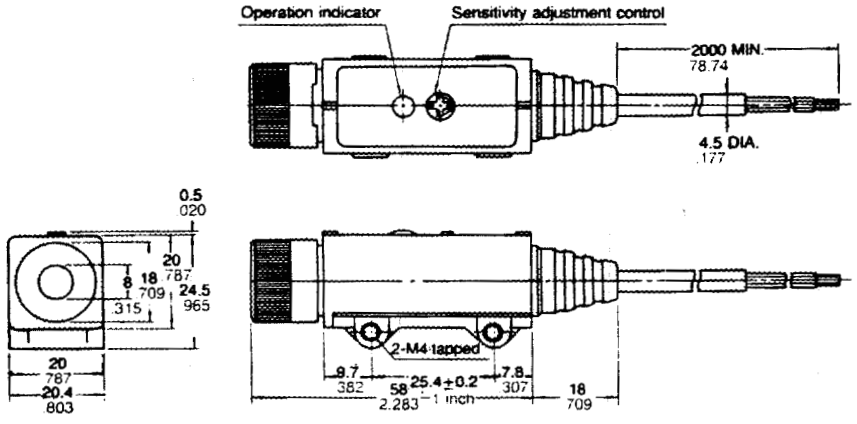
## DIMENSIONS

MP-F amplifier unit

mm inch

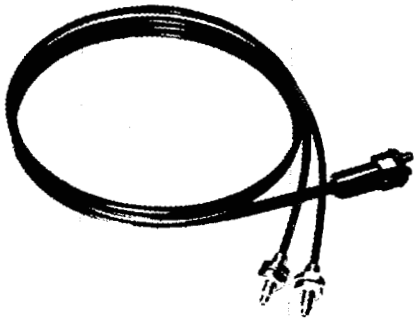


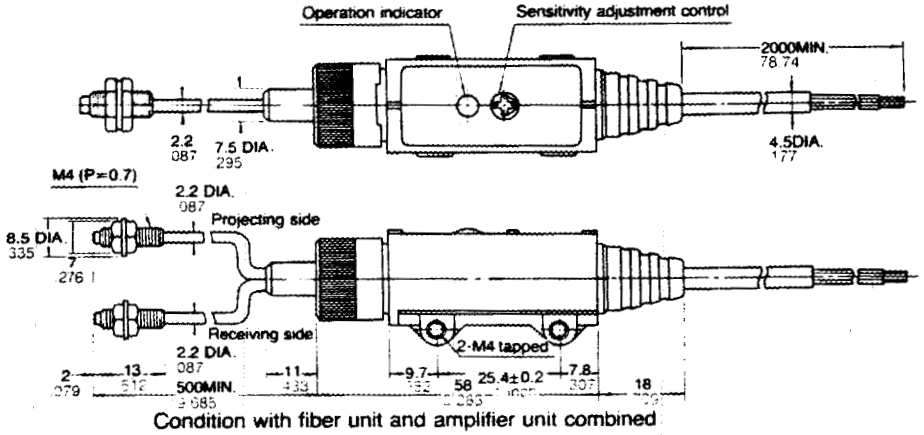
MP-F1A-DC12/24V
ON with light input
MP-F2A-DC12/24V
ON with light interrupted




General tolerance: ±1 ±.039

MP-F5 fiber unit
(Plastic fiber thru-beam type)





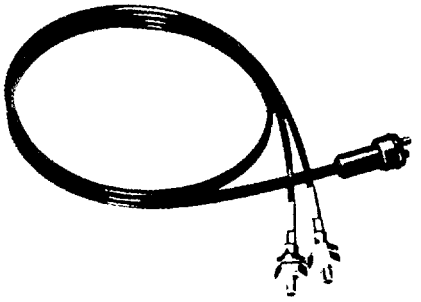

Condition with fiber unit and amplifier unit combined

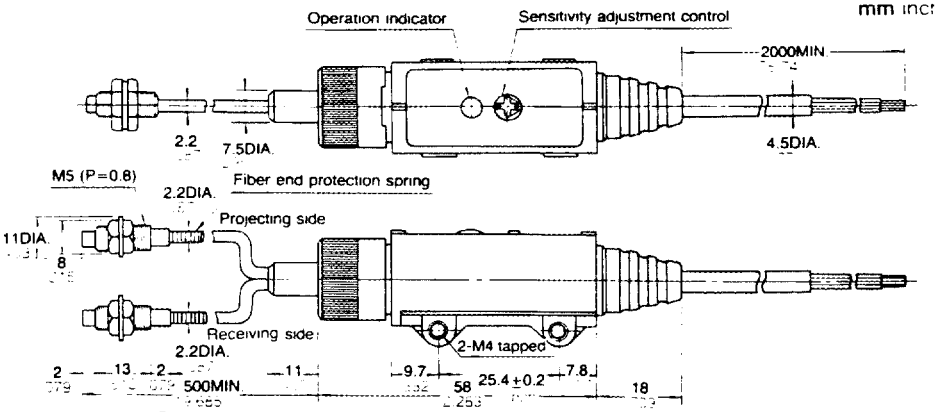
※Dimensions are the same other than fiber lengths for fiber length 1 m, 2 m and 3 m types. 1.1 yards, 2.2 yards and 3.3 yards type.

General tolerance: ±1 ±.039

## MP-F25 fiber unit
(Plastic fiber thru-beam type)

mm inch



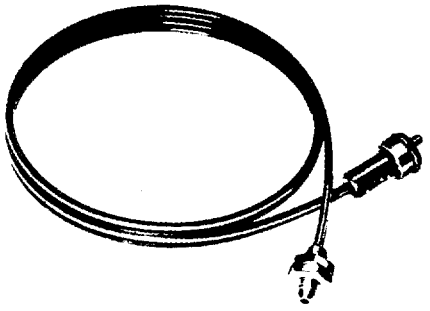


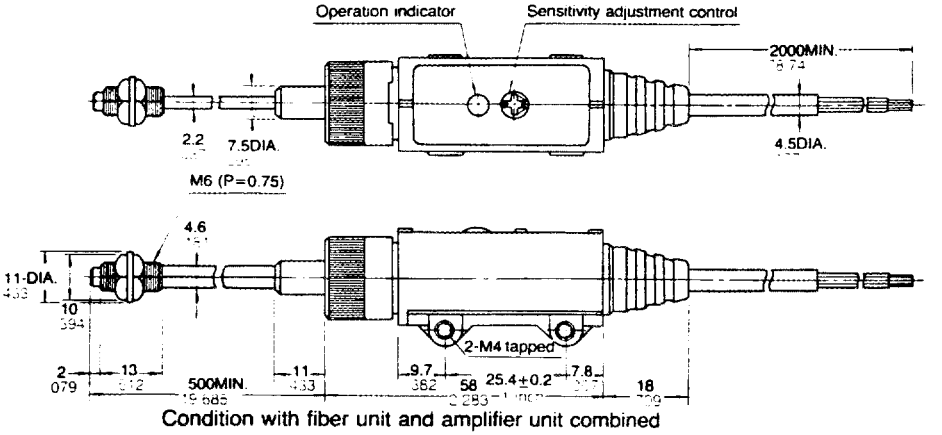

Condition with fiber unit and amplifier unit combined

※Dimensions are the same other than fiber lengths for fiber length 1 m, 2 m and 3 m types. 1.1 yards, 2.2 yards and 3.3 yards type.

General tolerance: ±1

## MP-FD1 fiber unit
(Diffuse reflective type)



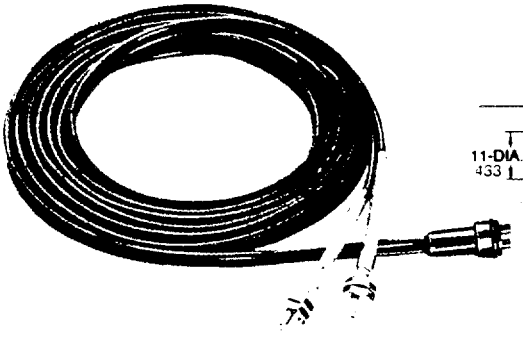


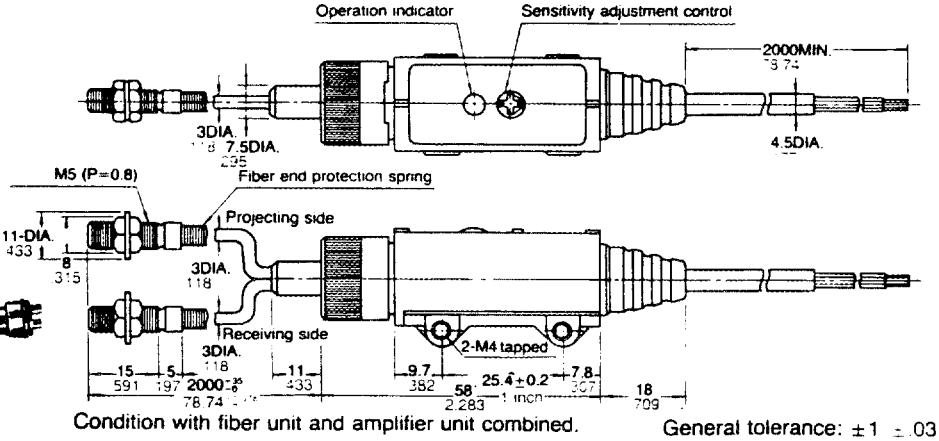

Condition with fiber unit and amplifier unit combined

※Dimensions are the same other than fiber lengths for fiber length 1 m, 2 m and 3 m types. 1.1 yards, 2.2 yards and 3.3 yards type.

General tolerance: ±1

## MP-FH5-02 fiber unit
(Glass fiber thru-beam type)

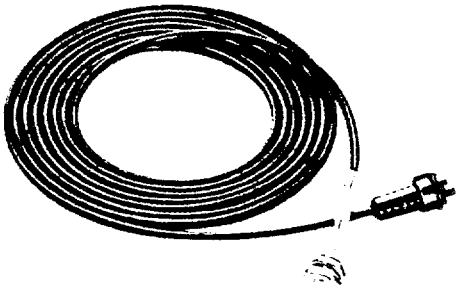


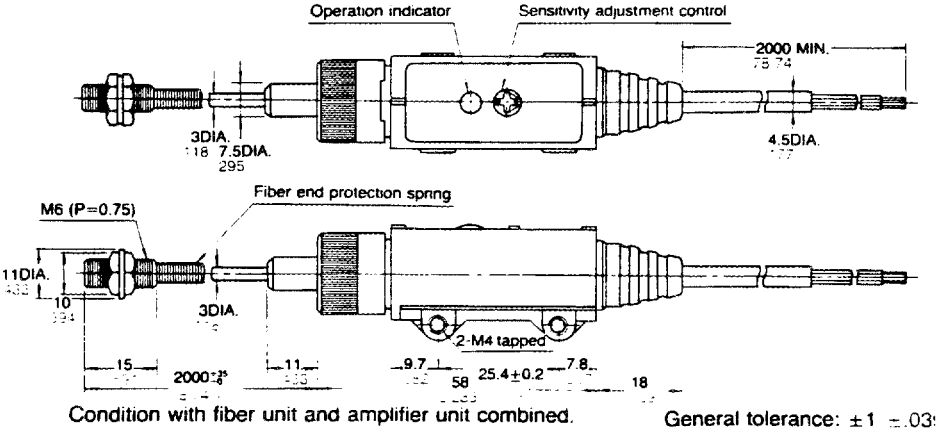



Condition with fiber unit and amplifier unit combined.

General tolerance: ±1

## MP-FHD1-02 fiber unit
(Glass fiber diffuse reflective type)



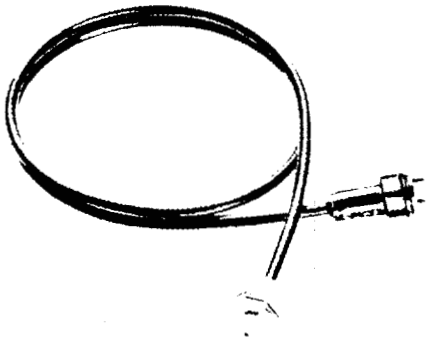


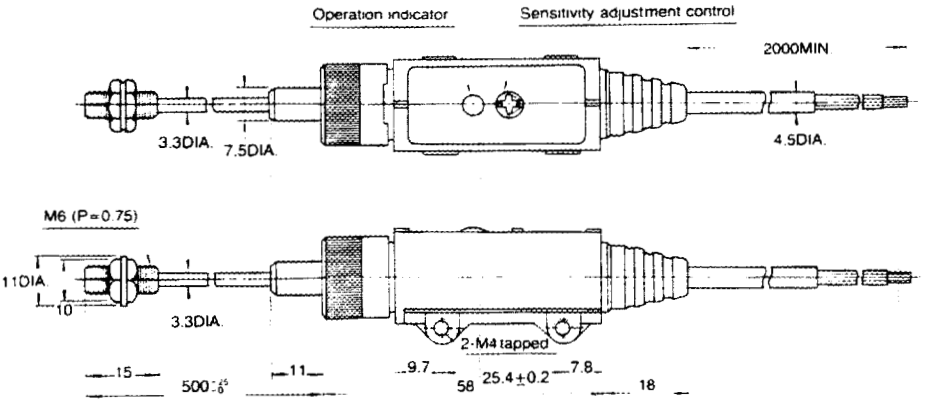

Condition with fiber unit and amplifier unit combined.

General tolerance: ±1

MP-FX1 fiber unit
(Coaxial fiber diffuse reflective type)

mm



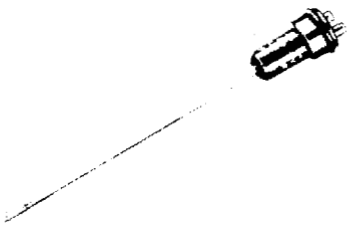


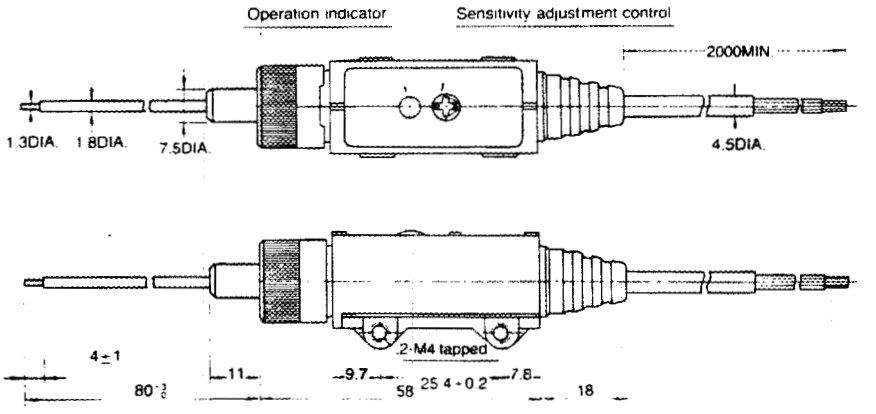

Condition with fiber unit and amplifier unit combined

※ Dimensions are the same other than fiber length for MP-FX1-01 (fiber length 1 m type).

General tolerance: ±1

MP-FSD1-7 fiber unit
(Metal tube diffuse reflective type)





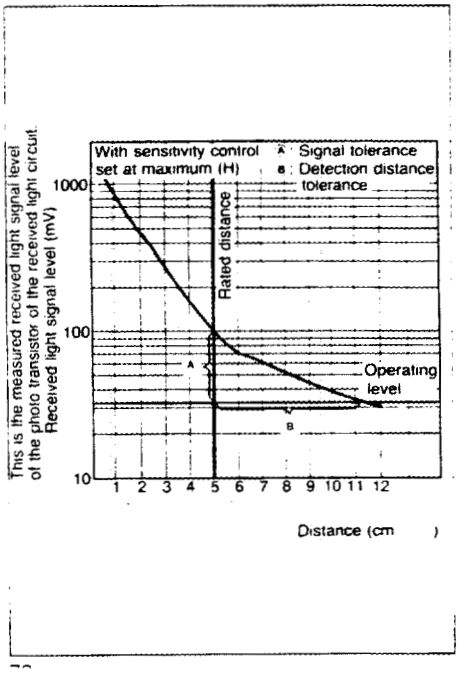

Condition with fiber unit and amplifier unit combined

General tolerance: ±1

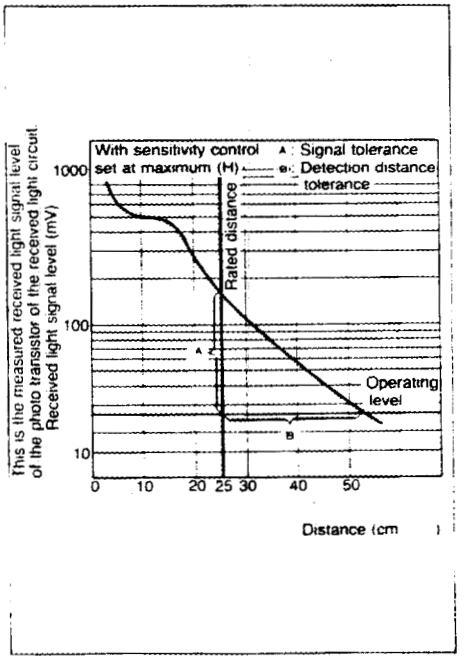
# DATA

1. Characteristic of light level received vs distance

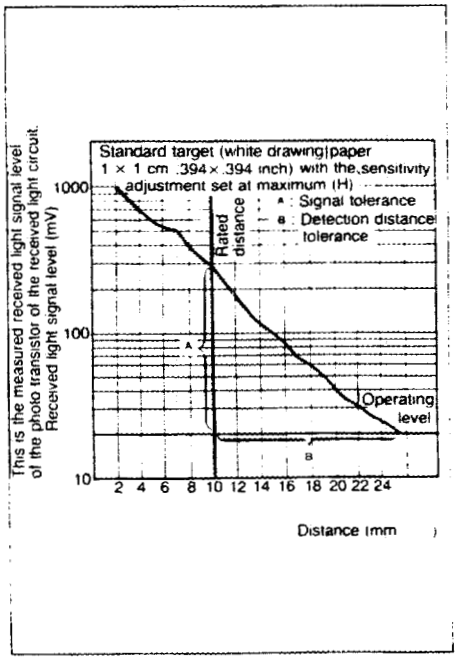
MP-F2A amplifier unit
MP-F5A fiber unit
(Plastic fiber thru-beam type 5 cm)



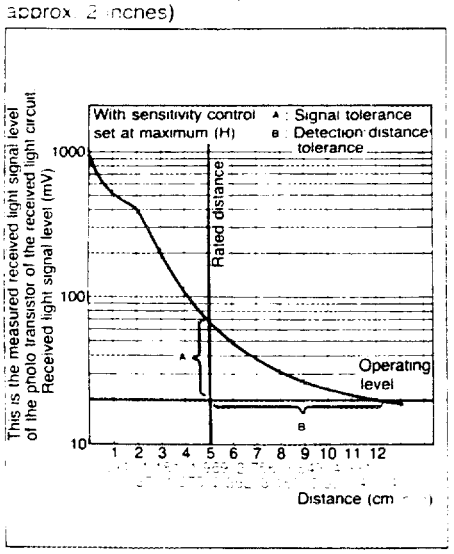

MP-F2A amplifier unit
MP-F25 fiber unit
(Plastic fiber thru-beam type 25 cm)



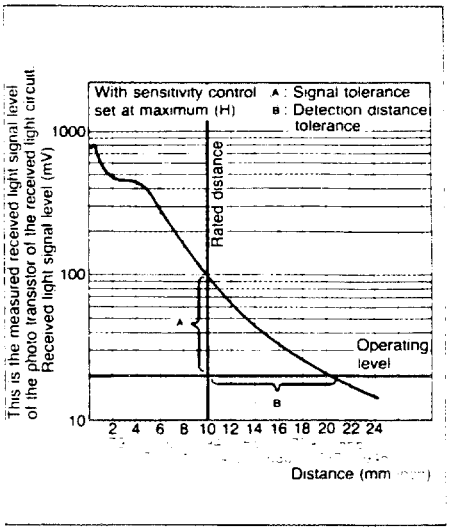

MP-F1A amplifier unit
MP-FD1 fiber unit
(Plastic fiber diffuse reflective type 1 cm)



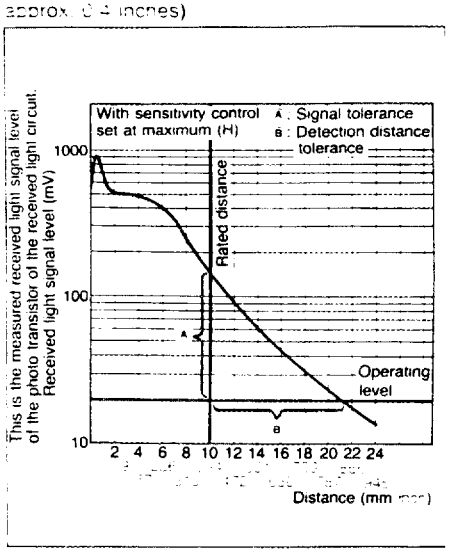
MP-F2A amplifier unit
MP-FH5-02 fiber unit
(Glass fiber thru-beam type 5 cm
approx. 2 inches)



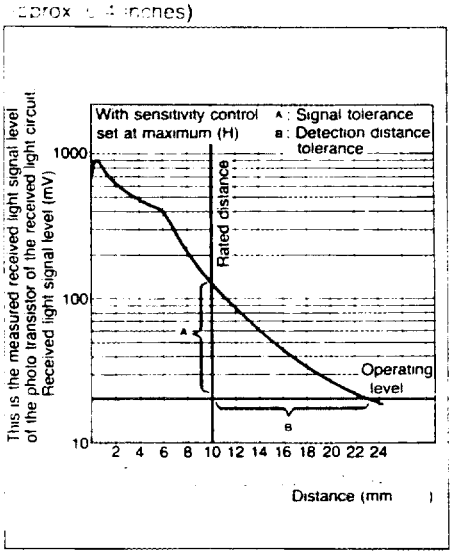

MP-F1A amplifier unit
MP-FHD1-02 fiber unit
(Glass fiber diffuse reflective type 1 cm
approx. 0.4 inches)




MP-F1A amplifier unit
MP-FX1 fiber unit
(Coaxial fiber diffuse reflective type 1 cm
approx. 0.4 inches)

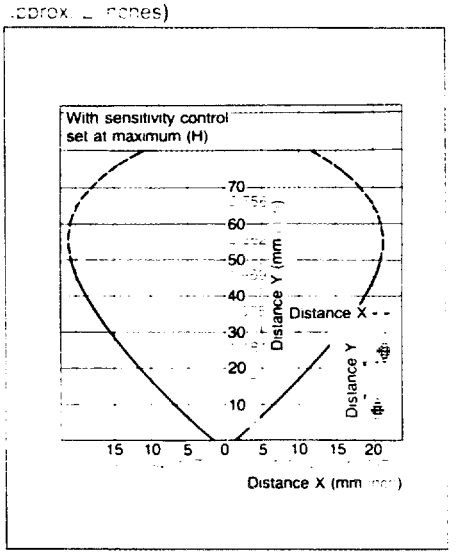



MP-F1A amplifier unit
MP-FSD1-7 fiber unit
(Metal tube diffuse reflective type 1 cm
approx. 0.4 inches)

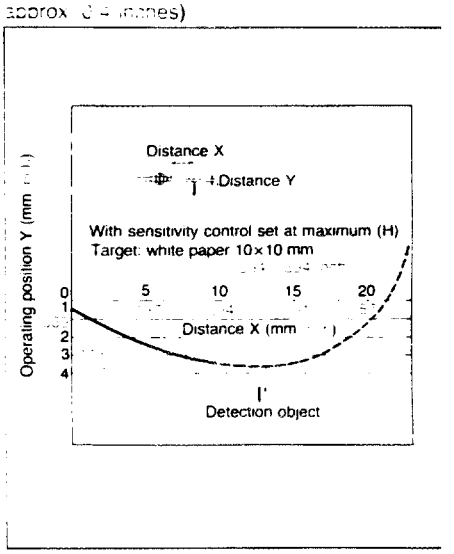



## 2. Operation range characteristics

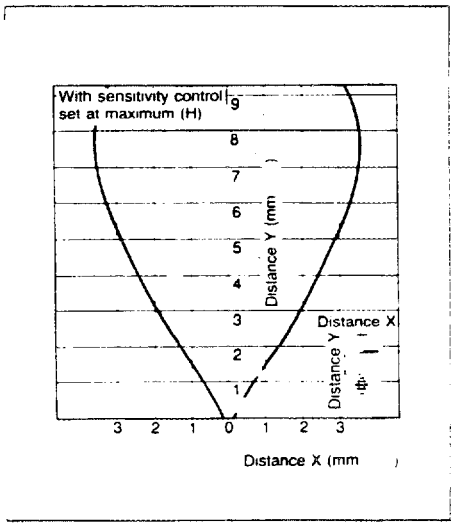
MP-F2A amplifier unit
MP-F5 fiber unit
(Plastic fiber thru-beam type 5 cm
approx. 2 inches)



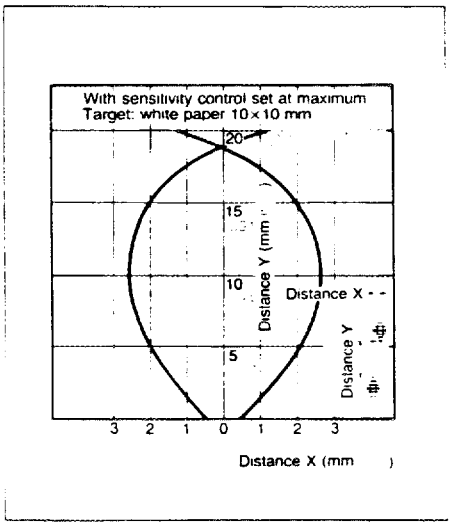

MP-F1A amplifier unit
MP-FD1 fiber unit
(Plastic fiber diffuse reflective type 1 cm
approx. 0.4 inches)



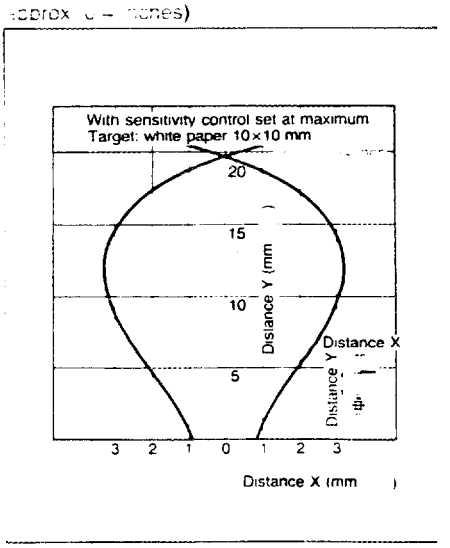

MP-F2A amplifier unit
MP-FH5-02 fiber unit
(Glass fiver thru-beam type 5 cm 2 inches)



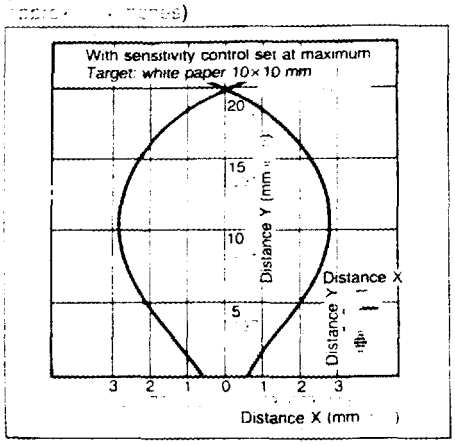

MP-F1A amplifier unit
MP-FHD1-02 fiber unit
(Glass fiber diffuse reflective type)



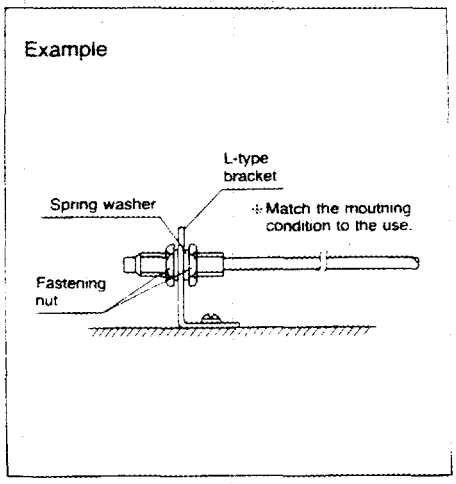

MP-F1A amplifier unit
MP-FX1 fiber unit
(Coaxial fiber diffuse reflective type 1 cm
approx. 0.4 inches)



MP-F1A amplifier unit
MP-FSD1-7 fiber unit
(Metal tube diffuse reflective type 1 cm [illegible])




# ATTACHING FIBER UNIT END SECTION




**List of fastening nuts and spring washers** (Unit: mm)

| Parts / Fiber unit | Fastening nut | Spring washer |
|---|---|---|
| MP-F5 (Thur-beam type) | M4 (P = 0.7) 4 pcs. | M4 type 2 pcs. |
| MP-F25 (Thru-beam type) | M5 (P = 08) 4 pcs. | M5 type 2 pcs. |
| MP-FD1 (Diffuse reflective type) | M6 (P = 0.75) 2 pcs. | M6 type 1 pce. |
| MP-FH5-02 | M5 (P = 0.8) 4 pcs. | M5 type 2 pcs. |
| MP-FHD1-02 | M6 (P = 0.75) 4 pcs. | M6 type 1 pce. |
| MP-FX1 | M6 (P = 0.75) 2 pcs. | M6 type 1 pce. |
| MP-FSD1-7 | Not used | Not used |

# CAUTIONS

**1. Regarding connection**

1) Because of the possibility of damage to the internal circuit due to erroneous connections, before applying power, carefully check the wiring.

2) For load relay, use a unit whose rated operating voltage is 12 V or 24 V DC. Because of the internal voltage drop in the MP-F photoelectric sensor operating voltage, care should be taken with voltage variation for the impressed voltage to the load relay.

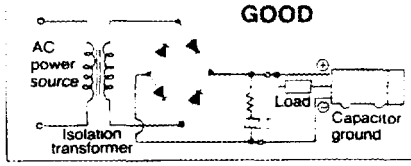
3) Due to the possibility of damage to the output section with loads greater than 80 mA, care should be taken not to overload the section. If wiring is run parallel to high voltage or power wiring, misoperation can occur from inductive noise, and this can be a cause of damage. For that reason, wiring should be done in separate conduit or channels.

4) For extension cables, wire of greater than 0.3 mm² AWG22 should be used in a length less than 100 m [illegible].

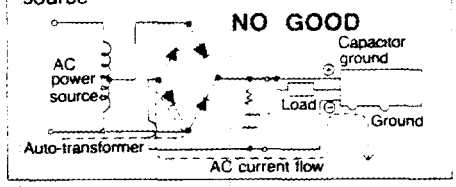
5) During mounting, if the unit is struck with a hammer or other heavy tool, there is the possibility of damaging the water-protection of the case. Sufficient care should be taken.

6) An isolating transformer should absolutely be used with the DC power source. If an auto-transformer (single winding transformer) is used for the DC power source, because the capacitor is grounded to the MP-F fiber photoelectric sensor, there is the possibility of an AC current flowing through one line of the source, causing burnout damage to either the photoelectric sensor or the power source.

When isolation transformer is used for power source




When auto-transformer is used for power source




7) When used with an ultrasonic welder or other high frequency device, to avoid misoperation due to an inductive current, the accessory mounting plate should absolutely be used.

8) In order to improve the noise resistance capability, when a capacitor is mounted in the diecast case, the special mounting bracket should be used. If a different bracket is used, it should be one that will provide insulation.

**2. Regarding ambient environment**

- For amplifier unit

1) Use in the range of −25°C to +55°C [illegible] ambient temperature.

2) Use in the range of 10.8 V to 26.4 V DC for operating voltage.

3) If a surge voltage greater than 500 V [±(1×40)μs single polarity full wave voltage] occurs, there is the possibility of damage to the internal circuit. For that reason a surge suppressor should be used.

- For fiber unit

1) Use in a light environment where the intensity is less than 1,000 lux for fluorescent lamp, less than 3,000 lux for an incandescent lamp, and less than 10,000 lux for daylight.

2) Avoid use of the plastic fiber type in locations where there is steam, dust, high level of corrosive gas, or where there can be adhesion of organic solvents. (The fiber is made of methacrylate material.)

3) Use the MP-FH5-02 and MP-FHD1-02 (glass fiber type) where the ambient temperature is within the range of −40°C to +200°C [illegible]. The fiber is made of glass and the protective covering is teflon resin. There is sufficient durability against the following liquids for momentary contact, but if there is adhesion to the end section, the light level may change and there is the possibility of misoperation.

| | | |
|---|---|---|
| Hydrochloric acid (20%) | Sulfuric acid (10%) | Ammonia (30%) |
| Transmission oil | B grade heavy oil | Methanol |

4) For the MP-FSD1-7 (metal tube type), use in an ambient temperature range of −40°C to +200°C [illegible]. The fiber is glass and the protective covering is stainless steel. There is sufficient durability against the following liquids for momentary contact, but if there is adhesion to the end section, the light level may change and there is the possibility of misoperation.

| | | |
|---|---|---|
| Hydrochloric acid (5%) | Sulfuric acid (10%) | Ammonia (30%) |
| Transmission oil | B grade heavy oil | Methanol |

5) For MP-FX1 (Coaxial reflection type), use in the range of −40°C to +70°C [illegible]. The fiber is methacrylate resin with a protective covering of polythylene, and for that reason adhesion of organic solvents should be avoided.

6) Both the fiber unit and amplifier unit are water-protected (IEC IP66), but object detection in water or where there is direct impingement of rain should be avoided.

**3. Regarding adjustment of diffused reflection type sensitivity**

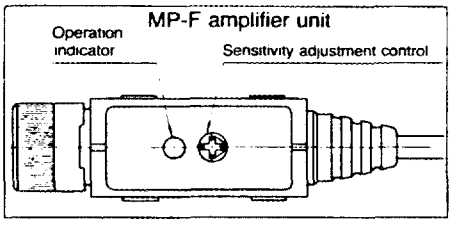
1) Temporarily fasten the fiber unit with the detecting surface positioned in the direction of the object to be detected.

2) With the condition of no object being present, slowly turn the sensitivity control counterclockwise from the maximum position (H), and determine the position where the operation indicator light goes out. If the light is extinguished even in the maximum position, that position is set as the H position.

3) With a target in the position to be detected, turn the sensitivity control slowly conterclockwise and determine the position where the operation indicator light goes out.
4) Set the control midway between the position of 2) and the position of 3).
5) Fasten the head of the fiber unit. When fastening, securely tighten the mounting so that there will be no shifting due to vibration or shock.
Note 1: If the position for 2) and 3) adjustments above are less than 2 graduations, change the detection surface position and repeat the steps 1) to 4), to suppress the external factors causing the variation due to ambient temperature change, or variation due to position change of the target.
Note 2: Because there is a difference in detection as a result of material, color, size, form, direction, and other ambient conditions, a check should be made with the actual target. Also, because there is a change in the light transmission due to the angle of bend of the fiber, avoid using close to the boundary limit of the operating region. Use the unit at about 2/3 the distance to the boundary limit.

**4. Regarding adjustment of the light axis for the separate type**

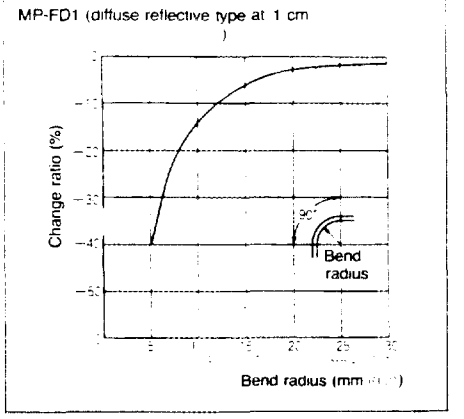
1) Set the projector and the receiver fiber unit in a straight line.
2) By means of adjusting the sensitivity control, it is possible to detect an opaque or translucent material. For an opaque material, set the adjustment to the maximum position (H) to increase the distance tolerance.




**5. Regarding mounting of fiber unit**

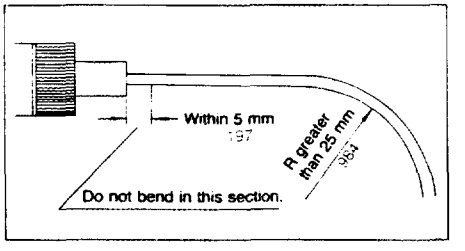
1) Securely mount the fiber unit to the amplifier unit.
2) Do not apply more than 5 kg tension to the fiber unit of the plastic fiber type.
3) The bending radius of the light fiber of the plastic fiber type should be kept as large as possible. If the bending radius is less than 5 mm [illegible] there is the possibility of damage to the light fiber. (Because there is a reduction is the light transmission due to a small bending radius, the actual condition of use should be checked.)

Bending radius vs received light signal level (representative example)

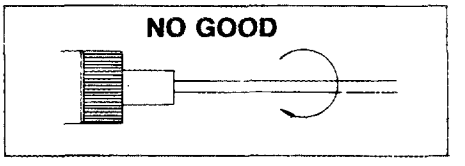



4) For the MP-FH5-02 and MP-FHD1-02 (glass fiber type), because the fiber material is a multicomponent material, to avoid a break in the fiber, the following points in particular should be given attention.

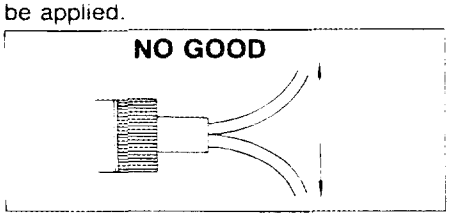
- Do not apply tension in excess of 5 kg to the fiber unit.
- Use a bend radius of greater than 25 mm .984 inch.
- Do not make a bend with 5 mm .197 inch of the base of the fiber of the cord.



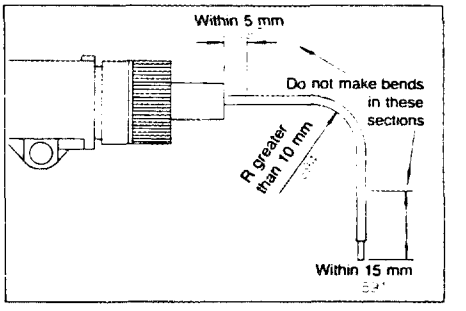

Do not twist the fiber cord.




- For the MP-FH5-02 (thru-beam type), the fiber cord is divided into 2 fibers at the base section, and tension should not be applied.

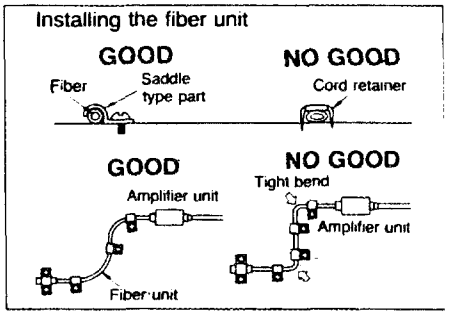



5) For the MP-FSD1–7 (metal tube type) do not apply tension greater than 5 kg to the fiber unit. A flexible metal tubing is used for the protective covering of the metal tube to permit using the most suitable position by bending.
However, there should be no bending 15 mm [illegible] from the end or 5 mm [illegible] from the base section. Do not hold the tube with pliers to make the bend. Bend with the hand in a radius greater than 10 mm .394 inch. In addition take care not to cause a shift in the light axis due to resonance with machine vibration.



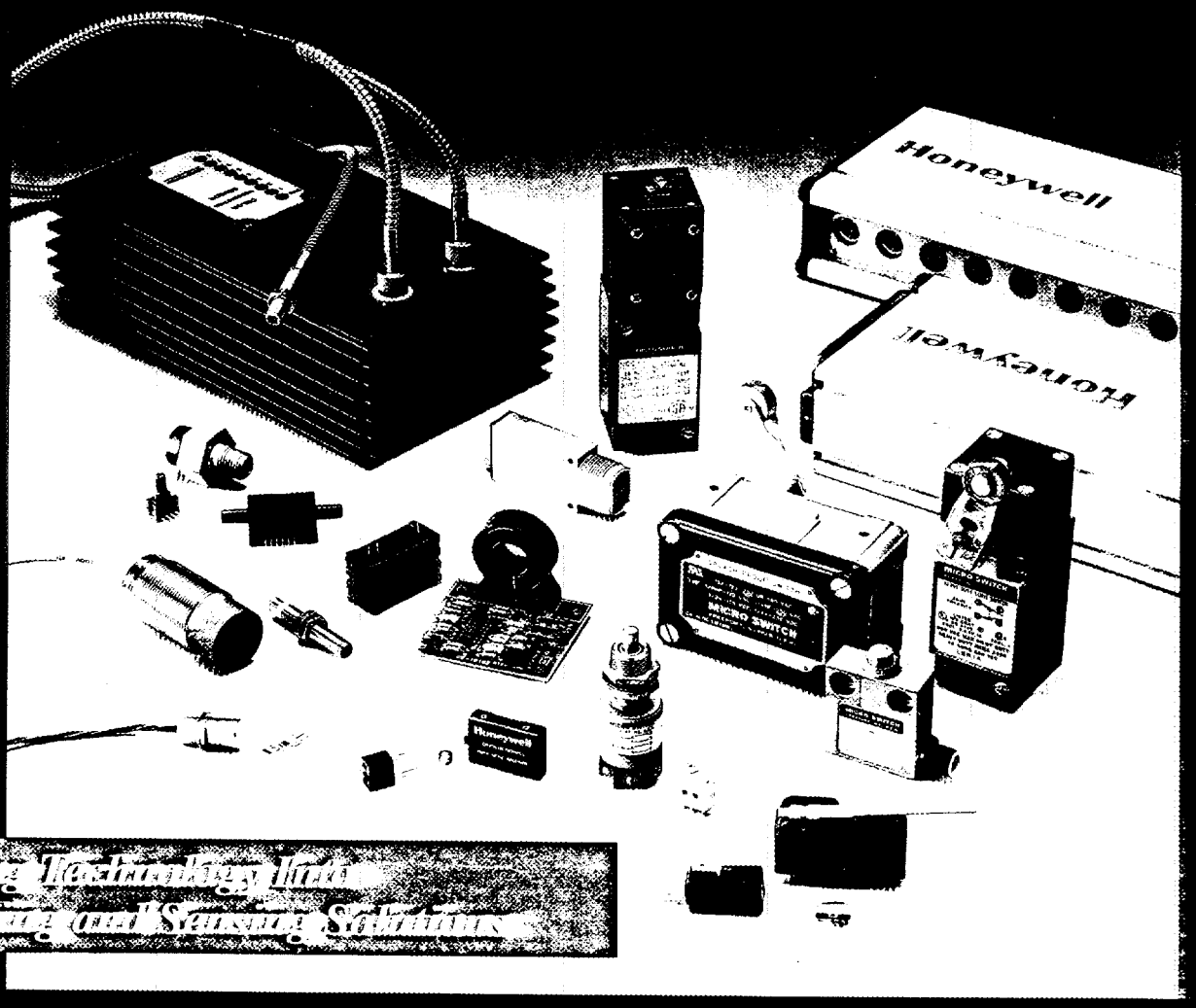

6) For the MP-FX1 (coaxial reflecting type), do not apply tension greater than 5 kg to the fiber unit. Make the bending radius as large as possible. If a bend less than 10 mm .394 inch is used, there is the possibility of damage to the fiber.

Installing the fiber unit



August 1993

# MICRO SWITCH
## Switches and Sensors Selection Guide

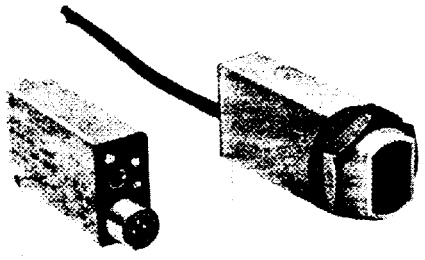



Innovating Technology Into
Switching and Sensing Solutions

# Photoelectric Sensors

## AC and DC Miniature High Performance

*MHP Series*



### GENERAL INFORMATION

MHP Series miniature high-performance photoelectric sensors are rugged, powerful controls packaged in a small, yet flexible housing design. They can be either side-mounted or thru-hole mounted.

All materials used to fabricate these products are chemically resistant. The housing is fully potted to withstand harsh industrial environments, including high-pressure washdown.

Units can be furnished with either preleaded cable or quick disconnect termination.

### FEATURES

- Withstands high-pressure washdown (1,200 psi) which simulates cleaning procedure used in food and beverage processing, exceeding NEMA 6P and IP67
- Ultrasonically welded lens, plus fully potted housing ensures watertight seal integrity
- Rugged housing withstands strong acids, alkalines, cutting fluids, and thermal shock
- 20-260 VAC, 2 wire; or 10-30 VDC with sink and source output in a single unit
- Quick-disconnect versions decrease downtime

### DC - MHP SCAN DISTANCES ORDER GUIDE

| Scan Type | Scan Distance | | Termination | Catalog Listing: Sinking with Self-Diagnostic | Catalog Listing: Sourcing with Self-Diagnostic | Catalog Listing: Sinking and Sourcing |
|---|---|---|---|---|---|---|
| **Retro** (Infrared) | 18 ft. | | Preleaded Connector | MHP-R31L MHP-R31Q | MHP-R32L MHP-R32Q | MHP-R33L MHP-R33Q |
| | 30 ft. | | Preleaded Connector | MHP-LR31L MHP-LR31Q | MHP-LR32L MHP-LR32Q | MHP-LR33L MHP-LR33Q |
| **Polar** (Visible red) | 8 ft. | | Preleaded Connector | MHP-P31L MHP-P31Q | MHP-P32L MHP-P32Q | MHP-P33L MHP-P33Q |
| **Diffuse** (Visible red) | 6 in. | | Preleaded Connector | MHP-DR31L MHP-DR31Q | MHP-DR32L MHP-DR32Q | MHP-DR33L MHP-DR33Q |
| **Diffuse** (Infrared) | 18 in. | | Preleaded Connector | MHP-D31L MHP-D31Q | MHP-D32L MHP-D32Q | MHP-D33L MHP-D33Q |
| **Thru Scan** (Infrared) | 100 ft. | Receiver | Preleaded Connector | MHP-TLR31L MHP-TLR31Q | MHP-TLR32L MHP-TLR32Q | MHP-TLR33L MHP-TLR33Q |
| | | Emitter | Preleaded Connector | MHP-TLE30L MHP-TLE30Q | | |
| **Convergent Beam** | 1.0 in. | (Visible red) | Preleaded Connector | MHP-C131L MHP-C131Q | MHP-C132L MHP-C132Q | MHP-C133L MHP-C133Q |
| | 2.5 in. | (Visible red) | Preleaded Connector | MHP-C231L MHP-C231Q | MHP-C232L MHP-C232Q | MHP-C233L MHP-C233Q |
| | 1.0 in. | (Visible green) | Preleaded Connector | MHP-CG131L MHP-CG131Q | MHP-CG132L MHP-CG132Q | MHP-CG133L MHP-CG133Q |
| **Fiber Optic*** | Next Page | Infrared | Preleaded Connector | MHP-F31L MHP-F31Q | MHP-F32L MHP-F32Q | MHP-F33L MHP-F33Q |
| | | Visible Red | Preleaded Connector | MHP-FR31L MHP-FR31Q | MHP-FR32L MHP-FR32Q | MHP-FR33L MHP-FR33Q |

* Fiber optic cables are ordered separately. Plastic cables require an **MHPFOA** adapter.

### AC - MHP SCAN DISTANCES ORDER GUIDE

| Scan Type | Scan Distance | | Catalog Listing: Preleaded | Catalog Listing: Connector |
|---|---|---|---|---|
| **Retroreflective** (Infrared) | 18 ft. | | MHP-R2AL | MHP-R2AQ |
| | 30 ft. | | MHP-LR2AL | MHP-LR2AQ |
| **Polarized Retro** (Visible red) | 8 ft. | | MHP-P2AL | MHP-P2AQ |
| **Diffuse Scan** (Infrared) | 18 in. | | MHP-D2AL | MHP-D2AQ |
| **Thru Scan** (Infrared) | 100 ft. | Emitter | MHP-TE2AL | MHP-TE2AQ |
| | | Receiver | MHP-TR2AL | MHP-TR2AQ |
| **Convergent Beam** (Visible red) | 1.0 in. | | MHP-C12AL | MHP-C12AQ |
| | 2.5 in. | | MHP-C22AL | MHP-C22AQ |
| **Fiber Optic*** | Next page | Infrared | MHP-F2AL | MHP-F2AQ |
| | | Visible Red | MHP-FR2AL | MHP-FR2AQ |

* Fiber optic cables are ordered separately. Plastic cables require an **MHPFOA** adapter.

Sensors

# Photoelectric Sensors
## HDMP/MHP Fiber Optic Cables

### GENERAL INFORMATION
MP/MHP-F fiber optic sensors are ideal for use where space is limited and/or target objects are very small. Since these controls are self contained, no separate amplifier is needed for signal conditioning.

Infrared sensors with glass cables provide the greatest scanning distance and are most stable when sensing a wide variety of colors.

Visible red sensors with plastic cables are a cost-effective, reliable approach to presence/absence and color contrast applications. They are ideal for use with lighter colors as required in color mark detection.

### FIBER OPTIC CABLES
**Glass cables.** Armor grip cables have a flexible metal jacket to help the cable withstand physical abuse. Monocoil PVC cables provide greater sealing and should be used in areas of high pressure washdowns. Both types of glass cables have stainless steel end tips and corrosion resistant mounting hardware.

**Plastic cables** can be cut to length in the field. Standard cables with 1 mm dia. core are suitable for most uses. Cables with a 0,5 dia. core are best for detection of tiny parts. An **MHPFOA** plastic cable adapter (sold separately), is required to assemble plastic cables to MHP sensors.

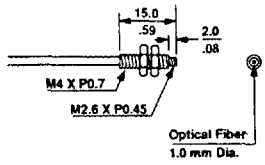
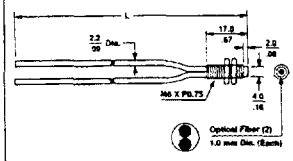
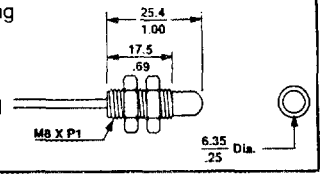
### FEATURES
- Fiber optic sensors suited for use in space constricted areas, especially where high-speed sensing of small parts is required
- High-performance construction, including high-pressure washdown sealing – adjustable sensitivity, alignment indicators, and selectable light/dark operate for installation ease
- Visible red or infrared light source for application versatility
- Choice of flexible plastic or glass fiber optic cables

### TYPICAL SCAN DISTANCES FOR FIBER OPTICS (in clean air)*

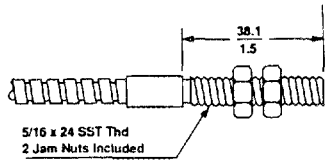
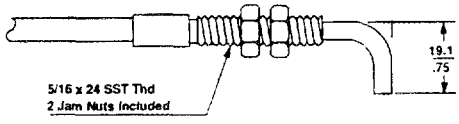
| Input Voltage | Sensor Type | Scan Type | Glass Cable w/o Lens** | Plastic Cable w/o Lens | Plastic Lensed FEF-PLT1 Cables |
|---|---|---|---|---|---|
| 10-30 VDC | Infrared | Diffuse | 2.3 in. | 0.21 in. | N/A |
| | | Thru scan | 14 in. | 3.50 in. | 41 in. |
| | Visible Red | Diffuse | 1.4 in. | 0.40 in. | N/A |
| | | Thru Scan | 10.0 in. | 3.30 in. | 50 in. |
| 20-260 VAC | Infrared | Diffuse | 2.86 in. | .71 in. | N/A |
| | | Thru Scan | 23.60 in. | 3.10 in. | 43.3 in. |
| | Visible Red | Diffuse | 1.70 in. | .61 in. | N/A |
| | | Thru Scan | 10.0 in. | 3.20 in. | 40 in. |

* Distance values are given as a guide to relative optical power and rated using 3 ft. (0,9 m) glass cables and 3.3 ft. (1 m) plastic cables, except thru scan glass cables w/lens.
** Lens accessories improve scan range 3 to 5 times. Use FE-FZ-L4 lens with glass cables, FE-PA-L1 lens with plastic thru scan cables.

### PLASTIC FIBER OPTIC CABLE ORDER GUIDE
Use with MHP/MPF. Each catalog listing for individual thru scan cables specifies a pair. (1 meter cables shown, except where noted.)

| Catalog Listing | Individual Thru Scan | Bifurcated Diffuse, Retro End Tip Detail | Individual Thru Scan |
|---|---|---|---|
| Threaded end tip<br><br>Individual: FEF-PAT4-M<br>Bifurcated: FEF-PAD6-M |  |  | Lensed end tip for long distance scanning.<br><br>Individual: FEF-PLT1  |

### GLASS FIBER OPTIC CABLES ORDER GUIDE **NOTE:** For washdown applications, monocoil cables should be used.

| Catalog Listing for MHP, MPG | End Tip Detail | Catalog Listing for MPF | |
|---|---|---|---|
| Threaded end tip. Armour grip .125 in. dia. bundle<br>Individual: FE-ITS6S-3<br>Bifurcated: FE-BTS6S-3<br><br>PVC monocoil.<br>Individual: FE-ITS6M-3<br>Bifurcated: FE-BTS6M-3 |  | Threaded end tip. Armour grip<br>Individual: FE-T2B-3<br>Bifurcated: FE-B2B-3<br><br>PVC monocoil<br>Individual: FE-T5B-3<br>Bifurcated: FE-B5B-3 | FO dia.<br>.09<br>.125<br><br><br>.09<br>.125 |
| Right angle end tip. Armour grip<br>Individual: FE-ITSAS6S-3<br>Bifurcated: FE-BTSAS6S-3<br><br>PVC monocoil.<br>Individual: FE-ITSAS6M-3<br>Bifurcated: FE-BTSAS6M-3 |  | Right angle end tip. Armour grip<br>Individual: FE-T2L-3<br>Bifurcated: FE-B2L-3<br><br>PVC monocoil<br>Individual: FE-T5L-3<br>Bifurcated: FE-B5L-3 | <br>.09<br>.125<br><br><br>.09<br>.125 |

# Photoelectric Controls
## Modular AC and DC

### Our Most Versatile Control – Select Your Specific Application Needs

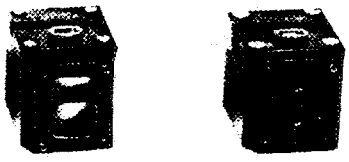
**STANDARD MP**
With MP Modular Photoelectric controls it is easy to select the right combination of components to suit your application needs. There are many choices of sensing heads (including fiber optics) and bases; plus, the option to add a multifunction timer/logic card. Standard MP has rugged NEMA 1, 3, 4, 12 and 13 sealed industrial construction.

MP is easy to assemble. Heads assemble to bases with four captive screws. Bases plug into receptacles that feature easy wiring with screw terminals, prewired cable or plug-in connectors. Logic cards plug into the head. Dual LED alignment indicators are visible from all sides. Heads rotate to four positions (plug-in and relay bases).

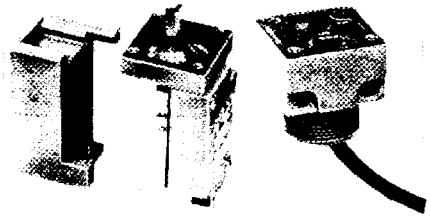
**HARSH DUTY MP**
MICRO SWITCH Harsh Duty Modular Photoelectric (HDMP) controls provide superior sealing and corrosion resistant components to withstand harsh environments. The HDMP series meets the extreme NEMA sealing tests 4, 4X, 6 and 6P. In addition, the HDMP has been successfully tested to MICRO SWITCH Test Specifications 060.167, Issue 2, Paragraph 4.9. This is a test specification for high pressure (1200 psi), high temperature (140°F) chemical washdown. This test simulates the cleaning procedure used by Food and Beverage processing plants – procedures which are more severe than the standard NEMA 4 hosedown.

### To Order

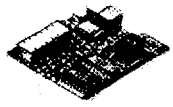
***Select*** **Photoelectric Sensor Head**

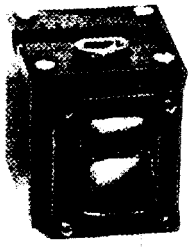


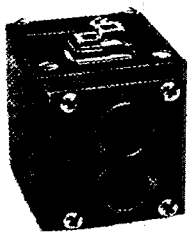
***Pick*** **Appropriate Base**



***Add*** **Timer/Logic Card (Optional)**







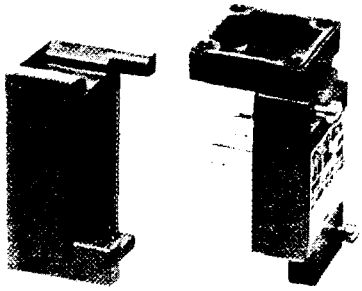
MPG

**HEADS ORDER GUIDE**

| Description | Catalog Listing Standard | Catalog Listing Harsh Duty |
|---|---|---|
| **RETROREFLECTIVE HEAD** | | |
| 30 ft. range, 10 msec response, plastic lens | **MPL2** | — |
| 30 ft. range, 1 msec response, plastic lens | **MPL6** | MPL6HD |
| **POLARIZED RETROREFLECTIVE HEAD** | | |
| 20 ft. range, 10 msec response, glass lens | **MPP1** | MPP1HD |
| 15 ft. range, 1 msec response, glass lens | **MPP6** | MPP6HD |
| **DIFFUSE HEAD** | | |
| 10 ft. range, 10 msec response, plastic lens | **MPD2** | MPD2HD |
| 3 ft. range, 10 msec response, plastic lens | **MPD4** | MPD4HD |
| 18 inch range, 1 msec response, plastic lens | MPD6 | MPD6HD |
| **THRU SCAN HEADS – 200 FT. RANGE** | | |
| Emitter, glass lens | MPE1 | MPE1HD |
| Receiver, 10 msec response, glass lens | MPR1 | MPR16HD |
| **MPF FIBER OPTIC HEADS**(MICRO SWITCH style, dual slot cables only) | | |
| Infrared, 10 msec response | **MPF1** | MPF1HD |
| Infrared, 1 msec response | **MPF6** | MPF6HD |
| **MPG FIBER OPTIC HEAD** (Universal style cables only) | | |
| Infrared, 1 msec response | **MPG6** | MPG6HD |

Popular fiber optic cables on facing page.

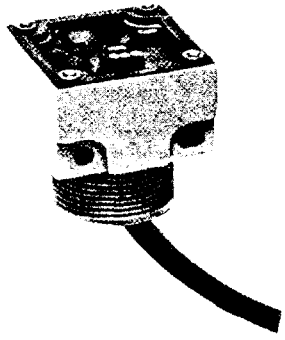
Many additional head options and cables are in the Industrial Catalog.



Receptacle Plug-in Base

## PLUG-IN BASES ORDER GUIDE

| Description | Catalog Listing | |
|---|---|---|
| | Standard | Harsh Duty |
| **AC INPUT VOLTAGE** | | |
| 92-132 VAC emitter base | MPS10 | MPS10HD |
| 92-132 VAC, 4 wire solid state AC relay 1 amp max. | **MPS11** | MPS11HD |
| Same as MPS11, but with output indicator | MPS11LD | MPS11HD-LD |
| 92-132 VAC, 4 wire bilateral FET (AC/DC) 100 mA max. | **MPS17** | MPS17HD |
| **DC INPUT VOLTAGES** | | |
| 10-30 VDC, complementary N.O. and N.C., sinking (NPN) | **MPS31** | MPS31HD |
| 10-30 VDC, N.O., sourcing (PNP) | MPS32 | **MPS32HD** |
| **RECEPTACLES** | | |
| Standard 4 terminal plug-in | **MPB10** | **MPB20** |



Mini-Base

## RELAY BASES – LIMIT SWITCH STYLE NON PLUG-IN ORDER GUIDE

| | Standard |
|---|---|
| **SPDT** | |
| 103-132 VAC, 6 amp | **MPV11** |
| 22-26 VAC/VDC, 6 amp | **MPV13** |

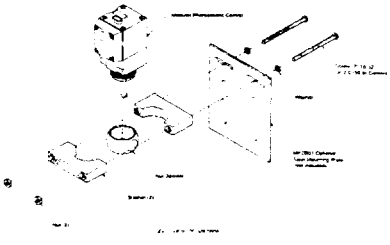
## MINI STYLE BASES PRELEADED

| Mini Style Bases | PRELEADED |
|---|---|
| | Standard |
| **AC INPUT VOLTAGE** | |
| 192-132 VAC, 4-wire solid state AC relay .5 amp max. | **MPT11** |
| 92-132 VAC, 6 amp SPDT relay, front/back mount | **MPW11** |

## 2-WIRE AC INPUT ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| | Standard |
| **HEAD** | |
| 30 ft. retroreflective, plastic lens | **MP2L2** |
| **BASE** | |
| 2-wire, 22-260 VAC/45-260 VDC universal voltage | **MP2S11** |
| **RECEPTACLE** | |
| Standard 4 terminal plug-in | **MPB10** |

**MPZB06, MPZB07, MPZB08**



## ACCESSORIES ORDER GUIDE

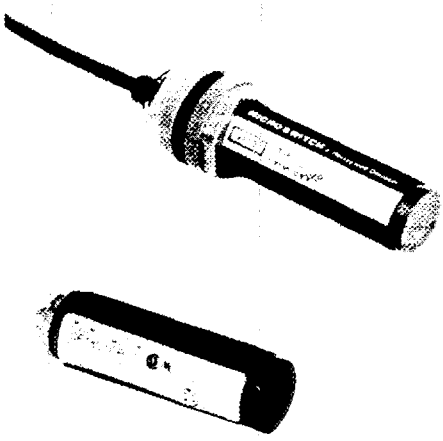
| | Catalog Listing |
|---|---|
| **MULTI-FUNCTION LOGIC CARDS** | |
| .15 to 15 second time adjustment (standard) | **MPA1** |
| **MOUNTING BRACKETS** | |
| Ball and swivel mounting bracket (fits 30 mm mini MP) | **MPZB06** |
| Ball and swivel vertical mounting plate | MPZB07 |
| Adapter (use with MPZB06 to fit 1/2" conduit hole) | MPZB08 |
| Combination of the MPZB06, 7, and 8 brackets | MPZB09 |
| Photoswitch 4000 (MLS8C) to limit switch style (Requires L-shaped underbracket) | MPZB11 |
| Pair of fiber cable adapters allows use of cuttable 1000 micron plastic cable | **MPZFOADPT*** |

* **MPZFOADPTHD** is harsh duty version.

## RETROREFLECTIVE TARGETS ORDER GUIDE

| Description | Efficiency | Catalog Listing |
|---|---|---|
| 3-inch diameter molded acrylic disc with plastic backing and rim, and .18 dia. mounting hole. Max. 150°F (66°C) ambient temperature. | 100% | **FE-RR1** |
| 1-inch diameter acrylic disc (no mounting hole). Max. 150°F (66°C) ambient temperature. | 45% | **FE-RR3** |
| 2.2" x 1" x .37" Rectangular molded acrylic reflector-mounting holes on each end. Max. 150°F (66°C) ambient temperature. | 65% | **FE-RR6** |

# Photoelectric Controls
## 18 mm Cylindrical



### GENERAL INFORMATION
CP18 Series photoelectric controls are designed for simple industrial and commercial applications that do not require heavy duty controls or sensitivity adjustments. The small package size of MICRO SWITCH CP18 Series photoelectric controls fits in limited access and/or restricted space areas.

### FEATURES
- 18 mm x 1 fully threaded housing
- Unique, one-piece polycarbonate lens/housing (patent pending)
  - Sealing rated to NEMA 6P (IP67)
  - Flat external lens surface
- Short housings: DC – 55 mm, AC – 75 mm
- Thru-, retroreflective and diffuse scanning
- Scan ranges from 100 mm to 30 meters
- Modulated infrared LED for ambient light rejection
- Standard 2-meter 3 conductor preleaded cable (AC or DC), or 4-pin DIN style (DC).
- Alignment indicator to facilitate installation
- 10 to 30 VDC and 20 to 132 VAC types available
- Fast response times: DC – 1 msec, AC – 20 msec
- High load capacity: DC – 150 mA, AC – 5 to 400 mA
- Protected against short circuit (DC), false pulse (on), reverse polarity (DC), industrial interference and transients

### 10 to 30 VDC CONTROLS ORDER GUIDE

| Scan Type | Output* | Scan Distance | Catalog Listings | | | |
|---|---|---|---|---|---|---|
| | | | Preleaded Cable | | Quick Disconnect | |
| | | | Light Operate | Dark Operate | Light Operate | Dark Operate |
| Diffuse | PNP<br>NPN | 100 mm<br>(3.94 in.) | **CP18D1DPL2**<br>**CP18D1DNL2** | **CP18D1DPD2**<br>**CP18D1DND2** | **CP18DIDPLC**<br>**CP18DIDNLC** | **CP18DIDPDC**<br>**CP18DIDNDC** |
| | PNP<br>NPN | 200 mm<br>(7.87 in.) | **CP18D2DPL2**<br>**CP18D2DNL2** | **CP18D2DPD2**<br>**CP18D2DND2** | **CP18D2DPLC**<br>**CP18D2DNLC** | **CP18D2DPDC**<br>**CP18D2DNDC** |
| | PNP<br>NPN | 400 mm<br>(15.74 in.) | **CP18D4DPL2**<br>**CP18D4DNL2** | **CP18D4DPD2**<br>**CP18D4DND2** | **CP18D4DPLC**<br>**CP18D4DNLC** | **CP18D4DPDC**<br>**CP18D4DNDC** |
| Retroreflective | PNP<br>NPN | 4 m<br>(13 ft.) | **CP18LDPL2**<br>**CP18LDNL2** | **CP18LDPD2**<br>**CP18LDND2** | **CP18LDPLC**<br>**CP18LDNLC** | **CP18LDPDC**<br>**CP18LDNDC** |
| Thru-scan Receiver | PNP<br>NPN | 30 m<br>(98 ft.) | **CP18RDPL2**<br>**CP18RDNL2** | **CP18RDPD2**<br>**CP18RDND2** | **CP18RDPLC**<br>**CP18RDNLC** | **CP18RDPDC**<br>**CP18RDNDC** |
| Emitter | — | — | **CP18EDX2** | — | **CP18EDXC** | — |

**NOTICE**

CP18 Series photoelectric controls are not designed for high pressure washdown or exposure to ketones, halogenated hydrocarbons, esters, amines or acids and alkalis. They should be cleaned with mild soap, warm water and a clean cloth.

### 20 to 132 VAC CONTROLS ORDER GUIDE

| Scan Type | Scan Distance | Catalog Listings/Preleaded Cable | |
|---|---|---|---|
| | | Light Operate | Dark Operate |
| Diffuse | 100 mm (3.94 in.) | CP18D1AAL2 | CP18D1AAD2 |
| | 200 mm (7.87 in.) | CP18D2AAL2 | CP18D2AAD2 |
| | 400 mm (15.74 in.) | CP18D4AAL2 | CP18D4AAD2 |
| Retroreflective | 4 m (13 ft.) | CP18LAAL2 | CP18LAAD2 |
| Thru-scan Receiver | 30 m (98 ft.) | CP18RAAL2 | CP18RAAD2 |
| Emitter* | — | CP18EBX2 (Use only with AC receiver) | |

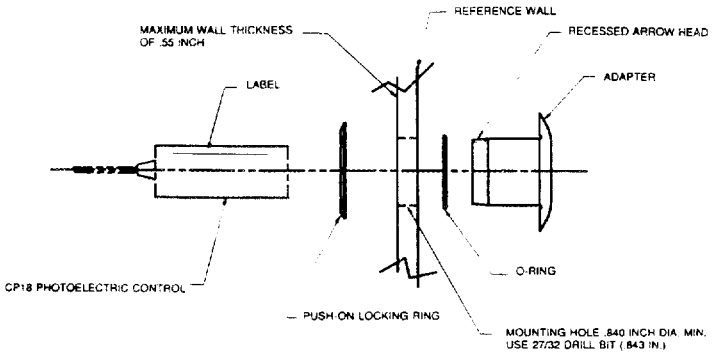
* 20-260 VAC/VDC

### FLUSH MOUNT QUARTER-TURN QUICK-ASSEMBLY BRACKET

**Catalog listing CPZ18B01** is a flush mount quick-assembly bracket which simplifies mounting the CP18 and offers a flush, protected sensing face. The CP18 label area is matched up with the internal thread of the bracket, slid into the bracket until flush on top, then a quarter-turn clockwise locks the control in place. (See drawing.) The locking ring is inserted from the back of the bracket and pushed up snug against your mounting surface.

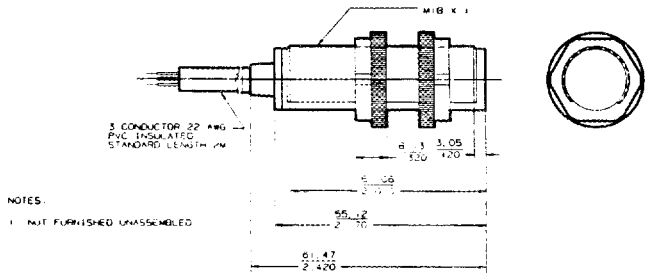
### ACCESSORIES ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| Swivel type mounting bracket assembly | CPZ18B02BK |
| Swivel bracket only | CPZ18B03 |
| Screw on right angle adapter — retro and thru scan only | **CPZ18RAW** |
| Screw on right angle adapter — diffuse | CPZ18RAO |
| Pair of Blue Mounting nuts | CPZ18BUNTS |
| Pair of Black Mounting nuts | CPZ18BKNTS |
| Flush mount/Quick Assembly mounting bracket assembly | CPZ18B01 |
| Conduit Adapter, aluminum (1/2"-14NPT) | 925AZ18S |
| Mounting bracket, aluminum | 925BZ18S |




### TYPICAL DIMENSIONS
(for reference only)

**DC, AC/DC Emitter**




$$AC = \frac{81{,}3}{3.2} \text{ Length}$$

### CONNECTOR CABLES ORDER GUIDE

| Connector Style | Cable Length | Catalog Listings |
|---|---|---|
| **4-Pin DC, Standard Key** Straight w/Aluminum Nut | 2 m (6 ft.) | 80256-A |
| | 5 m (16 ft.) | 80259-A |
| **4-Pin AC, Dual Key, 1/2 in.-20 UNF** Straight w/Aluminum Nut | 2 m (6 ft.) | 70432 |
| | 5 m (16 ft.) | 70434 |

# Photoelectric Sensors
## Subminiature Short Range

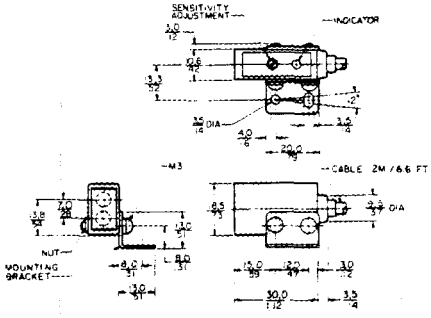
*FE7A Series*

### GENERAL INFORMATION
FE7A controls are self-contained and require no separate amplifier for signal conditioning. Each control has its own infrared light source, photodiode, amplifier circuitry, signal strength/alignment indicator, and output transistor. The FE7A operates on a broad range of 10 to 28 VDC and provides current sinking output up to 100 mA.

### FEATURES
- 2.75-inch diffuse scan range
- 5-foot thru scan range
- 10 to 28 VDC operation
- Sealing: NEMA 12 and IP64
- Modulated infrared LED for ambient light rejection
- Combination alignment/self diagnostic indicator
- False pulse and reverse polarity protection
- Short circuit protection

### TYPICAL DIMENSIONS
(For reference only)

**Horizontal Mount**




### DIFFUSE SCAN ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| Light operated (L.O.) sinking (NPN) output; horizontal mount | **FE7A-DA6-M** |

Mounting bracket is included with each unit.

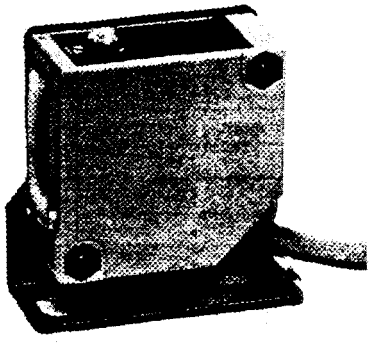
### THRU SCAN ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| Emitter, horizontal mount | **FE7A-TA6E-M** |
| Receiver, dark operated (D.O.) sinking (NPN) output; horizontal mount | **FE7A-TA6GR-M** |
| Emitter, vertical mount | FE7A-TA6VE-M |
| Receiver, dark operated (D.O.) sinking (NPN) output; vertical mount | FE7A-TA6VGR-M |

Mounting bracket is included with each unit.

# Photoelectric Sensors
## Miniature AC/DC Input, Relay Output

*FE7D Series*

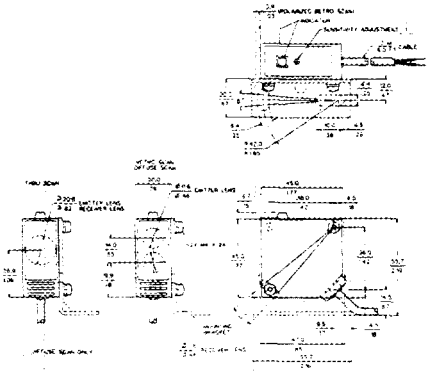


### GENERAL INFORMATION
FE7D Series photoelectric controls pack a full measure of high level performance into a compact, easy-to-apply package. They provide extended scanning ranges, accept wide range AC/DC voltage input, have a 1-amp SPST relay output, and comply with IP66 (IEC) enclosure seal standards.

### FEATURES
- High-performance scanning distances:
  - Thru scan, up to 33 feet (10 meters)
  - Polarized retroreflective scan, up to 9.8 feet (3 meters)
  - Diffuse (proximity) scan, up to 2.3 feet (.7 meter)
- Combination of self-alignment/self-diagnostic indicator simplifies setup
- All units mount horizontally or vertically for installation flexibility

### TYPICAL DIMENSIONS
(For reference only)

**FE7D Controls**



### RETROREFLECTIVE-POLARIZED SCAN ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| AC or DC input, 1 amp relay output, dark operated | **FE7D-RPR7-M** |
| AC or DC input, 1 amp relay output, light operated | **FE7D-RPS7-M** |

### DIFFUSE SCAN/SENSITIVITY ADJUSTMENT ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| AC or DC input, 1 amp relay output, dark operated | **FE7D-DS7-M** |
| AC or DC input, 1 amp relay output, light operated | **FE7D-DR7-M** |

### THRU SCAN ORDER GUIDE

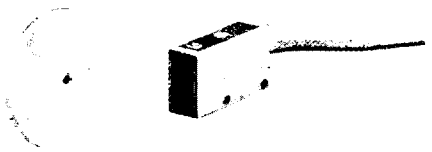
| Description | Catalog Listing |
|---|---|
| AC or DC Emitter | **FE7D-TX7E-M** |
| AC or DC input, 1 amp relay output, dark operated | **FE7D-TR7R-M** |
| AC or DC input, 1 amp relay output, light operated | **FE7D-TS7R-M** |

Mounting bracket is included with all units.

Sensors

# Photoelectric Sensors
## Subminiature Short Range

*FE7B Series*

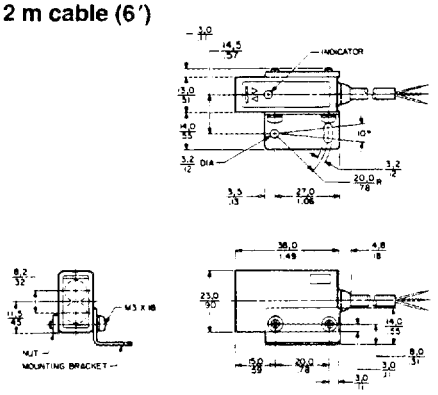


### GENERAL INFORMATION
The small package size of FE7B controls allow usage in limited access and/or restricted space areas. A mounting bracket (included) makes mounting and alignment easy. Each control is self-contained, incorporating a pulsed LED, phototransistor receiver and amplifier circuitry with solid state output in one package. The FE7B operates on a broad range DC voltage from 10 to 28 VDC and provides current sinking output up to 100 mA.

### FEATURES
- 6.5 foot polarized
- 7-foot retroreflective scan range with FE-RR1 reflector
- 6-inch diffuse scan range
- 5-foot thru scan range
- 10 to 28 VDC operation
- Sealing: NEMA 12 and IP64
- Modulated infrared LED for ambient light rejection
- Combination alignment/self diagnostic indicator
- Sensitivity adjustment
- Short circuit protection
- False pulse and reverse polarity protection
- Synchronous detection

### TYPICAL DIMENSIONS
(For reference only)

**Horizontal Mount**
**2 m cable (6′)**




### RETRO REFLECTIVE SCAN ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| Dark operated (D.O.) sinking (NPN) output; horizontal mount | **FE7B-RA6G-M** |
| Polarized dark operated (D.O.) sinking (NPN) output; horizontal mount | FE7B-RPA6-M |

Mounting bracket is included.

### DIFFUSE SCAN ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| Light operated (L.O.) sinking (NPN) output; horizontal mount | **FE7B-DA6-M** |
| Light operated (L.O.) sourcing (PNP) output; horizontal mount | FE7B-DD6-M |
| Light operated (L.O.) sinking (NPN) output; vertical mount | **FE7B-DA6V-M** |

Mounting bracket is included with each unit.

### THRU SCAN ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| Emitter — horizontal mount | **FE7B-TA6E-M** |
| Receiver — dark operated (D.O.) sinking (NPN) output; horizontal mount | **FE7B-TA6GR-M** |
| Emitter vertical mount | FE7B-TA6VE-M |
| Receiver, dark operated (D.O.) sinking (NPN) output; vertical mount | **FE7B-TA6VGR-M** |

Mounting bracket is included with each unit.

# Photoelectric Sensors
## Subminiature Fiber Optic

*FE7B-F Series*

### GENERAL INFORMATION
FE7B controls are available with visible red or invisible infrared emitters. The infrared type is most stable when sensing a wide variety of colors, while the visible red light source is better for use with lighter colors as required in color mark detection.

### FEATURES
- 0.32-inch visible red diffuse scan range
- 0.4-inch infrared diffuse scan range
- Glass fiber optic bundle is enclosed in bendable stainless steel tubing (2.76″ L.)
- FE7B features above apply

### ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| Sinking NPN, L.O. (light operated), infrared | **FE7B-FDA6-M** |
| Sinking NPN, L.O. (light operated), visible red | **FE7B-FDRA6-M** |
| Sourcing, L.O. (light operated), infrared | FE7B-FDD6-M |
| Sourcing, L.O. (light operated), visible red | FE7B-FDRD6-M |

Mounting bracket is included with each unit.

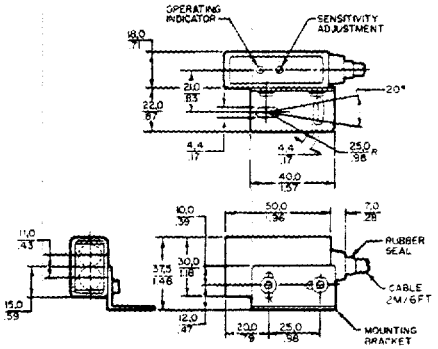
# Photoelectric Sensors
## Miniature Short Range

### GENERAL INFORMATION
FE7C retroreflective scan controls are self-contained and require no separate amplifier for signal conditioning. Each control has its own infrared light source, photodiode, amplifier circuitry, signal strength/alignment indicator, and output transistor. FE7C controls operate on a broad range of 10 to 28 VDC or from 85 to 250 VAC and provide a 100 mA current sinking output. The DC version's output is convertible from dark operated to light operated.

### FEATURES
- 10-foot retroreflective or polarized scan range with FE-RR1 reflector
- 15-inch diffuse scan range
- 20-foot thru scan range
- Self-contained either AC or DC operation
- Sealing: NEMA 12 and IP64
- Visible alignment indicator
- Combination alignment/self diagnostic indicator (DC)
- False pulse and short circuit protection (DC)

### TYPICAL DIMENSIONS
(For reference only)

**Horizontal Mount**




### RETRO REFLECTIVE SCAN ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| 85-250 VAC dark operated (D.O.); horizontal mount | **FE7C-RT2-M** |
| 10-28 VDC, convertible L.O./D.O. sinking output; horizontal mount | **FE7C-RC6G-M** |
| 10-28 VDC, convertible L.O./D.O. sinking output; vertical mount | **FE7C-RC6VG-M** |
| Polarized 10-28 VDC, L.O./D.O. sinking, horizontal | FE7C-RPC6-M |
| Polarized 85-250 VAC D.C., horizontal mount | FE7C-RPT2-M |

### DIFFUSE SCAN ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| 10–28 VDC convertible L.O./D.O. current sinking output; horizontal mount | **FE7C-DC6-M** |
| 10–28 VDC convertible L.O./D.O. current sourcing output; horizontal mount | FE7C-DF6-M |
| 10–28 VDC convertible L.O./D.O. current sinking output; vertical mount | FE7C-DC6V-M |

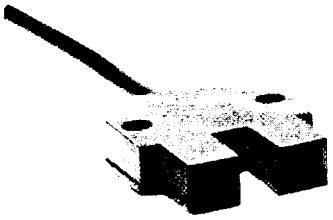
### THRU SCAN ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| Emitter — 85-250 VAC; horizontal mount | **FE7C-TT2E-M** |
| Receiver — 85-250 VAC dark operated (D.O.); horizontal mount | **FE7C-TT2R-M** |
| Emitter — 85-250 VAC; vertical mount | FE7C-TT2VE-M |
| Receiver — 85-250 VAC dark operated (D.O.); vertical mount | FE7C-TT2VR-M |
| Emitter — 10-28 VDC; horizontal mount | **FE7C-TC6E-M** |
| Receiver — 10-28 VDC convertible L.O./D.O. current sinking output; horizontal mount | **FE7C-TC6GR-M** |

Mounting bracket is included with each unit.

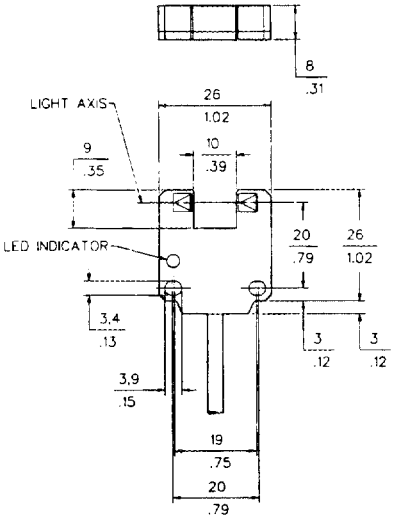
# Photoelectric Sensors
## Vane Controls

*FE5V Series*



**TYPICAL DIMENSIONS**
(For reference only)

**Modulated Controls**
**FE5V-TA6, FE5V-TB6**




### GENERAL INFORMATION

Each FE5V control contains a modulated or non-modulated infrared LED, phototran sistor receiver, and amplifier circuitry with solid state output contained in a single package. Units with a non-modulated LED have a smaller slit width to enable detection of smaller objects.

A red alignment indicator turns ON when the beam is not blocked. The housing complies with IP60 sealing standards. 12 VDC, 24 VDC and 12/24 VDC types are available.

### FEATURES

- 5 or 10 mm (.2 or .4 in.) scan distance (gap)
- Self contained DC operation
- Sealing: IP60
- Modulated or non-modulated types
- Visible alignment indicator
- Light operated or dark operated
- High-speed response: 500 Hz or 1 kHz

### TYPICAL APPLICATIONS

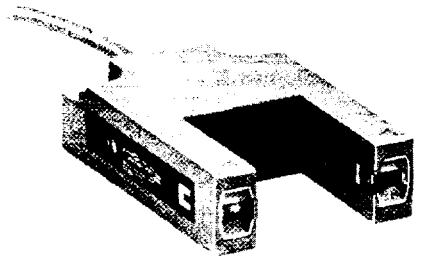
- Medical — Drip detection or counting
- Rotary cam detection
- Edge guide
- Machine detection
- RPM detection

### ORDER GUIDE

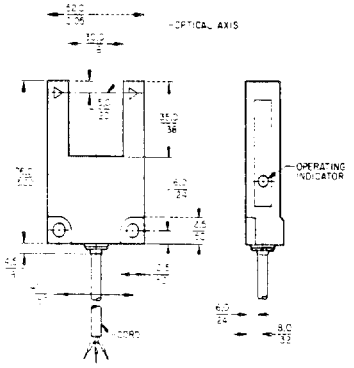
| Description | Catalog Listing |
|---|---|
| 12/24 VDC; modulated, dark operated, current sinking (NPN) output | **FE5V-TA6** |
| 12/24 VDC; modulated, light operated, current sinking (NPN) output | FE5V-TB6 |
| 24 VDC; non-modulated, dark operated, current sinking (NPN) output | FE5V-TA5X |
| 24 VDC; non-modulated, light operated, current sinking (NPN) output | FE5V-TB5X |
| 12 VDC; non-modulated, dark operated, current sinking (NPN) output | FE5V-TA4X |
| 12 VDC; non-modulated, light operated, current sinking (NPN) output | FE5V-TB4X |

# Photoelectric Sensors
## Vane Control

*FE8V Series*



**TYPICAL DIMENSIONS**
(For reference only)




### GENERAL INFORMATION

The FE8V Series vane type photoelectric controls feature a rugged die-cast housing and are self-contained. Each control has a pulsed infrared LED, phototransistor receiver, and amplifier circuitry with solid state output in one package.

The DC units are broad voltage input (10 to 28 VDC), and provide a 100mA current sinking or sourcing output. Response time is 2 msec On, 2 msec Off. DC units are protected against short circuits, false pulse, and reverse polarity.

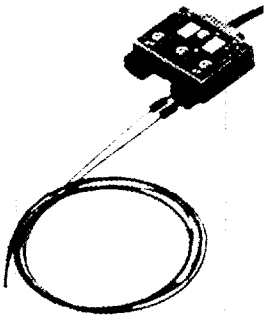
AC units operate on line voltages of 85 to 250 VAC, and provide a 5 to 100mA output, and 1.5mA leakage current. Response time is 50 msec On, 50 msec Off.

### FEATURES

- Modulated infrared LED for ambient light rejection
- Visible alignment indicator
- AC and DC types
- Rugged die-cast housing
- False pulse and short circuit protection in DC versions
- NEMA 4/IP67 sealing

### ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| 10-28 VDC Dark operate. sinking (NPN) output | **FE8V-TA6-M** |
| 10-28 VDC Light operate. sinking (NPN) output | FE8V-TB6-M |
| 85-250VAC Dark operate | **FE8V-TT2-M** |
| 85-250VAC Light operate | FE8V-TU2-M |



## GENERAL INFORMATION

FE5F Series Multiple Fiber Optic photoelectric controls have one, two or three emitter/receiver cells per unit, and are available with infrared, visible red, or high power visible red emitters. The single, double and triple units offer one, two, and three complete, independently adjustable transceiver sections per control. FE5F controls have NPN (current sinking) or PNP (current sourcing) outputs.

Self-diagnostic output and logic capabilities are available with the double unit. The self-diagnostic output turns On when the alignment LED is Red, indicating a marginal output. The adjustable delayed output interfaces with devices where a longer input signal is needed. The AND/OR logic unit has a separate output, switch selectable for either AND or OR function *in respect to the independent fiber optic circuitry*. Self-diagnostic and logic units have separate outputs for each transceiver cell that are immediate On/Off in addition to the extra output features. The high power visible red unit has twice the scanning power of the standard visible red.

Glass cables should be used with infrared units, where higher operating temperature or less color sensitivity is required in the application.

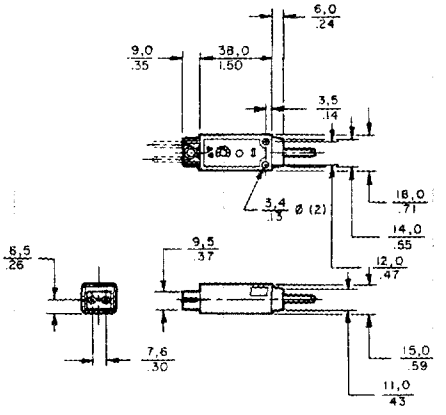
## FEATURES

- Miniature self-contained DC controls
- Single, double and triple control units
- Visible red or infrared LED
- Wide variety of thru-scan and diffuse scan fiber optic cables
- False pulse, short circuit and reverse polarity protection
- 1 msec response time standard; 0.5 msec single unit available
- Light operate/Dark operate switch standard
- AND/OR logic, delay output, self-diagnostic outputs available
- IP60 sealing

## TYPICAL DIMENSIONS

(For reference only)

**Single Unit**




## FE5F SERIES ORDER GUIDE

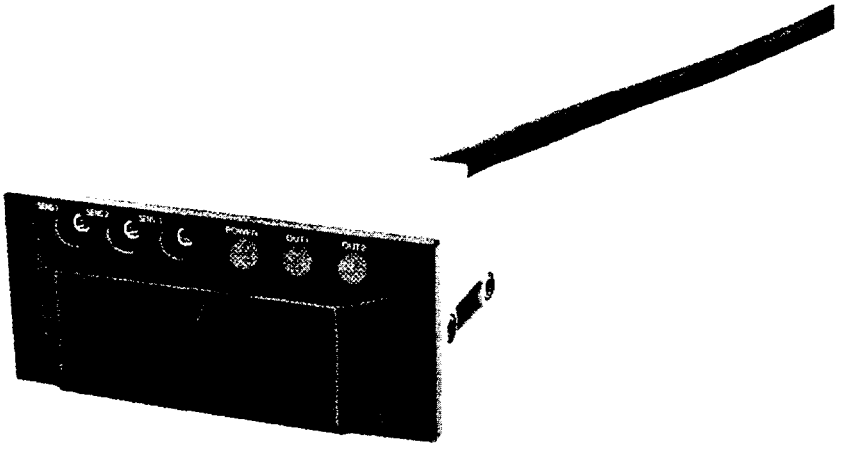
| Control Units | Control Type | Light Source | Output Type | Catalog Listing |
|---|---|---|---|---|
| One | Standard ON/OFF | Visible Red<br>High Power Red | NPN<br>NPN | **FE5F-1RC6-M**<br>**FE5F-1MC6-M** |
| Two | Standard ON/OFF | Visible Red<br>High Power Red | NPN<br>NPN | FE5F-2RC6-M<br>FE5F-2MC6-M |
| Three | Standard ON/OFF | Visible Red<br>High Power Red | NPN<br>NPN | **FE5F-3RC6-M**<br>**FE5F-3MC6-M** |

## SCAN RANGE (FIBER OPTIC CABLES)

| Scan Type | Fiber Optic Cable Listing | Fiber Dia. mm/in. | FE5F Control Type: Visible Red (R) Range mm/in. | High Power (M)* Range mm/in. | Infrared (N) Range mm/in. |
|---|---|---|---|---|---|
| Thru-scan | Plastic fiber<br>FEF-PAT4-M | 1/.04 | 100/3.94 | 200/7.87 | — |
| | FEF-PAT4S-M | 1,5/.06 | 200/7.87 | 400/15.75 | — |
| | FEF-PAT4C-M | 1/.04 curled | 70/2.76 | 140/5.51 | — |
| | FEF-PMT2-M | 1/.04 bendable | 100/3.94 | 200/7.87 | — |
| | FEF-PMT1-M | .5/.02 bendable | 40/1.57 | 80/3.15 | — |
| | Glass fiber<br>FEF-GAT4-M | 1/.04 | — | — | 120/4.72 |
| Diffuse scan | Plastic fiber<br>FEF-PAD6-M | 1/.04 | 30/1.18 | 50/1.10 | — |
| | FEF-PAD6S-M | 1,5/.06 | 50/1.10 | 80/3.15 | — |
| | FEF-PAD6C-M | 1/.04 curled | 15/.59 | 30/1.18 | — |
| | FEF-PMD2-M | 1/.04 bendable | 30/1.18 | 50/1.97 | — |
| | FEF-PMD1-M | .5/.02 bendable | 15/.59 | 30/1.18 | — |
| | Glass fiber<br>FEF-GAD6-M | 1/.04 | — | — | 40/1.58 |

* Scan distances may vary due to condition of fiber at connection to amplifier, and condition of fiber at cut. Diffuse scan distances are measured using a 5 x 5 cm (1.97 in.²) white finish matte paper.

# Collision Avoidance Sensors



## FEATURES

- Multiple scanners are enclosed in a single housing, minimizing wiring and speeding up installation
- Side scanning beam lobes provide 45° vision during turning operations
- These control functions can be set "on-the-fly," without manual intervention:
  - Selection of different operating frequencies to help prevent sensors from interfering with each other with crosstalk
  - Adjustment of frontal beam width to accommodate narrow aisles
  - Adjustment of right and left hand scanning lobes
- Fully adjustable 2-stage scanning system
- 3 meters long, 1 meter wide beam
- Narrow beam in vertical plane minimizes both floor reflection and false triggering

## TYPICAL APPLICATIONS

- Automatic Guided Vehicles (AGVs)
- Self-guided Vehicles (SGVs)
- Overhead Cranes and Hoists
- Driverless Lift Trucks
- Overhead Conveyors

## GENERAL INFORMATION

FE7W Series photoelectric sensors are primarily used to help prevent automatic guided vehicles (AGVs) from colliding with objects or persons in their path. These sensors mount on the front and/or back of AGVs operating indoors in a controlled environment.

Sensor functions are totally flexible and controllable without manual intervention. An on-board programmable logic controller (PLC) may be used to select operating frequencies, frontal beam width, and activate right and left side scanning lobes while the AGV is "on-the-fly," enroute to its next destination

## 2-STEP DETECTION

All FE7W Series sensors have two frontal scanning zones. Both zones are independently adjustable. They enable this 2-step, slow-before-stop operating sequence:

1. AGV speed is reduced if sensor detects an object in the first zone (Output 1), at up to 3 meters.
2. If sensor detects an object in the second, shorter zone (Output 2), at up to 2.5 meters — the AGV stops.

## ADDITIONAL FUNCTIONS

Listings FE7W-DA5K/DB5K are furnished with these additional functions:

1. Width of the frontal scan beam can be either 1 meter (39 in.) or 0,3 meter (11.8 in.) to accommodate narrower aisleways.
2. Right and left scanning lobes can be activated individually as the vehicle turns.
3. Eight selectable frequencies, instead of the four provided by FE7W-DA5 and FE7W-DB5. See Order Guide.

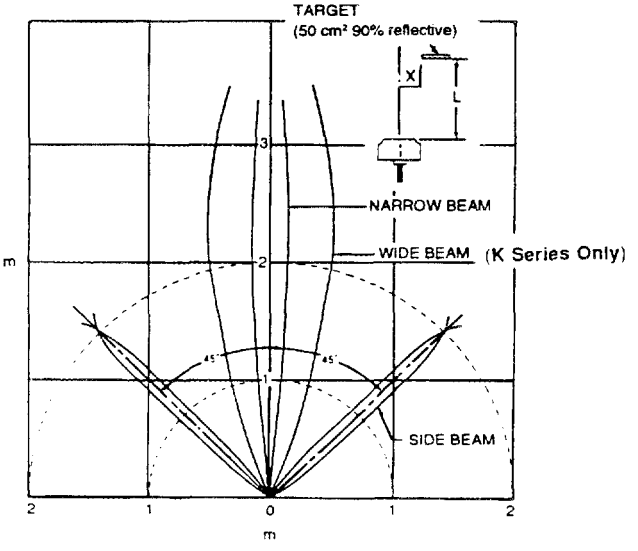
## FE7W ORDER GUIDE

| | | Catalog Listings | |
|---|---|---|---|
| NPN Output | Normally Open, Light Operate | FE7W-DA5K | FE7W-DA5 |
| (Sinking) | Normally Closed, Dark Operate | **FE7W-DB5K** | FE7W-DB5 |
| Function | Detection width variable | Yes | No |
| | Left and right detection | Yes | No |
| | 2-Step detection | Yes | Yes |
| | Frequency variable | 8 kinds | 4 kinds |

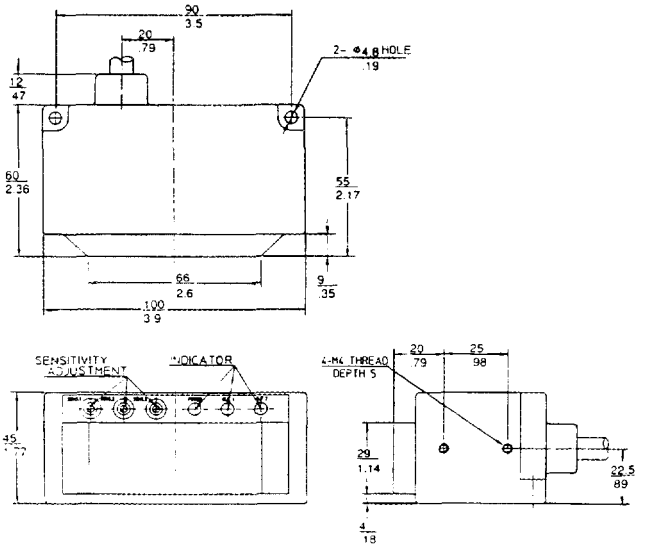
* Cable length for catalog listings above is 2 m (6.6 ft.). To specify 5 m (16.4 ft.) cable, add a -L5 suffix, e.g., FE7W-DA5K-L5. For 10 m (32.8 ft.) cable, add -L10.

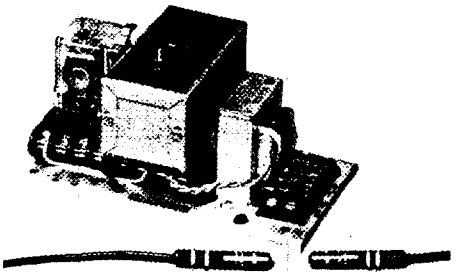
## EFFECTIVE BEAM SHAPE

**Horizontal (Top view, typ.)**




## TYPICAL DIMENSIONS (For reference only)





**FEATURES**

**LED Emitters And Photoreceivers**

- Up to 30-foot thru scan range
- Sealing: NEMA 1, 3, 4, 12 and 13
- Discrete emitters and receivers
- Remote sensing
- Small package size

**Amplifier Modules**

- Dual indicator LEDs (FE-MLS-TR3)
- Alignment and output LEDs (FE-MLS-TR5-14)
- Adjustable sensitivity
- Selectable light or dark operated
- Short circuit and false pulse protection
- Synchronous detection
- Time delay and pulsed logic modules
- Interchangeability with existing TRB control bases
- Color coded logic identification

**THRU SCAN LED EMITTERS AND PHOTORECEIVERS ORDER GUIDE**

| Description | Catalog Listing |
|---|---|
| 0.25 inch diameter tubular Delrin plastic housing LED emitter. Recommended thru scan range 3.5 feet. | **FE-MTE1** |
| 0.25 inch diameter tubular Delrin plastic housing photoreceiver (receiver). Use with FE-MTE1. | **FE-MTR1** |

**AMPLIFIER MODULES ORDER GUIDE**

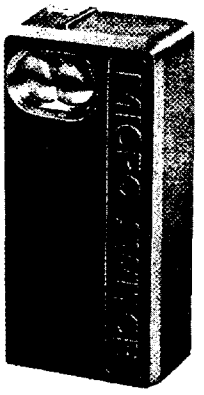
| Description | Catalog Listing |
|---|---|
| A simple ON-OFF amplifier circuit that responds immediately to a sufficient change in light at the phototransistor. The output is ON for the duration of the input signal. | **FE-MLS-TR3** |
| A combination ON and OFF delay circuit output which turns ON only if the input signal exceeds the preset ON delay. After the input signal ends the output remains ON for the duration of the preset OFF delay. 0.15 to 15.0 seconds typical range. | FE-MLS-TR5-14 |

**CONTROL BASES ORDER GUIDE**

| Description | Catalog Listing |
|---|---|
| Standard 2-socket, 115 VAC input model with plug-in DPDT relay. | **FE-TRB** |

# Photoelectric Controls
## Long Range

*MLS8C/9C Series*



### GENERAL INFORMATION

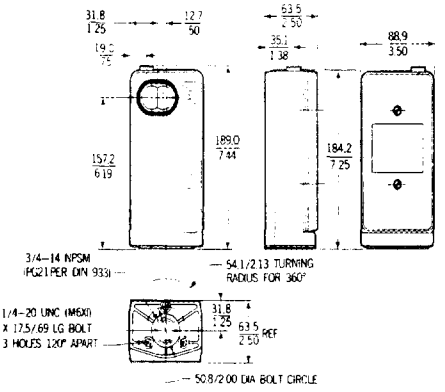
The controls provides On-Off response without a plug-in card or jumper. Optional logic function cards plug in for time delay, pulse, or other modified output. With or without logic card, the FE-MLS8C can be set to respond either to a dark signal (beam blocked) or a light signal (beam not blocked). FE-MLS8C cannot be disabled (for selective response to input signals).

Multi function logic card 0.15 to 15 sec. order FE-LCA1.

### FEATURES

- 40-foot retroreflective 15 foot polarized scan range with FE-RR1 reflector
- 5 or 9-foot diffuse scan range
- Self-contained AC operation
- Sealing: NEMA 1, 3, 4, 12 & 13
- UL listed
- Excellent immunity to ambient light and electrical noise
- Gunsight for easy mechanical alignment
- Enhanced sensitivity control
- False pulse protection in all power conditions
- Polycarbonate housing for strength and durability
- Easy wiring

### TYPICAL DIMENSIONS
(For reference only)




### RETROREFLECTIVE SCAN ORDER GUIDE

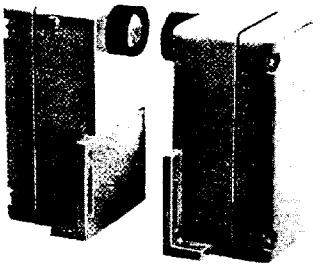
| Description | Catalog Listing |
|---|---|
| Immediate response (ON-OFF) with standard DPDT relay 115 AC input | **FE-MLS8C** |
| Immediate response (ON-OFF) with standard DPDT relay 115 AC input, polarized | **FE-MLS8C-P** |
| Immediate response (ON-OFF) with standard DPDT relay 198 to 264 VAC, 50/60 Hz input | FE-MLS8C-T230 |
| Immediate response (ON-OFF) with 22-26 VAC or 20-30 VDC DPDT relay | FE-MLS8C-T24 |

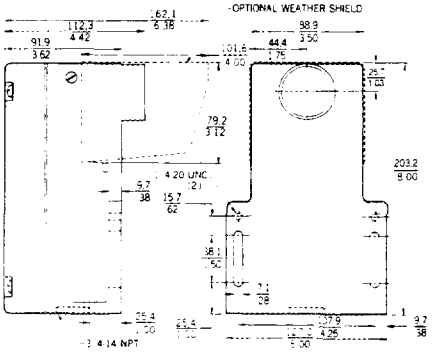
### DIFFUSE SCAN ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| 115 VAC input, immediate response (ON-OFF) with standard DPDT relay; 9-foot scan range | **FE-MLS9C** |
| 115 VAC input, immediate response (ON-OFF) with standard DPDT relay; 5-foot scan range | FEMLS9C-SR |

# Photoelectric Controls
## Long Range

*MLS2B Series*






### GENERAL INFORMATION

No logic circuit card is needed for simple ON-OFF response. The relay remains energized despite power loss for up to four line cycles (approx. 70 msec.). If flooded with intense ambient light, the control output locks off, rather than triggers. The receiver cannot be externally disabled (for selective response to input signals).

### FEATURES

- 2500-foot thru scan range
- *Self-contained AC operation*
- Sealing: NEMA 1, 3, 4, 12 & 13*
- UL-CSA listed
- High intensity LED pulsing for penetrability
- Alignment indicators
- False pulse and line transients protection
- Sensitivity adjustment
- Built-in L.O.-D.O. mode switch
- *Plug-in earphone alignment aid*
- Plug-in 10 amp DPDT relay
- Cast aluminum housing

### THRU SCAN ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| Emitter — 115 VAC input | **FE-MLS2EB-LR** |
| Receiver — 115 VAC input | **FE-MLS2RB-LR** |
| ON delay logic card 0.5 to 12 sec. | FE-LOG5 |
| OFF delay logic card 0.5 to 12 sec. | FE-LOG5R |

# Discrete Light Sources and Photoreceivers

## GENERAL INFORMATION

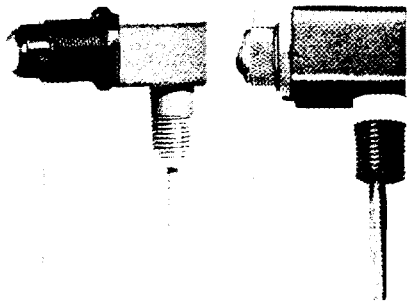
Discrete (separate) light sources and photoreceivers, like incandescent scanners, must be wired to a control base.

Most of the light sources contain an incandescent lamp, though a few contain a non-modulated, visible beam light-emitting diode (VLED). The photoreceiver contains either a low-impedance cadmium selenide photocell, or a high-speed, temperature-stable silicon phototransistor that responds to the incandescent lamp or VLED beam. The photosensor output signal is conditioned and amplified to operate the control base output device. **For information on photoreceivers in series and parallel, max. scan distance and beam image sizes see Industrial Catalog.**

## TEMPERATURE RANGE

The temperature range for light sources and photoreceivers—is 40°F to 158°F (–40° to 70°C), unless noted otherwise in the individual descriptions. (Ambient temperature for VLED light sources may extend lower, depending on the operating current's effect on diode internal temperature.)

## CAST ALUMINUM HOUSINGS



## TUBULAR ALUMINUM HOUSINGS

TPCOL

TPC2L

## PHOTORECEIVER ORDER GUIDE

| Description | Sensor | Listing |
|---|---|---|
| Standard general purpose photoreceiver with adjustable focus. | Plug-in photocell | **FE-PC1L** |

## LIGHT SOURCE ORDER GUIDE

| Description | Lamp | Listing |
|---|---|---|
| Standard general purpose light source with adjustable focus. Typical max. scan: 3-5 feet. | #12 plug-in lamp rated at 5,000-hour life at 150 mA, 6.3 VAC (or VDC) | **FE-LS1C** |
| Typical max. scan: 5-10 feet; adjustable focus. | #15 plug-in lamp rated for 10,000-hour life at 340 mA, 5.5 VAC (or VDC) | **FE-LS1LC** |

## PHOTOCELL ORDER GUIDE

| Description | Sensor | Listing |
|---|---|---|
| Smallest photoreceiver | Potted photocell | **FE-TPCOL** |
| Similar to TPCOL, but with phototransistor high-speed response and 180°F (82°C) upper temperature limit. | Potted phototransistor | **FE-TPCO4F** |
| Threaded housing; 10° field of vision | Potted photocell | **FE-TPC2L** |
| TPC2L with a blue-green filter for registration control of red/orange/brown registration marks against a lighter background. | Potted photocell | **FE-TPC2LBG** |
| Narrow 4° field of view for use in bright ambient light, or to detect smaller objects. | Potted photocell | FE-TPC3L |
| Similar to TPC2L, but with phototransistor high-speed response and 180°F (82°C) upper temperature limit. | Potted phototransistor | **FE-TPC4LF** |

## LIGHT SOURCE ORDER GUIDE

| Description | Lamp | Listing |
|---|---|---|
| Smallest size light source, 0.25 inch diameter. Typical max. scan: 3-4 inches; fixed focus. | Potted lamp rated for 100,000-hour life at 60 mA, 5 VAC (or VDC) | **FE-TLS1++** |
| Typical max. scan: 2-3 feet; adjustable focus. 0.38 inch diameter. | #7349 plug-in lamp rated for 5,000-hour life at 200 mA, 6.3 VAC (or VDC) | **FE-TLS3** |

++ Low-voltage (5 VAC) light source to be used only with G4B2, TRB1, or PE2-2 control base. These bases are standard control bases with a 10-ohm, 5-watt resistor wired in series with the LAMP terminals. A standard base can easily be adapted for low-voltage lamp use by wiring in the resistor.

## VISIBLE LED (VLED) LIGHT SOURCES ORDER GUIDE

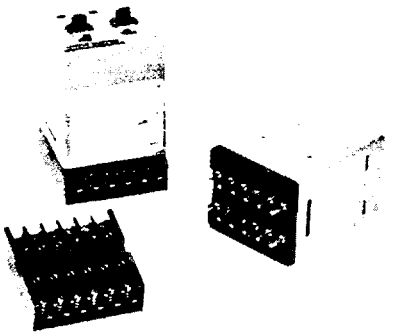
**(Not modulated, emits red visible light)** (For extremely long life; vibration and shock resistant.)

| Description | LED | Listing |
|---|---|---|
| Typical max. scan: 2 feet. Adjustable focus. Plug-in LED. Cast aluminum housing. | Rated for 100,000-hour life at 50 mA, 3-20 VDC | FE-TLD1 |

A 270-ohm, 3-watt current-limiting resistor is included with each VLED light source.

# Control Bases
## Self-contained

*FEC Series*



### GENERAL INFORMATION

The FEC control base is designed for use with all MICRO SWITCH 12 VDC 3-wire current sinking photoelectric controls. The control base is self contained and provides up to 100 mA load current to the sensors. It is offered in two versions; a standard control base with sensor On or Off operating mode switch and a 0.1 to 5 seconds On/Off-delay or one shot pulse control base with sensor On or Off operating mode switch. Standard items on both bases include a transformer that converts 110 or 220 VAC 50/60 Hz input to 12 VDC ±10%, a SPDT, 3 amp 250 VAC relay and LED indicators for Power, Input and Output.

### FEATURES

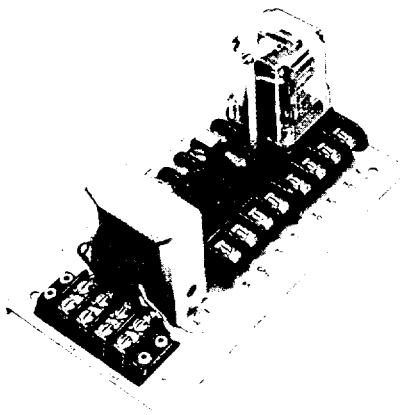
- Self-contained 110 or 220 VAC input
- AC to DC rectifier
- Compact
- SPDT, 3 A/250 VAC relay output
- Available in On/Off and On/Off delay or one shot pulse (.1 to 5 seconds)
- Three LED indicators for power On, input and output
- External inhibit function
- Easy terminal wiring and plug-in module capability
- Sealing: NEMA 12

### FEC SERIES ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| Standard On/Off control with sensor On or sensor Off mode selector switch. Supplies 12 VDC @ 100 mA. | **FEC-AS2-M** |
| On/Off delay (0.1 to 5 seconds) or one shot pulse with sensor On or sensor Off mode selector switch | FEC-AD2-M |

# Control Bases
## Modular

*TRB*



**TRB** 4.25"H x 3.75"W x 7"L

### GENERAL INFORMATION

TRB control bases include a transformer that steps line voltage down to power either a separate light source wired to the base, and a TR amplifier/logic module or an MLS-TR amplifier module (ordered separately).

TRB bases are available with two octal sockets (for an amplifier and an output device).

### TRB ORDER GUIDE

| Description | Catalog Listing |
|---|---|
| 115 VAC input model with plug-in DPDT relay. Standard 2-socket. Supplies 15 VDC @ 250 mA. | **FE-TRB** |

PANAMETRICS

# TRANSPORT™ PT868
## *PORTABLE LIQUID FLOWMETER*

***The TransPort is the smallest, lightest, full-featured transit-time flowmeter available. Despite its small size, it includes big features such as the capacity for 43,000 data points, 20 site location parameters, on-line pipe tables, graphic or alphanumeric LCD display and the ability to calculate energy flow.***

## *OVERALL SPECIFICATIONS.*

**Flow Accuracy:** *(% of reading with clamp-on transducers)*

Velocity > 1 ft/s (> 0.3 m/s), ±2% typical or ±0.5 to 1% calibrated accuracy.

Velocity ≤1 ft/s (≤0.3 m/s), ±0.03 ft/s (±0.01 m/s) maximum error*.

**Range:**

–40 to 40 ft/s (–12.2 to 12.2 m/s).

**Rangeability:**

400:1.

**Repeatability:**

±0.2% to 0.5% (clamp-on transducers).

**Energy Accuracy :**
*(% of reading)*

The accuracy of the energy measurement is a combination of the accuracy of the flow and temperature measurements.

Accuracy of 1% is typical for calibrated systems.

*Note:* Above specifications require straight run of 10 diameters upstream and 5 diameters downstream.

## *ELECTRICAL SPECIFICATIONS.*

**Internal Batteries:**

*Batteries:*

4 C-size NiCd high-energy rechargeable batteries.

*Battery Life:*

8 to 10 h of continuous operation typical.

*Recharge Time:*

16 to 20 h using external charger.

**Power Supply/Charger:**

*Input:*

100/120/200/260 VAC ±10%, 50/60 Hz, 5 W maximum.

*Output:*

12 VDC unregulated.

*Note:* The unit may also be powered/ charged by any regulated DC source that provides spike-free voltage of 10 to 28 VDC.

**Dimensions:**

*Size:*

5 x 9 x 2.3 in. (12.7 x 22.9 x 5.8 cm).

*Weight:*

2.2 lb (1 kg).

**Environmental:**

*Operating Temperature:*

14° to 122°F (–10° to 50°C).

*Storage Temperature:*

14° to 122°F (–10° to 50°C).

*Note:* To ensure maximum battery life, storage temperature exceeding 95°F (35°C) is not recommended for long periods of time.

**Operating Modes:**

*Flow Measurement:*

Transit-time clamp-on or wetted transducers.

*Energy:*

2 loop powered temperature transmitter inputs to calculate energy flow.

*Specifications continued on overleaf.*

* In most normal single-phase situations.

## *Electrical Specifications. (continued)*

### Input/Output Specifications:

***Keypad:***

30-key tactile feedback membrane keypad.

***Display:***

64 x 128 pixel LCD graphic display.

***Printer/ Terminal:***

One RS232 port for printer, terminal or PC.

***Analog Output:***

One 0/4 to 20 mA current output (550 Ω maximum load).

***Analog Input:***

Two 4 to 20 mA analog inputs with switchable 16 V supply for loop powered temperature transmitters.

***Acoustic:***

One pair of LEMO® coaxial transducer connectors.

Cable length 25 ft (8 m) standard, Up to 1000 ft (305 m) optional.

### Operational Specifications:

***Site Parameter Programming:***

Menu driven operator interface using keypad and "soft" function keys.

On-line help functions including pipe tables.

Storage for saving parameters for up to 20 sites.

***Data Logging:***

Memory capacity to log over 43,000 flow data points.

Keypad programmable for log units, update times, start and stop time.

***Display Functions:***

Graphic display shows flow in numeric or graphic format.

Also displays logged data.

***Printer Output:***

Supports several thermal and impact printers.

Output data in numeric or graphic ("strip chart") format.

## *Transducer Specifications.*

### Ultrasonic Transducers:

***Temperature Range (Clamp-On):***

–40° to 212°F (–40° to 100°C), standard.

–328° to 500°F (–200° to 260°C), optional.

***Frequency (Clamp-On):***

1 MHz, standard.

500 kHz, 2 MHz, 4 MHz, optional.

***Note:*** Transducers for special applications are available. Flowcells are also available. Consult factory for details.

***Mounting:***

Chain, strap or magnetic slide-track mounting fixtures.

### Temperature Transducers:

Loop powered 3-wire platinum RTD's; Clamp-on and wetted (thermowell) types are available.

***Accuracy:***

0.1°C, wetted RTD's (matched pairs).

***Range:***

–4° to 500°F (–20° to 260°C).

## *Available Options.*

### Thickness Measuring Mode:

***Transducer:***

Panametrics dual element transducer.

***Pipe Thickness Range:***

0.05 to 3 in. (1.3 to 76.2 mm).

***Pipe Materials:***

Most standard metal and plastic pipe materials.

***Accuracy:***

±1% typical or ±0.002 in. (±0.05 mm).

***Display Resolution:***

0.001 in. (0.01 mm).

## *Pipe Size & Materials.*

### Clamp-on Transducers:

***Materials:***

All metals and most plastics. (Consult the factory for concrete, composite materials and highly corroded or lined pipes.)

***Pipe Sizes:***

Outside diameter (OD) 0.5 to 200 in. (12.7 mm to 5 m).

***Pipe Wall Thickness:***

Up to 3 in. (76.2 mm).

### Wetted Transducers

***Materials:***

All metals and most plastics. (Consult the factory for concrete, glass, and cement.)

***Pipe Sizes:***

Inside diameter (ID) 0.04 to 200 in. (1 mm to 5 m).

**PANAMETRICS**

**MAIN OFFICES:**

Panametrics, Inc., 221 Crescent Street
Waltham, MA 02154-3497, USA
Phone 617-899-2719 • Toll Free 800-833-9438
Fax 617-894-8582

Panametrics, Ltd.
Shannon Airport, Shannon, Ireland
Phone 061-471377 • Telex 72161
Fax 061-471359

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# APPENDIX G
# LASER RANGEFINDERS

CRC

# Coleman Research Corporation

December 10, 1993

Mr. David Holcomb
Oak Ridge National Laboratory
Instrumentation and Controls Division
P.O. Box 2008
Building 3500
Oak Ridge, TN 37831-6010

Dear Mr. Holcomb:

Enclosed is the information you requested pertaining to Coleman Research Corporation's (CRC) coherent FMCW laser radar. One fiber-optic based system was delivered to NASA Langley Research Center this year and is operating there now. Its performance specifications meet the NASA requirement and are depicted on the enclosed product sheet. We are currently building a system with significantly enhanced speed and accuracy which will be operating next year. It will also incorporate several features not in the delivered NASA system such as an automatic focus tracking mode and a Doppler recovery mode to enable precise measurement of moving objects.

Should you have further questions please contact me.

Sincerely,

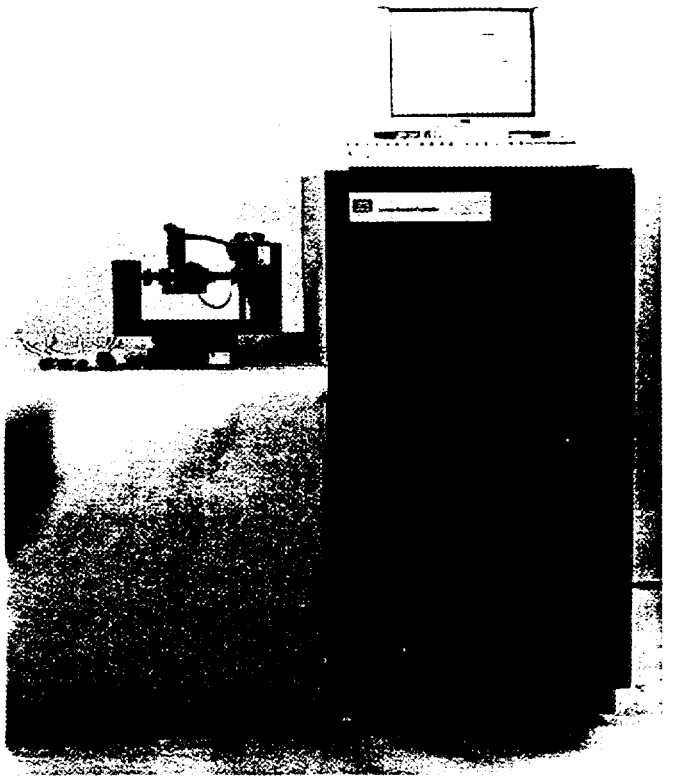
Steve Webber
Director of Operations

Enclosure

6551 Loisdale Court, Suite 800 • Springfield, Virginia 22150 • (703) 719-9200 • Fax: (703) 719-9229

# *Fiber-Optic Laser Measurement System*

**Coleman Research Corporation (CRC)** is pioneering the field of fiber-optic coupled laser radar. Our ***Fiber-Optic Laser Measurement System*** offers the inherent flexibility and ruggedness associated with a fiber-optic based approach unachievable with bulk optics (lenses and mirrors). The **CRC *Fiber-Optic Laser Measurement System***, pictured at right, offers unique capabilities and overcomes the shortfalls of other laser measurement technologies. Performance enhancements in both speed and accuracy can be provided.



## Technical Approach

- Coherent Laser Radar (CLR) using 70 GHz laser diode FM bandwidth
  - High measurement accuracy, speed, and range at **eyesafe** power levels
  - Measures any ordinary surface without the aid of retro reflectors or cooperative targets
  - Focused beam for superb angular determination
  - Immune to ambient lighting conditions (sunlight to total darkness)/surface shading or color
- Fiber Optic Coupled Components
  - Light weight, reliable, compact, economical to manufacture
  - Longer measurement range
  - Multiplexing for multiple scanners with a single receiver/transmitter unit
  - Scanners remoted from receiver/ transmitter
- Built-in Capability for Measurement Transformation and Formatting

CRC

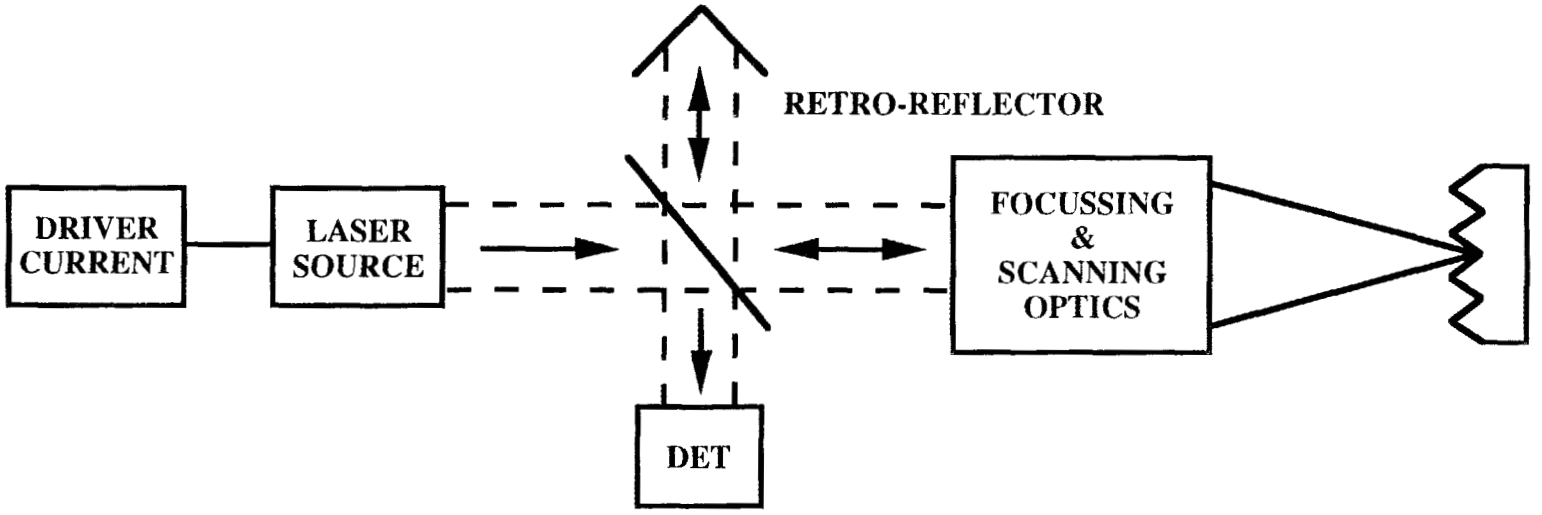
**Coleman Research Corporation**
***Digital Signal Division***
6551 Loisdale Court, Suite 800
Springfield, Virginia 22150
(703) 719-9200
FAX (703) 719-9229

# Coherent Laser Radar
# (CLR)

# Technical Approach

- **Coherent Laser Radar (CLR) using a very widely FM tuneable laser diode**
  - Immune to ambient lighting conditions (darkness, sunlight, flourescent, incandescent, etc.)
  - Yields high measurement accuracy, speed and range <u>at eyesafe power levels</u>
  - Measure off almost any surface
  - Focused beam → superb angular determination
- **Fiber coupled optical components**
  - Light weight, reliable, economical to manufacture
  - FO circuit design allows long measurement range
  - FO multiplexing enables multiple scanners with one receiver/transmitter
  - Portability
- **On-board capability for measurement transformation and formatting**
- **Industry standard hardware and software interfaces**
  - Major components developed with commercial-off-the-shelf products

# FMCW Coherent Laser Radar (CLR)




## CLR Principle of Operation

- Laser optical frequency swept linearly with time
- Laser light divided into transmitted and local oscillator beams
- Energy received from target is combined with local oscillator to achieve coherent detection
- Difference frequency generated due to laser sweep and round trip delay is proportional to range

# The Performance Advantage of FM Conerent Laser Radar (CLR)Provides the Technical Solution for 3-D Mapping

- Accuracy (average range error) Proportional to (1/Bandwidth)
- Speed (measurements/second) Proportional to $(\text{Bandwidth})^2$
- The Optical Bandwidth Employed by the FM Coherent Laser Radar Yields a Substantial Speed and Accuracy Advantage:

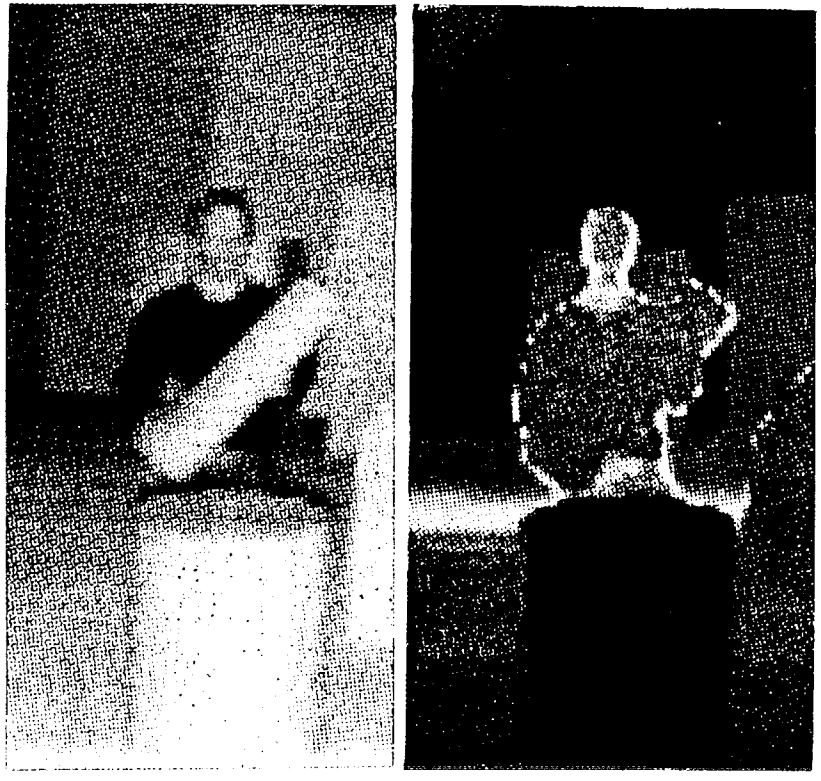
AM laser radar bandwidth (2 - 4 GHz)

FM Coherent Laser Radar bandwidth (200 - 300 GHz)

- No Susceptability to Lighting or Surface Shading
- Eyesafe

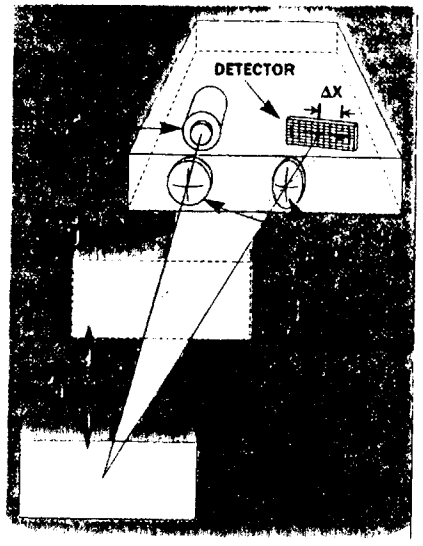
# Problems With Currently Available 3-D Mapping Technology

**AM Laser Radar:**



- Inaccurate 3-D Maps Because of Amplitude Bias (dark areas look closer than light area)
- Requires Controlled Lighting Conditions

**Structured Light:**




- Requires Frequent Camera Movement to Achieve Accurate Triangulation
- Requires Controlled Lighting Conditions

# FMCW Laser Radar

## Accuracy vs Integrated Measurement Time

## 2 cm Aperture, $10^{11}$ Hz FM Chirp, 10M Range

| T | $\sigma_R$ |
|---|---|
| $10^{-4}$ sec | 0.013 mm |
| $10^{-3}$ sec | 0.0042 mm |
| $10^{-2}$ sec | 0.0013 mm |

# Coherent Laser Systems

| | Performance: | Measurement: | Output: | Application: |
|---|---|---|---|---|
| **3-D Mapper**<br>*("Magic Flashlight")* | Emphasis on Accuracy | MAPS ONCE<br>Programmable Computer-Controlled Aiming of Beam<br>• Accommodate Complex or Plain Surface via Density of Measurements<br>• Track a Single Moving Object and Map its Movement | 3-D Map of an Unchanging Object or Structure | **3-D Precision Mapping**<br>- Map stable or slowly varying facility<br>**Directed high resolution feature mapping**<br>- features such as bumps, cracks, waviness or roughness<br>- small part/object recognition<br>- Precision Machining Measurement<br>**Precision end effector tracking**<br>- sensor positioning for characterization<br>- high precision tool positioning |
| **Vision System**<br>*("Robot's Eyes")* | Emphasis on Speed | CONTINUOUSLY MAPS<br>Raster-Scanned Beam–<br>• Scan Entire Scene to Provide CONTINUOUS UPDATE as Scene Changes<br>• Track all Movements Throughout the Scene | Real-Time Image of a Changing Scene – 3-D Digitized Data | **D & D**<br>- Automated robot control (navigation, obstacle avoidance, manipulator positioning with precision "target" correlation)<br>- Detection of changes in conditions (leaks, bulges, ruptures in containers) |

Same Fiber-Optic Laser Radar Base Technology with Different Scanning and Processing Concepts

Fiber-Optic construction - resistant to shock and thermal effects - more economic to manufacture and maintain

Computerized, Calibrated Eyes -- Not Degraded by Ambient Lighting, Color, or Shading

Robots will be able to perform autonomously because they vs. the operator can see with 3-D detail

CDB/93-061.7

SPAR

# SPAR AEROSPACE LIMITED
## ADVANCED TECHNOLOGY SYSTEMS GROUP

**9445 Airport Road**
**Brampton,L6S 4J3**
**Ontario,Canada**
**FAX No. (905) 790-4400**
**FAX VERIFICATION No. (905) 790-2800 Ext; 4113**
**TELEPHONE No. (905) 790-2800**

## TELECOPIER MESSAGE TRANSMITTAL

**(LEAD SHEET)**

**THIS TRANSMISSION CONSISTS OF 3 SHEETS PLUS LEAD SHEET**

**TO:** Mr. David Holcomb

**COMPANY:** Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, Tennessee 37831
U.S.A.

**FAX NUMBER:** (615) 574-4058

**FROM:** Cor van Kemenade

**PHONE:** (905) 790 2800 Ext.: 4707

**SUBJECT:** Preliminary Specification for a Rad Hard Laser Scanner

**DATE:** 9 December 1993

**Number:**_____

**Date:**_____

**Time:**_____

**Operator:**_____

**Dear David,**

**Further to our conversation of this morning, I have attached a copy of the preliminary specification for SPAR ATSG's Rad Hard Laser Scanner. A outline drawing is attached to the spec.**

**Unfortunately, the info I gave you over the phone was not quite correct. The outline drawing is actually being changed right now, but I don't have an update yet. I will sent you one as soon as possible.**

**Keep in mind though that this scanner is a true 3D scanner based upon a triangulation principle developed and patented by NRC and build by SPAR under a licence agreement with NRC. As a consequence of the triangulation methodolog, one will always have a larger sized sensorhead that will definitely not go through a 3" riser. In my opinion, you would have a hard time getting any type of robotic arm through such a riser anyway. The head itself contains a minimal amount of Electronics which allows for relatively easy radiation hardening.**

**I hope that this will give you sufficient information initially. Don't hesitate to call me if you have any questions.**

**Sincerely,**

**Cor van Kemenade**

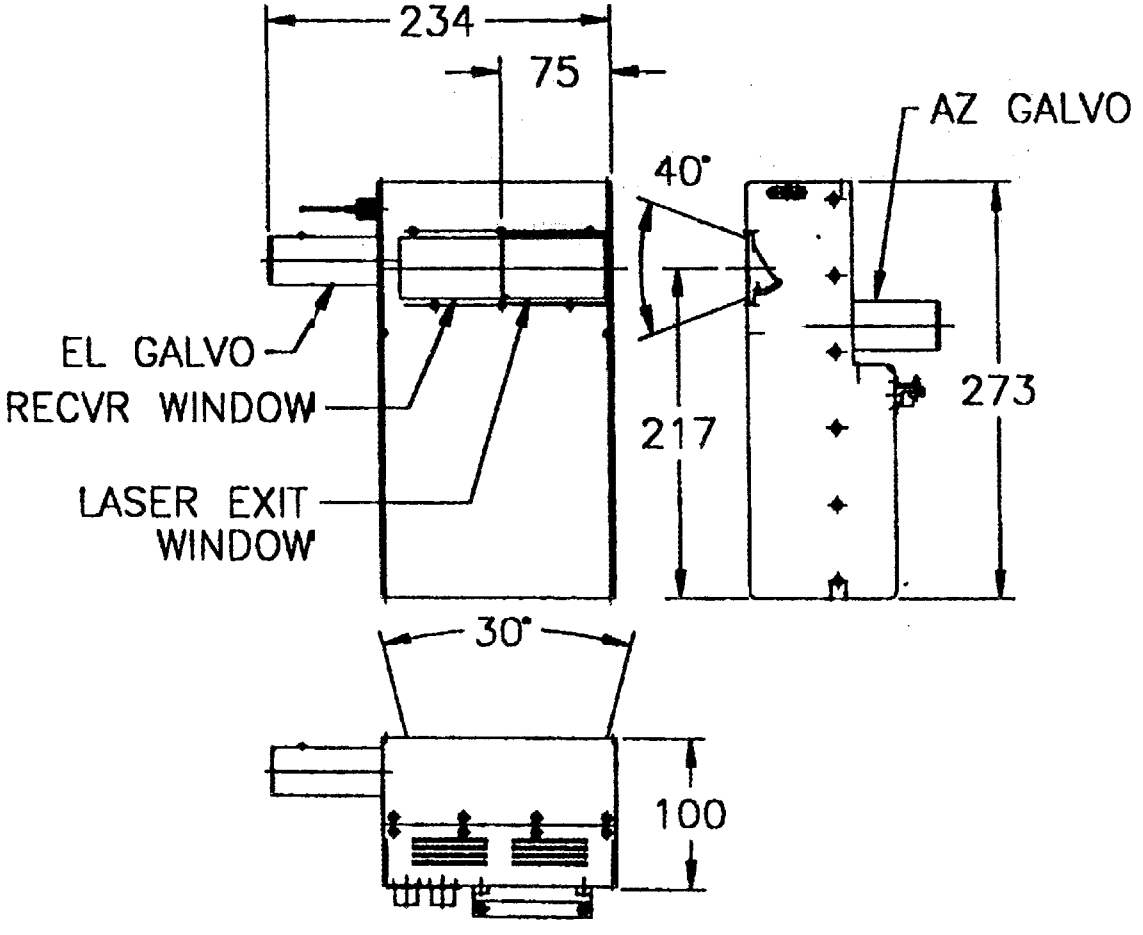
SPAR

## Laser Scanner Specifications*

# PRELIMINARY

| | |
|---|---|
| Field of View | 30 degrees X<br>50 degrees Y |
| Image Size | 512 x 512 |
| Image Acquisition Time | 5 seconds nominal |
| Minimum Range | 0.6 meters |
| Maximum Range | 10 meters nominal |
| Range Precision | 0.2 mm @ 0.6 meters<br>25 mm @ 10 meters |
| Range Accuracy | ≤ 5 times the range precision |
| Camera Head Dimensions | See drawing<br>All dimensions in millimeters |
| Camera Head Weight | ≤ 9 lbs |
| Camera to Control Electronics Separation | 10 meters maximum<br>(25 meters goal) |
| Control Electronics Size | TBD (19" rack mount) |
| Electronic Interfaces | TBD (BIT3 communications) |
| Camera Head Radiation Tolerance (γ) | 1 MRad (Si) total dose<br>(100 MRad (Si) goal) |

* Specifications are subject to change


234
75
AZ GALVO
40°
EL GALVO
RECVR WINDOW
LASER EXIT WINDOW
217
273
30°
100

# APPENDIX H
# ACCELEROMETERS

# Analog Dialogue

A forum for the exchange of circuits, systems, and software for real-world signal processing

**SINGLE-CHIP SURFACE-MICROMACHINED ACCELEROMETER (page 3)**

**Pulsewidth modulator increases laser-printer resolution (page 10)**

**High-performance ICs in single-supply analog circuits (page 15)**

Complete contents on page 3

Volume 27, Number 2, 1993

ANALOG DEVICES

# A Surface-Micromachined, Monolithic Accelerometer

## ADXL50 : the first commercially available surface-micromachined device. All signal-conditioning circuitry is on-chip

by Bill Riedel

The ADXL50* is a complete acceleration measurement system on a single monolithic chip. It's based on a differential capacitive, surface-micromachined polysilicon accelerometer integrated with signal conditioning circuitry, including a TTL-compatible self-test feature. The ADXL50 measures accelerations from 0 *g* to ±50 *g* with bandwidth from dc to 1 kHz, producing an output voltage proportional to the acceleration. This makes it the first commercially available monolithic device to successfully incorporate traditional electronic semiconductor circuits with micromachined structures.

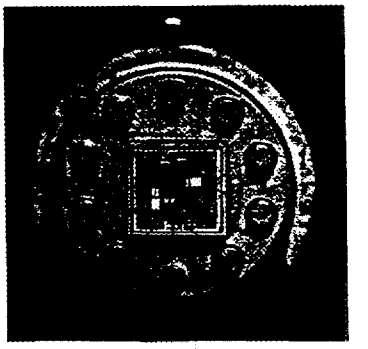
The ADXL50 is fabricated on Analog Devices' conventional BiCMOS production line which has been used extensively in the company's high-performance mixed-signal products. A surface-micromachining process produces tiny, highly complex mechanical structures from silicon (see sidebar on page 5, "Silicon that moves"). Since it uses many of the processing steps ordinarily used to manufacture traditional linear circuits, surface-micromachining lends itself readily to producing devices which combine both micromachined (mechanical) and semiconductor (electronic) elements on the same die. The ADXL50, exploiting this attribute, includes all necessary signal-conditioning, excitation, and test circuitry. Three external capacitors and a +5-volt regulated power supply are all that is required to measure accelerations to ±50 *g*.

The micromachined sensor behaves electrically like a variable differential capacitor operating in a force-balance electronic control loop. The result is a measuring system that, unlike piezoresistive micromachined devices, is inherently stable over wide temperature ranges and—because it balances electrostatic force against acceleration force—is relatively independent of the mechanical properties of silicon. This force-balanced design also produces a very linear response due to the resulting minimal physical excursion of the beam during a broad range of acceleration values; typical nonlinearity is <0.2%.

A unique capability of the ADXL50 is a digitally activated self-test function which allows the sensor beam to be electrostatically deflected at any time to verify the integrity of the sensor element. This tests its ability to respond to an acceleration force (and provide a warning in case of malfunction)—a "must" in applications such as airbag systems in automobiles.

### MEASURING ACCELERATION

Conventional techniques for detecting and measuring acceleration are all founded on principles first discovered by Newton and



outlined in his *Principia* in 1687. Newton's classical view holds that acceleration of a constant mass implies a force ($F = ma$, where $F$ is force, $a$ is acceleration, and $m$ is mass). Most accelerometers operate by detecting the restoring force exerted on a mass by an elastic restraint.

Consider a simple mechanical system consisting of fixed mass, $m$, attached to a spring with stiffness, $k$. If the mass is displaced a distance, $x$, due to acceleration, the restoring force of the spring is $F = kx$. Substituting into Newton's equation, we find that $a = kx/m$ and can derive the magnitude of the acceleration by observing the displacement, $x$, of the restrained mass. This fundamental principle is used by even the most sophisticated and expensive electromechanical accelerometers; it is also how the micromachined ADXL50 works.

### SENSOR MECHANISM

Figure 1 shows the layout of the ADXL50 chip. The heart of the chip is the surface-micromachined sensor located at the center of the die (Figure 2). Measuring only 500 μm × 625 μm (less than 1/2 mm$^2$), the ADXL50 sensor resembles the letter "H" when viewed from above. The long, thin legs of the "H" are tethers that anchor the micromachined element to the substrate; they are the only electrical and mechanical contact between the sensor structure and the rest of the chip. The tethers form the spring system

*Use the reply card for technical data. Circle 1

## IN THIS ISSUE

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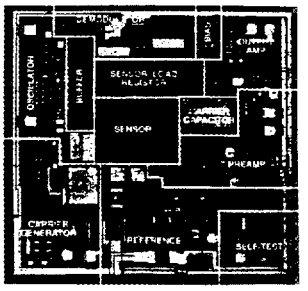



Figure 1. Layout scheme of the ADXL50 chip.

that suspends the central *test* (or *proof*) *mass* (the crossbar of the "H") in tension within a well in the substrate; the mass is free to move in a direction perpendicular to the tethers (along the axis of the "H" crossbar), in the same plane as the substrate surface. When the device is packaged in a TO-100 metal can, the package tab is aligned with the "H" crossbar, showing the direction of sensitivity (see photo on page 3).

Projecting from the central proof mass is a series of regularly spaced filaments resembling the fingers of a comb (Figure 2). Each of these filaments is actually one plate of a series of parallel-plate variable capacitors; the other plates are attached to the chip substrate and interdigitate with the plates attached to the freely moving proof mass. Altogether, 42 moving capacitor plates [interdigitated with the fixed plates], attached to the sensor proof mass, are connected in parallel electrically for a total capacitance of only 0.1 pF. The plates anchored to the moving mass form the central plate of a three-plate differential capacitor structure. The plates anchored to the substrate and interdigitated with the moving plates are alternately connected in parallel; the effect is of two capacitors sharing a common plate, with capacitances of $Cx_0/(x_0 + x)$ and $Cx_0/(x_0 - x)$, where $x_0$ is the center position and $x$ is the deflection caused by the acceleration (Figure 3).

Conceptually, the force exerted on the central proof mass by acceleration or deceleration in the direction of sensitivity causes it to move against the spring force of the tethers. This changes the relative spacing between the moving and fixed capacitor plates. The motion causes a fractional increase of capacitance on one side and a corresponding decrease on the other. The relative change in capacitance is proportional to the magnitude of acceleration, so acceleration can be determined by continually monitoring the electrical effects of capacitance changes.

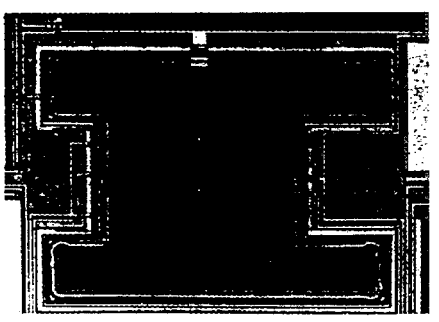


Figure 2. The acceleration sensor. Acceleration axis is vertical.

In actuality, the sensor operates within a force-balance electronic control loop; the proof mass, when accelerated, is restrained from moving (i.e., nulled, in the same manner as the summing point of an inverting operational amplifier) by the application of an opposing electrostatic force, generated by applying an inverted version of the output voltage to the capacitor plates. This feedback produces a system which behaves essentially like one with a much stiffer spring constant (less nonlinearity and good temperature stability).

The physical shape and layout of the ADXL50's capacitive sensor fulfills a requirement for simplicity. The sensor is formed from a single layer of polycrystalline silicon. Since capacitor density [the number of elements with a given capacitance that can be placed within an area] is proportional to $1/d$, *where d* is the width and spacing of the plates, this feature is patterned using extremely fine lithographic fabrication and etching tools. Careful consideration of stresses in the polysilicon which forms the sensor allows these small structures to remain essentially level when suspended freely above the substrate. The sensor tethers—the finest structures—measure about 2 μm on a side and are about 200 μm long. The total physical mass of the measurement beam (proof mass) is less than 0.1 microgram. At rest, the spacing between adjacent capacitor plates is less than 2 μm.

At these dimensions, silicon is highly elastic, easily withstanding shock and vibration—making it an ideal material for constructing finely patterned mechanical structures. In fact, on this scale, silicon has mechanical properties similar to those exhibited by steel at larger dimensions. As a result, the ADXL50's sensor is able to withstand physical shocks of 2000 *g* in any direction without suffering damage or deterioration in performance.

## CIRCUIT TECHNOLOGY

The complete chip measures approximately 9 $mm^2$ and is dominated by the signal-conditioning circuitry, which surrounds the centrally located (< 1-$mm^2$) sensor. The circuitry includes a push-pull oscillator, carrier generator, reference, preamplifier, self-test circuit and an uncommitted output amplifier—providing a high level of system integration (Figure 4*).

The sensor, described earlier, consists of a pair of differentially varying capacitors that respond to the displacement of the mass. Square waves, $V_A$ and $V_C$, at 1 MHz—of equal amplitude but 180° out of phase with one another—are applied to opposite plates of the capacitor pairs. Within each pair of plates, one side is biased to 3.4 V, the other to 0.2 V. The voltage at the proof mass, their electrical node, represents the degree of unbalance. At 0 *g* of acceleration, the central, moving set of capacitor plates is equidistant from each of the substrate-connected outer plates; their capacitances are equal, and—as a result—the two antiphase signals are equally coupled to the central plate and cancel each other, producing a nominal output voltage of 1.8 V (the midpoint of the 0.2-V and 3.4-V biased plates).

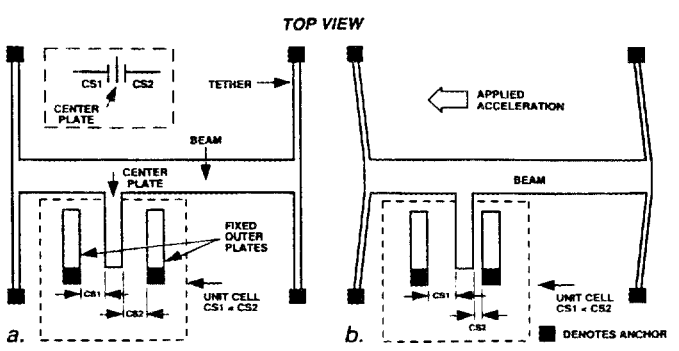



Figure 3. Simplified detail of the acceleration sensor showing one element of the differential capacitor.

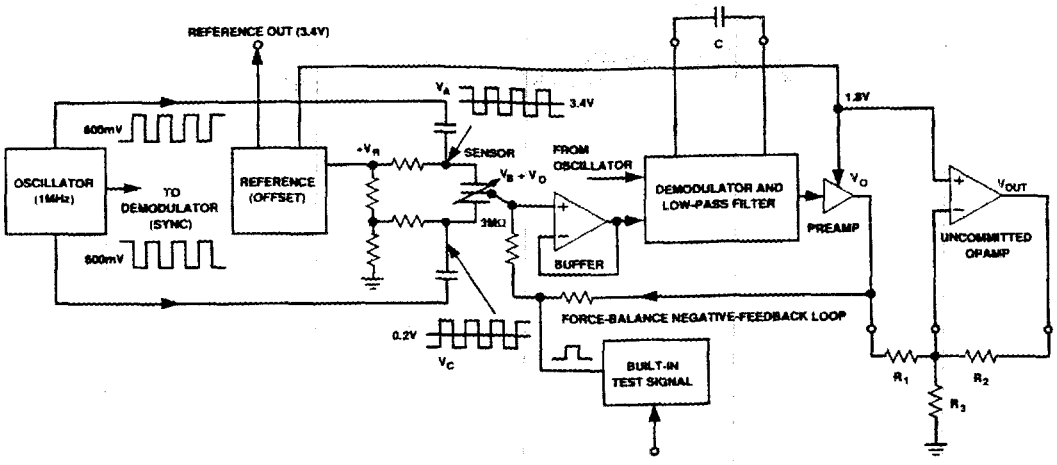



Figure 4. Simplified circuit details, showing the signal-conditioning circuitry and force-balance feedback loop of the ADXL50.

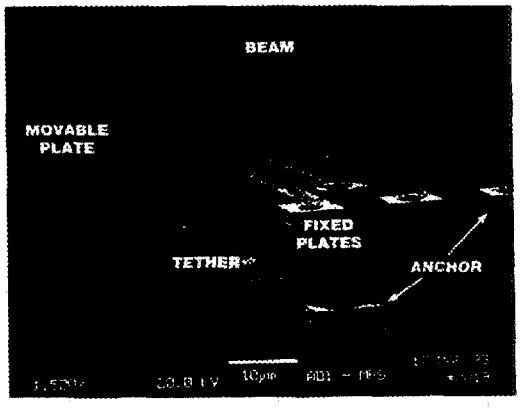
## SILICON THAT MOVES

Micromachining is a processing technique used to manufacture tiny mechanical structures from silicon. A silicon wafer of the type used to make semiconductors can be etched (or modified) to produce small beams, masses, gears, and other structures measuring only a few thousandths of an inch.

Micromachining comes in two varieties: *surface* and *bulk*. Prior to the ADXL50, all the available micromachined devices used bulk micromachining. It was discovered in the 1950s that acid solutions attack different planes of crystalline silicon at different rates, depending on the crystal orientation. By exposing an area of silicon with a specific crystalline structure to acid, cavities with precisely angled walls are created.

**Bulk micromachined** accelerometers have existed for several years. Typically they consist of a membrane or diaphragm of silicon, roughly 10 μm thick, that is vertically formed in the wafer by chemical etching. In the center of the membrane is a large mass of silicon. On the top surface of the device, near the edge of the membrane, thin-film piezo-resistors sensitive to strain and deformation are deposited. Most of the membrane is removed, leaving tethers with these resistors suspending the central mass. Vertical acceleration causes the test mass to move, deforming the diaphragm and changing the resistance of the piezo-resistors. Bulk micromachined devices are large by IC standards—about 20× the size of the surface-micromachined ADXL50. Large size, coupled with the fact that the process for manufacturing bulk micromachines is inconsistent with semiconductor-circuit fabrication techniques, requires that signal-conditioning be off-chip. Bulk-piezo-resistive accelerometers are very sensitive to temperature effects and difficult to test fully.

**Surface micromachining**, a more sophisticated technique than bulk micromachining, creates much smaller, more-intricate and precisely patterned structures. It adapts manufacturing techniques perfected for making ICs to produce mechanical structures close to the surface of the silicon substrate. Chemical machining is accomplished by depositing, then etching, multiple thin films and layers of silicon and silicon-oxide to form complex mechanical structures. The feature dimensions of surface micromachined devices are typically 1 to 2 μm, similar to the feature dimensions of conventional electronic circuits. Most importantly, surface micromachining lends itself to the inclusion of conventional electronic circuitry on the same die. Thus, the surface-micromachined ADXL50 includes signal conditioning, resulting in a fully scaled, -referenced and -temperature-compensated volt-level output. Surface-micromachining leverages the cost economies of standard IC wafer-processing techniques, producing a highly integrated product at low cost.




When the sensor experiences acceleration along the axis of sensitivity, the separations between adjacent plates will become unequal; one capacitance will increase while the other decreases. The 0.1-pF total capacitance generated between the beams changes by ±0.01 pF for ±50-*g* accelerations. The sensor structure can actually resolve as small a change as 20 *atto*farads ($20 \times 10^{-18}$ F), corresponding to a beam displacement of 0.2 Å. This resolution is a consequence of the precision of the associated signal-conditioning circuitry.

The output from the sensor array is a biased high-impedance square wave, $V_B$. This output is buffered and presented to the input of a phase-sensitive demodulator, which is synchronized with the 1-MHz carrier; it rectifies and low-pass filters the signal. The single-pole filter's cutoff frequency is established by a single external capacitor; for example, 25 nF for 1 kHz.

The synchronous demodulator drives a preamp, which is referenced to +1.8 volts. The output of the preamp is fed back to the sensor through a 3-MΩ isolation resistor. This feedback voltage, applied to the sensor plates as a bias, causes an electrostatic restoring force to oppose the sensor's motion. In effect, the force-balance control loop acts to keep the sensor from moving, holding it close to its at-rest position. The correction voltage required to hold the sensor's proof mass (or central plate)

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in the 0-*g* position is a direct measure of the applied acceleration. This voltage is available to the user at the output of the preamp.

The ADXL50 chip also contains an uncommitted op amp. Without further conditioning, the output of the single-supply ADXL50 's preamplifier is 1.8 V at 0-*g* acceleration, with a span of approximately ±1 V for a ±50-*g* acceleration range (i.e., 19 mV/*g*). The uncommitted op amp can be used to alter the 0-*g* voltage and/or amplify and filter the acceleration signal. In Figure 4, the noninverting input of the op amp is connected to +1.8-V signal, derived from an internal precision +3.4-V reference source. The scaling factor in the diagram is given by the ratio, $-R_2/R_1$, (since the amplifier is in inverting mode). For independent adjustment, gain is adjusted with $R_1$ and offset is adjusted with $R_3$. Therefore, if the span desired is ±2.25 V for the complete ±50 g range, $R_2/R_1$ should be chosen such that:

$$\frac{R_2}{R_1} = \frac{V_{o\ span}}{V_{pr\ span}} = \frac{2.25}{1.0}$$

where $V_{pr\ span}$ is the output from the preamplifier and $V_{o\ span}$ is the desired span of the uncommitted amplifier output. Thus:

$$R_2 = 2.25 \times R_1$$

$R_3$ can be found from the following standard equation:

$$R_3 = 1.8\ \text{V}\ \frac{R_2}{V_{o0} - 1.8\ V}$$

where $V_{o0}$ is the 0-*g* output level. Stated otherwise,

$$V_{o0} = 1.8\ V\left(1 + \frac{R_2}{R_3}\right)$$

With $R_1$ = 100 kΩ, $R_2$ = 225 kΩ, and $R_3$ = 579 kΩ, the output analog signal range will be +0.25 to +4.75 V for ±50 *g*, with +2.5 V at 0 *g*. With 25 nF, the output signal's −3-dB bandwidth is 1 kHz, using the single-pole, 1-kHz filtering of the preamp. More-sophisticated configurations can provide multi-pole filtering without the use of additional active components.

## SELF-TEST

Another unique attribute of the ADXL50 that sets it apart from alternative designs is the inherent ability to self-test the sensor and all associated on-chip signal-conditioning circuitry *in place* by applying a digital command. Most rudimentary sensors—particularly the commonly used electromechanical devices—cannot be adequately tested to ensure they are operating correctly. Even sophisticated sensors with accurate, continuous outputs can only be tested under controlled circumstances on precision vibration test-beds.

To self-test the ADXL50, a CMOS- or TTL-level digital stimulus is applied to the self-test input. This produces a voltage pulse which is injected into the feedback signal to the sensor. The resulting electrostatic force causes a deflection of the proof mass against the tethers as though it were responding to a negative full-scale acceleration. Though always available, self-testing would generally be programmed to occur each time at power-up.

## AUTOMOTIVE APPLICATIONS

There are many on-board automotive systems that need a reliable, low cost way to measure acceleration. The most obvious and immediate application for the ADXL50 is in next-generation, single-point air-bag systems (see sidebar, "Air-bag Accelerometers"), where the ADXL50's output provides acceleration information for the "is-a-crash-occurring?" decision to initiate the explosive charge to deploy the air bag.

Another automotive application of accelerometers related to safety is in automatic door-lock-release mechanisms. In the event of a collision that results in significant structural damage to the vehicle, passengers are often trapped in the vehicle, unable to be rescued, because the doors remain locked. Automatic door-lock release on impact could, in many instances, have prevented this; an accelerometer incorporated in the door lock would detect the rapid deceleration that occurs on impact, releasing the door locks.

Airbag systems and automatic door-lock release systems are forms of "passive safety" which make the consequences of collisions less dangerous. In addition, automobile companies are developing "active safety" systems which attempt to avoid collisions. Such systems include ABS (antilock brake system), ASR (acceleration slip regulation), and sophisticated new suspension systems that monitor and react to varying road conditions; in addition to increasing the level of safety, these also provide a more comfortable ride through improved vehicle control. *Active suspension systems* continuously monitor road conditions and vehicle dynamics and compensate through the use of power hydraulics and actuators in the suspension to restore the vehicle to a neutral orientation (or even a biased orientation, "leaning" into a corner for improved control). A simplified version is known as an *adaptive suspension system*, which responds to road conditions and vehicle dynamics by altering the response of the suspension components through changing such parameters as shock absorber or strut valving; the difference is that it does not employ restorative power devices. Both active and adaptive systems rely on measuring shock and vibration through monitoring wheel- and body motions—functions requiring the use of accelerometers.

An advanced form of vehicle control, derived from ABS/ASR systems, is based on monitoring *lateral acceleration*; when it is combined with longitudinal acceleration and vehicle velocity values, suspension settings may be altered side-to-side or front-to-back to make maximum use of the adhesion potential of the tires. Developments in this area include "yaw-rate" sensors, a special category of accelerometer which measures the rate of rotational velocity change. The resulting information may be used by the chassis control system to alter suspension settings as well as to more actively intervene in vehicle dynamics by selectively applying individual wheel braking (without driver input!). Selectively applying particular braking combinations applies yaw moments to counter undesired rotations of the vehicle. Various forms of such systems are already being used in racing applications such as "Indy" cars. As the cost of such systems is reduced, they will find use in vehicles for the general public.

The full-scale acceleration range of interest for suspension and "active-safety" applications is in the range of ±2 *g*, for which Analog Devices is developing future versions of the ADXL50.

## NON-AUTOMOTIVE APPLICATIONS

Acceleration is a fundamental physical quantity, manifested in many guises—gravity, vibration, and seismic activity are a few examples. Measuring acceleration continuously, accurately, and at low cost opens up numerous applications for the ADXL50 and future members of its family.

Manufacturers of portable computers continue to seek ways to make their products more rugged and reliable. The elements most prone to damage (and the catastrophic loss of stored information) are mass-storage devices, particularly hard-disc drives. The delicate mechanism that reads and writes information to the discs floats above them on a controlled flow of air; sudden movement can easily cause a problem, destroying data and drives alike. An accelerometer can detect the onset of potentially damaging shocks and institute "countermeasures" to prevent disc damage.

Many of us have had the disappointing experience of opening a large package to find the delicate contents damaged or destroyed due to mishandling. How did the damage occur, and who is to blame? If a package recorder—consisting of an accelerometer, a timer, and a data logger—were included with the consignment, these questions could be easily answered. Such recorders may soon be the norm for delicate, expensive items in transportation.

Military applications include smart detonation systems for missiles and bombs. Here an accelerometer forms part of the fuze system, detecting impact by the associated rapid deceleration. The continuously varying output of the ADXL50 would be quickly analyzed to establish the precise instant when the explosive charge should be detonated to produce maximum target damage.

The ADXL50 can also be used to monitor the health of machines. Rotating machines exhibit characteristic vibration signatures; as fatigue cracks or wear develop in portions of the machine, the signature changes. By continuously monitoring the machine's vibration, it is possible to be warned of imminent failure. Applications range from aircraft engines to heating, ventilation and air-conditioning (HVAC) systems.

## FUTURE DEVELOPMENTS

The ADXL50 is Analog Devices' first micromachined acceleration sensor. It is the first of a *family* which will include a more sensitive device with a full-scale range of $\pm 2\ g$, a less-sensitive device for more-severe shock measurements, digital-output devices, and other formats. Also in development is a family of rate sensors. Future devices will also be available in a variety of packages.

Since the micromachined sensing element is so small, it is possible to incorporate several on a single chip, oriented to either the same or orthogonal axes. Thus monolithic dual-axis sensors can be constructed, allowing vector measurements of acceleration in the plane of the chip surface. Alternatively, two or more sensors can be aligned in the same plane, allowing for redundant sensing in fail-safe applications. In either instance, some sharing of the support circuitry (and perhaps even on-chip signal processing) will provide even greater economic value. Until multiple devices become available, the ADXL50's small size permits a high degree of compactness using separate devices.

The ADXL50 is available in a 10-pin T0-100 metal can with various grades, suitable for consumer, industrial, military, and automotive applications. DIP packaging is also in development. Pricing is $38.50 in 100s, decreasing to <$10 in large volumes.

*The team that developed the ADXL50, headed by Dr. Richard Payne, includes Steve Sherman, Terry Core, Sarkis Ourfalian, Bob Tsang, Dave Quinn, Paul O'Brien, John Chang, Carl Roberts, Lew Long, and many others at ADI's manufacturing plant in Wilmington MA.*

## AIR BAGS AND ACCELEROMETERS

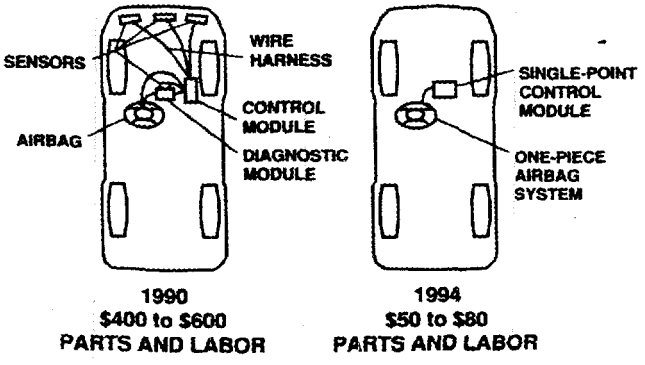
Automotive air bags have dramatically reduced fatalities and severe injuries of vehicle occupants involved in head-on collisions. As a result, many car makers have engaged to outfit all cars with them within the next 3 years; and legislation in the USA and elsewhere will mandate some form of passive restraint in all cars and trucks by 1995. This has resulted in a huge demand for a low-cost, highly reliable air-bag system.

Within an airbag system, the electronic control module makes the decision when to fire the airbag. Currently, most airbag systems in production use several electromechanical crash sensors, acting as on-off electrical switches, mounted at the front of the car. Their output is sent to the control module, which combines their outputs with that of an electromechanical "safing" sensor and decides whether to fire the airbag. The safing sensor is used to reduce the chances for a false deployment, which would be likely if only the output of the crash sensors were considered; the crash sensors have a fairly low trip point and can be fooled by potholes, etc. To trigger the airbag, at least one crash sensor and the safing sensor must close. These distributed systems are expensive to install, and reliability is compromised by the number of interconnections and the inability to self-test the sensors.

The new approach in airbags is to use a "single-point sensing system," where a single accelerometer (such as the ADXL50) is mounted in the passenger compartment, doing away with the crash sensors mounted at the front of the car and the associated wiring harnesses. Also, the output of the accelerometer is continuous, rather than on-off, with voltage proportional to the acceleration. This enables the system to use a more-sophisticated decision-making algorithm in its microcontroller to distinguish between a crash condition and other events —rather than relying on a majority vote of several switches. "Smart" algorithms use signal-processing approaches similar to those used in speech recognition and predictive methods to perform the decision.

An 8-mph (12.8 km/h) head-on crash into a solid wall should not deploy; a ≥12-mph (19.2-km/h) crash should deploy. In some situations, the decision to fire the airbag has to occur in <15 ms from the start of the crash. The system's goal is to fire the airbag by the time the occupant has moved 5 in (0.13 m).

Single-point sensing provides significant cost reductions and increased system reliability through elimination of the many components and connections associated with multi-point systems. Furthermore, the continuous and linear output of the ADXL50 enables the use of more sophisticated deployment algorithms by the airbag system controller, resulting in a more accurate system with fewer unnecessary airbag deployments.



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|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LOW Hz | HIGH kHz | LINEAR RANGE g | SHOCK LIMIT g | MIN/MAX C | SIGNAL GROUND ISOLATED FROM MOUNTING SURFACE | SEAL | CABLE CONNECTION | MOUNTING |
| **PIEZOELECTRIC** | | | | | **MINI-STRUCTURE MEASUREMENT** | | | | | | |
| 12 | 2.0 pC/g | 0.085 | 1 | 2.8 | 500 | 1000 | -65/+150 | N/A | N/A | N/A | Cond. Epoxy |
| 22 | 0.4 pC/g | 0.14 | 1 | 10 | 4000 | 10000 | -73/+150 | Yes | Silicone | Side | Adhesive |
| 23 (3X) | 0.4 pC/g | 0.8 | 1 | 10 | 2000 | 10000 | -73/+150 | Yes | Silicone | Side | Adhesive |
| 2220D | 2.5 pC/g | 3.1 | 1 | 10 | 1000 | 5000 | -55/+260 | No | Hermetic | Side | Screw |
| 2222C | 1.4 pC/g | 0.5 | 1 | 8 | 1000 | 10000 | -73/+177 | Yes | Silicone | Side | Adhesive |
| **ISOTRON** | | | | | | | | | | | |
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| 2250A/AM1-10 | 10.0 mV/g | 0.4 | 4 | 15 | 500 | 2000 | -55/+125 | Yes | Epoxy | Side | Adhesive |
| 7250A/AM1-2 | 2.0 mV/g | 1.8 | 4 | 20 | 5000 | 10000 | -55/+125 | Yes | Hermetic | Side | Screw |
| 7250A/AM1-10 | 10.0 mV/g | 1.8 | 3 | 20 | 500 | 10000 | -55/+125 | Yes | Hermetic | Side | Screw |
| 7253A-10 (3X) | 10.0 mV/g | 2.5 | 4 | 15 | 500 | 2000 | -55/+125 | Yes | Epoxy | Top | Both |
| **PIEZOELECTRIC** | | | | | **LOW 'G' MEASUREMENT** | | | | | | |
| 770XA-200 | 200.0 pC/g | 62 | 1 | 4 | 850 | 2000 | -55/+288 | Both | Hermetic | Side | Stud |
| 770XA-1000 | 1000.0 pC/g | 120 | 1 | 2 | 500 | 1000 | -55/+288 | Both | Hermetic | Side | Stud |
| **ISOTRON** | | | | | | | | | | | |
| 7751-500 | 500.0 mV/g | 64 | 0.4 | 1.5 | 10 | 2000 | -55/+125 | No | Hermetic | Side | Stud |
| **PIEZOELECTRIC** | | | | | **SHOCK MEASUREMENT** | | | | | | |
| 2225 | 0.75 pC/g | 13 | 1 | 10 | 10000 | 20000 | -55/+177 | No | Epoxy | Top | Stud |
| 2225M5A | 0.025 pC/g | 13 | 1 | 15 | 50000 | 100000 | -55/+177 | No | Epoxy | Top | Stud |
| **ISOTRON** | | | | | | | | | | | |
| 2255B-01 | 0.1 mV/g | 2 | 7 | 30 | 50000 | 200000 | -55/+125 | No | Epoxy | Top | Stud |
| 2255B-1 | 1.0 mV/g | 2 | 1.5 | 30 | 5000 | 100000 | -55/+125 | No | Epoxy | Top | Stud |
| 7255A-01 | 0.1 mV/g | 5 | 10 | 10 | 50000 | 200000 | -55/+125 | Yes | Hermetic | Top | Stud |
| **PIEZOELECTRIC** | | | | | **HIGH FREQUENCY MEASUREMENT** | | | | | | |
| 7240B | 2.7 pC/g | 4.8 | 1 | 20 | 1000 | 5000 | -55/+260 | No | Hermetic | Side | Stud |
| 7201-10 | 10.0 pC/g | 18 | 1 | 12 | 12000 | 20000 | -55/+260 | No | Hermetic | Side | Stud |
| **ISOTRON** | | | | | | | | | | | |
| 7259A-10/25 | 10/25 mV/g | 4.4 | 5 | 30 | 500 | 10000 | -55/+125 | No | Hermetic | Side | Stud |
| **ISOTRON** | | | | | **MACHINE MONITORING** | | | | | | |
| 5216MX-100 | 100.0 mV/g | 70 | 3 | 6 | 80 | 5000 | -55/+93 | Yes | Hermetic | Top | Stud |
| **PIEZOELECTRIC** | | | | | **HIGH TEMPERATURE MEASUREMENT** | | | | | | |
| 2273A | 3.0 pC/g | 27 | 1 | 6 | 10000 | 10000 | -185/+400 | No | Hermetic | Side | Stud |
| 2276 | 10.0 pC/g | 30 | 1 | 5 | 3000 | 3000 | -55/+482 | No | Hermetic | Side | Stud |
| 6222S-20/50/100A | 20/50/100 pC/g | 91 | 10 | 9/6/6 | 2k/1k/500 | 4k/2k/1k | -55/+260 | Yes | Hermetic | Side | Screw |
| 6233 | 10.0pC/g | 100 | 10 | 4 | 1000 | 2000 | -55/+482 | (DIFF) | Hermetic | Side | Screw |
| 6233C-50/100 | 50/100 pC/g | 110 | 10 | 2.5/2 | 500/250 | 2k/1k | -55/+482 | Yes | Hermetic | Side | Screw |
| 6240M10 | 5.0 pC/g | 90 | 10 | 2 | 200 | 1000 | -55/+650 | Yes | Hermetic | Side | Screw |
| **PIEZOELECTRIC** | | | | | **NUCLEAR MEASUREMENT** | | | | | | |
| 2273AM1 | 10.0 pC/g | 32 | 1 | 5 | 500 | 3000 | -55/+370 | Yes | Hermetic | Side | Stud |
| 2273AM20 | 10.0 pC/g | 34 | 1 | 5 | 500 | 3000 | -55/+370 | Yes | Hermetic | Top | Stud |
| 76M10 | 25.0 pC/g | 100 | 10 | 2 | 500 | 2000 | 0/+357 | Yes | Hermetic | Side | Screw |
| 83M2 (2X) | 5.0 pC/g | 40 | 10 | 0.5 | 100 | 500 | -55/+345 | Yes | Hermetic | Top | Stud |
| **PIEZOELECTRIC** | | | | | **LOW TEMPERATURE MEASUREMENT** | | | | | | |
| 2271A | 11.5 pC/g | 27 | 1 | 6 | 1000 | 10000 | -270/+260 | Yes | Hermetic | Side | Stud |
| 2272 | 13.0 pC/g | 27 | 1 | 5 | 1000 | 2000 | -270/+260 | No | Hermetic | Side | Stud |
| **PIEZOELECTRIC** | | | | | **GENERAL VIBRATION MEASUREMENT** | | | | | | |
| 2221D | 17.0 pC/g | 12 | 1 | 6 | 1000 | 5000 | -55/+177 | No | Epoxy | Side | Screw |
| 2221F | 10.0 pC/g | 11 | 1 | 12 | 1000 | 3000 | -55/+260 | No | Hermetic | Side | Screw |
| 2223D (3X) | 12.0 pC/g | 41 | 1 | 6 | 1000 | 2000 | -55/+177 | Yes | Epoxy | S/S/T | Screw |
| 2224C | 12.0 pC/g | 16 | 1 | 6 | 1000 | 2000 | -55/+177 | No | Epoxy | Top | Screw |
| 2226C | 2.8 pC/g | 2.8 | 1 | 5 | 1000 | 2000 | -55/+177 | No | Epoxy | Top | Adhesive |
| 2228C (3X) | 2.8 pC/g | 15.3 | 1 | 4 | 1000 | 2000 | -55/+177 | Yes | Epoxy | S/S/T | Screw |
| 2229C | 2.8 pC/g | 4.9 | 1 | 5 | 1000 | 2000 | -55/+177 | Yes | Epoxy | Top | Stud |
| 7201-50 | 50.0 pC/g | 25 | 1 | 6 | 2000 | 10000 | -55/+177 | No | Hermetic | Side | Stud |
| 7221 | 10.0 pC/g | 11 | 1 | 10 | 1000 | 5000 | -55/+177 | No | Hermetic | Side | Screw |
| 770XA-50/100 | 50/100 pC/g | 25/29 | 1 | 6/5 | 2k/1k | 10k/5k | -55/+288 | Both | Hermetic | Side or Top | Stud |
| **ISOTRON** | | | | | | | | | | | |
| 2256-10/100 | 10/100 mV/g | 5 | 1 | 5 | 500/50 | 2k/2k | -55/+125 | Yes | Epoxy | Top | Adhesive |
| 2258-10/100 (3X) | 10/100 mV/g | 15 | 1 | 4 | 500/50 | 2k/2k | -55/+125 | Yes | Epoxy | S/S/T | Screw |
| 7251-10/100 | 10/100 mV/g | 11 | 1 | 10 | 500/50 | 5k/5k | -55/+125 | Yes | Hermetic | Side | Screw |
| 7254-10/100/500 | 10/100/500 mV/g | 20 | 1 | 10 | 500/50/10 | 5k/5k | -55/+125 | No | Hermetic | Side | Stud |

"NOTE: (3X) = TRIAXIAL, (2X) = BIAXIAL, (DIFF) = DIFFERENTIAL OUTPUT"

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ENDEVCO CORPORATION, 30700 RANCHO VIEJO ROAD, SAN JUAN CAPISTRANO, CA 92675 USA (714) 493-8181 FAX (714) 661-7231 0492

# ENDEVCO® Standard Piezoelectric and ISOTRON® Accelerometers

### Why Accelerometers ?

Vibration and shock measurements are vital to the development, testing, and operational monitoring of structures and machines in all fields of engineering. Although there are many different types of transducers that can be used to sense vibratory motion, accelerometers are commonly chosen because of their high accuracy, wide-band frequency and dynamic response, small size, light weight, long life and ease of installation. Most accelerometers used today are either the piezoelectric (PE) or piezoresistive (PR) type.

### Piezoelectricity and Accelerometry

The word *piezoelectricity* literally means "pressure electricity" in Greek, and has been defined by W.G. Cady as electric polarization produced by mechanical strain in crystals belonging to certain classes. The production of electrical output by mechanically-induced strain in a crystal is called the direct piezoelectric effect. Piezoelectric accelerometers utilize this effect by using a spring-mass system to generate a force proportional to the amplitude and frequency of vibration. The force is then closely coupled to a PE element which resembles a capacitor and produces an open-circuit voltage proportional to acceleration. There are many types of crystals, from natural crystal, such as quartz, to man-made ferroelectric ceramics. Each type of crystal possesses certain unique characteristics which, if cleverly applied, can enhance the performance of an accelerometer.

### Advantages of Piezoelectric Accelerometers

Compared to other types of accelerometers, piezoelectric accelerometers have the following advantages:

- Self-generating–no external power source required
- Ruggedness–no moving parts
- High signal-to-noise ration–extremely wide dynamic range
- Wide temperature range–a function of the crystal material used
- Long term stability–proven track records

### ENDEVCO® Piezoelectric Accelerometers

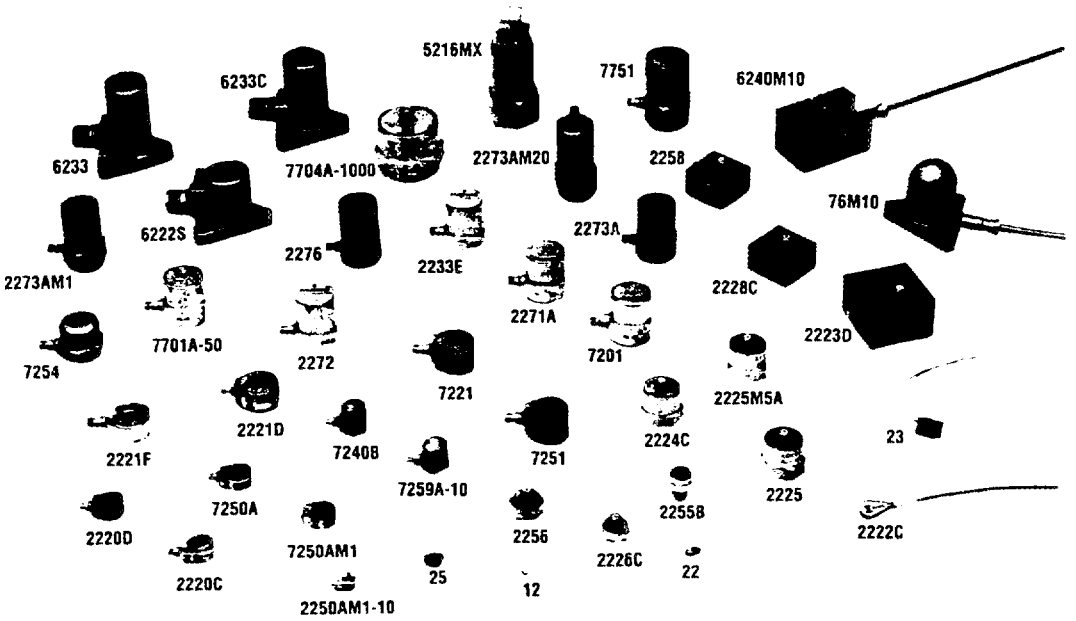
Unlike other PE accelerometer manufacturers that only specialize or embrace one chosen crystal type, ENDEVCO employs many different kinds of crystal materials in our designs, so that their unique physical characteristics can be fully utilized to yield superior performance. Having the unusual capability of manufacturing our own PE crystal materials in-house also enables us to design accelerometers that are smaller in size, widest in temperature limit, strongest in survivability, and easiest to install. Some special features of ENDEVCO PE accelerometers are:

- Lightweight–down to less than 0.1 grams
- Center-hole mounting–Annular shear design allows 360° cable orientation
- Low base strain and thermal transient output ISOSHEAR® design
- Integral cable–designed for close quarters

### ISOTRON® Accelerometers

ISOTRON accelerometers are PE accelerometers with internal hybrid electronics. ISOTRON provides transducer design flexibility in addition to all the advantages of PE accelerometers. Electronic gain can be used to reduce transducer size or increase output sensitivity. Frequency response can be tailored with electronic filtering for specific applications, or to suppress seismic resonance of the accelerometer. Since output impedance of the signal is very low, a coaxial receptacle is not required, thereby allowing the use of solder pins with smaller, more flexible, low-cost cables. All ISOTRON accelerometers are powered by constant current source, its low impedance, single-ended output can be fed directly into recording devices without the need of external charge amplifiers, as required with PE accelerometers.

ENDEVCO offers a wide range of accelerometers that can satisfy your vibration measurement requirements. Our extensive selection of standard catalog products, along with our superior technical expertise, provides our customers with the resources needed to meet the ultimate measurement challenges. For additional applications assistance please contact the Application Engineering staff at our California headquarters, or your local ENDEVCO Sales Engineer.




ENDEVCO

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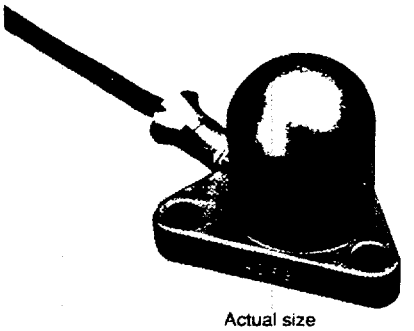
# Piezoelectric Accelerometer

**ENDEVC**
**MODEL**
**76M10**

## Model 76M10

- Requires No External Power
- Radiation Hardened
- 3500 psi (24 MPa) Water Pressure
- +675°F (+357°C) Operation
- Case Isolated
- Hermetically Sealed



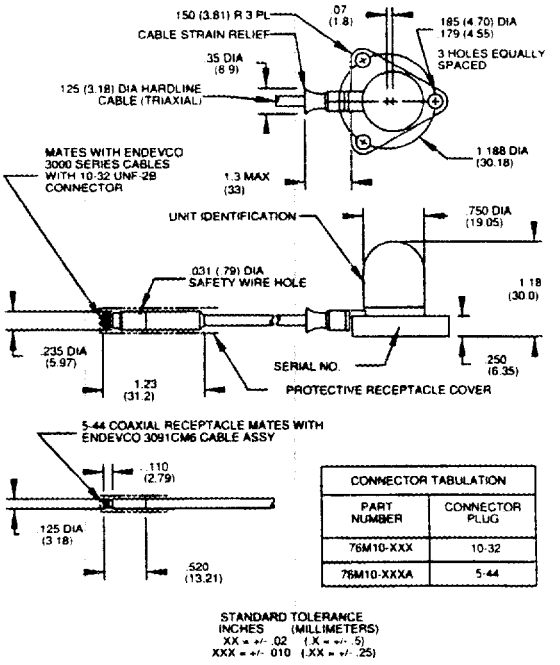
Actual size

### DESCRIPTION

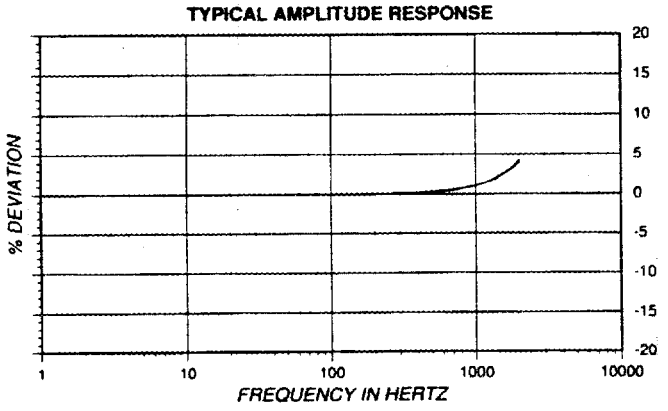
The ENDEVCO® Model 76M10 is a precision piezoelectric accelerometer designed for measuring shock and vibration in such severe environments as pressurized water reactors and boiling water reactors. This accelerometer is suitable for long-term exposure to nuclear radiation in temperatures up to +675°F (+357°C) with water pressures as high as 3500 psi (24 MPa), or up to +900°F (+482°C) in dry air. The accelerometer is a self-generating device that requires no external power source for operation.

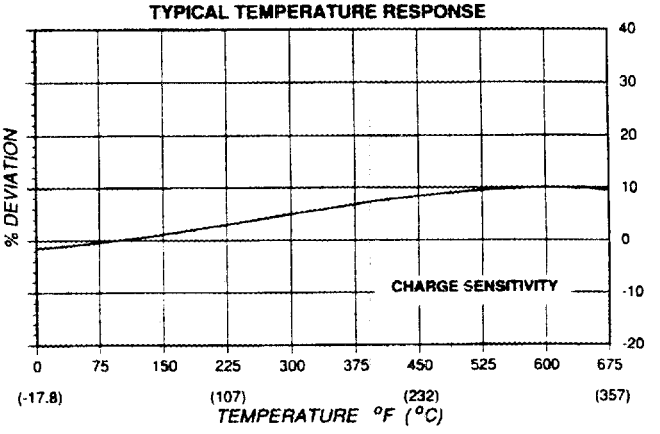
The 76M10 features ENDEVCO's PIEZITE® Type P-14 sensing elements in our patented ISOBASE® construction, to provide for flat charge temperature response over the desired operating range. The ISOBASE construction provides mechanical isolation from the mounting base, resulting in low strain sensitivity, acoustic sensitivity, dynamic pressure sensitivity and transient temperature sensitivity. The 76M10 is hermetically sealed and utilizes a hardline cable with the output isolated from case. A 10-32 receptacle on the end of the hardline assembly provides for interface with our 3090C, 3075M6 or 3091F cable assemblies.

ENDEVCO Signal Conditioner Models 2721B, 2775A or 6634B are recommended for use with this high impedance accelerometer.




| CONNECTOR TABULATION | |
|---|---|
| PART NUMBER | CONNECTOR PLUG |
| 76M10-XXX | 10-32 |
| 76M10-XXXA | 5-44 |

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ENDEVCO
MODEL
76M10

# Piezoelectric Accelerometer

## SPECIFICATIONS

The following performance specifications conform to ISA-RP-37.2 (1964) and are typical values, referenced at +75°F (+24°C) and 100 Hz, unless otherwise noted. Calibration data, traceable to National Institute of Standards and Technology (NIST), is supplied.

| DYNAMIC CHARACTERISTICS | Units | |
|---|---|---|
| CHARGE SENSITIVITY | | |
| TYPICAL | pC/g | 25 |
| MINIMUM | pC/g | 20 |
| FREQUENCY RESPONSE | | See Typical Amplitude Response |
| RESONANCE FREQUENCY | kHz | 12 |
| AMPLITUDE RESPONSE, ± 8% [1] | Hz | 50 to 2000 |
| TEMPERATURE RESPONSE | | See Typical Curve |
| TRANSVERSE SENSITIVITY | % | ≤ 5 |
| AMPLITUDE LINEARITY<br>Per 500 g, 0 to 2000 g | % | 0.6 |
| **ELECTRICAL CHARACTERISTICS** | | |
| RESISTANCE (Excluding hardline cable) | GΩ | ≥ 1 |
| At +675°F (+357°C) | MΩ | ≥ 10 |
| ISOLATION (Excluding hardline cable) | MΩ | ≥ 100 |
| At +675°F (+357°C) | MΩ | ≥ 10 |
| HARDLINE CABLE RESISTANCE<br>Two places at +675°F (+357°F) | MΩ/ft | 25 |
| GROUNDING | | Signal return isolated from case |
| **ENVIRONMENTAL CHARACTERISTICS** | | |
| TEMPERATURE RANGE | | |
| TRANSDUCER/HARDLINE CABLE | | +32°F to +675°F (0°C to +357°C) |
| CONNECTOR | | +32°F to +350°F (0°C to +177°C) |
| HUMIDITY | | |
| TRANSDUCER/HARDLINE CABLE | | Hermetically sealed |
| CONNECTOR | | Epoxy sealed, non-hermetic |
| PRESSURE RANGE [2] | psi (MPa) | 3500 (24) |
| SINUSOIDAL VIBRATION LIMIT [3] | g | 500 |
| SHOCK LIMIT | g | 2000 |
| BASE STRAIN SENSITIVITY | equiv. g pk/μ strain | 0.002 |
| THERMAL TRANSIENT SENSITIVITY [4] | equiv. g pk/°F (/°C) | 0.07 (0.13) |
| PRESSURE SENSITIVITY | equiv. g/psi (/MPa) | 0.005 (0.000345) |
| RADIATION | | |
| INTEGRATED GAMMA FLUX | rad | Up to $6.2 \times 10^{10}$ |
| INTEGRATED NEUTRON FLUX | N/cm² | Up to $3.7 \times 10^{16}$ |
| **PHYSICAL CHARACTERISTICS** | | |
| DIMENSIONS | | See Outline Drawing |
| WEIGHT (Excluding hardline cable) | gm (oz) | 100 (3.5) |
| CASE MATERIAL [5] | | Inconel |
| HARDLINE CABLE | | Triaxial, 0.125 inch diameter, Inconel jacketed, mineral oxide insulated. The model number suffix "-XXX" indicates cable length in inches. |
| CONNECTOR [6] | | Receptacle must be handled with care. Supplied protective cap must be in place when handling and removed by turning counter clockwise. |
| MOUNTING TORQUE | lbf-in (Nm) | 14 (1.6) |
| **CALIBRATION** | | |
| SUPPLIED: | | |
| CHARGE FREQUENCY RESPONSE | % | 50 to 2000 Hz |
| | dB | 2000 Hz through resonance |
| CHARGE SENSITIVITY | pC/g | |
| CAPACITANCE | pF | |
| TRANSVERSE SENSITIVITY | % | |

**ACCESSORIES**

| | |
|---|---|
| P/N EH534 | MOUNTING SCREW<br>8-32 UNC x 0.5 in socket head cap |
| P/N EHM689 | HEX WRENCH, 9/64 in |
| Model 3090C-120 (10 ft) | CABLE ASSEMBLY FOR 76M10-XXXX |
| Model 3091CM6-120 (10 ft) | CABLE ASSEMBLY FOR 76M10-XXXA |

**NOTES**

1. Low-end response of the transducer is a function of its associated electronics.
2. Unit is proof tested in water at room temperature to a pressure of 3500 psi (24 MPA).
3. Limited also by cable clamping of hardline cable.
4. 1 Hz high pass filter.
5. Chemical and physical material certificates for external hardware (except connector) supplied.
6. 76M10 supplied with 10-32 connector. 76M10A supplied with 5-44 connector.

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# Piezoelectric Accelerometer

**ENDEV MODEL 2273A**

## Model 2273A

- Requires No External Power
- Nuclear or High Temperature Environments
- +750°F (+399°C) Operation
- Case Grounded
- Radiation Hardened

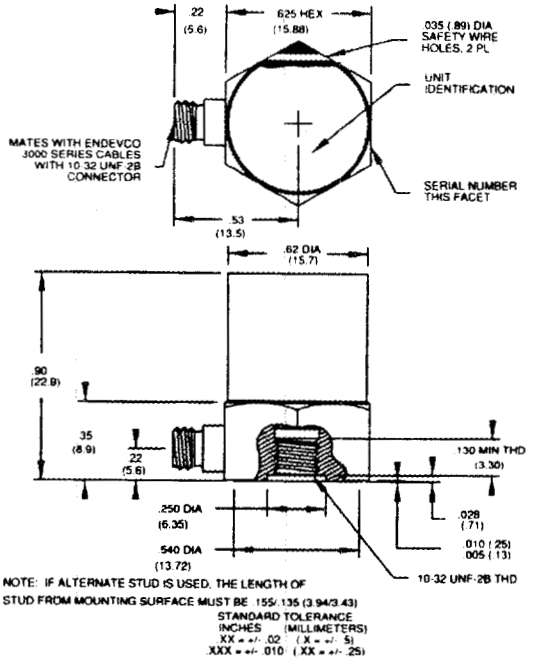
Actual size

### DESCRIPTION

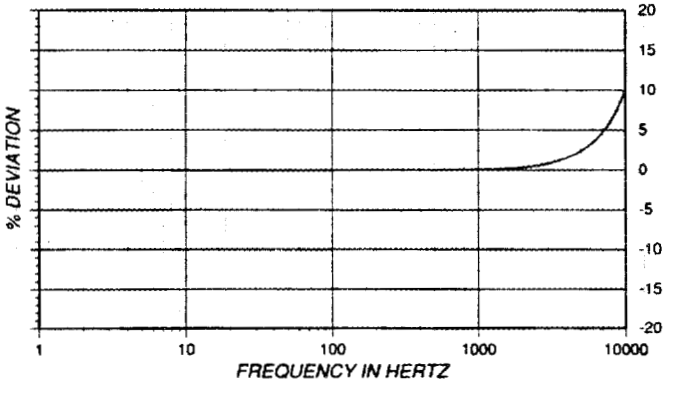
The ENDEVCO® Model 2273A is a precision piezoelectric accelerometer for use in industrial or laboratory applications involving high temperature or nuclear environments, and is capable of operation in the presence of Gamma and Neutron radiation. The 2273A incorporates a side mounted 10-32 receptacle and hex base construction with a 10-32 or M5 center stud mount. The accelerometer is a self-generating device that requires no external power source for operation.

The 2273A features ENDEVCO's PIEZITE® Type P-14 crystal in our patented ISOBASE® construction, to provide for flat temperature response over the range of -300°F to +750°F. In addition, ISOBASE construction provides mechanical isolation of bending motion from the mounting base. These features, together with an all-welded hermetically sealed enclosure, assure accurate and reliable data at high temperatures.

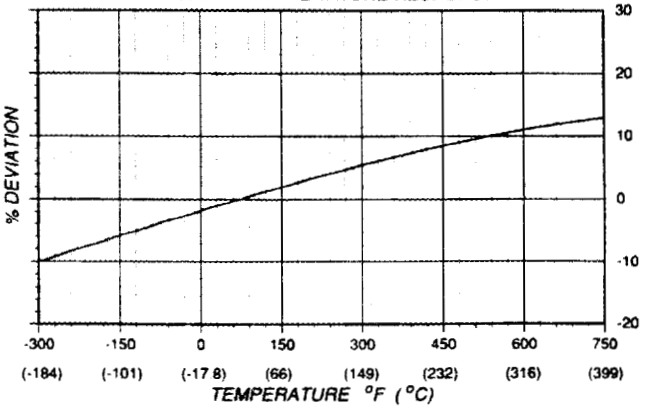
ENDEVCO Signal Conditioner Models 104/109, 2721B, 2775A, 6634B or 68203 are recommended for use with this accelerometer. The 2771A Remote Charge Convertor is also compatible for applications using this high impedance accelerometer.




**TYPICAL AMPLITUDE RESPONSE**




**TYPICAL TEMPERATURE RESPONSE**




ENDEVCO

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ENDEVCO
MODEL
2273A

# Piezoelectric Accelerometer

## SPECIFICATIONS

The following performance specifications conform to ISA-RP-37.2 (1964) and are typical values, referenced at +75°F (+24°C) and 100 Hz, unless otherwise noted. Calibration data, traceable to National Institute of Standards and Technology (NIST), is supplied.

| DYNAMIC CHARACTERISTICS | Units | |
|---|---|---|
| CHARGE SENSITIVITY | | |
| TYPICAL | pC/g | 3.0 |
| MINIMUM | pC/g | 2.5 |
| FREQUENCY RESPONSE | | See Typical Amplitude Response |
| RESONANCE FREQUENCY | kHz | 30 |
| AMPLITUDE RESPONSE [1] | | |
| ± 2% | Hz | 20 to 2000 |
| ± 5% | Hz | 1 to 6000 |
| TEMPERATURE RESPONSE | | See Typical Curve |
| TRANSVERSE SENSITIVITY | % | ≤ 3 (≤ 1 available on special order) |
| AMPLITUDE LINEARITY | % | 1 |
| Per 500 g, 0 to 10 000 g | | |

| ELECTRICAL CHARACTERISTICS | | |
|---|---|---|
| OUTPUT POLARITY | | Acceleration directed into base of unit produces positive output. |
| RESISTANCE | GΩ | ≥ 1 |
| At +750°F (+399°C) | MΩ | ≥ 10 |
| CAPACITANCE | pF | 110 |
| GROUNDING | | Signal return connected to case |

| ENVIRONMENTAL CHARACTERISTICS | | |
|---|---|---|
| TEMPERATURE RANGE | | -300°F to +750°F (-184°C to +399°C) |
| HUMIDITY | | Hermetically sealed |
| SINUSOIDAL VIBRATION LIMIT | g | 1000 |
| SHOCK LIMIT [2] | g | 10 000 |
| BASE STRAIN SENSITIVITY | equiv. g pk/μ strain | 0.004 |
| ELECTROMAGNETIC SENSITIVITY | equiv. g rms/gauss | 0.0003 |
| RADIATION | | |
| INTEGRATED GAMMA FLUX | rad | Up to $6.2 \times 10^{10}$ |
| INTEGRATED NEUTRON FLUX | N/cm² | Up to $3.7 \times 10^{18}$ |

| PHYSICAL CHARACTERISTICS | | |
|---|---|---|
| DIMENSIONS | | See Outline Drawing |
| WEIGHT | gm (oz) | 25 (0.88) |
| CASE MATERIAL | | Stainless Steel |
| CONNECTOR | | 10-32 UNF-2A Thd mates with Endevco 3075M6 Cable Assembly or equivalent. |
| MOUNTING TORQUE | lbf-in (Nm) | 18 (2) |

| CALIBRATION | | |
|---|---|---|
| SUPPLIED: | | |
| FREQUENCY RESPONSE | % | 20 to 6000 Hz |
| | dB | 6000 Hz thru resonance |
| MAXIMUM TRANSVERSE SENSITIVITY | % | |
| MOUNTED RESONANT FREQUENCY | kHz | |
| CAPACITANCE | pF | |

### ACCESSORIES

| | |
|---|---|
| Model 3075M6-120 (10 ft) | CABLE ASSEMBLY, High Temp. |
| Model 2981-3 | MOUNTING STUD, 10-32 to 10-32 |

### OPTIONAL ACCESSORIES

| | |
|---|---|
| Model 3090C-120 (10 ft) | CABLE ASSEMBLY, for under +500°F |
| Model 2981-4 | MOUNTING STUD, 10-32 to M5 |
| Model 2985 | INSULATED MOUNTING STUD |

### NOTES

1. Low-end response of the transducer is a function of its associated electronics.
2. Shock pulses of short duration may excite transducer resonance. Shock level above the sinusoidal vibration limit may produce temporary zeroshift which will result in erroneous velocity or displacement data after integration.

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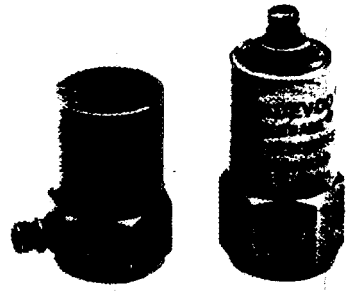
# Piezoelectric Accelerometer

**ENDEVC**
**MODEL**
**2273AM**
**AM**

## Model 2273AM1/AM20

- Requires No External Power
- Reactor and Loose Parts Monitoring
- +750°F (+399°C) Operation
- Case Isolated
- Radiation Hardened
- Top/Side Mounted Connectors

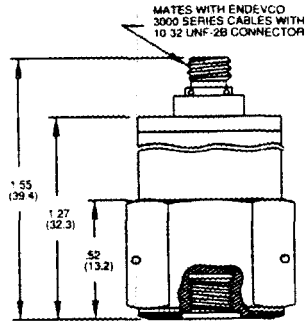


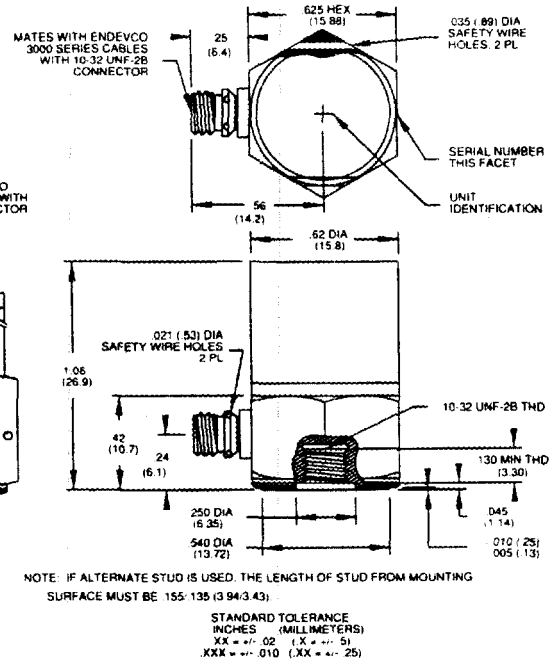
Actual size

### DESCRIPTION

The ENDEVCO® Models 2273AM1 and 2273AM20 piezoelectric accelerometers are specifically designed for use in reactor vibration and loose parts monitoring systems. The 2273AM1 and 2273AM20 are differentiated only by the location of their connectors, the AM1 being side mounted and the AM20 utilizing a top mount configuration. The accelerometer is a self-generating device that requires no external power source for operation.

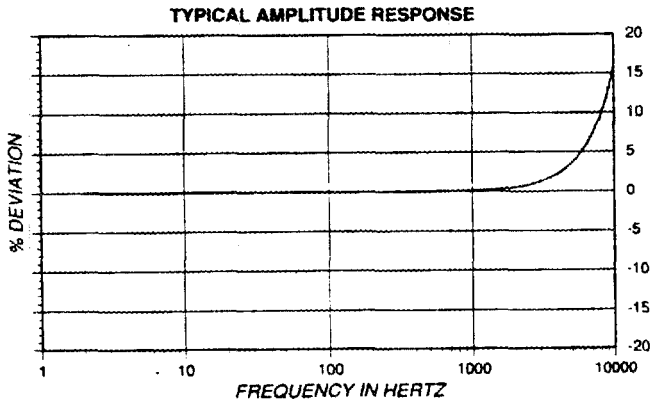
The 2273AM1/AM20 feature ENDEVCO's PIEZITE® Type P-14 sensing elements in our patented ISOBASE® construction, to provide for flat charge temperature response over the range of -65°F to +750°F. In addition, ISOBASE construction provides mechanical isolation of the seismic system from the mounting base, resulting in very low strain sensitivity. The unit is constructed using Inconel and provides for hermeticity through welding and glass-to-metal fusion at the connector.



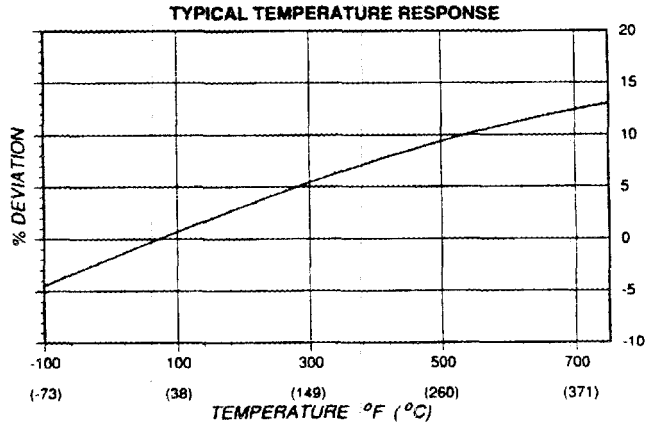




ENDEVCO Signal Conditioner Models 104/109, 2721B, 2775A, 6634B or 68201 are recommended for use with this accelerometer. The 2771A Remote Charge Convertor is also compatible for applications using this high impedance accelerometer.

**TYPICAL AMPLITUDE RESPONSE**




**TYPICAL TEMPERATURE RESPONSE**

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# ENDEVCO MODEL 2273AM1/ AM20

# Piezoelectric Accelerometer

## SPECIFICATIONS

The following performance specifications conform to ISA-RP-37.2 (1964) and are typical values, referenced at +75°F (24°C) and 100 Hz, unless otherwise noted. Calibration data, traceable to National Institute of Standards and Technology (NIST), is supplied.

| DYNAMIC CHARACTERISTICS | Units | |
|---|---|---|
| CHARGE SENSITIVITY | pC/g | 10 |
| FREQUENCY RESPONSE | | See Typical Amplitude Response |
| RESONANCE FREQUENCY | kHz | 27 |
| AMPLITUDE RESPONSE [1] ± 5% | Hz | 20 to 5000 |
| TEMPERATURE RESPONSE | | See Typical Curve |
| TRANSVERSE SENSITIVITY | % | ≤ 3 |
| AMPLITUDE LINEARITY Per 1000 g, 0 to 3000 g | % | 1 |
| **ELECTRICAL CHARACTERISTICS** | | |
| OUTPUT POLARITY | | Acceleration directed into base of unit produces positive output at center socket of receptacle. |
| RESISTANCE | GΩ | ≥ 1 |
| At +700°F (+399°C) | MΩ | ≥ 10 |
| ISOLATION | GΩ | ≥ 1 |
| CAPACITANCE | pF | 660, ± 200 |
| GROUNDING | | Signal return isolated from case |
| **ENVIRONMENTAL CHARACTERISTICS** | | |
| TEMPERATURE RANGE | | -67°F to +750°F (-55°C to +399°C) |
| HUMIDITY | | Hermetically sealed |
| SINUSOIDAL VIBRATION LIMIT | g | 500 |
| SHOCK LIMIT [2] | g | 3000 |
| BASE STRAIN SENSITIVITY | equiv. g pk/μ strain | 0.002 |
| RADIATION | | |
| INTEGRATED GAMMA FLUX | rad | Up to $6.2 \times 10^{10}$ |
| INTEGRATED NEUTRON FLUX | N/cm² | Up to $3.7 \times 10^{18}$ |
| **PHYSICAL CHARACTERISTICS** | | |
| DIMENSIONS | | See Outline Drawing |
| WEIGHT | gm (oz) | 32 (1.1) |
| CASE MATERIAL | Inconel | |
| CONNECTOR | | Coaxial receptacle with 10-32 UNF threads designed to mate with Endevco Model 3075M6-XXXX Cable assembly or equivalent. |
| MOUNTING TORQUE | lbf-in (Nm) | 18 (2) |
| **CALIBRATION** | | |
| SUPPLIED: | | |
| CHARGE FREQUENCY RESPONSE | % | 20 to 5000 Hz |
| | dB | 5000 Hz through resonance |
| CHARGE SENSITIVITY | pC/g | |
| MAXIMUM TRANSVERSE SENSITIVITY | % | |
| CAPACITANCE | pF | |
| TEMPERATURE RESPONSE | | At +75°F [ref],+400°F, +700°F (+24°C [ref], +204°C, +371°C) |
| CHARGE SENSITIVITY | % | |
| RESISTANCE | MΩ | |

**ACCESSORY**

Model 3075M6-120 (10 ft) CABLE ASSEMBLY, High Temp

**OPTIONAL ACCESSORY**

Model 2981-4 MOUNTING STUD, 10-32 to M5

**NOTES**

1. Low-end response of the transducer is a function of its associated electronics.
2. In shock measurements, minimum pulse duration for half-sine or triangular pulses should exceed 0.2 ms to avoid excessive high frequency ringing.

Continued product improvement necessitates that Endevco® reserve the right to modify these specifications without notice. Endevco maintains a program of constant surveillance over all products to ensure a high level of reliability. This program includes attention to reliability factors during product design, the support of stringent Quality Control requirements, and compulsory corrective action procedures. These measures, together with conservative specifications have made the name Endevco synonymous with reliability.

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# Piezoelectric Accelerometer

**ENDEVC**
**MODEL**
**2276**

## Model 2276

- Requires No External Power
- Nuclear or High Temperature Applications
- +900°F (+482°C) Operation
- Inconel Construction
- Case Grounded
- Radiation Hardened

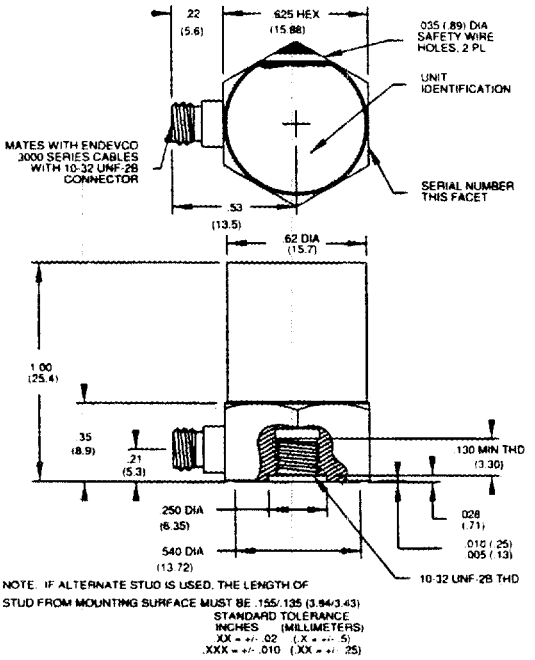
Actual size

### DESCRIPTION

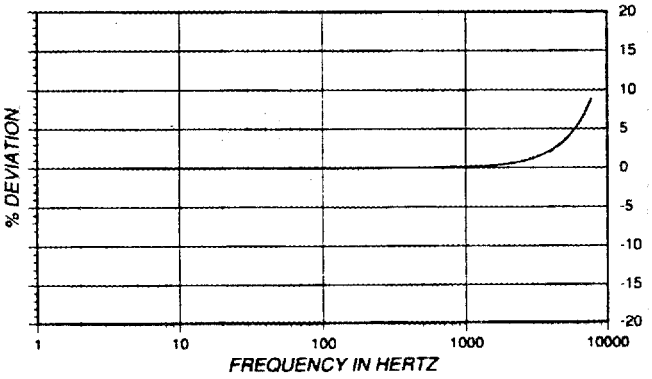
The ENDEVCO® Model 2276 is a precision piezoelectric accelerometer for shock and vibration measurement of structures subjected to very high temperatures and is capable of operation in nuclear environments during the presence of Gamma and Neutron radiation. This accelerometer features a side mounted 10-32 receptacle and hex base construction with a 10-32 or M5 center stud mount. The accelerometer is a self-generating device that requires no external power source for operation.

The 2276 features ENDEVCO's PIEZITE® Type P-14 sensing element in our patented ISOBASE® construction, to provide for flat charge temperature response over the range of -65°F to +900°F. In addition, ISOBASE construction provides mechanical isolation of bending motion from the mounting base. The unit is constructed using Inconel, and provides for hermeticity through welding and glass-to-metal fusion at the connector. Signal return is connected to case.

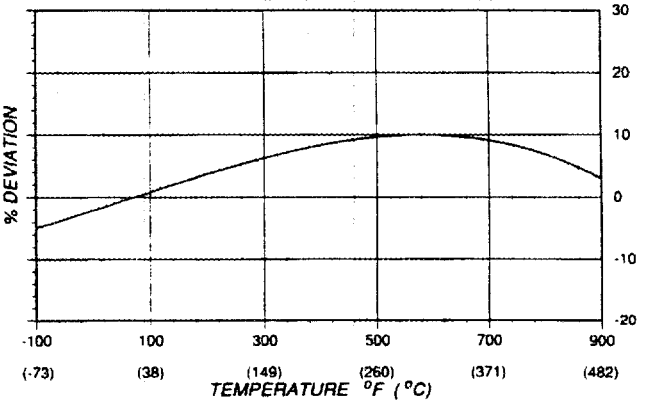
ENDEVCO Signal Conditioner Model 2721B is recommended for use with this accelerometer. The 2771A Remote Charge Converter is also compatible for applications using this high impedance accelerometer.




**TYPICAL AMPLITUDE RESPONSE**




**TYPICAL TEMPERATURE RESPONSE**

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# ENDEVCO MODEL 2276 Piezoelectric Accelerometer

## SPECIFICATIONS

The following performance specifications conform to ISA-RP-37.2 (1964) and are typical values, referenced at +75°F (+24°C) and 100 Hz, unless otherwise noted. Calibration data, traceable to National Institute of Standards and Technology (NIST), is supplied.

| DYNAMIC CHARACTERISTICS | Units | |
|---|---|---|
| CHARGE SENSITIVITY | | |
| TYPICAL | pC/g | 10.0 |
| MINIMUM | pC/g | 9.0 |
| FREQUENCY RESPONSE | | See Typical Amplitude Response |
| RESONANCE FREQUENCY | kHz | 27 |
| AMPLITUDE RESPONSE [1] ± 5% | Hz | 1 to 5000 |
| TEMPERATURE RESPONSE | | See Typical Curve |
| TRANSVERSE SENSITIVITY | % | ≤ 3 (≤ 1 on special order) |
| AMPLITUDE LINEARITY Per 1000 g, 0 to 3000 g | % | 1 |
| **ELECTRICAL CHARACTERISTICS** | | |
| OUTPUT POLARITY | | Acceleration directed into base of unit produces positive output. |
| RESISTANCE | GΩ | ≥ 1 |
| At +900°F (+482°C) [2] | KΩ | ≥ 100 |
| CAPACITANCE | pF | 660, ± 200 |
| GROUNDING | | Signal return connected to case. |
| **ENVIRONMENTAL CHARACTERISTICS** | | |
| TEMPERATURE RANGE | | -67°F to +900°F (-55°C to +482°C) |
| HUMIDITY | | Hermetically sealed |
| SINUSOIDAL VIBRATION LIMIT | g | 500 |
| SHOCK LIMIT [3] | g | 3000 |
| BASE STRAIN SENSITIVITY | equiv. g pk/μ strain | 0.002 |
| RADIATION | | |
| INTEGRATED GAMMA FLUX | rad | Up to $6.2 \times 10^{10}$ |
| INTEGRATED NEUTRON FLUX | N/cm² | Up to $3.7 \times 10^{18}$ |
| **PHYSICAL CHARACTERISTICS** | | |
| DIMENSIONS | | See Outline Drawing |
| WEIGHT | gm (oz) | 30 (1.1) |
| CASE MATERIAL | | Inconel |
| CONNECTOR | | 10-32 coaxial connector |
| MOUNTING TORQUE | lbf-in (Nm) | 18 (2) |
| **CALIBRATION** | | |
| SUPPLIED: | | |
| FREQUENCY RESPONSE | % | 20 Hz to 5000 Hz |
| | dB | 5000 Hz through resonance |
| SENSITIVITY | pC/g | |
| MAXIMUM TRANSVERSE SENSITIVITY | % | |
| MOUNTED RESONANCE FREQUENCY | kHz | |
| CAPACITANCE | pF | |

**ACCESSORIES**

Model 2981-3 ADAPTER STUD, 10-32 to 10-32
Model 3075M6-120 (10 ft) CABLE ASSEMBLY, High Temp

**OPTIONAL ACCESSORIES**

Model 3090C-120 (10 ft) CABLE ASSEMBLY, for under +500°F
Model 2981-4 MOUNTING STUD, 10-32 to M5

**NOTES**

1. Low-end response of the transducer is a function of its associated electronics.
2. Because of low resistance at high temperatures, the signal conditioner must be capable of operating with the specified source resistance.
3. Shock pulses of short duration may excite transducer resonance. Shock level above the sinusoidal vibration limit may produce temporary zeroshift which will result in erroneous velocity or displacement data after integration.

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# ENDEVCO® TECHNICAL PAPERS

The State-Of-The-Art in measuring vibration, shock, force, pressure and turbulence plus ac and dc Signal Conditioning equipment is presented here. The literature below will be sent to you with no obligation. It represents the "technical know-how" for which Endevco has become internationally recognized as the leader in the design, manufacture and distribution of piezoelectric and piezoresistive transducers and related instrumentation.

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ENDEVCO Dynamic Test Handbook ..... 102
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EP 159 Miniature Coaxial Connector Assembly Instructions ..... A540

**AVAILABLE FOR PURCHASE**

Shock and Vibration Measurement Technology Textbook (Price $40) ..... PN 29005
Dynamic Pressure Measurement Technology Textbook (Price $40) ..... PN 30096

To request literature, it is not necessary to indicate the complete title, simply indicate the item number for each item of interest on your letterhead or postcard.

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# APPENDIX I
# STRAIN GAUGES

David,
I'm sorry about this oversight. My secretary was ill for several days and when she returned I had put it in the wrong place for quick handling
Bud Dublin
1/21/93

ISI
INDUSTRIAL SENSORS & INSTRUMENTS, INC.
308 TEXAS AVENUE, SUITE 104
ROUND ROCK, TEXAS 78664
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(512) 255-3790

March 4, 1993

MEMORANDUM

To: Frank Cuta, Development Engineer, Battelle PNL (VIA FAX ONLY (509) 375-3614)
From: Bud Dublin, ISI
Subj: Inputs for nuclear waste monitor pressure transducers

The rough guidelines that I have for your application are:

1. Specific gravity of measurand fluid - 1.5
2. pH = 13
3. t = 150° F.
4. Submersion ≈ 16 ft ( approximately 12 psi Full Scale Output, FSO)
5. Radiation ≈ 800 rads/hr
6. 3.75" dia max O. D. (inside 4" pipe)
7. $H_2$ outgassing; therefore, intrinsically safe or explosion proofing required

We have verbal confirmation of a paper from Los Alamos that gives projections for our technology of a life of $(10)^{11}$ rad of accumulated radiation exposure for the gage backing and adhesive combination. This is far beyond your projected life requirement of 2 years. Conventional strain gage metallic foils resist radiation well.

At this point I have checked on several sensing element materials and it appears that some of the titanium alloys are viable candidates. They have high strength to modulus ratios to promote the desired attributes of the sensor that we discussed on the phone, with high resistance to hydrogen embrittlement (a problem with some Ti alloys.) I will continue informal checking, though part of our development, should we be selected to produce a custom sensor, would entail materials selection specifically for the application.

Additional information that ultimately will be necessary is:

a. What is the specific chemical composition of the measurand fluid? This is necessary to evaluate the long term exposure characteristics of the sensing element materials to the fluid for corrosion, embrittlement, and intra-granular degradation properties related to structural and elastic stability.

b. Does the fluid tend to crystallize, scale, or cause other long term effects that tend to "bridge" or otherwise provide localized reinforcement or redundancy of the sensing element? This is particularly important if an aneroid "capsule" of two corrugated diaphragms, edge welded to provide a low stiffness, sealed, force collector over a relatively large area is used to drive a bending beam, etc. In that case it can seal off the entry to the capsule over time, and gradually change the sensitivity of the sensor.

c. I believe that a manifolded, purgeable, and regulated reference pressure source, of clean dry inert gas, to provide common reference for all sensors in a given array, would provide near optimum performance for the application. Sealing reference pressures or evacuating reference cavities, for absolute indication, would be more difficult to manage and compensate in my opinion.

d. The sensor array should be open and easily cleanable with simple washdown in the event that maintenance is required.

A resolution of 0.1 in-H2O for a 25psi full scale range gives the requirement to resolve approximately 1 part in 6,000. It is feasible to exceed this resolution by a factor greater than ten; much greater than ten with proper signal conditioning and processing.

Intrinsically safe xener-resistor "barrier" modules are available from several manufacturers; Stahl, MTL, and Pepperl and Fuchs (P&F) are examples. In short, they limit the power available from cutting or shorting the leadwires of the transducer, on the safe side of the barriers, so that insufficient energy for ignition is available. They tend to cause some difficulty in conventional strain gage sensor calibration because the shunt used across one arm of the transducer's Wheatstone Bridge measuring circuit, to simulate a precise calibration increment (always in the "safe zone") must straddle at least a portion of the barrier. This effect may be compensated for by a smart data acquisition system, however.

Please call me if you need anything else.

**INDUSTRIAL SENSORS & INSTRUMENTS, INC.**
808 Tryon Avenue, Ste. 104, Round Rock, Texas 78664
(512) 255-0790 FAX 255-8655

# FAX



| | |
|---|---|
| DATE: 1/5/94 | FROM: Bud Dudlin |
| TO: Dr. David Holcomb | PHONE: (512) 255-3790 |
| COMPANY Oak Ridge Nat'l Lab | FAX NO: (512) 255-8655 |
| FAX NO: (615) 574-4058 | |

SUBJECT:

Dave,

The reference is:

$10^{18}$ n/cm²

$\gamma < 10^{11}$ rad/hr

Review and Status of Radiation Effects Studies on Strain Gages, Charles R. Tallman, Los Alamos Scientific Laboratory, October, 1972. Thanks again for your interest —

Bud Dudlin

P.S. I have a design for a tactile sensor that I would like to build —

metallic foil strain gauge

polymer flexed gauge

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# TRANSDUCER SELECTION GUIDE

## INTRODUCTION:

This document is intended to assist users in determining the characteristics of transducers, instrumentation, and systems for specific applications in order to best utilize the advanced capabilities of ISI. The special capabilities of ISI include:

1. Continuous operation to temperatures in excess of 500 °F.
2. Temperature compensation to better than 0.1% FSO per 100 °F temperature change for zero shift.
3. Temperature compensation to better than 0.1% FSO per 100 °F temperature change for span shift.
4. Output to 10 mV/V with "conventional" strain gages (this level of output must be accomplished coincidentally with item 5, below.)
5. Design for optimum fatigue life to resolution ratio.
6. Design for exposure to corrosive media.
7. Selection of materials to eliminate magnetic interference.
8. Design for the use of semiconductor strain gages.
9. Design for optimizing transducer reliability.
10. Design for specific environmental exposure:
    a. Pressure compensation to over 25,000 psi
    b. Subsea/marine
    c. High shock/vibration
    d. Remote outdoor conditions
    e. Downhole oil/gas well
    f. Rotating installations
    g. Inertness to product exposure (example-food)
    h. Other* (customer specification)
11. Design for optimization of precision and stability.

12. Design of multiple component transducers with minimized "cross-talk."

ISI has signal conditioning and instrumentation that provide levels of precision and stability consistent with that of their transducers that are themselves capable of over 200 °F operating temperatures. Standard enclosures for this equipment are available that are suitable for use in remote outdoor locations regardless of climatic conditions.

## THERMAL CONSIDERATIONS:

The most significant considerations from a thermal point of view are those of items 1-3 above. The adjustment of the transducer for temperature compensation (the reduction of variation in output as a function of temperature) is the main element of manpower required to build a transducer. Since manpower is the most costly element of any transducer, temperature compensation is one of the most expensive "components" of the transducer.

Virtually all strain gage transducers utilize a Wheatstone bridge measuring circuit to convert the variation of resistance of four strain gage "arms" hooked into the Wheatstone configuration to generate a signal proportional to the measurand. Numerous things such as production tolerances in the strain gages, asymmetries in leadwire connections within the bridge, and small variations in geometric orientation have small but significant effects on output as functions of temperature. These effects cause "zero shift," (i.e., variation of no-load output), of the transducer as a function of temperature. For the purposes of this discussion it is adequate to characterize the effect as generally being of the order of up to ±2% of the full scale output (FSO) of the transducer per 100 °F of temperature change without circuit compensation. ISI has the capability to adjust this shift to less than 0.1% FSO per 100 °F of temperature change.

There is a change of Young's Modulus (Modulus of Elasticity) of the transducer's sensing element that in virtually all sensor materials results in the sensing element undergoing a decrease in spring rate with increasing temperature. There is a variation of gage factor (sensitivity to strain) of the strain gages with temperature that may provide either increase or decrease in strain gage response with increasing temperature. In virtually all cases the decrease in Young's Modulus is of greater magnitude than the absolute value of the change in gage factor. The net effect, then, on span shift is generally of the order of ±1.3% FSO per 100 °F and is always in the direction of the transducer becoming more sensitive with increasing temperature. ISI can adjust this error to 0.1% FSO or less per 100 °F of temperature change. Once the required

correction has been determined for a given strain gage/sensing element material combination it may be applied on a standard component or "batch" correction basis.

It is important to emphasize that temperature compensation by analog circuit adjustment is accompanied by an increase in the complexity of the bridge circuit, hence an increase in cost in general. Very significant savings may be realized by keeping the actual temperature compensation accomplished to the absolute minimum required for the application. In general the ratio in cost between zero and span compensation is approximately two to one. That is, it costs approximately twice as much to accomplish zero shift compensation as it does span compensation since zero shift must be individually adjusted while span compensation may be accomplished on a batch basis once the parameters have been determined.

The final comments about thermal compensation relate to the simplicity of the bridge circuit itself. It is a corollary that the simpler the circuit, the fewer the interactions within the circuit. The result is that thermal repeatability is best with the simplest possible configuration. The use of data processing techniques to calculate corrections of data for both thermal and mechanical errors is effective with modern data acquisition systems. A decrease in component count increases the reliability of the circuit by reducing not only the probability of component failure, but also by reducing solder joint count. The bottom line is that temperature compensation by measuring temperature and correcting the transducer for its repeatable thermal errors may provide the most accurate and dependable results with "smart" data acquisition systems. Analog compensation of the transducer itself generally provides the best performance with simple data acquisition systems.

Thermal consideration is incomplete without discussing the maximum operating temperature limit. ISI has developed a significant edge through its research efforts. There are basically three levels of maximum long-term operating temperature available from ISI: 350, 400, and 500+ °F. Even the lowest of these limits generally exceeds capabilities of competitive devices. The 400 °F limit is adequate for most industrial applications, and is only slightly more expensive than the 350 °F limit. The upper temperature limit is mainly a function of the insulation integrity of the leadwires and the solder melting point. Stable performance for over 60 hours at approximately 750 °F has been observed by one of our customers.

Other variables interact with temperature limit. For instance, pressure in direct contact with the strain gages acts to reduce the operational limit. ISI's

present limit, based on keeping zero shift to a fraction of 1% FSO, after more than 3 hours exposure, is at simultaneous conditions of 500 °F temperature and 25,000 psi pressure.

## MECHANICAL CONSIDERATIONS:

The mechanical aspects of transducer design tend to be the dominant factors in determining performance. Typical deflections of the order of a thousandth of an inch (0.001 in.) in the sensing element result in tens or even hundreds of thousands of counts of resolution. Mechanics to the molecular level must be considered. Transducer design encompasses broad interdisciplinary effects and is beyond the scope of this paper except in summary of bottom line effects that may be observed and obtained consistently.

The full scale output limit of a strain gage transducer is mainly related to approaching a mechanical limit within the transducer itself. It may be limited by the strain within the sensing element (the mechanical part that carries the load), the strain in the strain gages, the bond stress between the sensing element and the strain gage, etc. ISI has developed capabilities to extend the working range or resolution of their transducers. Sensors utilizing "conventional" metallic foil bonded strain gage technology with outputs to over 10 mV/V are feasible with concessions on fatigue life. Ordinary limits are 2-3 mV/V for such sensors. This increase in output translates into an increase of resolution of 3 to 5 times that of competitive sensors. Such increase in capability requires extensions in numerous design areas. Some useful observations are:

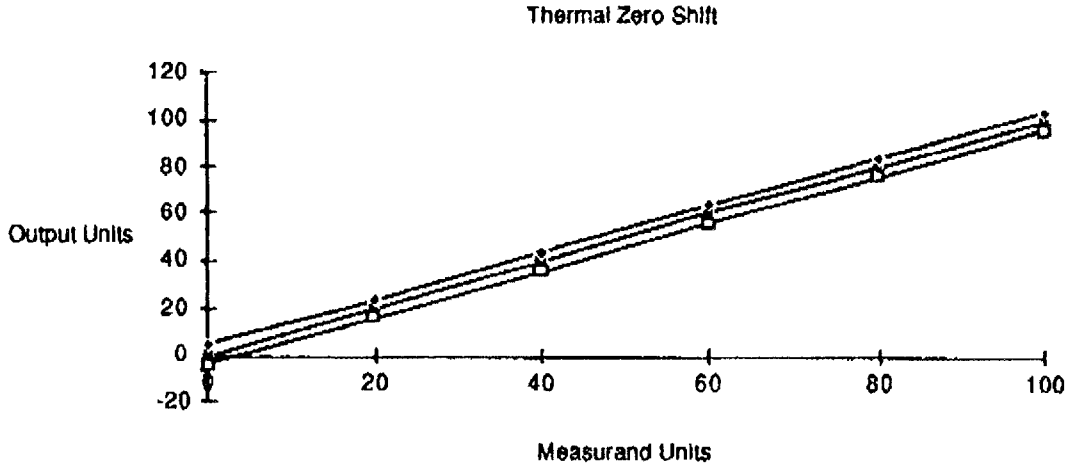
1. Increase in output increases non-linearity, non-repeatability, and hysteresis as percentages of FSO, however, thermal error components decrease against the same reference.
2. New materials offer capabilities of extending working strain limits simultaneously with increased resistance to corrosion.
3. The strain gage itself is most often the source of limit.
4. Seldom do adverse maximums of error components occur simultaneously.
5. The "worst" data point is generally the "zero" value; (where there is little or no restoring force). Fortunately, little data of real significance occurs near zero in most practical uses. Unfortunately, the zero reading is the most often observed value and is often a source of criticism or loss of confidence in the more useful portions of the transducer's range.
6. Not all design results can be explained by theoretical analysis. There is a strong empirical influence in transducer design and

usually given in terms of percentage of FSO. It is determined during a specific calibration cycle; (i.e., it is not allowed to use the ascending values for one run with the descending values of another.) As a general rule the hysteresis of a given sensor tends to improve with age. This is due to a conditioning effect on the molecular structure of the element as the sensor is "exercised" and where minor dislocations in the material grain structure produce a more stable state. Both sensor geometry and material properties affect the hysteresis of the sensor.

**NON-REPEATABILITY** - (or repeatability) is a measure of the ability of a transducer to repeat itself. It is a direct comparison between corresponding incremental values of successive calibration runs. There is no limit as to the number of calibration runs that may be involved, however, it is required that the comparison be between all increments of two successive calibration runs. As with previous specifications it is usually given as a percentage of FSO. Non-repeatability tends to improve with age for similar reasons to those for hysteresis.

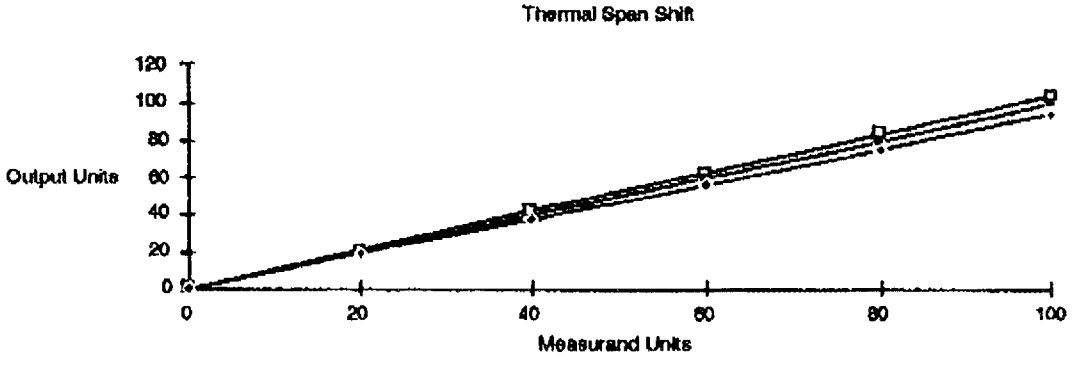
**THERMAL ZERO SHIFT** - is the measure of thermal stability of the no load output of the transducer. It generally varies as a reasonably linear function of temperature and is the effect of production tolerance accumulation for bridge components, variations in inter-bridge wiring, and other lesser order effects that accumulate to a specific response for a given transducer. The statistical variation of zero shift for an uncompensated unit may be expected to be of normal distribution with the standard deviation being of the order of ±1-2% per 100 °F. The mean of the distribution is not necessarily centered about zero, though it should not be far askew. ISI's standard specification for compensation adjustment is ±0.2% FSO per 100 °F. Typical performance from room temperature to 400 °F is for a total thermal zero shift of ±0.1% FSO or less.

Thermal zero shift is the translation of the output versus measurand curve to a parallel position on change of temperature as shown below:




**THERMAL SPAN SHIFT** - is variation of sensitivity as a function of temperature. The main components working to cause this variation are changes in the stiffness or Young's Modulus of the material of the sensing element and the gage factor (sensitivity) of the strain gages as functions of temperature. Without compensation adjustment it is always "positive" in sense; that is, that sensitivity increases with increase in temperature. The major factor is that of material stiffness and as a result the uncompensated output generally increases in the order of 1-3% FSO per 100 °F change in temperature for most materials. Unlike thermal zero shift there is little deviation for a given sensor design, and once the determination of correction is made it may be installed on a batch basis.

Thermal span shift is the rotation of the output versus measurand curve about the zero measurand value as shown below:



**MISCELLANEOUS** - There are numerous other specifications that may be used to characterize transducer performance. Most of them are readily interpreted, and less subject to "specsmanship" than are the above listed values. The potential buyer is cautioned, however, that if there is any question about a given specification that he should question it and not waver until it is explained to his satisfaction.

## CONCLUSION AND SUMMARY:

It is impossible to cover all aspects of custom transducer design and development in this brief paper. In general we at ISI feel that most users tend to over specify the requirements of their application. This almost always results in the sensor being more expensive than required and often compromises the economic feasibility of the application. It is better to under specify if there must be error at the outset since it is generally easy to increase performance from a simple configuration; however, if success is achieved with a sensor that is more complex than that required, seldom is the unit made less complex and expensive. The tendency is to "live with it" and this can accumulate into major long term expense over the life of a product, particularly if considerable sales volume results. The following observations are offered from ISI's experience.

A. Resolution is often confused with accuracy. As an example, if one is looking for small variations in load from a substantial base load the tendency is to over specify accuracy even if the actual value of the base load is relatively unimportant. The truth of the matter is that **variation** of a fraction of a pound may be determined very accurately by a 7500 pound capacity load cell of only moderate accuracy. An error of 0.25% FSO would result in an error of 19 pounds in the absolute load value, however, the **change** in signal due to a small variation in load is virtually unaffected by the error in absolute load.

B. While exceptions apply to specific designs, the thermal variations of sensor output as functions of temperature without compensation in the circuit may be expected to be in the ranges of ±1 to 2% FSO/100 °F for zero shift and +1 to 3% FSO/100 °F for span shift.

C. The simpler the sensor, the more repeatable it will be with respect to both mechanical and thermal performance; however, the repeatability of a compensated unit is generally better than ±0.1% FSO mechanically and ±0.1% FSO/100 °F thermally.

Simplicity also carries benefits in increasing reliability and reducing cost.

D. Surprising results often occur with respect to material properties. It is not unusual for an aluminum alloy sensor to have a yield/ultimate strength greater than an alloy steel or high strength stainless steel sensor of the same sensitivity. With such comparison the aluminum alloy sensor often weighs half that of the steel equivalent; and in general the performance is comparable if not superior to that of the steel unit. The cost of an aluminum alloy sensor is less than a steel unit by a significant increment.

E. Material and geometric properties may be used to optimize mechanical performance (non-linearity, hysteresis, and repeatability.)

Thank you for your consideration of ISI for your sensor, instrument, and system integration requirements. We are interested in providing the best possible product at the best possible price. Special attention is also given to providing delivery consistent with your needs. For information or quotation relative to your specific requirement contact:

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# REVIEW AND STATUS OF RADIATION EFFECTS STUDIES ON STRAIN GAGES

Charles R. Tallman
Los Alamos Scientific Laboratory

## Introduction

A strain-gage system may be more sensitive to electrical, mechanical, chemical and thermal property changes induced in its several components due to irradiation than other measuring systems. This is primarily true because the st induced changes in the electrical resistance of the strain element is small, i.e being measured in parts per million. In this system then, any change is usually significant. Further, the critical interdependence of the components in this system adds to the complexity in understanding the behavior of the system. For example, measured changes in the electrical resistance of the gage may arise no only from the direct electrical property change in the resistive element, but can also occur due to mechanical, chemical, electrical, and thermal-property changes in the gage backing, or bonding material or even the substrate on which the gage is attached.

Most experiments studying radiation effects on strain gages have usually concentrated on complete systems in environments closely duplicating those of the final application. These experiments provide answers to particular, unique situations but often have not provided enough understanding so that the results could be applied generally. To achieve progress in developing a strain-gage system for radiation service, one must determine the dominant effects of radiat on the components in this system. Some understanding of these effects can be achieved by reviewing the scientific data on metals, ceramics, and organic materials exposed to radiation. From these basic studies we then can begin to understand the results of system experiments conducted on various strain-gage systems of different gage alloys, bonding methods, and reactor environments. A brief review of the theoretical and experimental studies of basic damage mechanisms expected in these materials will be given before examining the syst experiments.

Feb. 1970

Radiation Effects on Metals

High-energy-neutron irradiated metals suffer structural damage. The impinging neutrons create defects in the metal lattice by several mechanisms[1] illustrated in Fig. 1. The neutron collides with an atom in the metal lattice and transfers some of its energy, which, assuming elastic collision, is proportional to the energy of the bombarding neutron and to the ratio of the neutron mass to the struck atom's mass. After the initial collision the neutron continues to knock other atoms, usually with enough energy to displace them from their lattice position. For example a 300-eV neutron will have just enough energy to transfer 19 eV to a copper atom, which is sufficient to dislodge this atom from its lattice site. The neutron, however, proceeds with 281 eV, eventually losing this energy by striking many atoms vibrating them violently. If the bombarding neutron has more than this displacement energy (300 eV) the struck atom will have enough energy to collide with other atoms knocking them out of position. The energy transfer in this collision is much greater because the colliding atoms are of equal mass, and thus this energy is dissipated in a very localized area. The neutron, in contrast, can travel deeply into the metal (depending upon the direction and cross-section), thus scattering defects throughout the metallic structure. The knocked-on atoms will finally stop and will lodge at an interstitial site. Two types of simple point defects are created: vacancies and interstitials. Other, more complex, defects are also created such as divacancies and other quasistable multiple defects. Dienes and Vineyard[2] have calculated that a 1-MeV neutron bombarding copper will create about 1000 vacancy-interstitial pairs of defects. Another effect of neutron bombardment is a "thermal spike". A neutron of less than 300 eV, not enough to displace a copper atom by direct collision, can dissipate its energy through collisions that violently vibrate the atoms. This thermal disturbance, or spike is very short, both in duration and range. Extremely high temperatures occur within a 30-Å diameter (≈ 1000 atoms for copper) even with a 300-eV neutron. Temperatures above the melting point are achieved in a period of $5 \times 10^{-12}$ s, but this heat is quickly conducted to the surrounding atoms so that a sphere of 60 Å diameter has a temperature of 460 K in $2 \times 10^{-11}$ s. The affected area could be reoriented into metastable phases, or this energy could promote the diffusion of vacancies and interstitials. Other defects are created when very-high-energy neutrons (several million electron volts) strike the metal.

Enough energy can be transferred to the knock-on atom to strip off electrons, thus ionizing the atom. The ionized knock-on atom can then cause appreciable damage in the lattice and, because the collision cross-section for charged particles is relatively high, dissipate this energy in a very short distance. Low-energy neutrons (several eV) cannot cause structural damage, but they can create defects through transmutation of the host atoms into impurity atoms. These transmuted atoms act as foreign atoms in the lattice and will affect the properties of the material.

Of greatest concern in strain-gage metal wire and foil, is a change in the electrical resistivity.[3] The defects introduced in the structure cause the conduction electrons to scatter, with the general result of increased electrical resistivity. Figure 2 shows that the resistivity for several metals increases linearly with neutron dose.

The rate of increase in resistivity is strongly dependent upon the temperature during irradiation and can be sensitive to many other factors, e.g., initial defects introduced by heat treatment (rapid quenching, precipitates), grain size, cold work energy, and complex structure of the alloy.

To illustrate the effect of temperature, Fig. 3 shows that the resistivity of a copper specimen decreases upon isochronal heating after irradiation of a low temperature. These step changes in resistivity (see Fig. 3) have been attributed to annealing various kinds of defects. Neutron bombardment however creates too complex a situation to allow a detailed analysis on this basis.

At very low temperatures little energy is available to promote diffusion and thus the annealing rate is low. Although small, some annealing[4] occurs in copper at tempature as low as 7 K. Higher-melting materials have a higher activation energy for diffusion and thus require higher annealing temperatures for defect removal. Further, their resistivity increases to higher levels under irradiation at a given temperature than that of a material with lower melting temperature. Some materials, however, exhibit unexpected resistivity changes upon irradiation. Explanations[5] offered for these anomalies are radiation-induced clustering of defects initially present due to rapid quenching or heat treatment, or phase changes nucleated at thermal spikes resulting in increased local order.

Mechanical-property changes in the metal strain-gage foil or wire are also important. Most metals are embrittled by the introduction of defects, and the hardness increases. The ductility can be lowered severely, to the extent that rupture will occur at elongations substantially lower than without radiation. These effects are probably due to the pinning of the dislocation motion by the defects present. Another major effect is that of energy deposition increasing the apparent activation energy of surface reactions Because foil strain gages have a high surface-to-volume ratio, any enhanced surface chemical activity could measurably change the electrical and mechanical properties of the foil. Young[6] has observed that the initial rate of oxidation single copper crystals increased under irradiation.

It is particularly important for foil strain gages to minimize the chemical activity between the strain gage and the cement or encapsulant. Mechanical properties can also be affected by surface conditions, particularly by crack propagation and fatigue. Thermal expansion and thermal conductivity are also changed by irradiation, which is also of concern to strain-gage applications.

Gamma irradiation at energy levels of fission reactors has little effect on metals other than that of raising the temperature due to energy deposition. However, in high-flux regions these temperature increases can be a significant problem.

Radiation Effects on Insulators

Insulating materials in strain-gage application are either organic or inorganic. The latter include ceramic cements, flame-sprayed $Al_2O_3$ or powdered MgO, and in some cases $SiO_2$. These materials are even harder than metals to analyze for radiation effects, but some general conclusions can be drawn from research studies. Irradiation of polycrystalline $Al_2O_3$ shows several property changes: microscopic growth, microcracking, decrease in thermal conductivity, and slight decrease in Young's modulus--all the result of lattice displacement defects. The interstitial atom in the lattice produces swelling and high stress, which may cause the initiation of a crack. Also, lattice defects reduce the thermal conductivity by increased phonon scattering. Transmutation produces impurity atoms, a particularly serious phenomenon if gas evolution occurs, as it does in n,$\alpha$ reactions. Materials

containing elements such as beryllium or boron will emit $\alpha$ particles which become helium atoms in the lattice. These then nucleate to form gas pockets or bubbles that cause severe swelling or even disintegration of the structure under thermal cycling.

Ionization and electronic excitation produced by fast neutrons and gamma irradiation may leave a charged site as electrons are stripped from an atom or trapped at defects. These charged regions interact with photons and thus affect the optical properties such as light transmissions and coloration. The electrical resistivity of $Al_2O_3$ decreased from $10^{11}$ to $10^{8}$ $\Omega$ after a neutron irradiation of $3.5 \times 10^{18}$ nvt. Ionic crystals such as MgO also show some decrease in electrical resistivity. The mobility of ions is directly affected by the presence of vacancies. The loss of insulation resistance from ionic conduction due to temperature and nonstoichiometry is similarly explained.

Photoconduction is another phenomenon that occurs in ceramics. This process involves the direct interaction of a gamma photon with one of the bound electrons in the atom. The photon is absorbed and the electron is ejected into the conduction band. The higher the atomic number (i.e., the higher the number of electrons) the greater the probability for this event. Other interactions, e.g., Compton process and pair production occur at other energy levels of gamma irradiation resulting in decreased insulation resistance and non-ohmic effects such as rectification and photovoltaic effects. However, inorganic oxides are particularly stable and their decreases in insulation resistance are usually insufficient to cause concern in strain-gage installatic Often reported experimental difficulties stem from the combination of effects caused by the atmosphere surrounding the installation. Moisture and air in the presence of ionizing radiation lead to the production of nitric acid. The direct-charge transport either through the ionized gas or by surface conduction of the chemical products can be several orders of magnitude greater than that occurring through the bulk ceramic.

On the other hand, the electrical resistivity of organic insulators degrades significantly under gamma radiation. Electric insulation primarily fails because of mechanical and physical deterioration rather than because of electric-property changes. Organic insulators suffer complex chemical reaction

which drastically alter the properties of the original material. Chemical reactions occur through photon/electron interactions and because of ionization from fast neutrons. Depending upon the organic structure, either polymer chain sissioning occurs with gas evolution of reactive chain fragments or additional cross-linking occurs with the formation of brittle three-dimensional networks. Photoconduction is also a dominant effect in organic insulators, and some materials have shown resistivity decreases amounting to several orders of magnitude. The side effect of gas evolution under irradiation is of major concern because great quantities of gas can be released. Tenfold increases of the initial volume are not unusual. This gas can create high pressures in confined cavities. For halogenated hydrocarbons the release of corrosive halogens and halogen acids can attack nearby components. In strain-gage applications the high surface-to-volume ratio makes these materials particularly sensitive to chemical activity. In pressure transducers, outgassing can create sufficient pressure to cause zero offsets. Physical properties such as tensile strength and melting point may decrease, and solubility of organic insulators may increase. Those organic materials that embrittle may crack or flake off under stress-cycling or vibration.

## Radiation Effects of Semiconductors

The majority of active defects introduced in semiconductors by neutron bombardment are in the form of defect clusters. These defect clusters act as recombination centers for the electron-hole charge carriers. The number of charge carriers, their mobility, and life time are affected by the defects present. The electrical conductivity[7] decreases by as much as four or five decades from initial values with a neutron fluence of $10^{17}$ nvt; Fig. 4 illustrat this effect. Maximum resistance is reached when the bombardment has progressed until all carriers are trapped. Heavily doped semiconductor strain gages[8] with initial carrier concentrations of $10^{15}/cm^3$ are less sensitive, but an upper limit of useful performance is found at fast-neutron fluences of $\sim 10^{15}$ nvt.

## Radiation Effects Experiments

Experimental apparatus (capsules) of varying complexity have been designed for insertion into nuclear-reactor test ports. All include provisions for maintaining an inert atmosphere of helium as well as a small flow to purge any outgassed materials from the capsule. Cooling of the capsule is often requir

due to the gamma and neutron energy deposition. For instance, LASL's Omega West reactor at 8 MW has a gamma heating level of 0.2 W/g (C). Depending upon the heat-transfer conditions this could result in high temperatures and large temperature gradients. Pressure transducers with no provision for cooling other than convection have reached equilibrium temperatures of over 800°F.

Experiments have been made on static strain gages both under prestress and at zero-stress conditions. In other experiments the strain gages were cycled either in tension or in compression to ≈ 1000 μs. Most experiments have been conducted at controlled temperature including room temperature as well as $LN_2$ and $LH_2$ temperatures.

One of the first strain-gage irradiation-effects capsules[9] used by the U. S. Naval Research Laboratory is shown in Fig. 5. This apparatus was used to determine the behavior of strain gages both under stress and in a relaxed state. The capsule was well-designed to avoid the problems of temperature and atmospheric effects. The first experiments were conducted in the Low Intensity Testing reactor at Oak Ridge National Laboratory in May 1956. Nichrome V foils and constantan foil gages bonded by Allen Pl ceramic cement to carbon steel beams were tested as 1/2-bridge pairs. Both gage alloys were tested in four bridge systems one unstressed and one stressed.

The resistance of individual gages and the resistance to ground were read during the irradiation. The bridge-circuit unbalance was also read. Resistance to ground (Fig. 6) was the major problem, with insulation resistance dropping to 100 Ω at a fast-neutron dose of $3 \times 10^{17}$ nvt. The effects of stress-loading were not significant, Fig. 7, and the resistance changes in individual nichrome gages were larger than in constantan gages. Interestingly these results of over 16 years ago are not too different from recent data.

A German translation[10] of this experiment revealed that the strain gages were backed with a phenolic resin. I suspect that the severe loss in insulation resistance occurred because of radiation damage of this backing and possibly because of adverse chemical reaction with the Allen Pl cement. More recent experiments with unbacked gages bonded with ceramic cements such as Bean-H have been successful in maintaining high insulation resistance under irradiation.

Extensive experimental work has been conducted in the last ten years, particularly in connection with the Rover and NERVA programs. The General Dynamics (GTR) reactor in Fort Worth, TX, with its unique capability for

large dewar cryogenic irradiations played a significant role in these efforts. The Plumbrook reactor in Sandusky, OH, was also used extensively for high-flux and high-heating-rate experiments.

It would be impractical to review all these experiments, many of which provided as much insight by their failures as by their successes. Many experiments were reported and their results published.[11,12] However, a review of some results may illustrate the progress made in this field.

The first efforts were concentrated on the Microdot weldable strain gage. This strain-gage system was considered most suitable for high-radiation service, being enclosed in a metal envelope and insulated with compacted MgO. A large number of Microdot weldable gages were irradiated at GTR and at Plumbrook, and were included in several Rover and NERVA reactors.

In GTR Experiment 11, twelve weldable strain gages were irradiated connected as six-1/2- bridge systems attached to six tapered steel beams.[13] The beams were cycled to 1000 μin./in. throughout the test, and the whole assembly was held at $LN_2$ temperature during the irradiation. The sensitivity or gage factor was not significantly affected but the zero balance was changed by ~ 100 μin./in. on four bridges and that change was as high as 400 μin./in. on two bridges for a neutron dose of $10^{16}$ nvt ($E_n$ > 1.0 MeV). The insulation resistance dropped about one decade during irradiation, but remained in all cases sufficiently high (above 20-50 MΩ). This early experiment was typical of many, and pointed to the major problem, i.e., to the fact that the resistivity change induced in the strain gages and lead wires was not identical in the two halves of the bridge and that the resulting bridge balance was disturbed. A test using a similar fixture was made at the Plumbrook reactor at a much higher neutron dose.[14] This experiment was conducted at 135°F and the fast-neutron fluence reached was $10^{19}$ nvt ($E_n$> 1.0 MeV). The spread in zero shift for the eight pairs of 1/2-bridge circuits is shown in Fig. 8. The alarming problem was the inconsistency in the magnitude of the zero balance between strain-gage bridges. The overall envelope of this zero-shift variation is shown in Fig. 9. The experiment did not reveal any serious problem due to a drop in insulation resistance, although resistance did drop to 30 MΩ from the initial value of 500 to 1000 MΩ. A later test was conducted at Plumbrook including both weldable strain gages and ceramic-cemented foil gages using the same fixture

and reactor environment.[15] The gages were cycled to ~ 500 μin./in. and exposed to a fast-neutron fluence of $1.6 \times 10^{18}$ nvt ($E_n > 1.0$ MeV).

Again the measured bridge unbalance of the gages wired as 1/2-bridge systems was excessive and inconsistent. Figure 10 shows the zero-balance shift for the Microdot gages, and Fig. 11 the results of the Bean-H ceramic-cemented Budd C9610 foil gages. The C9 foil gages also exhibited a large spread in zero balance between individual bridges.

The difference between the Microdot and the C9 610 foil gages is significant and illustrates that the induced resistivity change is very dependent upon the alloy and its processing. Behavior between gages of the same type in the same radiation environment depends upon whether the gages are identical metallurgically. Pettigrew[16] in his 1969 presentation to SESA reported remarkably good performance of the weldable strain gages in tests of 1/2-bridge circuits to $1.9 \times 10^{19}$ nvt. He found no significant effect on gage factor, hysteresis, or linearity, but the reported resistance change in each gage was quite large. Figure 12 shows the percent change in resistance with neutron dose. Note that the gages do not change identically. Gages 3 and 4 show ~ 0.33% deviation, whereas Gages 2 and 4 deviate by ~ 1%. This 1% change in resistance would result in a bridge unbalance of $5.5 \times 10^3$ μin or a bridge unbalance of 550% of full scale for the gages paired as 1/2 bridges where 1000 μin./in. was full-scale.

Other gages and techniques were also thought to be suitable. Lyn Hostettler at Aerojet General Corp. working with BLH developed the flame-sprayed $Al_2O_3$ or ZrO-insulated and bonded high-temperature strain gage using the 92:8 w/o Pt:W alloy wire gage. Steve Wnuk, Jr. reported this radiation resistant strain gage development.[17] Several radiation-effects experiments of this flame-sprayed gage were made at the GTR reactor on the NERVA program. In one experiment 72 strain gages tested in 1/2-bridge pairs were irradiated to a neutron fluence of $2.3 \times 10^{16}$ nvt while at 650° to 750°F ambient temperatur Seven gages opened, four showed a large change in output, but 52 gages worked fairly well indicating only a 5.5% output change. The insulation resistance of these 36 pairs of gages dropped from 28 to 1.7 MΩ during irradiation but then recovered to 10 MΩ after test. Other tests of flame-sprayed bonded strain gages indicated significant better performance of $ZrO_2$ over $Al_2O_3$ bonded gages both in insulation resistance and in zero shift with dose.

I have found that moisture absorption can be extreme in the open-pallet tests at the GTR high-humidity Fort Worth facility or in $LN_2$ tests during warmup. The radiation effects on ceramic-cemented or flame-sprayed ceramic-bonded strain gages can be completely dominated or seriously affected by the presence of moisture. The reported tests of flame-sprayed gages were also made with very-high-voltage excitation up to 60 Vdc. The high electric field combined with radiation-induced photoconduction and ionic conduction on the gage surfaces where moisture had been absorbed is a bad set of circumstances. The most successful tests have been made in a dry and inert atmosphere where moisture sealants were used over the ceramic. High bridge voltages are not recommended because they enhance the leakage conduction.

In one experiment problems developed in the bond between the gage and the beam. Unfortunately the magnitudes of the strain was not reported other than that the problem occurred in compression cycles on aluminum strain beams while thermally cycled to $LN_2$ temperature. Apparently the total thermal plus applied strain exceeded the limit for this bonding method.

Reactor Applications

Concurrent with these radiation-effects experiments in test reactors, diagnostic measurements of reactor core deflection, pressure vessel strains, bolt tensile loads, and core support loads were required in the development testing of Rover and NERVA reactors.

Although controlled experiments could not be easily made in these reactors, much was accomplished in learning what techniques do work. Successful measurements[12] were made under the very severe environmental conditions inside these reactors. Gamma heating levels of 5 W/g and neutron fluences of over $10^{18}$ nvt ($E_n > 1.0$ MeV) were met in some locations with ambient temperature variations from + 70° to - 425°F. At LASL we began with Microdot weldable strain gages of the active-dummy type in one integral steel envelope with integral, swaged stainless-steel-sheathed MgO insulated cables. Our major problem was that of cable resistance changes due to temperature extremes and temperature gradients. The strain-gage 1/2-bridge was located in a reactor plenum at near-$LH_2$ temperature, whereas the leads were routed to a pass-through in the pressure vessel. At a distance of only a few inches from the cooled pressure vessel the cables would reach up to 1000°F due to gamma heating. Figure 13 shows a weldable strain gage installed for core-deflection measurement.

Our solution to the gamma-heating problem was to use four gages in a complete bridge at the measurement point in combination with a constant-current excitation system. We experimented with ceramic-cemented foil strain gages for some applications because the need for four gages made it difficult to obtain a small assembly including the brazed, sealed stainless-steel-enclosed termination of the steel-sheathed lead. Moisture-sealing of the ceramic cement and the termination of the four single-conductor swaged leads became the major problem. The final scheme for ceramic-cemented foil strain gages is shown in Fig. 14. The new techniques were also used for assemblies that could accept the larger space required by Microdot weldable strain gages or had strain levels in excess of + 5000 μin./in. which prohibited the use of ceramic cement. An example of the use of full-bridge weldable gages and another installation of these gages are shown in Figs. 15 and 16, respectively. The success of these techniques in a given reactor test provided encouragement for further refinement and attempts in the next test. Although good experimental test data was obtained the problem of radiation-induced resistivity change in the strain-gage wire or foil, causing a zero balance shift, was still with us.

The data clearly indicated that the radiation-induced resistivity change was not consistent, and that predictions of bridge unbalance or the use of compensating techniques were not satisfactory. This then prompted us to continue our radiation-effects testing on larger quantities of strain gages in our Omega West Reactor.

LASL Radiation Effects Program

A test capsule was constructed which could strain-cycle four constant-strain test beams.[18] This capsule was water-cooled by flowing ~ 4.55 ℓ/min (1 gpm) of refrigerated water through the base to remove the 0.2-W/g gamma-heat deposition. A helium purge maintained an inert atmosphere within the capsule. The strain beams were repeatedly deflected to a fixed displacement by two graphi pistons driven by helium pressure. The small helium leakage around the pistons provided the purge gas. Figure 17 shows this capsule with the cover removed. The vertical access tube in the Omega West reactor has a diameter of ~ 8.9 cm (3.5 in.) and drops through ~ 8.0 m (20 ft) of water to reach the reactor core. This capsule then was limited to a 7.0-cm (3-in.) diameter to allow easy inserti into this access tube. A complete strain bridge was bonded to each side of the four steel strain beams and was oriented as shown in Fig. 18. Two bridges were tested of each of the following:

- Bean-H ceramic-cemented die-cut Dentronics foil gages Model H1802ST of 92Pt-8W alloy.
- BLH FAET-12B-12S6 ET constantan foil gages polyimide-backed and bonded with EPY 500 epoxy.
- Micromeasurements EA06 125TM-120 constantan alloy also backed with polyimide and bonded with Mbond 610 epoxy.

The ceramic-cemented gages were overcoated with RK 692 polyimide varnish for moisture sealing. The gage hookup wire was Pyre-ML varnish (polyimide)-insulated. These leads were soldered to stainless-steel-sheated two copper conductor MgO-insulated cables leading out of the capsule.

You might ask, why did you even experiment with an organic backing and with epoxy-bonded strain gages in light of all the past evidence of rapid deterioration of organic materials under irradiation? However, polyimide organic film has proven to be highly radiation-tolerant. Tests conducted at LASL[19,20] and elsewhere have demonstrated that this material is not significantly degraded after a fast-neutron exposure of $10^{18}$ nvt ($E_n > 1.0$ MeV) and $10^{10}$ rad of gamma radiation. Cyclic flexing tests at $LN_2$ temperature were made without failure aft this radiation exposure. This high radiation tolerance is attributable to the cyclic structure of the polymers. The imide[21] structure is characterized by double-bond linkage between one nitrogen atom and two carbonyl groups. These groups are usually attached to a benzene ring in polymers. Figure 19 shows this basic structure. This polyimide material exhibits outstanding mechanical properties at temperature extremes: 3.14-rad (180 deg) bends in LHe can be made without fracture. The zero-strength temperature for the film (20 psi load for 5 s to failure) is 1472°F. Although the electrical resistivity does decrease with temperature, the decrease in solid-bulk polyimide from $10^{17}$ Ωcm at room temperature to $10^{11}$ Ωcm at 572°F, however, is still sufficiently high for a good insulator. A 1-mil-thick layer one inch square would have a resistance of 40 MΩ at 572°F. These excellent high-temperature properties and radiation-test results gave us hope that this polyimide would be an excellent radiation-tolerant strain-gage backing material. Fortunately, about the same time, the strain-gage manufacturers became interested in this material because of its other excellent properties.

The strain-gage irradiation tests of these ceramic-cemented foil gages and of the polyimide-backed epoxy bonded gages were surprisingly successful.

The zero-balance changes for these four types of strain-gage bridges are shown in Fig. 20. The duplicate units behaved essentially identically. Sensitivity changes vs neutron dose are plotted in Fig. 21. No resistance-to-ground less than 10 MΩ was observed. Several very interesting conclusions can be drawn from this experiment.

- Polyimide-backed strain gages using epoxy bonding can be used successfully up to a fast-neutron fluence of $7 \times 10^{18}$ nvt ($E_n > 1.5$ MeV), and to a gamma radiation dose of at least $10^{11}$ rad. No significant mechanical, or electrical degradation was experienced.

- Polyimide-varnish-insulated wires can be used to a fast-neutron fluence of $7 \times 10^{18}$ nvt ($E_n > 1.5$ MeV) and to a gamma radiation dose of at least $10^{11}$ rad without loss of insulation or physical degradation.

- Constantan can be processed into metal-foil strain gages that have essentially identical resistivity changes with neutron dose and thus, when used in a full-bridge system, maintain bridge balance.

- Constantan is a better choice for radiation service than other alloys tested, i.e., Karma, platinum/tungsten. However, even constantan is sensitive to fabrication processes.

- Bean-H ceramic cement sealed with polyimide varnish is satisfactory for bonding unbacked metal-foil strain gages exposed to $7 \times 10^{18}$ nvt ($E_n > 1.5$ M and $10^{11}$ rad. Zero return immediately upon cycling to $\pm$ 1000 μin./in. did not reveal any creep or bond loss. The insulation to ground was over 10 MΩ throughout the experiment.

- Although previous radiation-effects experiments warn of neutronically induced flux-sensitive emf sources, no dc potentials were observed in these bridges.

- Leads can be attached satisfactorily in dry helium by using standard 63Pb 37Sn solder for irradiation environments that do not exceed the recommended maximum temperature for solders.

Although 32 strain gages were irradiated in this experiment, individual changes in gage resistance were not available because the gages were wired in complete bridge circuits. We tested complete bridges simply because we had

found them best in our reactor installations. However, the distribution of resistivity changes in a large sample of gages versus neutron dose would be of interest so that the most probable zero drift for a set of strain gages cou be determined. Of interest are also the fabrication processes that most significantly affect the resistivity changes during irradiation. The experiment clearly showed that close control at each step of strain-gage fabrication is essential to produce metallurgically identical gages. Any variation in resistance between strain gages of the same alloy is due to slight changes in the structure brought about by variations in the original melt, rolling-induced cold work, annealing times and temperatures, and final etching processes and packaging. Apparent strain compensation is a good example: sometimes gages are heat-treated to achieve a given apparent strain curve by affecting the electrical resistance change with temperature. However, any heat treatment that will affect this behavior will also affect the electrical resistance change due to radiation. Therefore, two gages of different heat treatment assembled in one bridge will probably not have the same radiation sensitivity, although original tests may have indicated good matching for temperature compensation. Conversely, the radiation-induced changes probably will affect the apparent strain curves. Further, we should expect that the radiation-induced resistivity change will be much greater at cryogenic temperatures, where the thermal annealing of defects is minimum, than at elevated temperatures. These interrelationships of various effects can best be minimized by locating the four gages of a bridge in the same temperature and radiation environment. In reactors of very high gamma heating rates (and thus high temperature gradients) it is particularly important to carefully choose the strain-gage locations.

## Current Experiments

Studies are in progress to determine some of these irradiation effects. An extensive experiment (GTR 23) at $LN_2$ temperature has just been completed at the GTR Fort Worth, TX, facility. One of the two similar strain-gage capsules used in this experiment is shown in Fig. 22. Note that the fixture is similar to that shown in Fig. 15 except that a bellows is used instead of graphite pistons to deflect the strain beams.

Each strain gage was measured individually by using a four-wire system developed by Bob Crabtree of General Dynamics. The change in resistance due to strain and radiation was measured in a manner not often used for strain-gage systems. Figure 23 shows the measuring circuit. The voltage across the strain gage was fed to the digital voltmeter input, and a second potential developed across a resistor in series with the gage was fed to a voltage-to-frequency converter. This frequency signal, which was proportional to the current through the strain gage, was used to vary the time base of the integrating digital voltmeter. (This arrangement is sometimes made available on digital voltmeters as a ratiometer option.) The digital output of the voltmeter gave directly the resistance ratio of the strain gage to the fixed-series resistor. The fixed resistor was thermally insulated to minimize thermal-drift effects. Resolution and drift in reading the resistance ratio was within $\pm$ 10 $\mu\Omega/\Omega$ throughout the experiment. Through a multichannel data-logger system, we were able to measure 80 individual strain gages. Several alloys were investigated: constantan, Karma, Micromeasurements Alloy-C (similar to old Armour Alloy-D), Dentronics 1800 series, Dentronics 2100 series, and amorphous alloys.

The constantan tested was of 6, 12, and 36 ppm per °F apparent strain compensation. Several strain-gage backing materials and bonding methods were tested: polyimide-backed, epoxy bonded, and ceramic-cemented unbacked gages. These gages and the variations among them are summarized in Fig. 24. The results have not yet been computer-reduced and plotted, but some preliminary hand-reduced data can be reviewed. Figure 25 shows the measured change in resistivity vs neutron fluence. This increase for constantan does conflict with the Smith and Redler results of 1958, but maybe attributed to alloy or process differences. Figure 26 shows that Karma decreases in resistivity with neutron dose. The data are consistent with the reported decrease observed at room temperature. In the room-temperature exposure test, H302 ST die-cut Karma alloy Dentronics foil gages, ceramic-cement-bonded to steel, exhibited a decrease of -0.9% in resistivity at $4 \times 10^{18}$ nvt ($E_n > 1.5$ MeV) when measuring the bridge resistance. The GTR-23 experiment indicates that the resistance of this foil and cement on aluminum beams at $LN_2$ temperature decreased - 0.710 $\pm$ 0.197% at a neutron dose of $10^{18}$ nvt. The resistivity change observed in these two cases accounting for neutron dose level, temperature, and small-sampl

$\pm 2\sigma$ scatter, is reasonable. Preliminary results from this GTR-23 experiment are listed in Fig. 27. Note that the 2100 series Dentronics alloy shows a factor-of-18 smaller change for equivalent neutron dose than constantan. Further, the $\pm 2\sigma$ deviation of $\pm$ 0.009 is much less than that for MM constantan gages of $\pm$ 0.035) or BLH gages ($\pm$ 0.072). This deviation is the important factor in maintaining bridge balance when four bridges are used in a bridge circuit. Note also that bonding material and substrate affect the overall measured change in the foil's electrical resistivity with neutron dose. Further, Karma alloy bonded to stainless steel with ceramic has a different result than those gages encapsulated in ceramic only, and heat treatment of constantan to achieve a compensation of 36 ppm results in a resistivity change of 0.396 $\pm$ 0.079, whereas the 13-ppm constantan has a change in resistivity of 0.548 $\pm$ 0.072 percent for a neutron dose of $10^{18}$ nvt.

Experimental Plans

Because resistivity changes are of major concern a simpler radiation-effects experimental capsule has been designed that will allow 40 strain gages to be irradiated passively without stress-cycling. The temperature is maintained at 300 K by using refrigerated water circulating through the base. Several capsules are being manufactured, so that a sample size of 40 gages of each type and bonding material can be tested. The radiation-induced changes in the apparent strain curve can also be measured over a limited temperature range. If process control is sufficiently documented in cooperation with the vendor, we may be able to identify the processing steps that have the greatest effect on changing the resistivity during irradiation, as well as the best strain-gage alloy.

Our goal is to find the best alloy and bonding procedure for transducers that will show the least change in zero balance and sensitivity at neutron fluences in excess of $10^{18}$ nvt ($E_n > 1.0$ MeV). We have already experimented with pressure transducers using the MM EA06-125 TM-102 polyimide-backed constantan gage bonded with M-bond 610 epoxy. The Bell & Howell CEC Model 4-402-0178 and the Precise Sensors Model 70002 both showed excellent performance in the GTR 23 irradiation test, having less than 1% zero-balance shift and a

sensitivity change of 2% at a neutron dose of $10^{17}$ nvt ($E_n > 1.0$ MeV). These transducers are not significantly affected by gamma-heating levels of 0.05 W/g.

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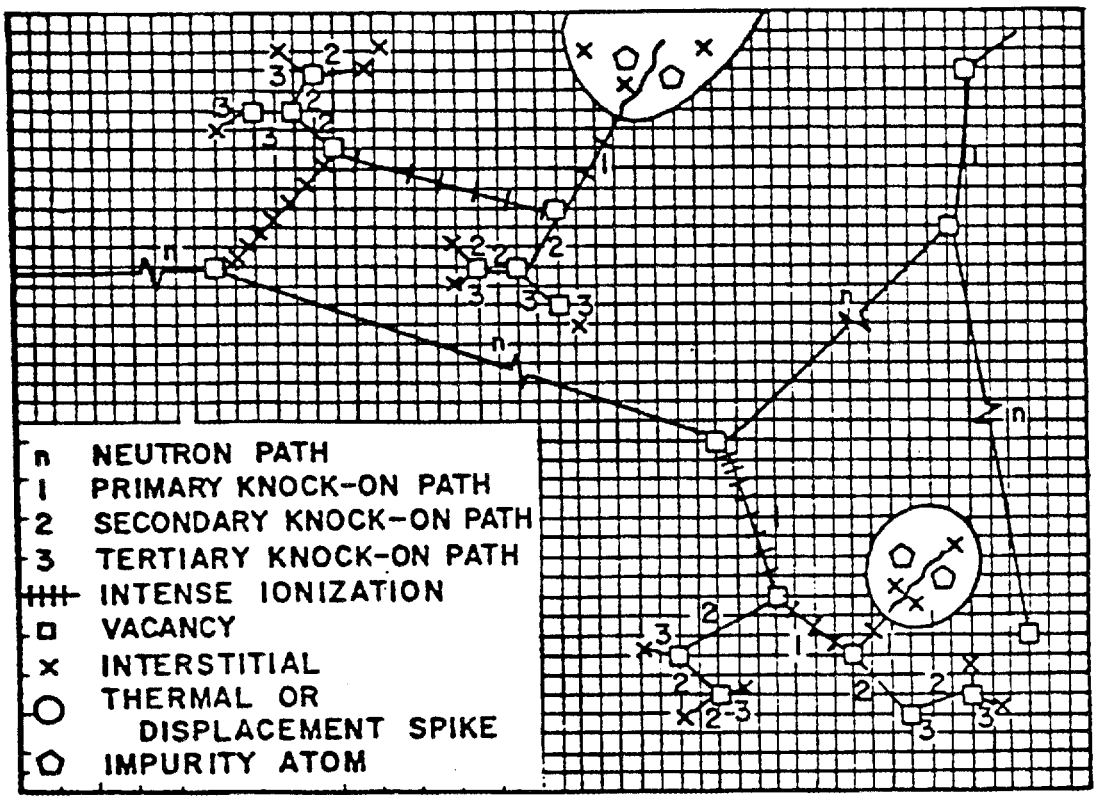



FIGURE 1. SCHEMATIC SHOWING FIVE MECHANISMS OF FAST NEUTRON RADIATION

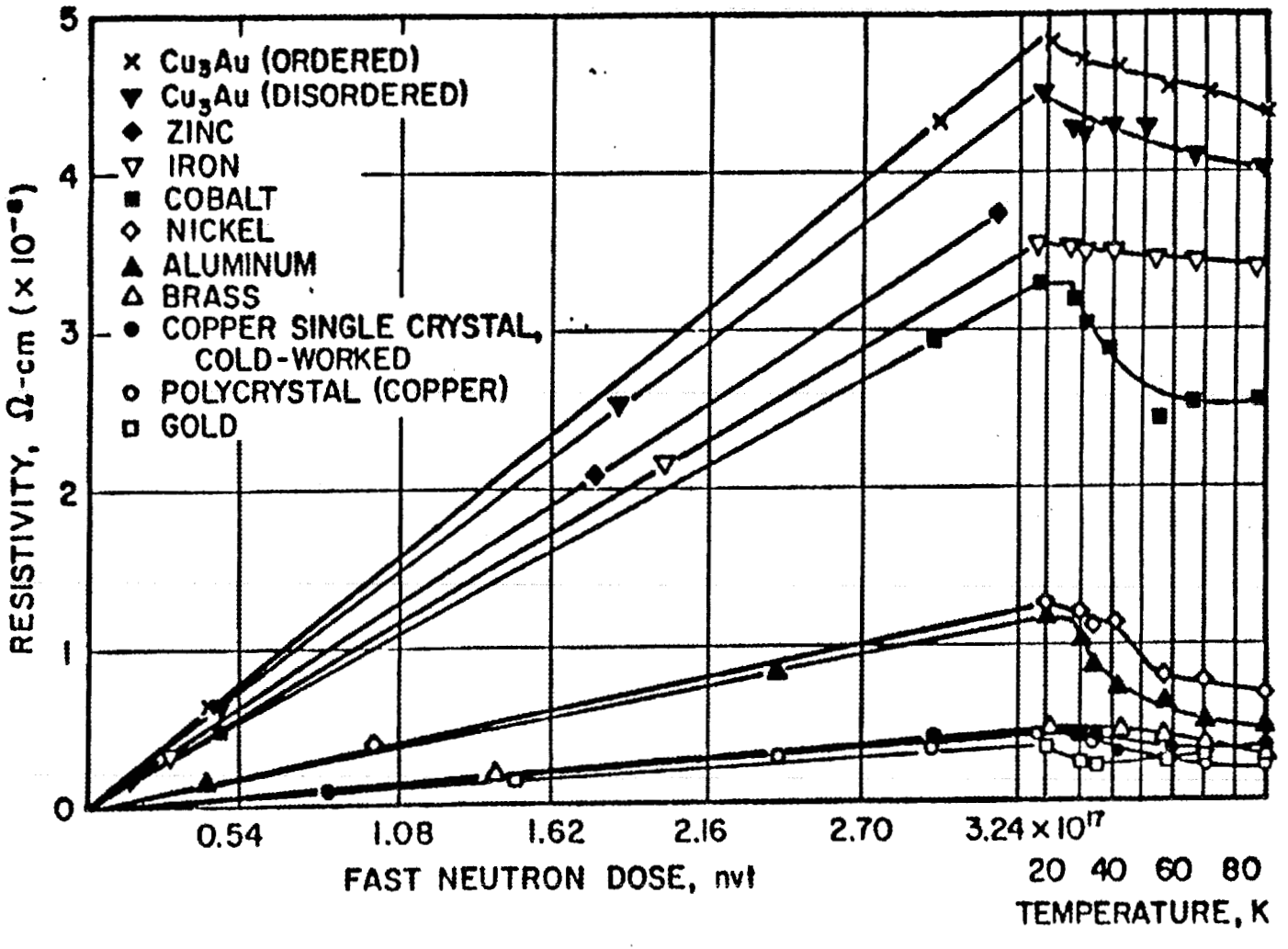



FIGURE 2. THE CHANGE IN ELECTRICAL RESISTIVITY OF SEVERAL METALS AND ALLOYS AS A FUNCTION OF IRRADIATION DOSE AT 20°K.

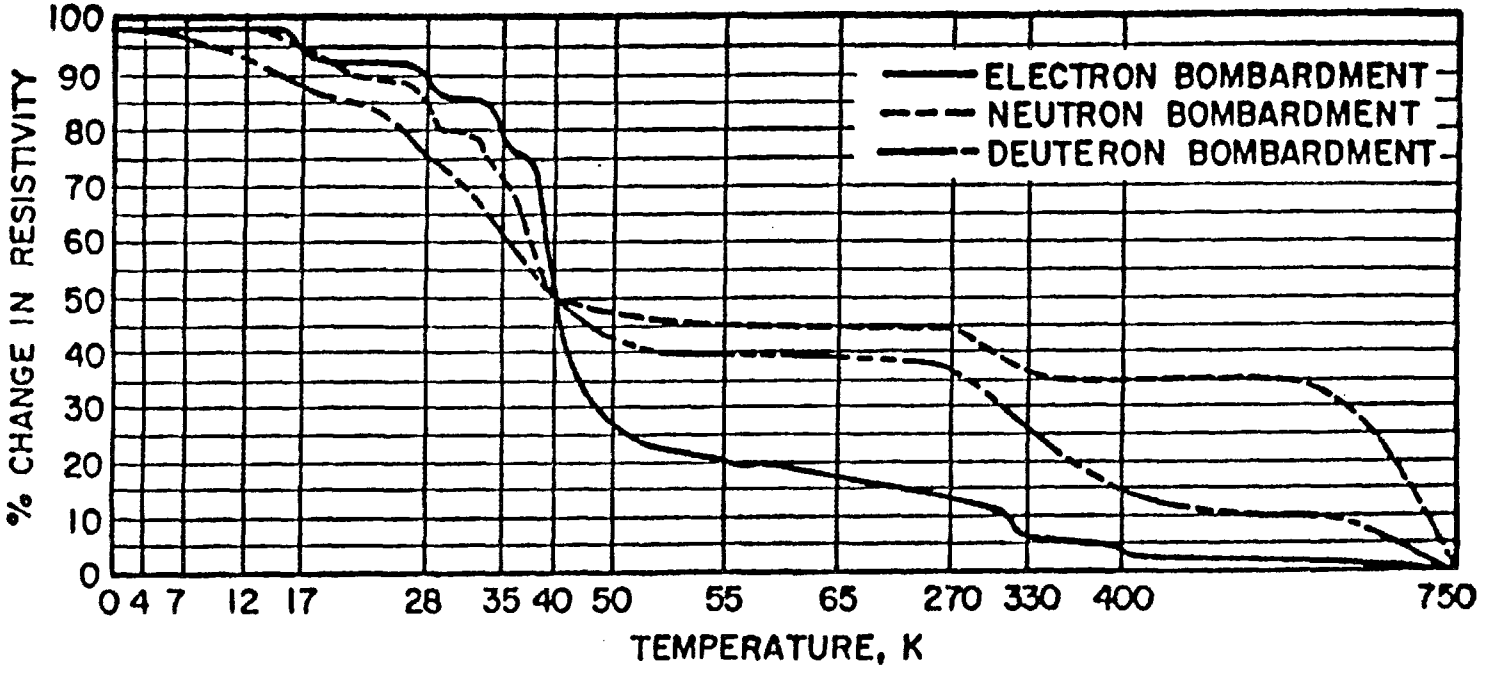



FIGURE 3. A SCHEMATIC PLOT OF THE THERMAL ANNEALING OF THE IRRADIATION-INDUCED ELECTRICAL RESISTIVITY INCREASE IN COPPER. NOTE THAT IN GENERAL THE AMOUNT OF RESISTIVITY RECOVERED AT ANY GIVEN TEMPERATURE VARIES WIDELY BETWEEN TYPES OF IRRADIATION.

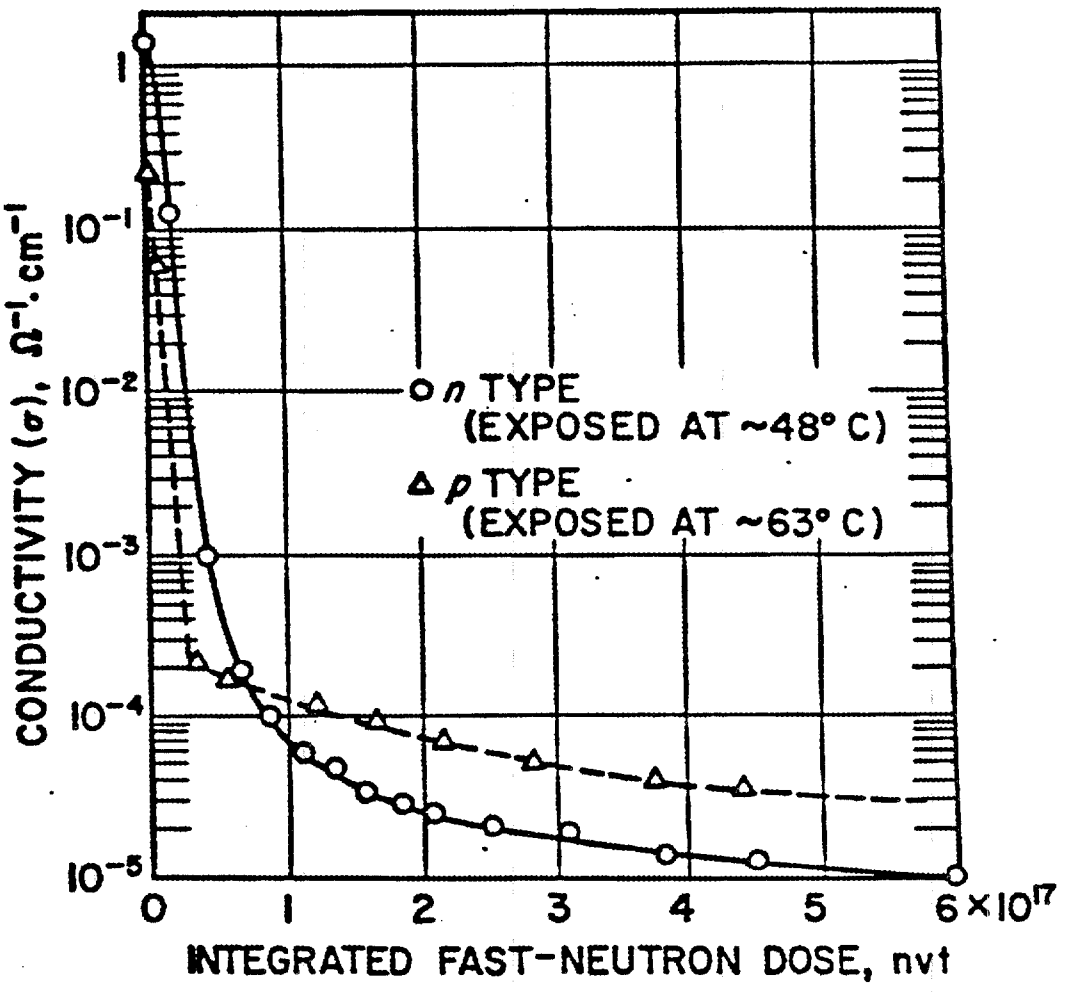



FIGURE 4. LOG CONDUCTIVITY VS INTEGRATED FAST-NEUTRON FLUX FOR BOTH N- AND P-TYPE SILICON.

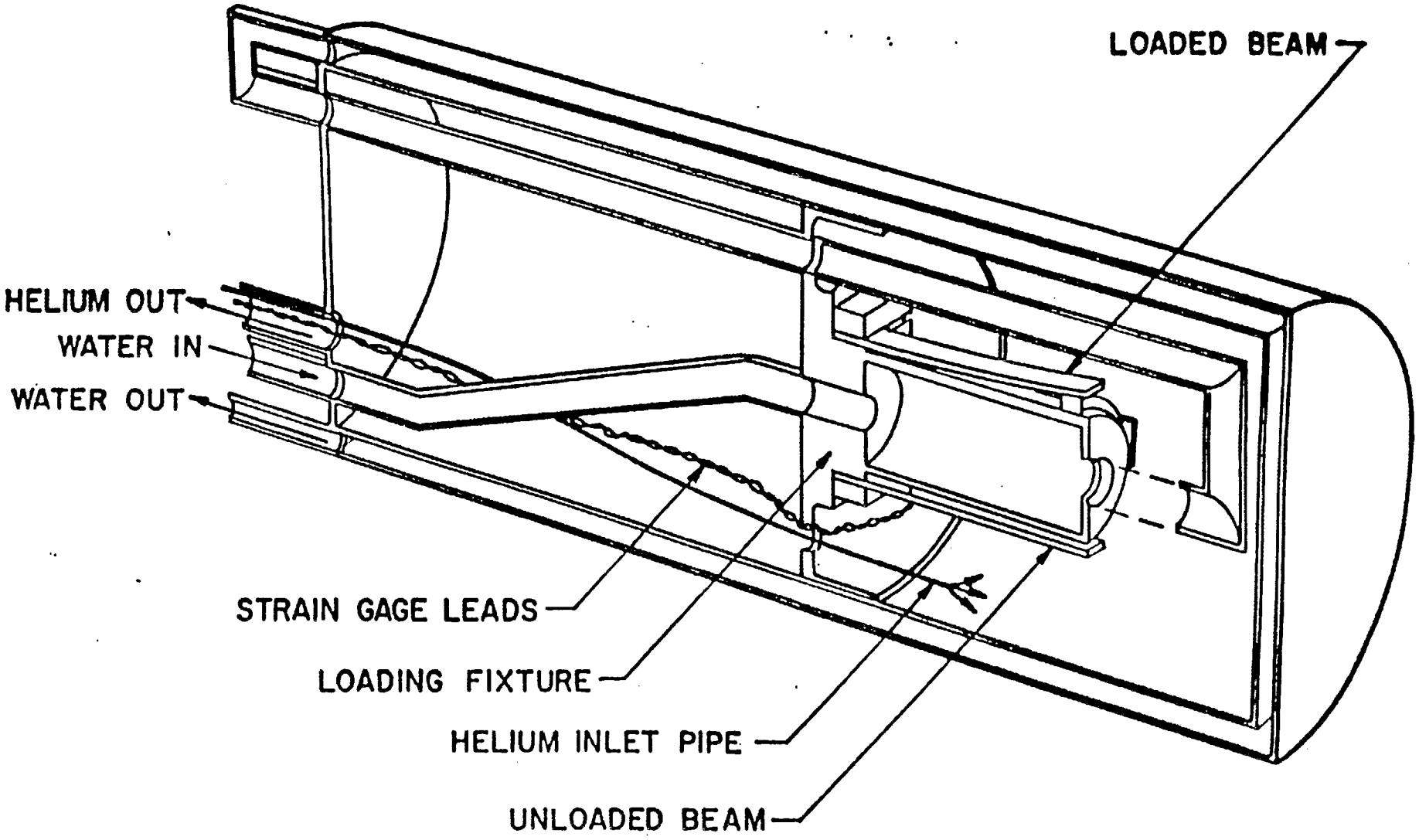



FIGURE 5. STRAIN GAGE TEST FIXTURE USED FOR IRRADIATION EXPERIMENTS BY R. C. SMITH AND N. J. RENDLER

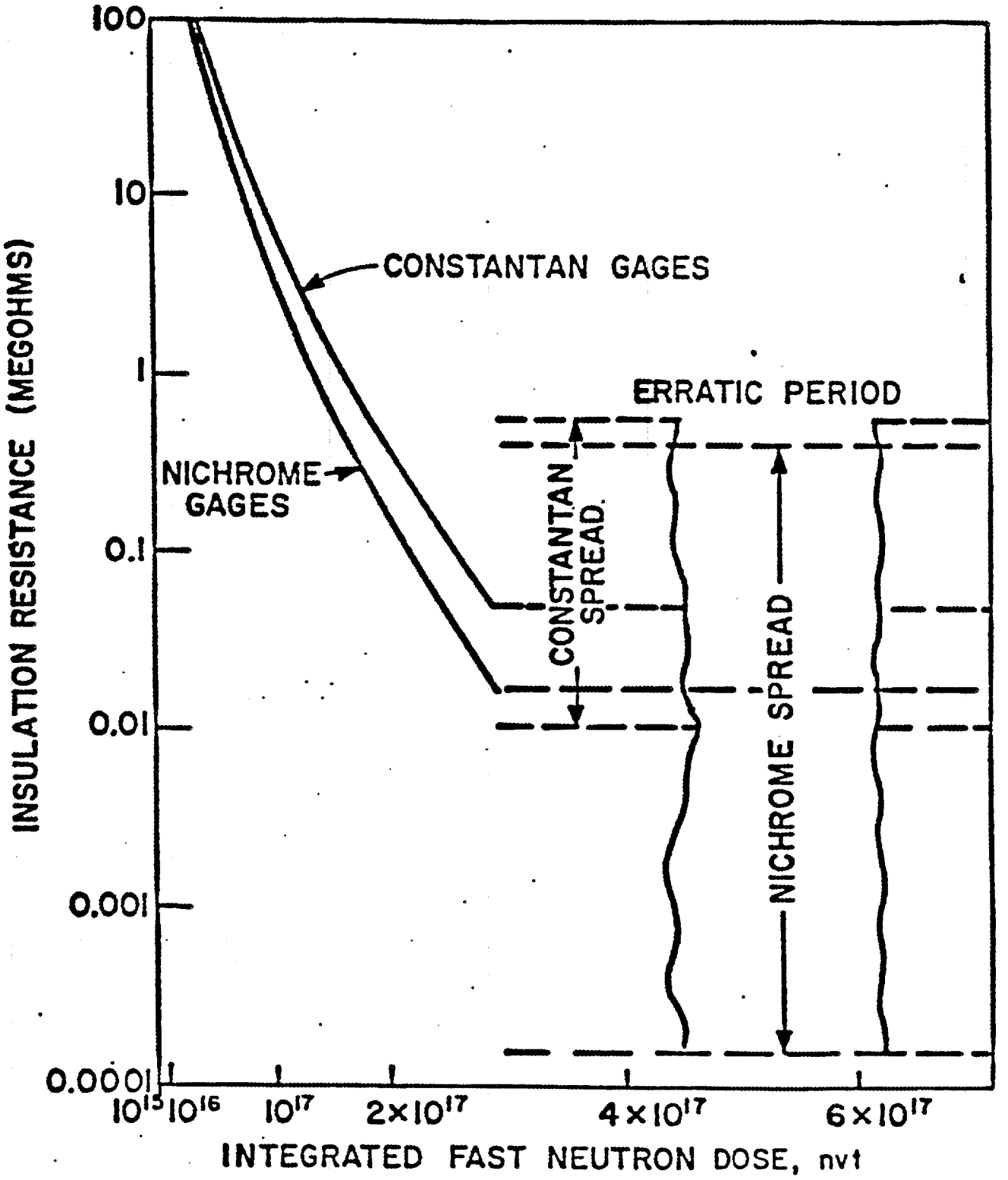



FIGURE 6. RESISTANCE TO GROUND VS NEUTRON DOSE OCCURING IN SMITH & RENDLERS STRAIN GAGE CIRCUIT.

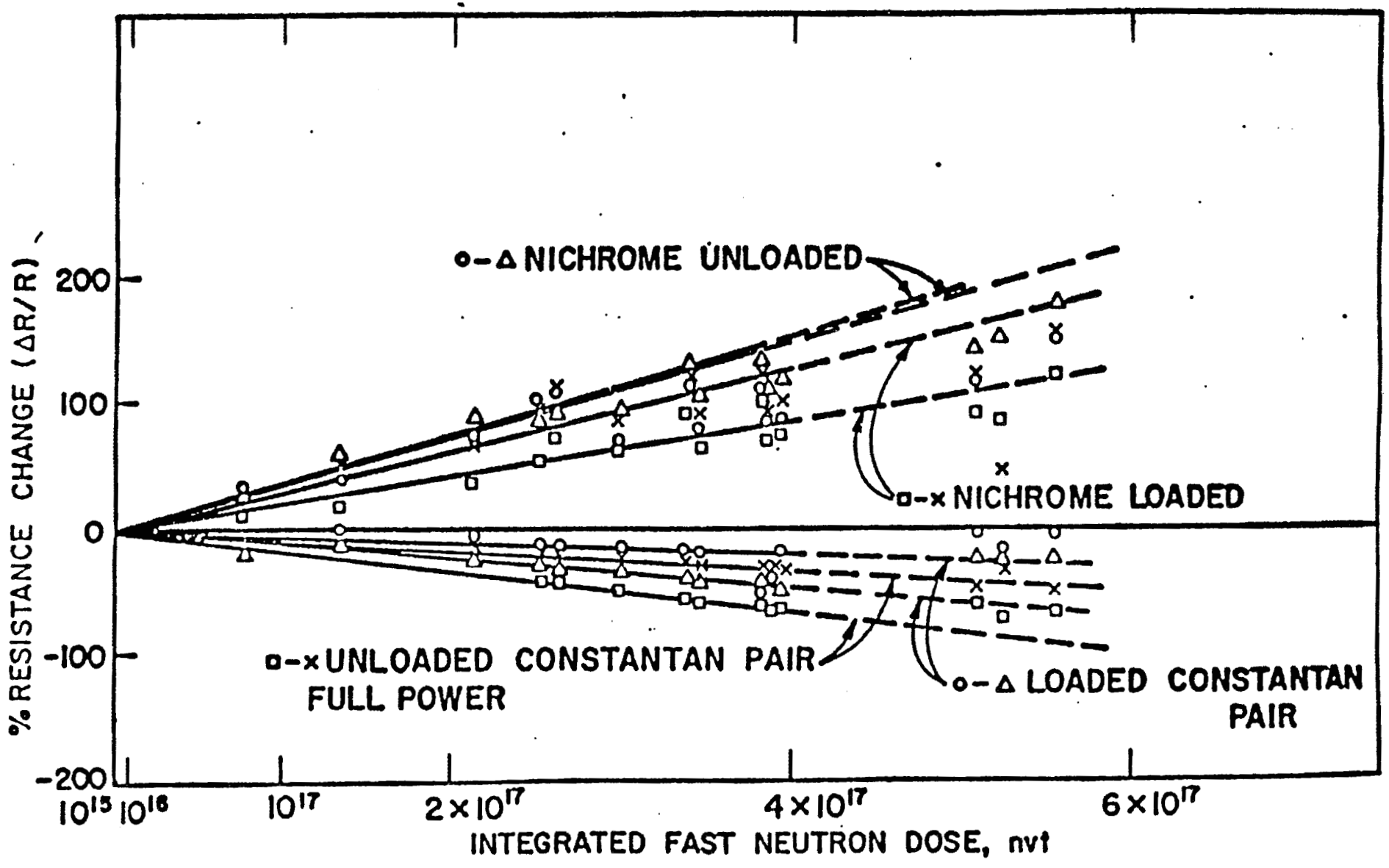



FIGURE 7. CHANGE IN ELECTRICAL RESISTIVITY IN CONSTANTAN AND NICHROME STRAIN GAGES VS NEUTRON DOSE MEASURED BY SMITH & RENDLER 1958.

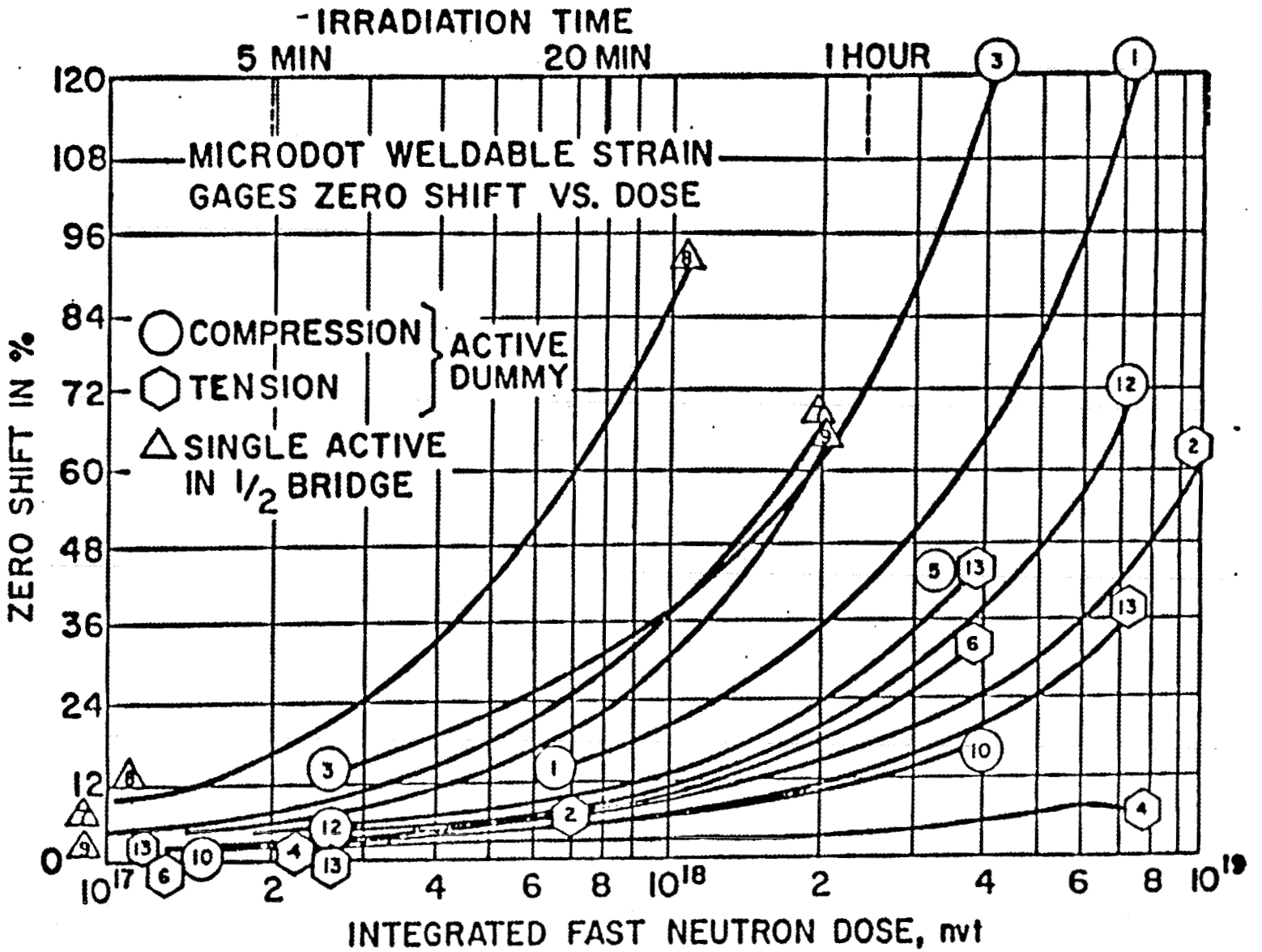



FIGURE 8. % CHANGE IN ZERO BALANCE OF 1/2 BRIDGE WELDABLE STRAIN GAGES CIRCUITS VS FAST NEUTRON DOSE.

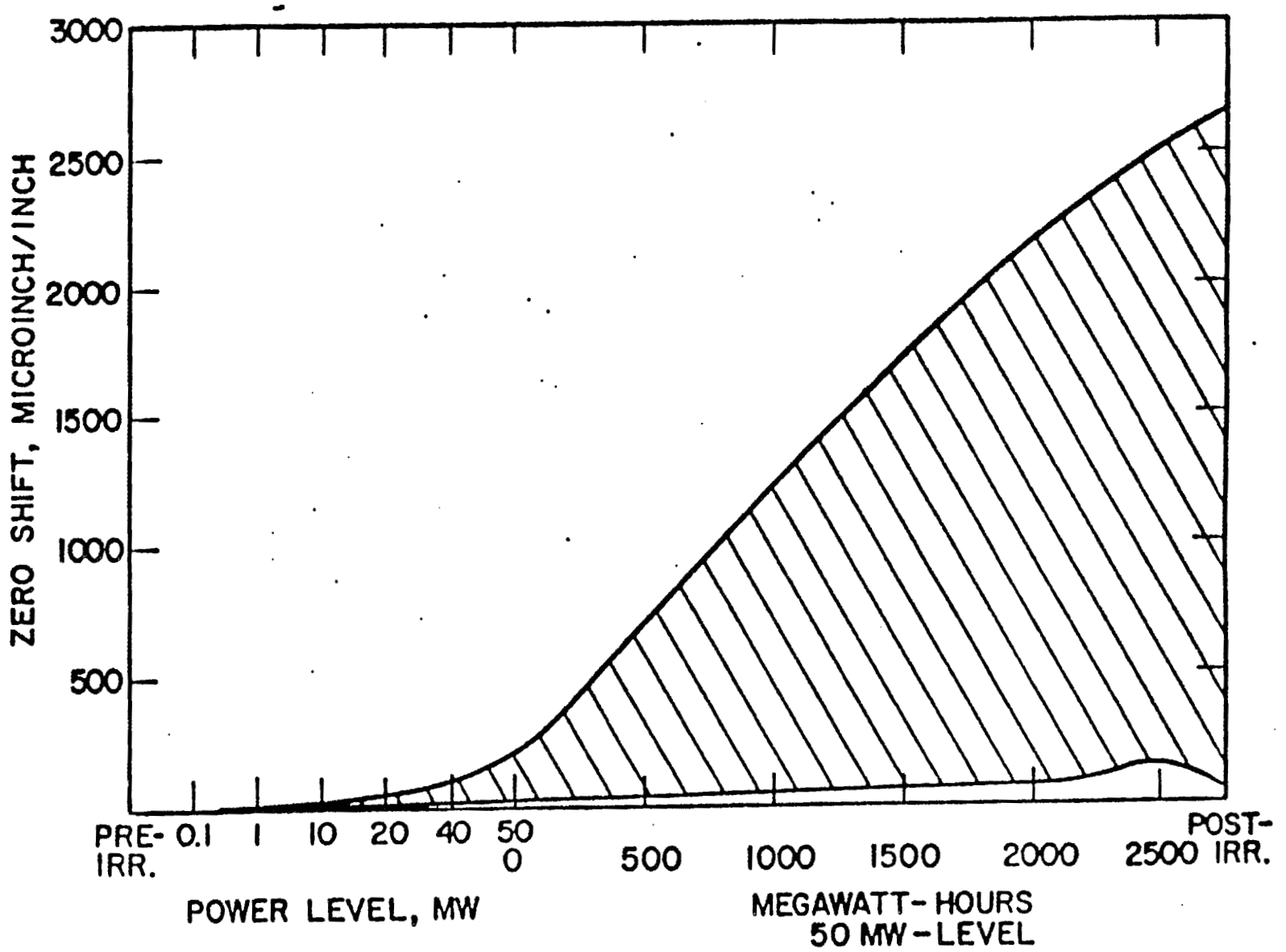



FIGURE 9. ZERO SHIFT IN EQUIVALENT MICRO IN./IN. FOR MICRODOT WELDABLE STRAIN GAGES VS REACTOR POWER AND HOURS AT THE PLUMBROOK TEST.

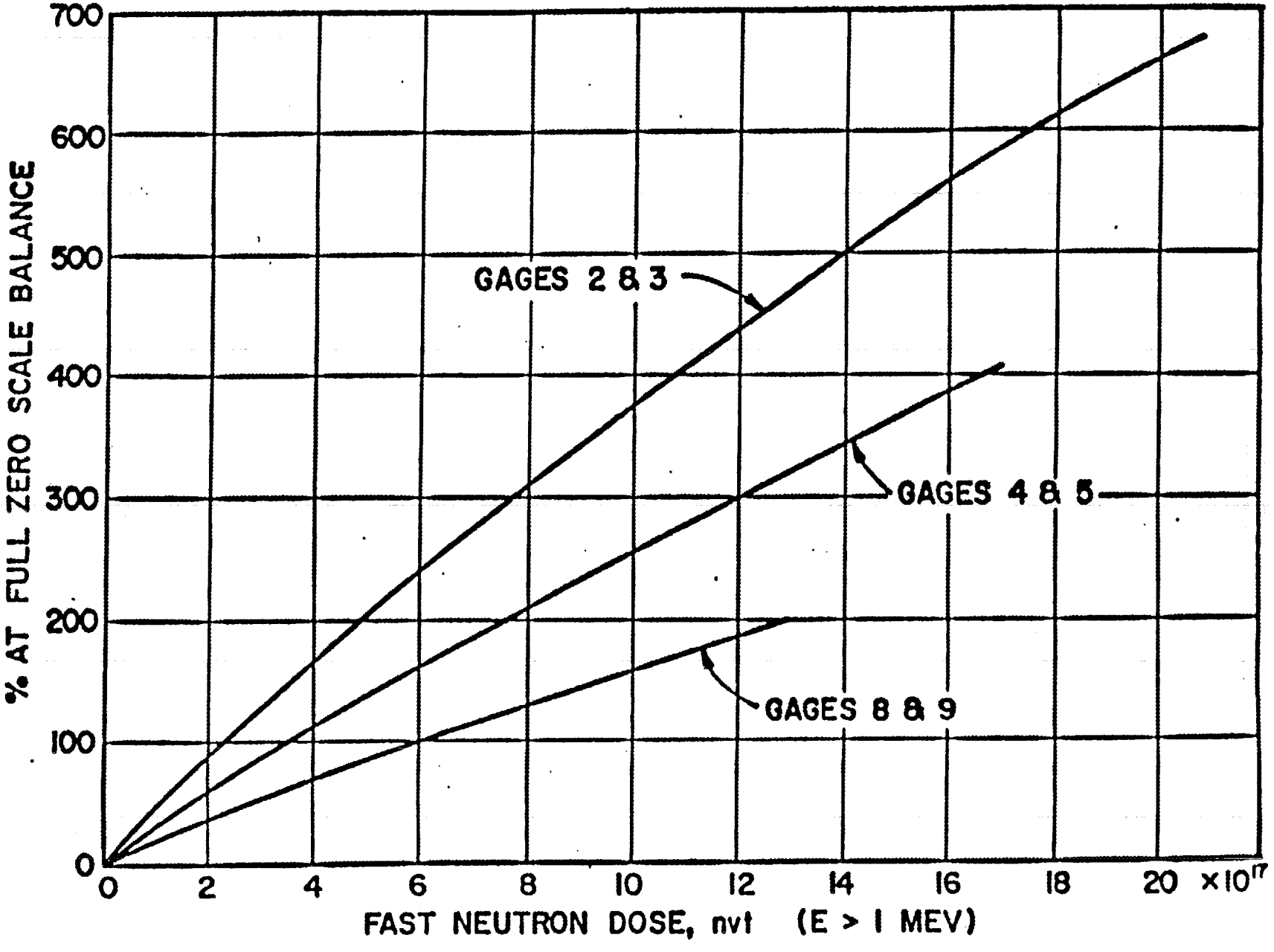



FIGURE 10. ZERO SHIFT VS NEUTRON DOSE FOR MICRODOT WELDABLE STRAIN GAGES TESTED IN THE PLUMBROOK REACTOR.

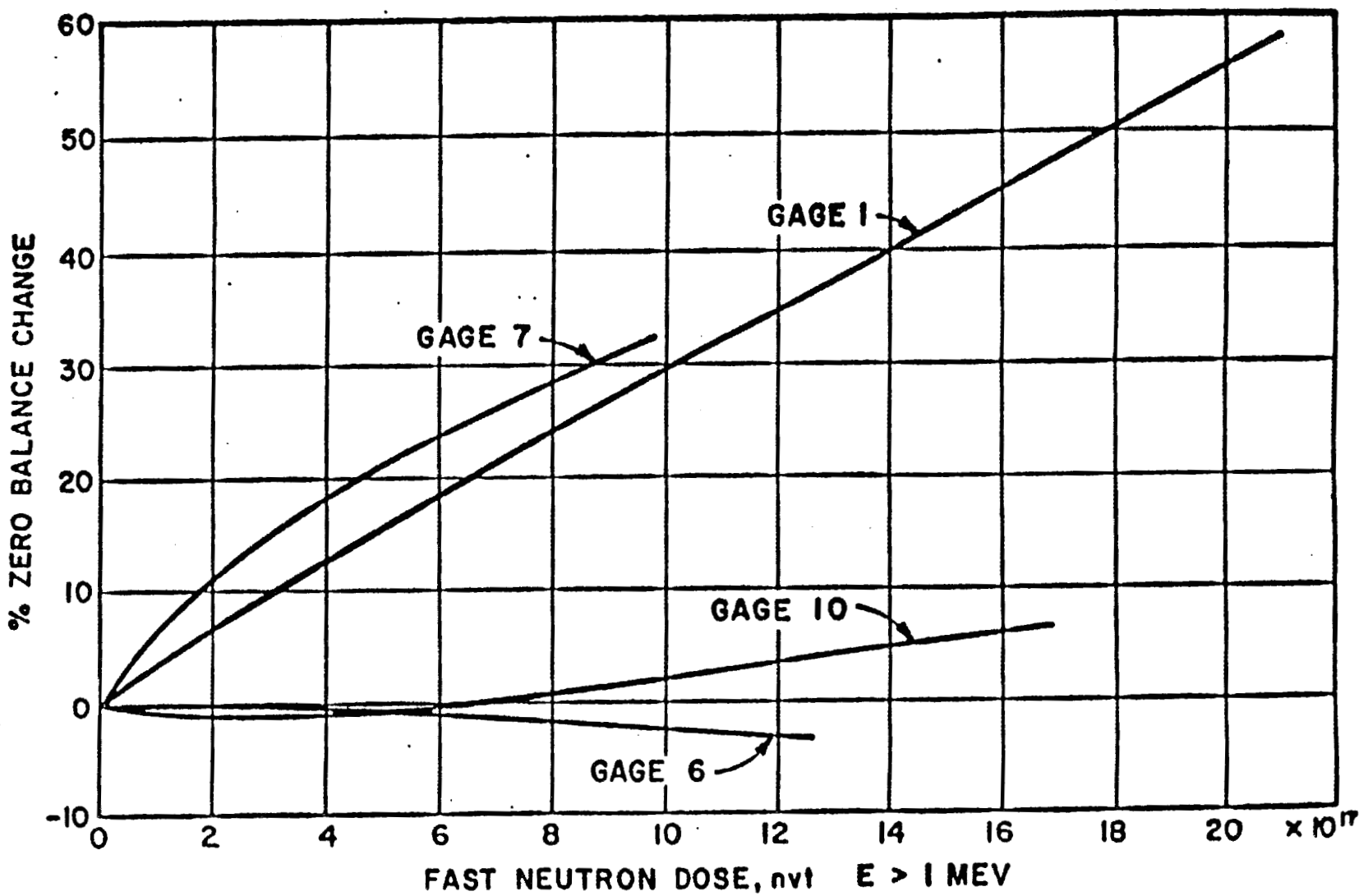



FIGURE 11. ZERO SHIFT VS NEUTRON DOSE FOR BUDD C9-610 GAGES BONDED WITH BEAM H CERAMIC TESTED IN THE PLUMBROOK REACTOR.

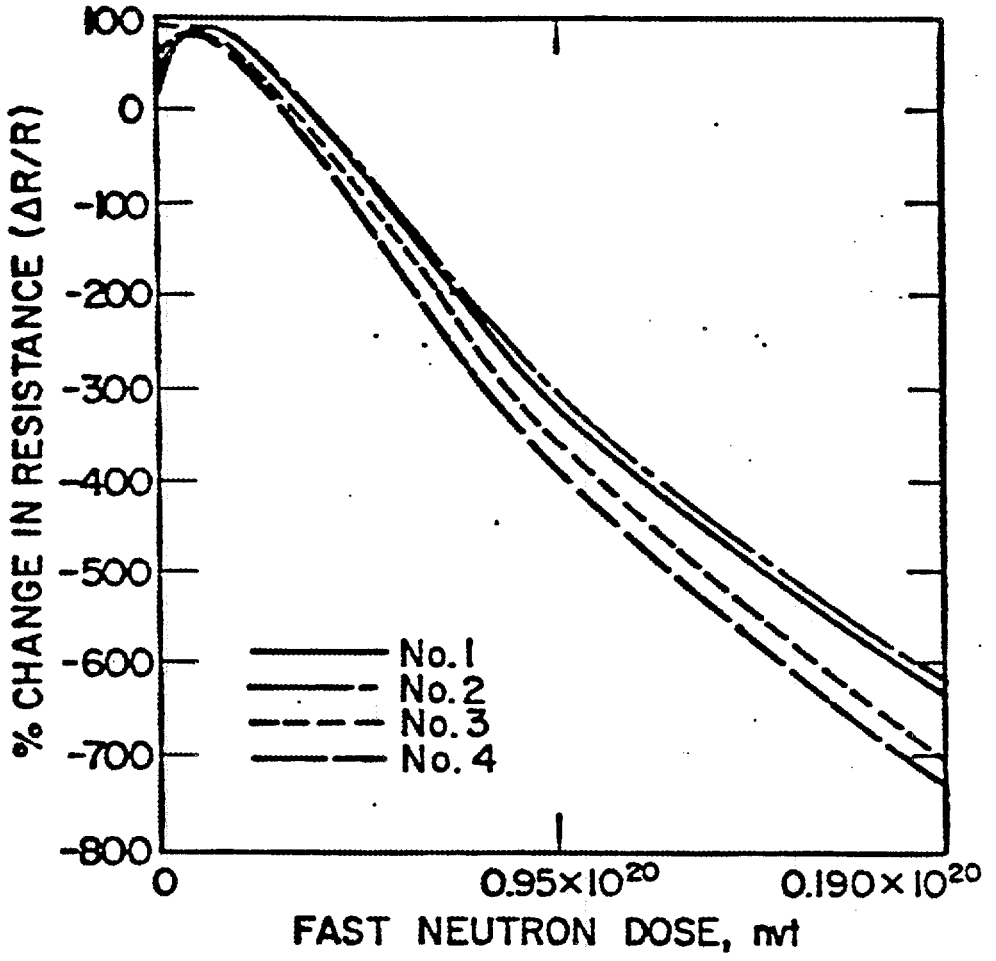



FIGURE 12. CHANGE IN ELECTRICAL RESISTIVITY VS NEUTRON DOSE FOR MICRODOT WELDABLE STRAIN GAGES.

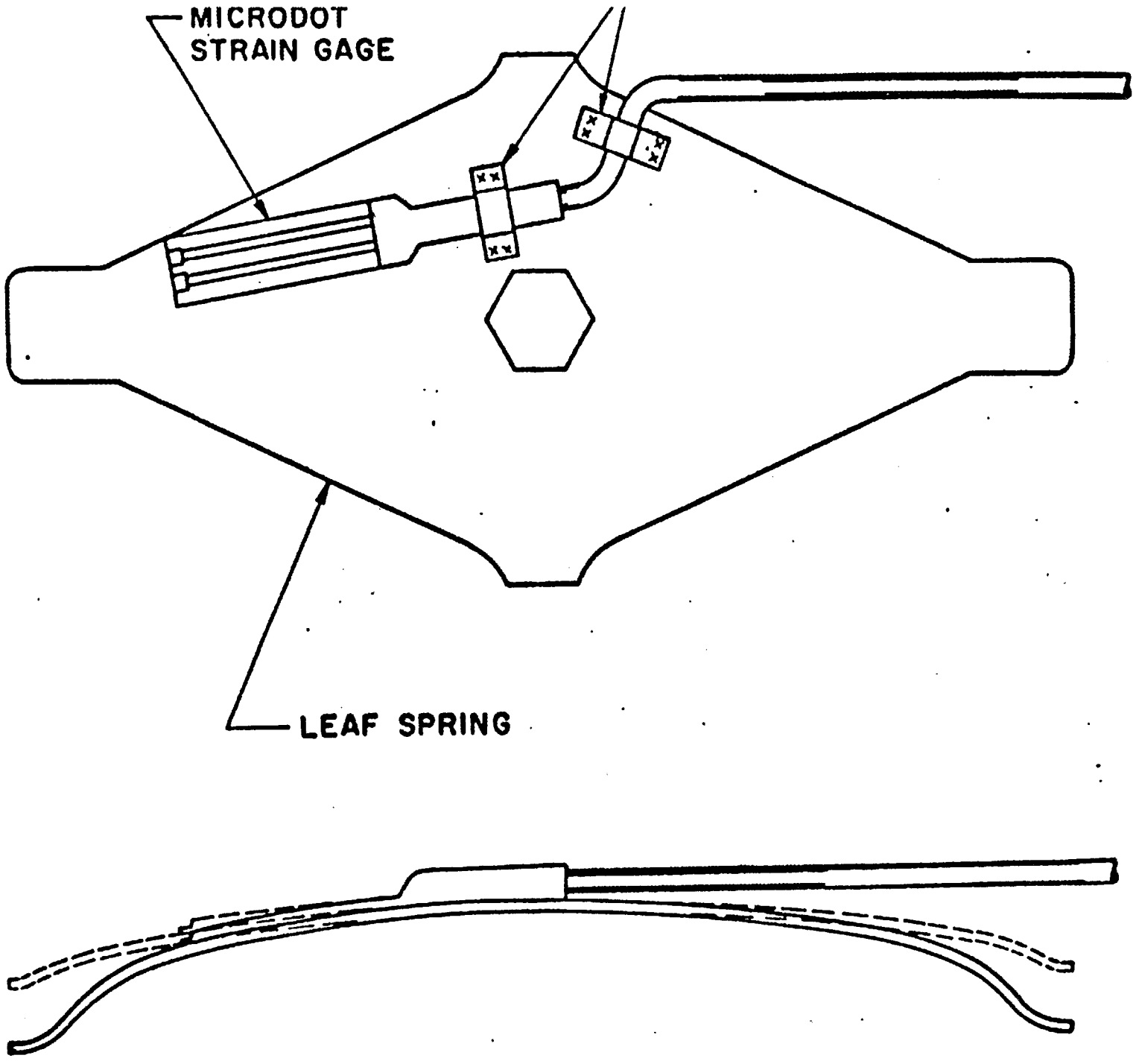



FIGURE 13. 1/2 BRIDGE WELDABLE STRAIN GAGE INSTALLATION USED FOR CORE DEFLECTION MEASUREMENTS

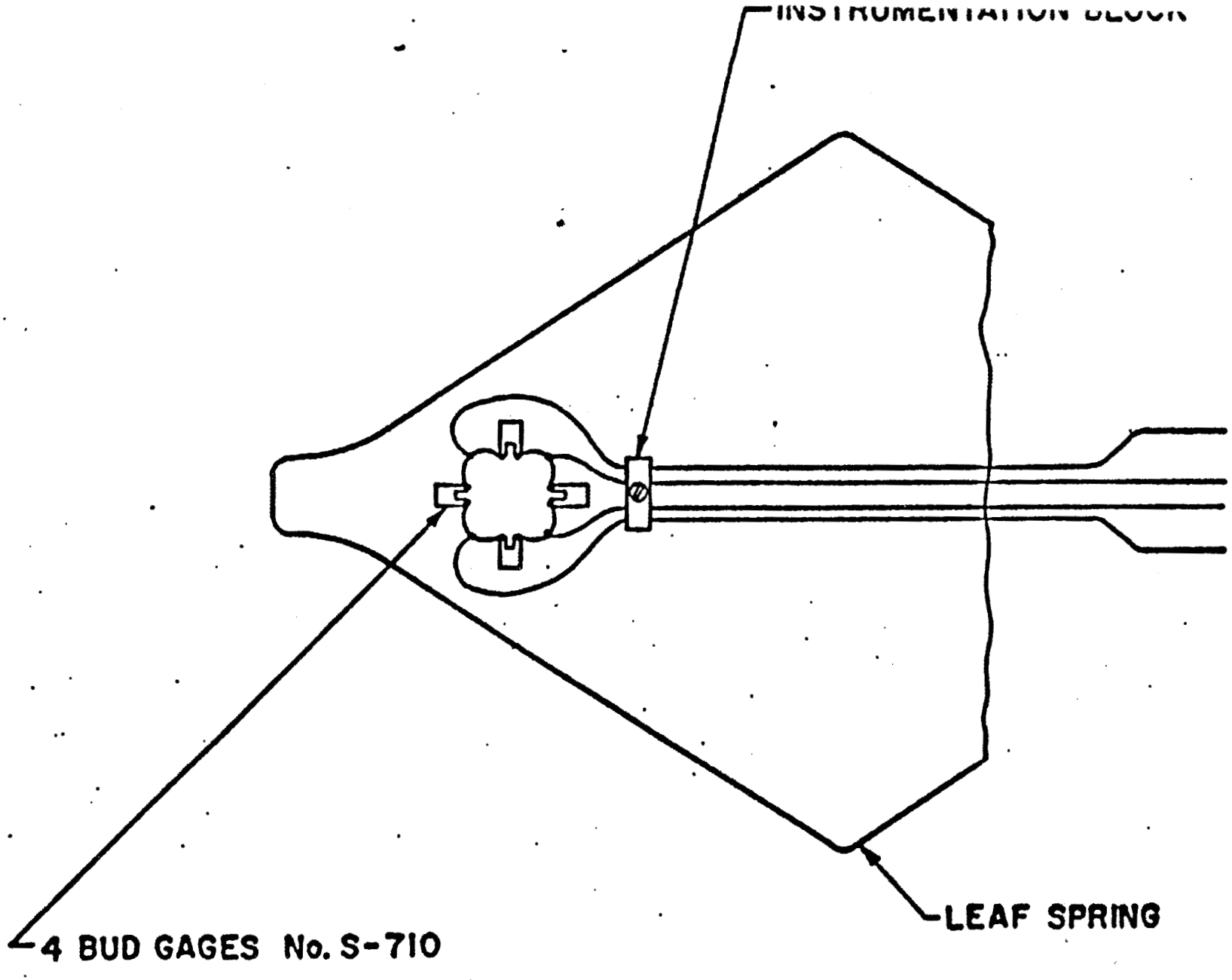



FIGURE 14. CERAMIC CEMENTED FOIL STRAIN GAGES USED FOR CORE DEFLECTION MEASUREMENTS

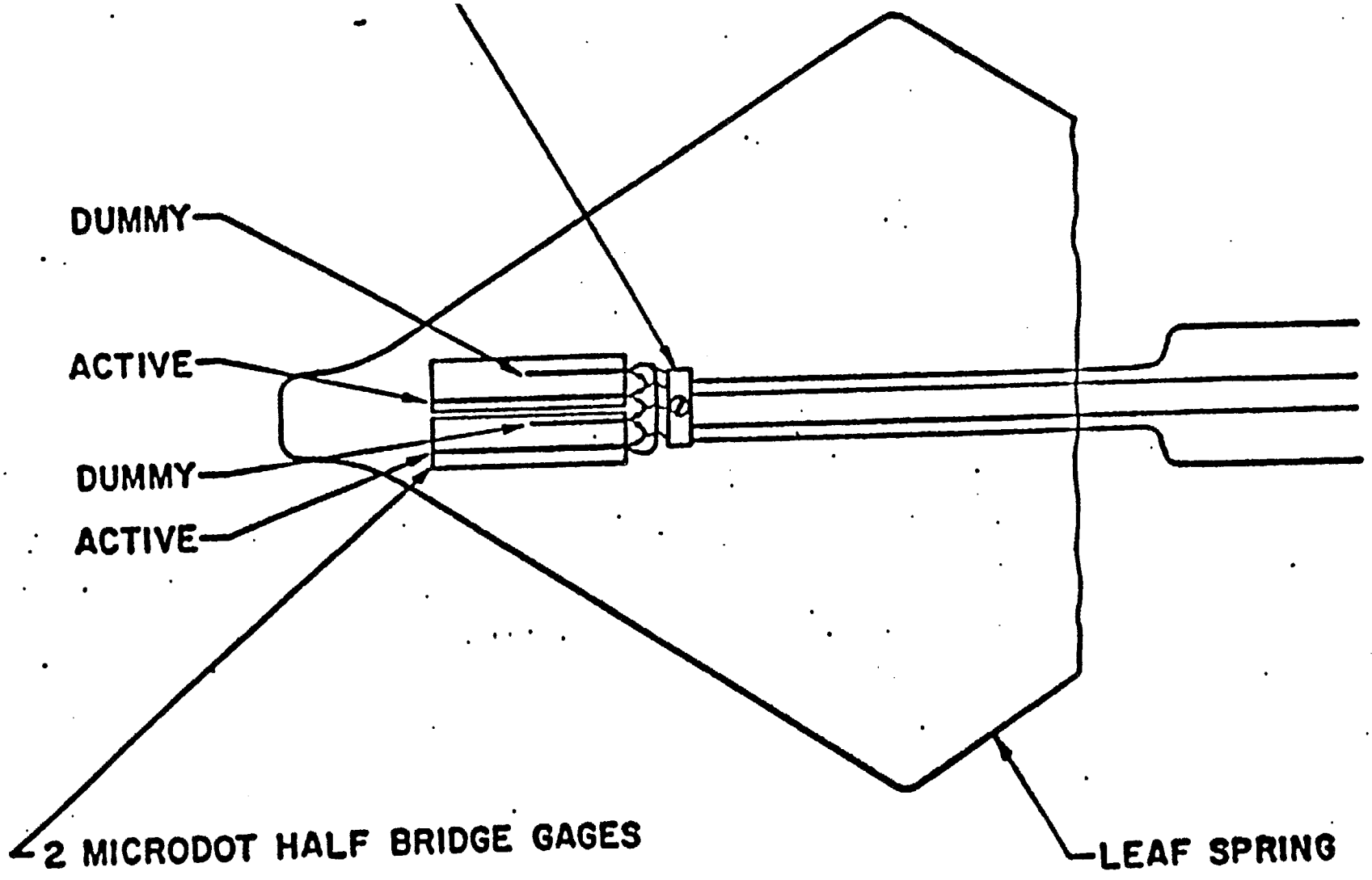



FIGURE 15. A FULL BRIDGE ASSEMBLY OF MICRODOT WELDABLE STRAIN GAGES USED FOR CORE DEFLECTION MEASUREMENTS

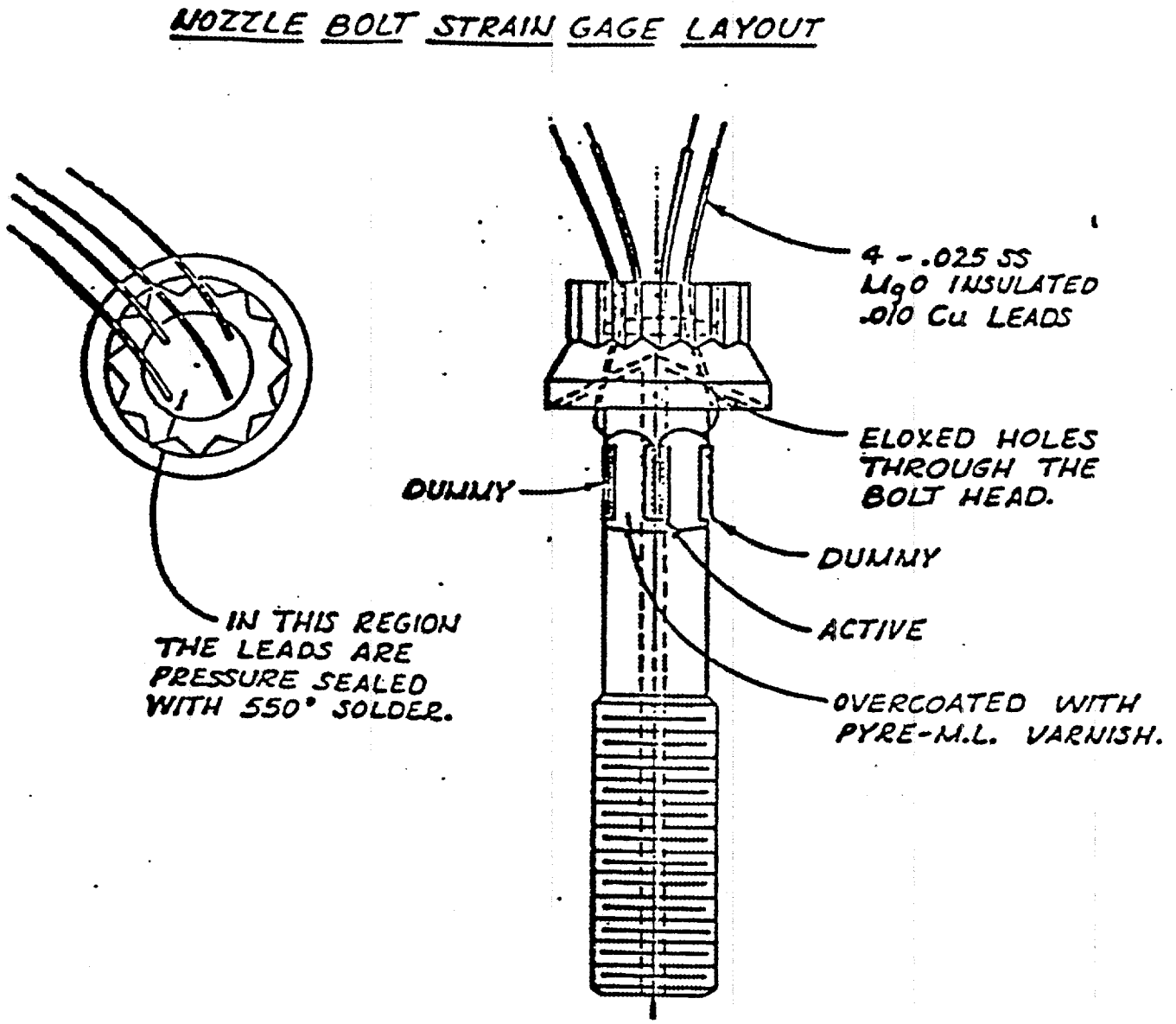



FIGURE 16. A FULL BRIDGE MICRODOT WELDABLE STRAIN GAGE INSTALLATION FOR BOLT TENSILE LOAD MEASUREMENT.

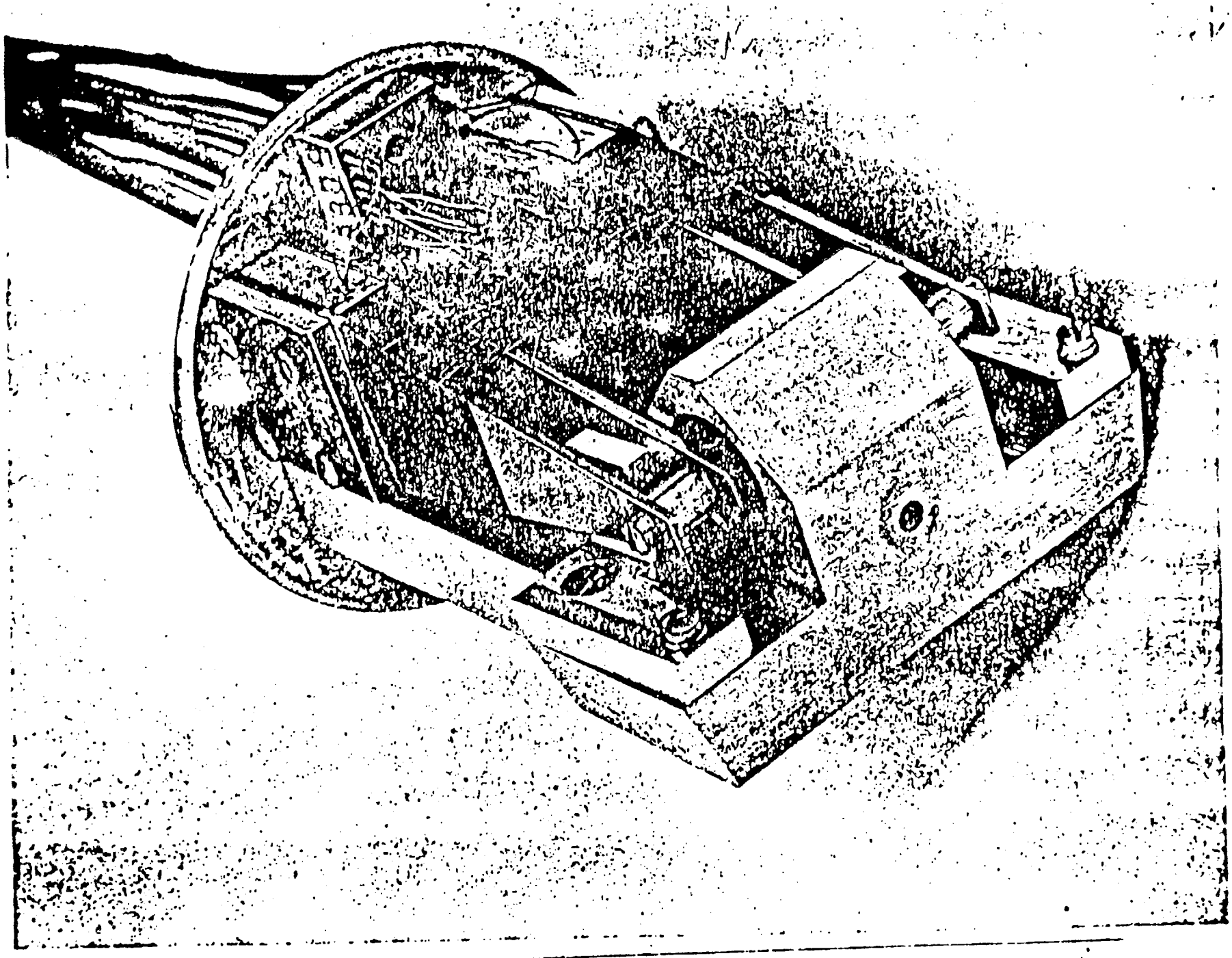


FIGURE . DYNAMIC STRAIN GAGE FIXTURE FOR IRRADIATION EXPERIMENTS AT THE OMEGA WEST REACTOR

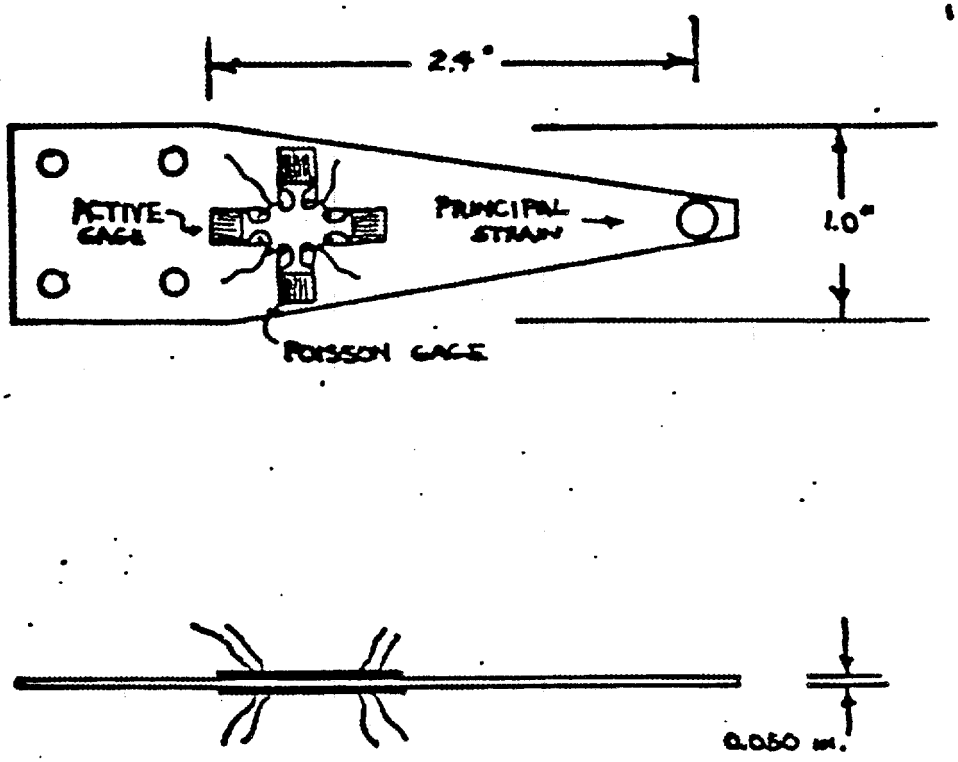



FIGURE 18. STRAIN GAGE ORIENTATION ON TEST BEAM

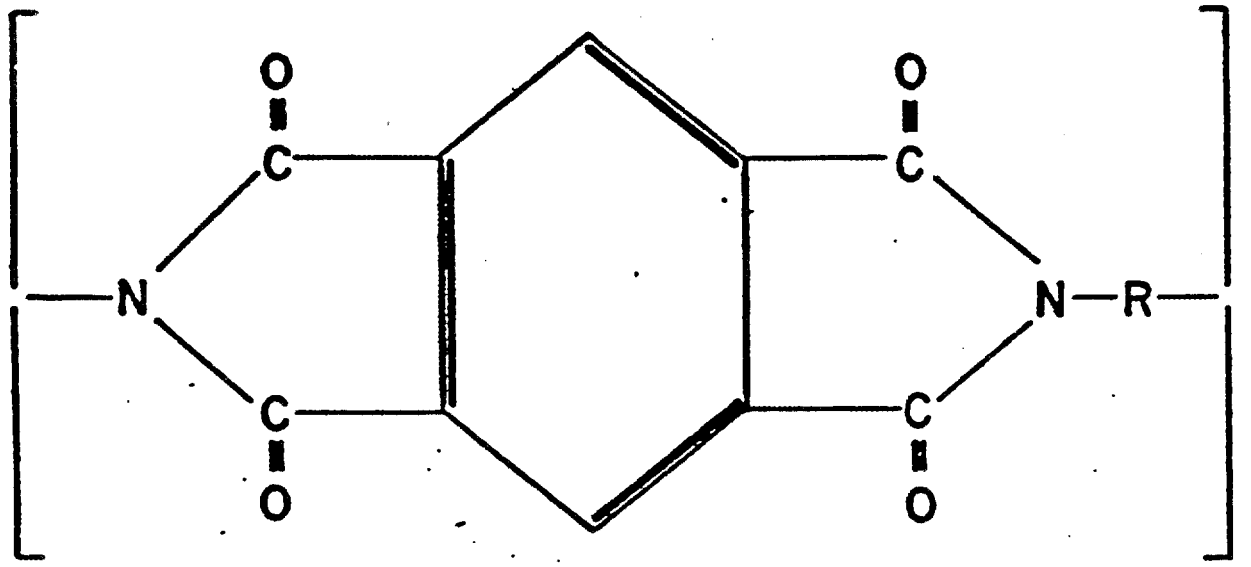



FIGURE 19. POLYMIDE POLYMER STRUCTURE

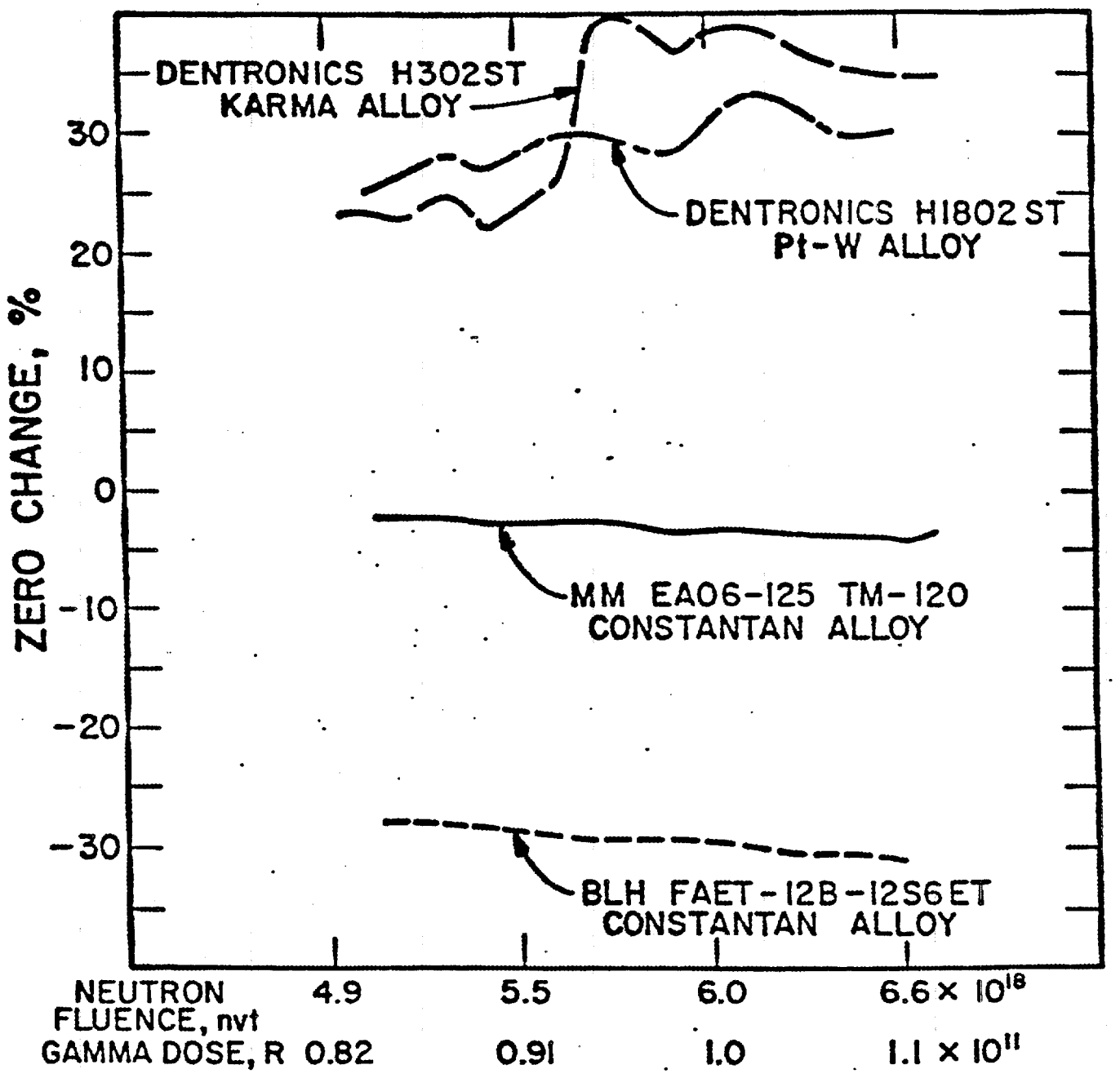



FIGURE 20. BRIDGE ZERO CHANGE AS A FUNCTION OF RADIATION DOSE FOR PT-W, KARMA AND CONSTANTAN FOIL GAGES

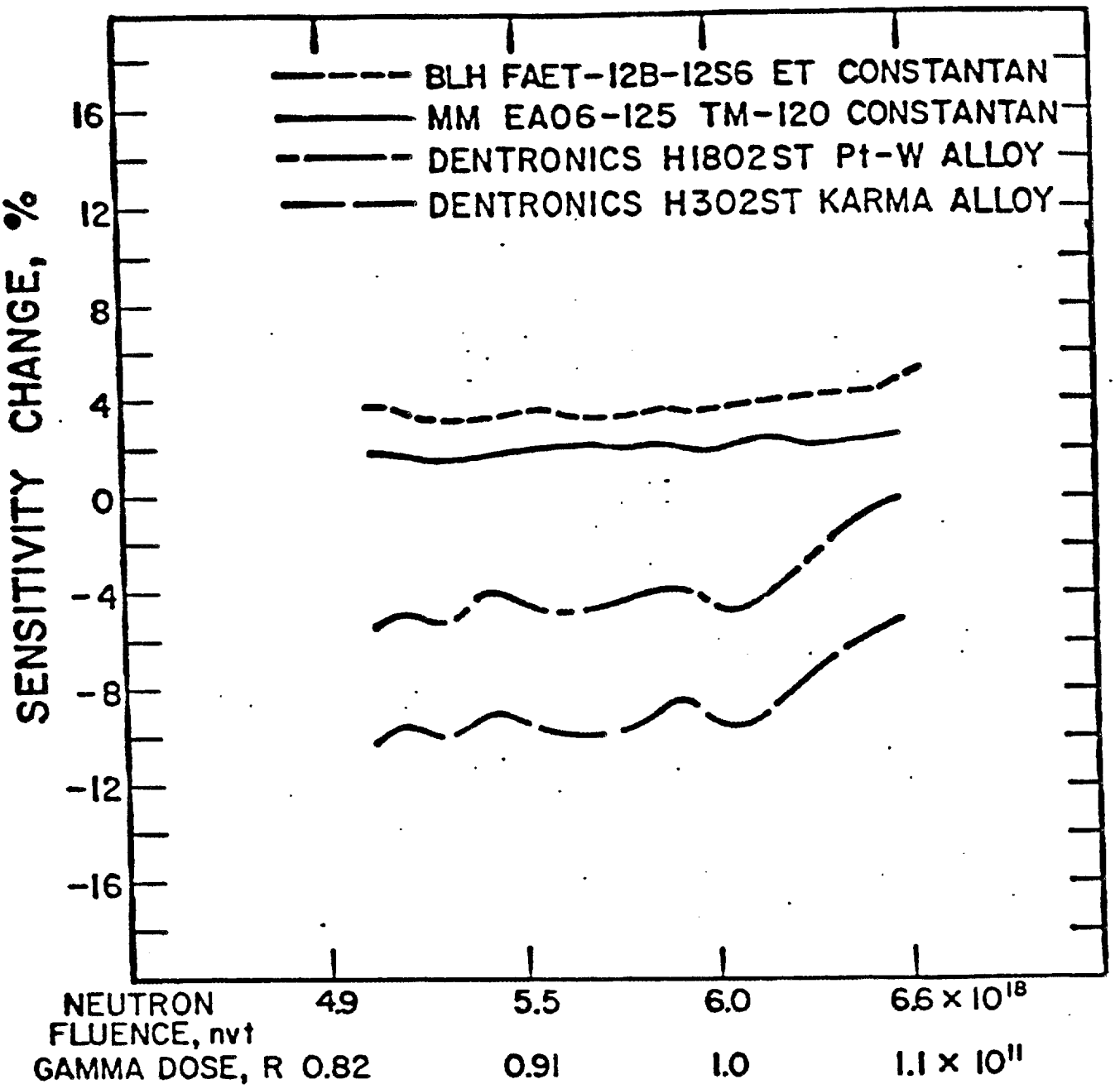
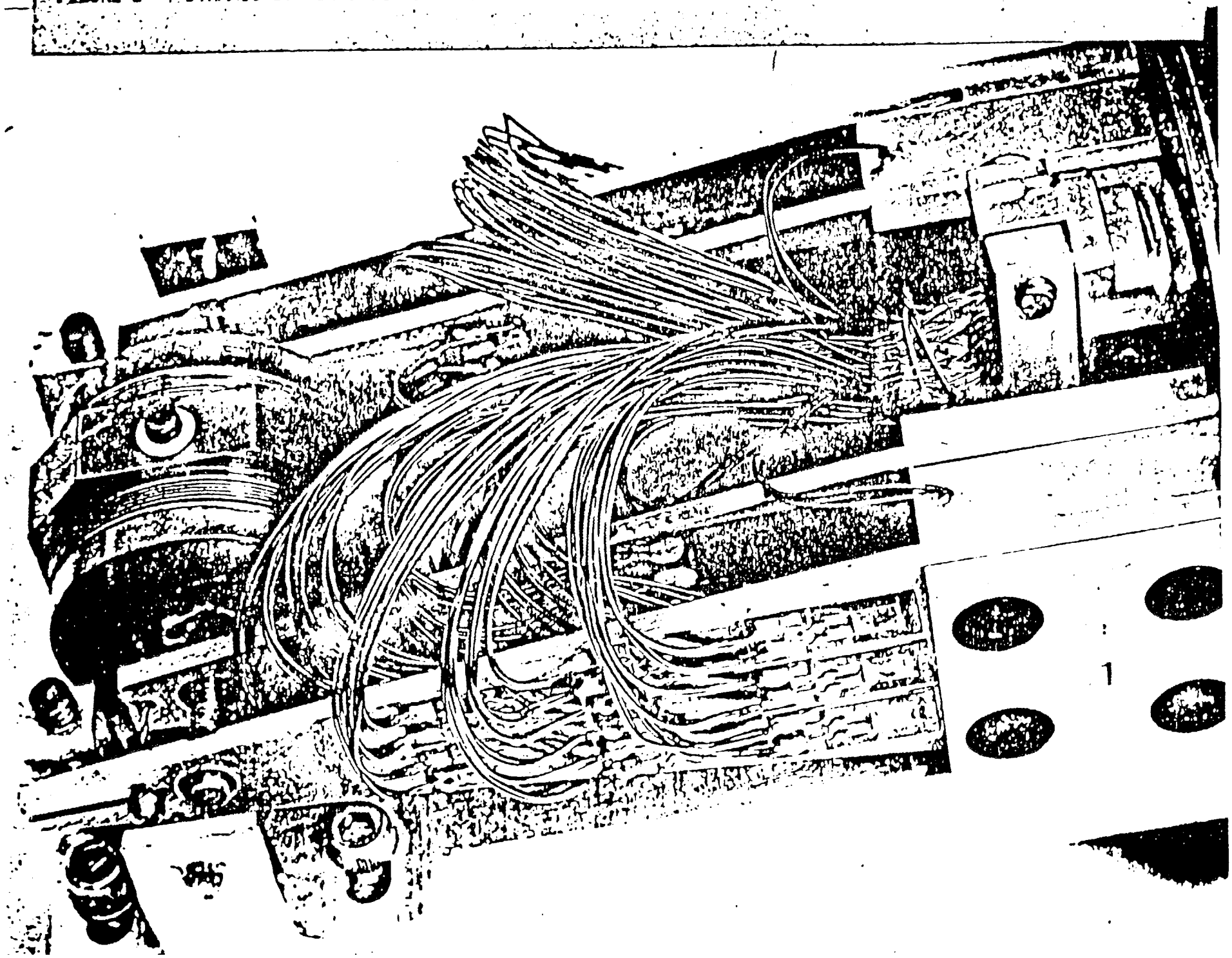



FIGURE 21. BRIDGE SENSITIVITY CHANGE AS A FUNCTION OF RADIATION DOSE FOR PT-W, KARMA AND CONSTANTAN FOIL GAGES

FIGURE 2 . DYNAMIC STRAIN GAGE FIXTURE FOR IRRADIATION E RIMENTS AT THE GIR REACTOR.



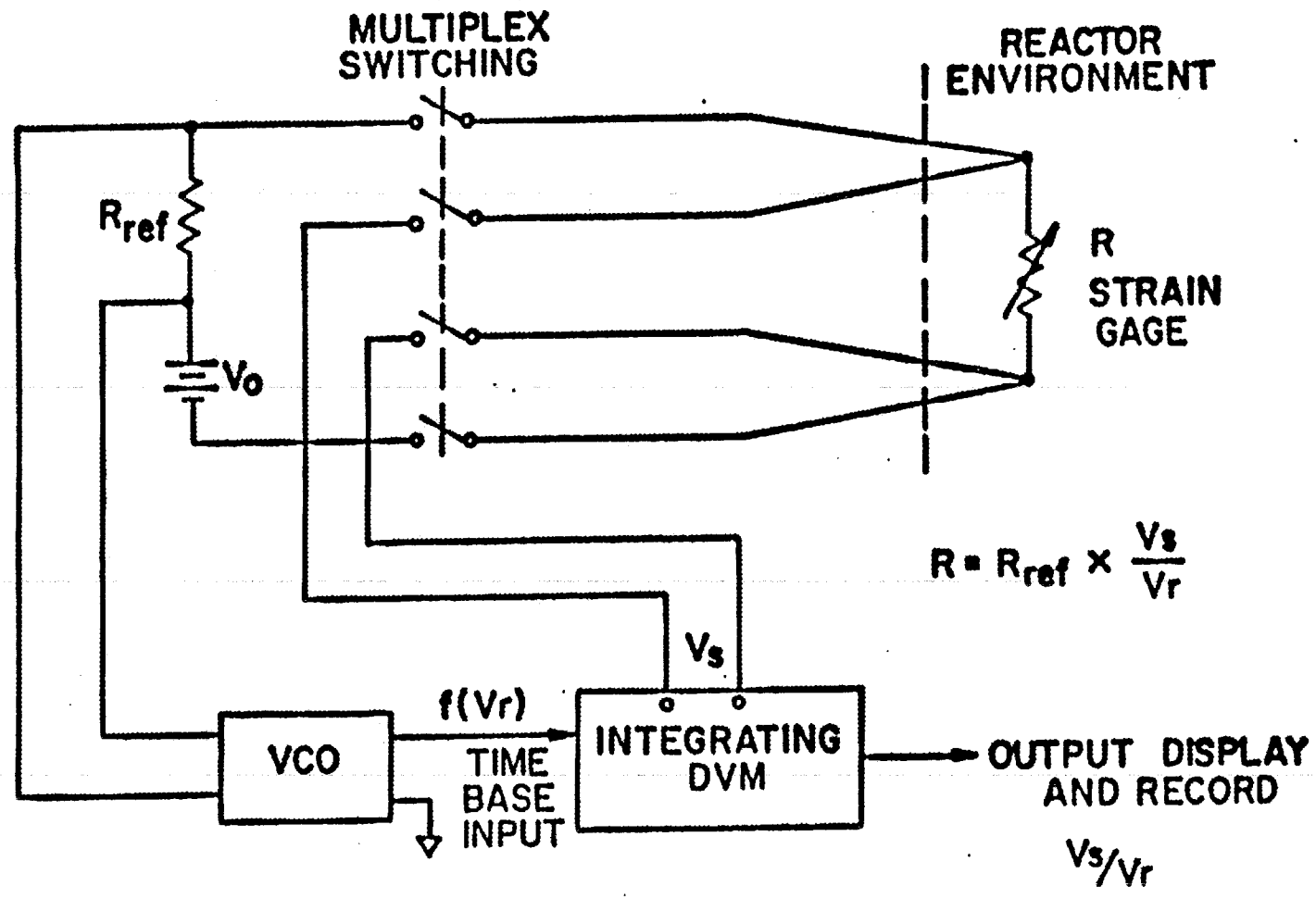



FIGURE 23. RATIOMETER METHOD OF STRAIN GAGE MEASUREMENT USED BY CRABTREE GTR-23

## RADIATION EFFECTS EXPERIMENT GTR-23
## FIGURE 24

| Number | Gage Type | Material | Backing | Bonding | Beam Material | Type of Test |
|---|---|---|---|---|---|---|
| 4 | H 2102 L | $Al_{5.5}$ $Cr_{22}$ $Co_{0.5}$ $Fe_{56}$ | None | Bean H Ceramic | SS | Dynamic Strain C |
| 5 | " | " | " | " | Al | " |
| 4 | H 1802 L | $Pt_{92}$ $W_8$ | " | " | SS | " |
| 5 | " | " | " | " | Al | " |
| 4 | H 302 L | Karma | " | " | SS | " |
| 2 | " | " | " | " | Al | " |
| 5 | EA 13 125 AD | Constantan - 13 ppm comp | Polyimide (MM) | M Bond 610 (MM) | Al | " |
| 5 | EK 13 125 AD | Karma (13 ppm) | " | " | " | " |
| 5 | EC ST 125 AD | Alloy C (MM) no comp. | " | " | " | " |
| 5 | FAE-12-125 13 ET | Constantan (13 ppm) | Polyimide (BLH) | " | " | " |
| 4 | CEA 06-250 US | Constantan (6 ppm) | Polyimide MM | " | " | " |
| 4 | FAE 12-12-S36 ET 120 | Constantan (36 ppm) | Polyimide (BLH) | " | " | " |
| 3 | H 1802 L | $Pt_{92}$ $W_8$ | None | Bean H Ceramic | Al | Static Bet Bonde Al |
| 3 | H 2102 L | $Al_{5.5}$ $Cr_{22}$ $Co_{0.5}$ $Fe_{56}$ | " | " | " | " |
| 3 | H 302 HL | Karma | " | " | " | In ceramic canon not bonded to A |
| 3 | H 1802 H1 | $Pt_{92}$ $W_8$ | " | " | " | " |
| 3 | H 2102 | $Al_{5.5}$ $Cr_{22}$ $Co_{0.5}$ $Fe_{56}$ | " | " | " | " |
| 3 | H 1802 L | $Pt_{92}$ $W_8$ | " | " | " | Static and Un Bo free of ceramic Al base |
| 3 | H 2102 | $Al_{5.5}$ $Cr_{22}$ $Co_{0.5}$ $Fe_{56}$ | " | " | " | " |
| 5 | $Pd_{81.4}$ $Si_{18.2}$ | Amorphous Alloy | None | Bean H Ceramic | Al | Dynamic |
| 2 | $(Pt_{4.5}$ $Ni_{55})P_{25}$ | " | " | " | " | " |

Total 80 gages

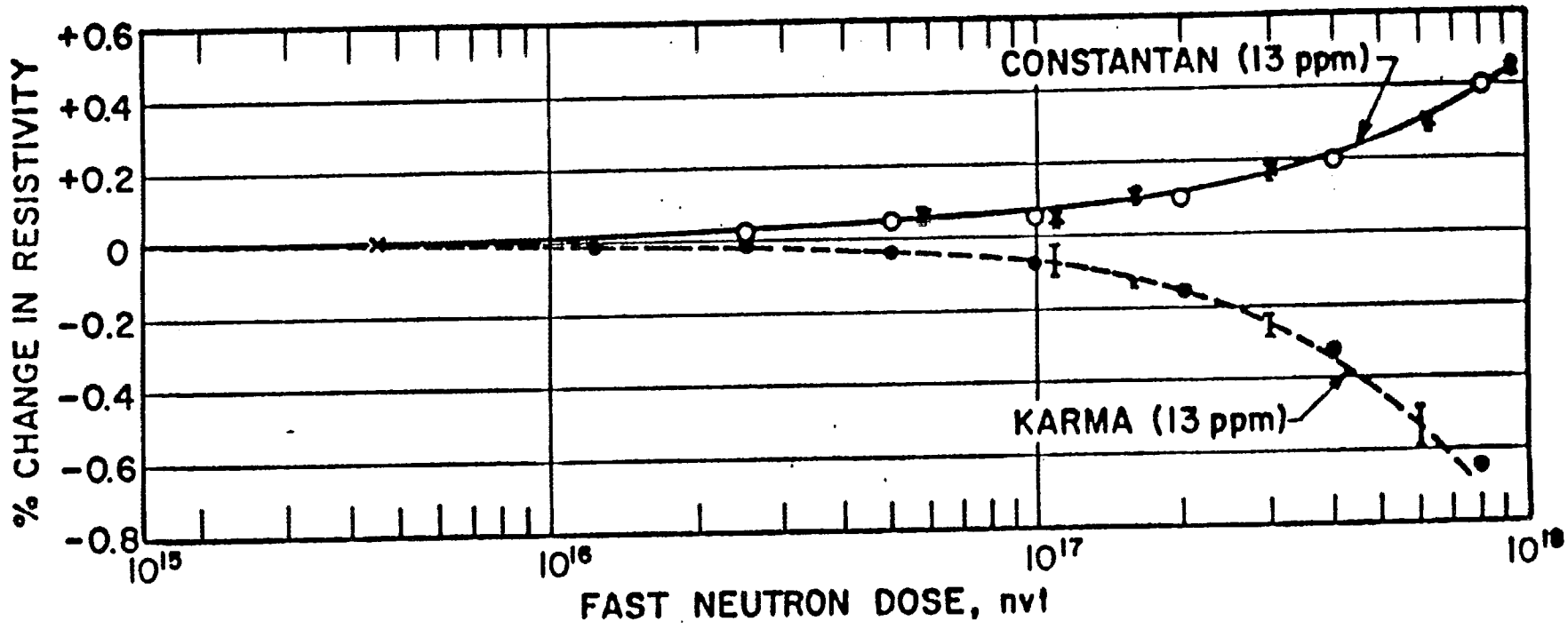



FIGURE 25. % CHANGE IN RESISTIVITY VS FAST NEUTRON DOSE AT $LN_2$ FOR CONSTANTAN AND KARMA STRAIN GAGE ALLOYS

FIGURE 26. % CHANGE IN RESISTIVITY MEASURED AT $10^{18}$NVT AT $LN_2$ FOR VARIOUS STRAIN GAGES

| ALLOY AND TYPE | RESISTIVITY CHANGE % ΔR/R at $10^{18}$nvt at $LN_2$ | |
|---|---|---|
| CONSTANTAN 36 ppm BLH | + .396 ± .079 | |
| CONSTANTAN 13 ppm BLH | + .548 ± .072 | WITHIN 95% CONFIDENCE LI<br>THESE ARE THE SAME POPUL |
| CONSTANTAN 13 ppm MM | + .569 ± .035 | |
| KARMA [EPOXY BONDED] TO Al 13 ppm MM | -.952 ± .107 | |
| KARMA [CERAMIC BONDED] TO SS 13 ppm DENITRONICS | -.710 ± .197 | |
| ALLOY C MM | + .0978 ± .01 | |
| H 2102 DENTRONICS [CERAMIC BONDED TO SS] | + .032 ± .014 | WITHIN 95% CONFIDENCE<br>THESE ARE THE SAME PO |
| H 2102 DENTRONICS [CERAMIC BONDED TO AL] | + .037 ± .045 | TAKING ALL THREE AS O<br>.0312 ± .0089 |
| H 2102 DENTRONICS [FRGE) | .0233 ± .012 | |

FREE

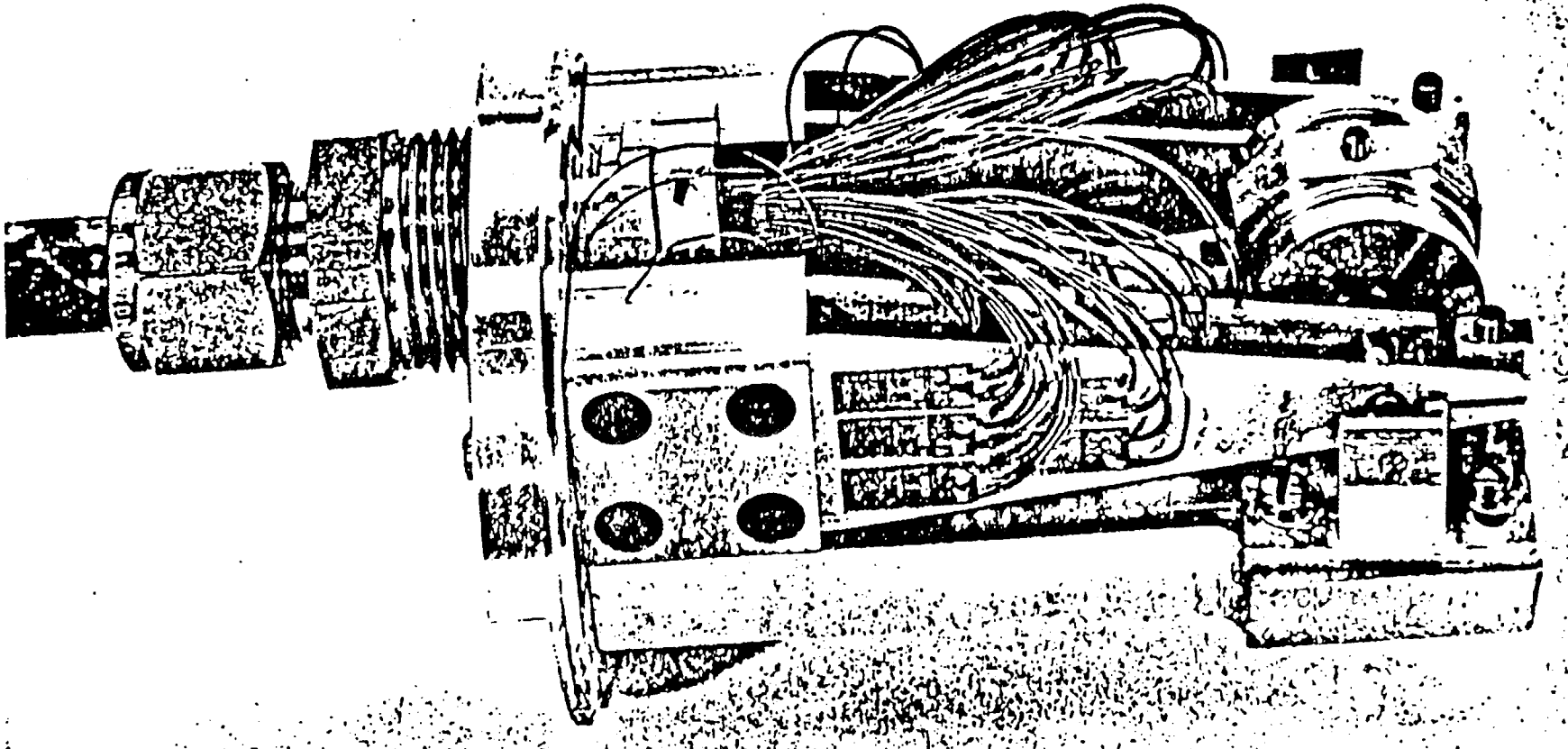


FIGURE 27. DYNAMIC STRAIN GAGE FIXTURE FOR IRRADIATION EXPERIMENTS IN THE OMEGA WEST REACTOR

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RADIOACTIVITY - ACTIVE RADIATION, Measurements and Data Corporation. Copyright 1973. Home Study Course 40/22. By Milton H. Aronson - Editor and Publisher - Measurements and Data Corporation, Richard E. Moore, Department of Radiology, University of Minnesota.

RADIOACTIVITY - PART II, Measurement and use, as above.

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THE EFFECTS OF NUCLEAR RADIATION ON TRANSDUCERS by W. E. Chapin, J. E. Drennan and D. J. Hamman. Report No. 43, Battelle Memorial Inst., Columbus, Ohio 1966.

# Silicon or Foil: Which Strain Gage should be used in Force Transducers?

### The Future vs. the Past

The semiconductor (silicon) strain gage has revolutionized force sensors since its invention at Bell Telephone Laboratories in the early 1950s. It wasn't until 1960, due to the work of W. P. Mason and R. N. Thurston, that silicon strain gages became commercially available. At that time it was expected that silicon strain gages would obsolete foil strain gages. Instead, foil gages have found a niche in short term stress analysis and have slowly been losing ground in force sensing applications as new companies learn to use silicon gages. Transducers based on silicon gages are extremely rugged, yet produce powerful signals and allow for a wide bandwidth and short response time. These features are necessary in manufacturing applications due to the harsh environment in which the transducer must operate.

> "Transducers based on silicon gages are extremely rugged, yet produce powerful signals..."

### Gage Factor Considerations

Foil gages have a gage factor of 2 to 4 while silicon gages have a gage factor of 50 to 175. Gage factor is a measurement of the sensitivity of the strain gage and is defined as the resistance change per unit of initial resistance divided by the applied strain.

$$\Delta R = GF \times R \times \varepsilon$$

$\Delta R$: Change in resistance measured to calculate force
GF: Gage Factor
R: Initial resistance
$\varepsilon$: Strain

Transducers using foil gages must be pushed near the yield point to get the output required due to the low gage factor. Silicon gage transducers are designed so that the stress at rated load is 10 to 50 times below the yield point. One must be careful when reading force sensor literature since many manufacturers of foil gage transducers use the tensile strength rather than the yield stress in calculating the factor of safety.

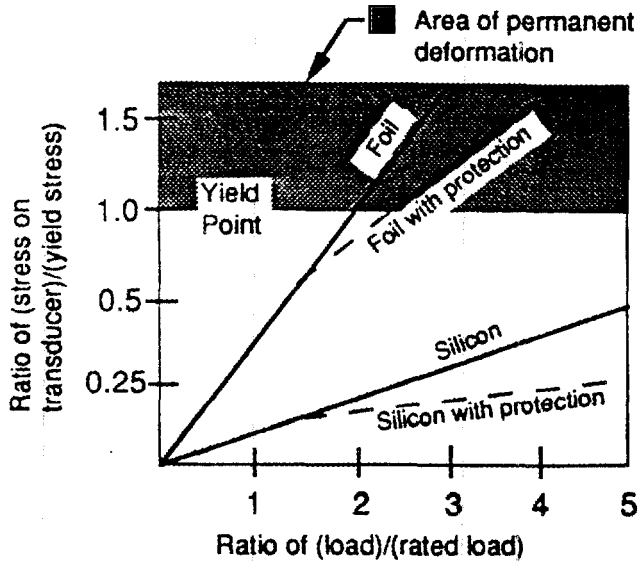



**Figure 1. Typical force transducer stress vs. load using foil gages or silicon gages with and without overload protection.**

### The Problem Of Exceeding the Yield Stress

When a transducer's yield strength is exceeded the structure is permanently deformed requiring sensor readjustment.

This often requires the sensor to be returned to the factory causing unacceptable lost production time. Production lost due to a broken sensor can far exceed the cost of the sensor. The failure of foil gage transducers in production has even caused some manufacturers to avoid using force sensors on the production line. But the acceptance of silicon gage transducers in the manufacturing environment is now being realized.

### *The Success of Robotic Force Sensing*

Adept Technology, Inc., a robot manufacturer, has been selling a robotic Force Sensing Module (FSM) since 1989 based on silicon strain gages. Robotic force sensors represent a special challenge due to the high and often unpredictable loads applied to the sensor, as well as the high number of cycles involved. Adept has over two hundred sensors in the field, yet there has never been a need to recalibrate or replace a sensor due to a crash or fatigue failure. This type of success has further bolstered the use of silicon gages in force transducer.

**"Adept has over two hundred sensors in the field, yet there has never been a need to recalibrate or replace a sensor due to a crash..."**

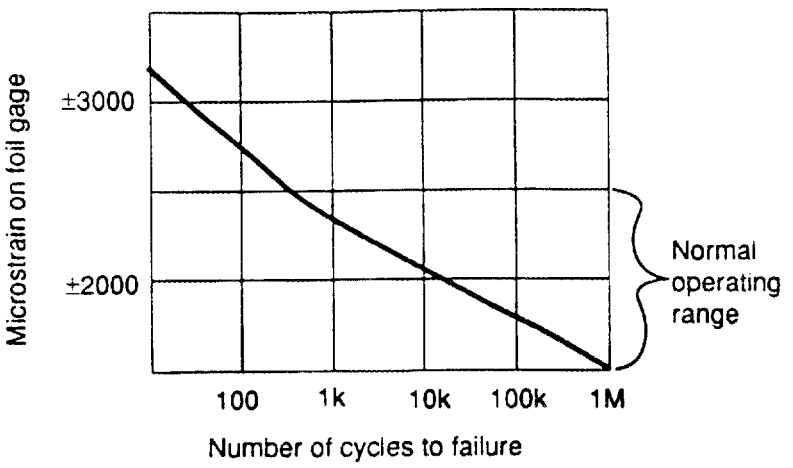



**Figure 2. Fatigue life curve for common foil gage, constantan (S-T-C condition).**

### *Additional Overload Protection for Silicon Transducers*

A technique invented by Thurston Brooks of Hughes STX and used in Adept FSMs increases the already high factor of safety of silicon gage transducers. This technique uses hardened overload pins to protect the transducer. The pins are pressed into the hub of the sensor and float in the outer wall. When the sensor exceeds the rated load, the overload pins contact the outer wall and absorb the additional load. This technique has been tried on foil gage transducers, but has failed since the transducer operates so close to the yield point that when the overload pins start to fully absorb the load the sensor starts to yield. When the sensor yields it is permanently damaged since precise overload pin positioning is critical to successful operation. See Figure 1. Ironically, foil transducers need this overload protection much more than silicon gage transducers, but only silicon gage transducers can use this protection method successfully.

**"...foil transducers need this overload protection much more than silicon gage transducers, but only silicon gage transducers can use this protection..."**

### *Fatigue Life*

Fatigue life problems have also plagued manufacturers using force sensors. Since silicon gage transducers have such a low stress point at rated load, they

**"...silicon gage transducers have such a low stress point at rated load they can be designed for infinite life."**

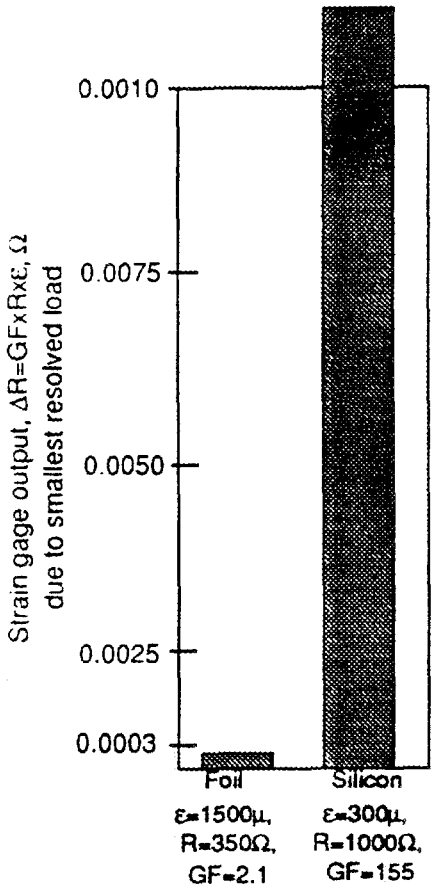



**Figure 3. Typical foil and silicon strain gage output due to a load equal to the resolution of a 12 bit A/D converter (1/4096).**

can be designed for infinite life.

Foil gage transducers have two fatigue problems. The first is that the stress on the transducer at rated load results in a limited life span. The second is that the foil gages have limited life spans as well. See Figure 2. A foil gage transducer can fail at anywhere from 100 to 1 million cycles. While this type of performance is acceptable for the research lab, a factory production line can accumulate 1 million cycles on a transducer in a matter of weeks.

The Adept FSM has been tested at 150% of rated load for over 25 million cycles with no failure. When the FSM was inspected following this test no sign of fatigue could be found. There are silicon gage force sensors that have over 1 billion cycles in production and show no signs of failure. Only this type of ruggedness is acceptable on a factory production line.

### *Powerful Output Signal*

Considering all the problems associated with foil gage transducers why push them to such a high stress point at rated load? Looking at the change in resistance vs. strain it is easy to see why. Due to the low gage factor of foil gages, strain levels must be from 1500 to 2500 microstrain to produce an acceptable signal. But even at those strain levels the signal is weak, and low-level electrical noise affects the resolution of the sensor. While silicon gages require strain levels of only 50 to 300 microstrain (1/5 to 1/30 the strain on foil gages), they still produce signals that are 35 times stronger than foil gages. Force sensors typically use 12 to 16 bit A/D converters to produce high-resolution digital signals. A force sensor using a 12 bit A/D converter resolves rated load of 1:4096. To achieve this resolution a force sensor using foil gages must resolve $2.7 \times 10^{-4}$ ohms, which is difficult. See Figure 3. To make matters worse, induced electrical noise can mask this small change in resistance. Transducers based on silicon gages produce a strong signal output with high electrical noise immunity.

**"While silicon gages require strain levels of only 50 to 300 microstrain (1/5 to 1/30 the strain on foil gages), they still produce signals that are 35 times stronger..."**

### *Higher Bandwidth*

The use of filtering can reduce induced electrical noise to acceptable levels on most foil gage transducers; however filtering reduces the bandwidth and response time of the transducer. New applications in production such as deburring, polishing and drilling require a wide bandwidth output with fast response time. When silicon gages are used filtering requirements are reduced allowing for wide bandwidth and extremely fast response times. Transducers using silicon gages have made demanding automated applications like deburring possible.

### *Change In Output with Temperature*

One shortcoming that strain gages have had is a shift in output with change in temperature (ΔT). There are two different temperature-related problems. One is that the resistance of the strain gage changes with ΔT and the other is that the gage factor changes with ΔT. A change in gage resistance and expansion of the transducer minus the expansion of the gage due to ΔT combine to cause a zero shift. A change in gage factor due to ΔT causes a span or gain shift. Silicon gages have a larger span shift than foil gages. Foil and silicon

gage's zero shift is similar due to the use of the Wheatstone bridge.

### Temperature Problem Solved

The zero and span shift temperature problem has been solved using a variety of techniques. Recently, Assurance Technologies, multi-axis force/torque sensor manufacturer, has developed a simple correction method that reduces the change in output due to temperature to near zero for their multi-axis force sensor. Regardless of the type of gage used, temperature effects ultimately depend on the type of compensation method used.

### Linearity and Hysteresis

The accuracy of a force sensor is directly related to the linearity of the strain gage. The linearity of silicon gages is equivalent to the linearity of foil gages due to the low strain levels needed. Hysteresis is related to the amount of epoxy and plastic between the strain gage and the transducer. Foil gages use a plastic backing along with an epoxy film to mount them to the transducer. The plastic backing causes creep and hysteresis. Silicon gages are mounted directly to the transducer with epoxy. A new silicon gage mounting method uses a micro coat of epoxy that reduces hysteresis even further.

### Conclusion

The demand for force sensors in the manufacturing environment has made silicon gages a requirement. Transducers with silicon gages are rugged, long-lived and have low noise and high sampling rates. The foundation of force sensing success is the silicon strain gage. This can be seen with Adept Technology's Force Sensing Module and the many other manufacturers who have come to rely on force sensing on the production line.

*Written by Robert Little of Assurance Technologies, Inc. Mr. Little is a summa cum laude graduate of the University of Pittsburgh in Mechanical Engineering. Currently completing his thesis for his Masters of Science at the North Carolina State University. His working experience includes seven years of research and development in the study of transducer and semiconductor gage design for use in measuring force and torque.*

# TransPort PT868, The Ultimate Port

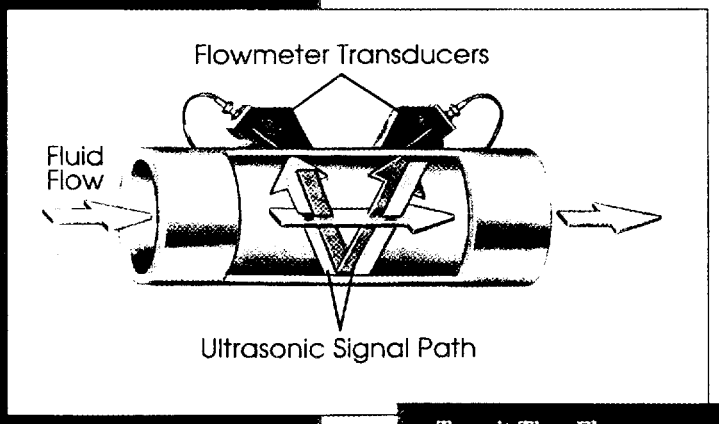
## TransPort Uses The Transit-Time Flow Measurement Technique.

n this method, two transducers serve as both ultrasonic signal generators and receivers. When mounted on a pipe, they are in acoustic communication with each other, meaning the second transducer can receive ultrasonic signals transmitted by the first transducer and vice versa.

In operation, each transducer functions as a transmitter generating a certain number of acoustic pulses, then as a receiver for an identical number of pulses.

The time interval between transmission and reception of the ultrasonic signals is measured in both directions. When the liquid in the pipe is not flowing, the transit-time downstream equals the transit-time upstream. When the liquid is flowing, the transit-time downstream is less than the transit-time upstream.

The difference between the downstream and upstream transit-times is proportional to the velocity of the flowing liquid and its sign indicates the direction of flow.




***Transit-Time Flow Measurement Technique.***

*THE COMPLETE SOLUTION.* The Panametrics TransPort flowmeter system has everything needed to successfully perform clamp-on flow measurements in the field. Included in its microprocessor-based electronics are an ultrasonic thickness gage function (transducer optional) which accurately determines pipe wall thickness for proper setup of the transducers, and a waveform display function for troubleshooting.

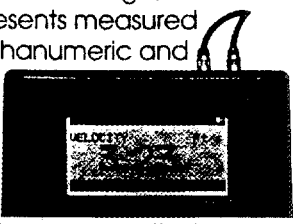
Self-contained, built-in rechargeable batteries for up to ten hours of portable operation are standard, as are digital and analog outputs for data uploading and chart recording (a portable printer is optionally available). To calculate energy flow rates, TransPort comes with inputs for optional RTD temperature sensors.

The complete TransPort system, including the meter, two transducers, clamping fixtures and all ancillary equipment, is contained in a durable carrying case about the size of a briefcase, perfect for easy transporting from site to site.

*ON-SITE DATA LOGGING LETS YOU TAKE IT ALL WITH YOU.* To complete the system, we've built in a powerful data logging function that can store up to 43,000 data points for later uploading to a personal computer. You can collect data in the field, then import it into standard spreadsheet or TransPort Data Manager™ custom software for analysis and storage in your office. TransPort Data Manager also permits operation and data retrieval remotely from a personal computer.

A separate memory function stores up to 20 sets of site parameters, eliminating the need to re-enter data when returning to a site for additional measurements. The meter can even be programmed to automatically begin and end measurements at predetermined times for unattended operation.

*AN ALPHANUMERIC AND GRAPHIC LIQUID CRYSTAL DISPLAY COMPLETES THE PICTURE.* TransPort's large, multi-function LCD presents measured data in both alphanumeric and graphic forms. In addition, it helps make programming easy by presenting a software menu that walks you through data entry and function selection.



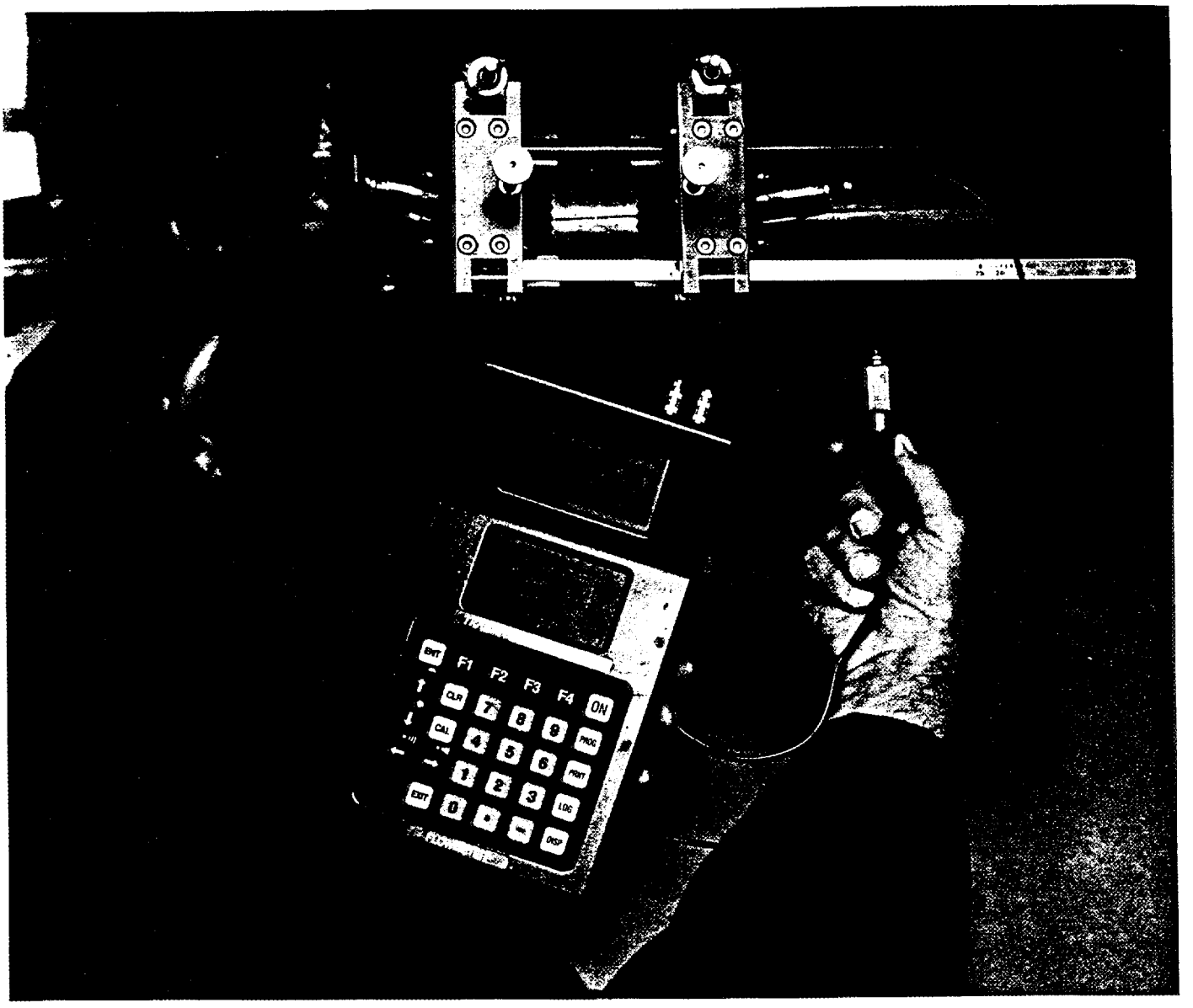
Standard alphanumeric functions include flow velocity, volumetric or energy flow rates and totalized flow in single or double line displays in either English (U.S.A.) or metric units.

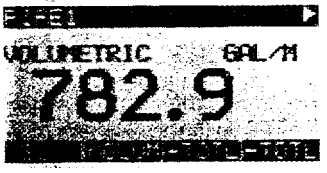
In graphic mode, the LCD shows both real-time and logged data. The result is a chart recording right on the display; very useful for reviewing data and observing trends while on site.

*DIGITAL SIGNAL PROCESSING BRINGS HIGHER ACCURACY TO TWO-PHASE APPLICATIONS.* Panametrics' patented acoustic signal-coding technique extends the benefits of transit-time measurement to applications in liquids with higher concentrations of entrained solids or gas bubbles than was previously possible.

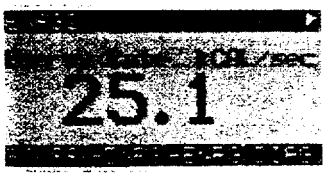
Digital signal-processing (DSP) and correlation detection increase TransPort's effective signal-to-noise

# ıle Flowmeter – From Panametrics.

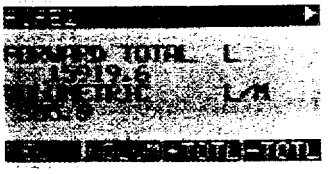


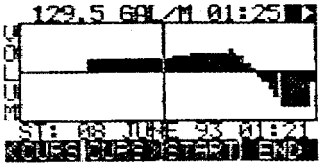

*Volumetric Flow Rate.*



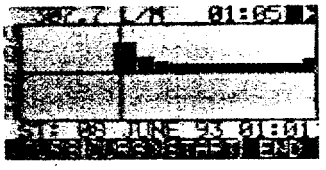

*Energy Measurement.*



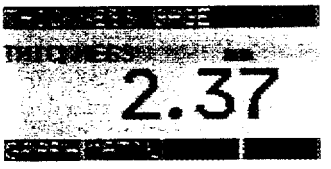

*Dual Display.*



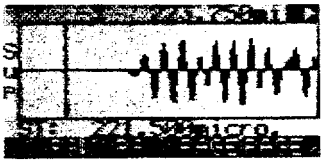

*Bidirectional Real-Time Graphic Display.*




*Logged Data Display.*




*Pipe Wall Thickness Measurement.*



*Diagnostic Waveform Display.*

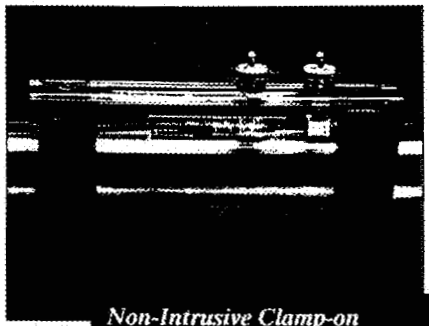
*20 Sets of Site Parameters.*

*Large Alphanumeric and Graphic Liquid Crystal Display (LCD) has Multiple Functions Including Measurement Display, Data Logging and Diagnostics.*

ratio significantly. DSP also eliminates electronic drift adjustments. Now, the higher accuracy of TransPort is available for many applications where only less accurate meters could be used before.

### *Accuracy Without Penetrating The Pipeline.*

There's no longer any need to break into the pipeline to get accurate flow measurement. Now you can get it with a TransPort flowmeter.



*Non-Intrusive Clamp-on Transducers Mean No Leaks, Corrosion or Contamination.*

TransPort's accuracy is typically 1/2 to 2% of reading. For greater accuracy, both clamp-on and wetted installations can be calibrated. With TransPort you get high accuracy without pressure drop or pipeline obstruction.

### *So Versatile You Can Use It Anywhere.*

TransPort lets you measure flow rate with a turn-down ratio of 400 to 1, in pipe sizes from 1/2 inch (12.7 millimeters) to more than 16 feet (5 meters), at temperatures up to 500°F (260°C). Use TransPort to measure the flow rate of potable water, effluent water, ultra-pure liquids, and corrosive or erosive liquids, as well as to perform mass or energy balances in heating and cooling systems.

TransPort can also be used to troubleshoot other flowmeter installations. From pure water to crude oil, this meter does it all.

### *Quick And Easy To Use.*

It's possible to make your first flow measurement within minutes of opening the box. TransPort is that easy to use. Simply input the site parameters, clamp the transducers onto the pipe, adjust the spacing, and you're underway. No ancillary equipment is needed, and there's no need to break into the pipeline.

TransPort's software is menu driven. On-line help functions include pipe dimensions and sound speed data for various liquids and pipe materials. When needed, you can measure liquid sound speed and pipe wall thickness directly with the meter. An experienced user can make scores of different measurements in a single day. TransPort is ideal for all kinds of flow survey work.

### *Built To Be Economical And To Stay Economical.*

To be of real value, a portable flowmeter must be as economical to own and operate as it is capable in the field. Using the latest microcircuit and manufacturing technologies, TransPort is built to stay in service for many years. Completely solid state, the device never wears out or needs servicing, which means no downtime and no maintenance costs.

TransPort's state-of-the-art design is more economical to produce, and we pass the savings on to you. TransPort is affordable and will continue to save money by streamlining your measurement process and trimming labor costs.

## TransPort Uses Digital Signal Processing For Higher Accuracy In Two-Phase & Perfectly Clean Liquids.

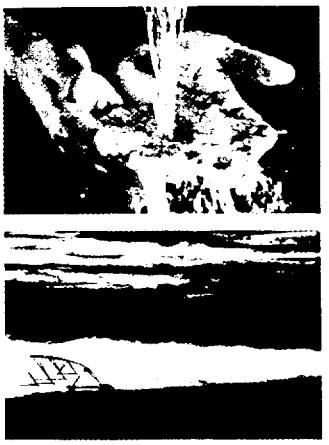
TransPort's patented digital signal-processing (DSP) technique greatly increases its signal-to-noise ratio for accurate, drift-free flow measurement in two-phase liquids containing entrained solids, liquid droplets or gas bubbles. TransPort operates in these and other difficult applications where conventional transit-time flowmeters fail.

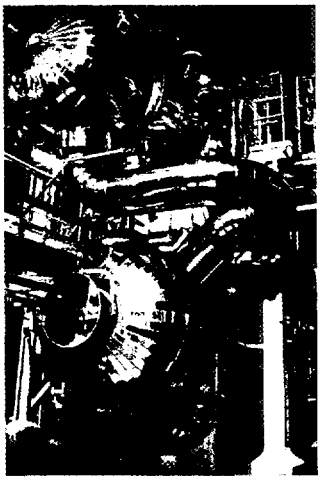
TransPort also accurately measures flow rate in perfectly clean liquids containing no "scatterers," where Doppler-type flowmeters cannot work. TransPort is suited for all standard transit-time applications, plus many that would prevent other transit-time flowmeters from working.

Compared to Doppler-type ultrasonic flowmeters, the TransPort flowmeter is more accurate. That's because TransPort's transit-time method gives an actual measurement of the fluid velocity. Doppler-type ultrasonic flowmeters are less accurate because they measure the velocity of the moving particles in the fluid, not the average flow rate of the fluid. You no longer need a less accurate Doppler-type flowmeter for these "dirty" applications.

TransPort offers all the superior performance of a technologically advanced transit-time flowmeter in a compact, lightweight, portable package.

*The Complete TransPort System Fits in a Compact Carrying Case.*





*INDUSTRIES:*

**AEROSPACE**
**AGRICULTURE**
**ENERGY MANAGEMENT:**
- Hot Water • Chilled Water

**FOOD & BEVERAGE**
**MANUFACTURING**
**MEDICAL**
**PETROCHEMICAL:**
- Refining • Chemical Processing
- Process Control

**PHARMACEUTICAL**
**POWER:**
- Fossil Fuel • Nuclear • Hydroelectric

**PULP & PAPER**
**SEMICONDUCTOR MANUFACTURING:**
- Ultra-pure Liquids • De-ionized Water

**SEWAGE TREATMENT**
**WATER & WASTE WATER MANAGEMENT**

*TYPICAL APPLICATIONS:*

**ACIDS**
**CORROSIVE, EROSIVE & TOXIC LIQUIDS**
**CRYOGENICS:**
- Argon • LPG • Nitrogen

**PETROLEUM PRODUCTS:**
- Benzene • Crude Oil • Ethylene • Fuels
- Heating, Lubricating Oil • Propane
- Solvents • Xylene

**POTABLE WATER**

*USES:*

- Balancing Systems • Batching • Billing/Accounting • Check Metering
- Cooling • Efficiency Studies • Flow Surveys • Heating • Large Pipes
- Leak/Rupture Detection • Pollution Control • Process Control
- Small Pipes

**PANAMETRICS**

**MAIN OFFICES:**

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Fax 617-894-8582

Panametrics, Ltd.
Shannon Airport, Shannon, Ireland
Phone 061-471377 • Telex 72161
Fax 061-471359

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Phone 886-7-587-5347
Fax 886-7-587-5349

Cheam, Surrey,
Panametrics, Ltd.
Phone 081-643-5150
Fax 081-643-4225

Northenden, Manchester
Panametrics, Ltd.
Phone 061-946-0355
Fax 061-946-0334

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# APPENDIX J
# FORCE/TORQUE SENSORS

JR3

*Multi-Axis Load Cell Technologies*

JR3. Inc.
22 Harter Avenue
Woodland, CA 95776

(916) 661-3677
Fax (916) 661-3701

December 8, 1993

David Holcomb
Oak Ridge National Laboratory
Instrumentation and Controls Div.
PO Box 2008
Bldg. 3500
Oak Ridge, TN 37831-6010

Dear Mr. Holcomb,

Here is literature describing JR3 sensors and sensor systems. The literature describes only our standard commercial sensors, not special designs or modifications. Sensor rated loads have ranged from 1.5 lb to 25,000 lb.

JR3 sensors with external electronics have been modified to customer specifications for use in radioactive environments. The use of metal foil strain gages, and the absence of any semiconductor devices within the sensor give an inherent resistance to moderate levels of radiation. We are currently involved in a program with Dr. Marc Decreton at the SCK/CEN Nuclear Research Center in Belgium nuclear agency to study the effects of high radiation levels on JR3 sensors. Since the tests in Belgium may not apply directly to your application, we would be willing to provide test samples modified for radiation resistance for evaluation under conditions more suited to your needs.

I'm including a drawing showing the sealing method we use with sensors intended for deep sea submergence. The sensor interior pressure must be equalized with to the external pressure. This sealing method, or a modification of it may be suitable for your needs.

If you need additional information, or if I can help you in any other way, please let me know.

Sincerely,

Wayne Johnson
Applications Engineer

JR3. Inc.
22 Harter Avenue
Woodland, CA 95776

(916) 661-3677
Fax (916) 661-3701

By measuring the forces on three orthogonal axes, and the moment or torque about each of these axes, a six degree of freedom sensor can completely define the loading at the sensors location. Use of six degree of freedom sensors in robotic systems allows adaptive process control based on force feedback without unnecessary restrictions on process orientation. In research applications, the six degree of freedom sensor system allows simple collection of data completely defining the loads applied to the sensor by complex systems.

***JR3*** sensors are produced in many load ratings and bolt patterns. The size of the sensor varies, depending on force and moment ratings and required mounting dimensions. ***JR3*** sensors are very stiff, resulting in minimal degradation of system dynamics and positioning accuracy. The high stiffness also results in a higher resonant frequency than obtained with more compliant sensors.

## *JR3* Serial Sensors

***JR3*** sensors with onboard electronics use the latest technology to provide force and torque data at very high bandwidths and with very low noise. Signals from foil strain gage bridges are amplified, and converted to digital representations of the force and moment loading data by electronic systems contained within the sensor. Data is transmitted to the receiver electronics in a synchronous serial format. All low level analog signals and the A/D circuitry are within the sensor body, shielded from electromagnetic interference by the metal sensor body.

Data for all six axes is returned at a rate of 8 kHz. The digital data stream from a single sensor can be monitored by several different receivers simultaneously. The use of multiple receivers allows system control and monitoring or data collection to be performed by totally separate systems

The data stream includes information about sensor characteristics and calibration, and feedback monitoring the sensor power voltage. The stored sensor calibration data allows sensors to be changed with no need for any adjustment of the receiver circuitry. Feedback of the sensor power voltage allows use of long lengths of small gage wire in the sensor cable. Power and data signals can be passed through slip rings if necessary. Stiff, expensive sensor cables are no longer needed.

## *JR3* Sensors with external electronics

Under some conditions, such as high temperature, chemical exposure, or radioactivity, it may be preferable to locate the electronics remotely from the sensor. For these applications, ***JR3*** sensors are available with no electronics on board. The external electronic systems for these sensors provides the same serial data stream as the sensors with on board electronics, allowing the same receivers to be used with either type of sensor. Analog voltage output is also provided by the electronic system used with these sensors.

JR3
Multi-Axis Load Cell Technologies

# DSP BASED RECEIVERS for FORCE - TORQUE SENSORS

JR3, Inc.
22 Harter Avenue
Woodland, CA 95776

(916) 661-3677
Fax (916) 661-3701

***JR3*** DSP based bus compatible receivers, designed for use with ***JR3*** Force-Torque sensors which transmit serial data, use the latest technology to provide 6 degree-of freedom force and torque data at very high bandwidths. Use of a powerful Digital Signal Processing (DSP) chip allows the ***JR3*** receivers to provide decoupled and digitally filtered data at 8 kHz per channel. This data rate is an order of magnitude faster than previously available.

The receiver boards for the VMEbus and ISA (IBM-AT) bus are the first two examples. Both boards share a common architecture, consisting of the Digital Signal Processor and a shared dual-ported address space of 16k 2 byte words to which both the host and the DSP can read and write. Use of the dual ported RAM allows the host to read data from the DSP with very little overhead. It also allows the host to reconfigure the DSP on the fly, by writing configuration commands to the RAM.

The receiver card contains circuitry to receive the serial digital data stream from the sensor, as well as circuitry to monitor and adjust the power supply voltage at the sensor. The automatic remote power supply adjustment and the differential digital data signals mean that the sensor cable requirements are very forgiving. Long, small gage wires can be used, and the power and data signals can be passed through slip rings if necessary. Stiff, expensive sensor cables are no longer needed.

The DSP is used to process the raw data from the sensor. It performs several functions, including offset removal, data decoupling, saturation detection, digital low pass filtering, and force vector magnitude calculation. The processed data, and various status registers are located at specific locations in the dual ported RAM.

## VMEbus receiver

The VMEbus receiver card, a single height (4H) double wide (6U) card, occupies a 32k byte block in the VME's A24 address space. The base address is selected by dip switches on the card. Data and register locations are at specific offsets from the base address.

## ISA (IBM-AT) receiver

The ISA (IBM-AT) bus receiver card, which plugs into a 16 bit slot on the ISA bus, uses both the 62 pin and the 36 pin connector. The receiver occupies 4 consecutive I/O addresses in the range of 000 to 3FF hexadecimal. The base address is selected by dip switches on the card. The two lower I/O addresses form a 16 bit address register, the two upper addresses form a 16 bit data register. The address to be read or written (in the dual port shared address space) is written to the address register, then the data is then read from or written to the data register. Block transfers, where only the initial address need be written, are supported.

# JR3

Multi-Axis Load Cell Technologies

## STAND ALONE RECEIVER for SERIAL DATA FORCE - TORQUE SENSORS

JR3, Inc.
22 Harter Avenue
Woodland, CA 95776

(916) 661-3677
Fax (916) 661-3701

***JR3***'s stand alone receiver processor, designed for use with ***JR3*** Force-Torque sensors which transmit serial data, offers versatile interfacing options for applications which cannot use one of ***JR3***'s bus compatible receivers. The system has a serial I/O port and a high speed parallel output port. It can receive commands from, and send data to, terminals, or a variety of computers and controllers using the serial I/O port. The parallel output port can transfer data at high speed to computers or directly to robotic or industrial controllers. This microprocessor based receiver system can provide decoupled, digitally filtered data at up to 800 Hz per axis.

The serial port may be programmed for baud rates from 300 to 19,200. The port can be switched from RS-423 (generally RS-232 compatible), to RS-422 protocol, and can be used with a simple serial terminal, or a computer running a terminal emulation program. The serial port is used for set up and control of the ***JR3*** system. Data can be transmitted as ASCII formatted data, or as a continuous stream of binary packeted data. The data can be either raw or processed force and moment data for any or all axis. Raw data is amplified, filtered sensor data. Cross coupling is not removed. Processed data is decoupled, may be digitally filtered and can include global force and moment vectors, maximum and minimum values, and rate of change data for any of the axis or vectors.

The high speed parallel output port is driven internally via a DMA (Direct Memory Access) channel to allow rapid response to a request for data. Raw or processed data is available parallel port. This port uses 18 discrete lines; 1 data request input, 1 data valid output, and 16 data output lines. It can communicate with simple, inexpensive parallel boards such as the Data Translation DT-1417 for the VMEbus, or the Metrabyte PIO-12 for the IBM PC.

# JR3

Multi-Axis Load Cell Technologies

## 16 CHANNEL COMPARATOR LOAD THRESHOLD MONITORING RECEIVER

JR3, Inc.
22 Harter Avenue
Woodland, CA 95776

(916) 661-3677
Fax (916) 661-3701

The ***JR3*** 16 channel comparator load threshold monitoring receiver, used with ***JR3*** Force-Torque sensors which transmit serial data, monitors the forces on three orthagonal axes, and the moment or torque about each of these axes. Sixteen optically isolated outputs may be set by the user to monitor any axis, or the vector sum of all forces.

The comparator receiver contains circuitry to receive the serial digital data stream from the sensor, as well as circuitry to monitor and adjust the power supply voltage at the sensor. The automatic remote power supply adjustment and the differential digital data signals mean that the sensor cable requirements are very forgiving. Long, small gage wires can be used, and the power and data signals can be passed through slip rings if necessary. Stiff, expensive sensor cables are no longer needed.

The serial data from the sensor is converted to analog form. The analog representations of the loading levels are filtered by a low pass filter with user selectable cutoff frequencies. The filtered analog signals are compared to the user adjusted setpoints, causing the optically isolated outputs to change state when loads go above or below the selected threshold. User selectable hysteresis ensures stable output from the comparators.

The outputs may be selected to be active and follow the load state, or to latch until reset. Each setpoint can be set to monitor any of the six axes, or the vector sum of all forces. The outputs are optically isolated and have the capability to sink up to 75 milliamps. Outputs may be powered from the electronics system voltage, or may be fully isolated with power from an external supply.

The electronic system allows system offsets and loads due to gravity to be removed from the loading data through use of the REMOVE TARE input.

# JR3

*Multi-Axis Load Cell Technologies*

## SERIAL SENSOR SYSTEM PRICES

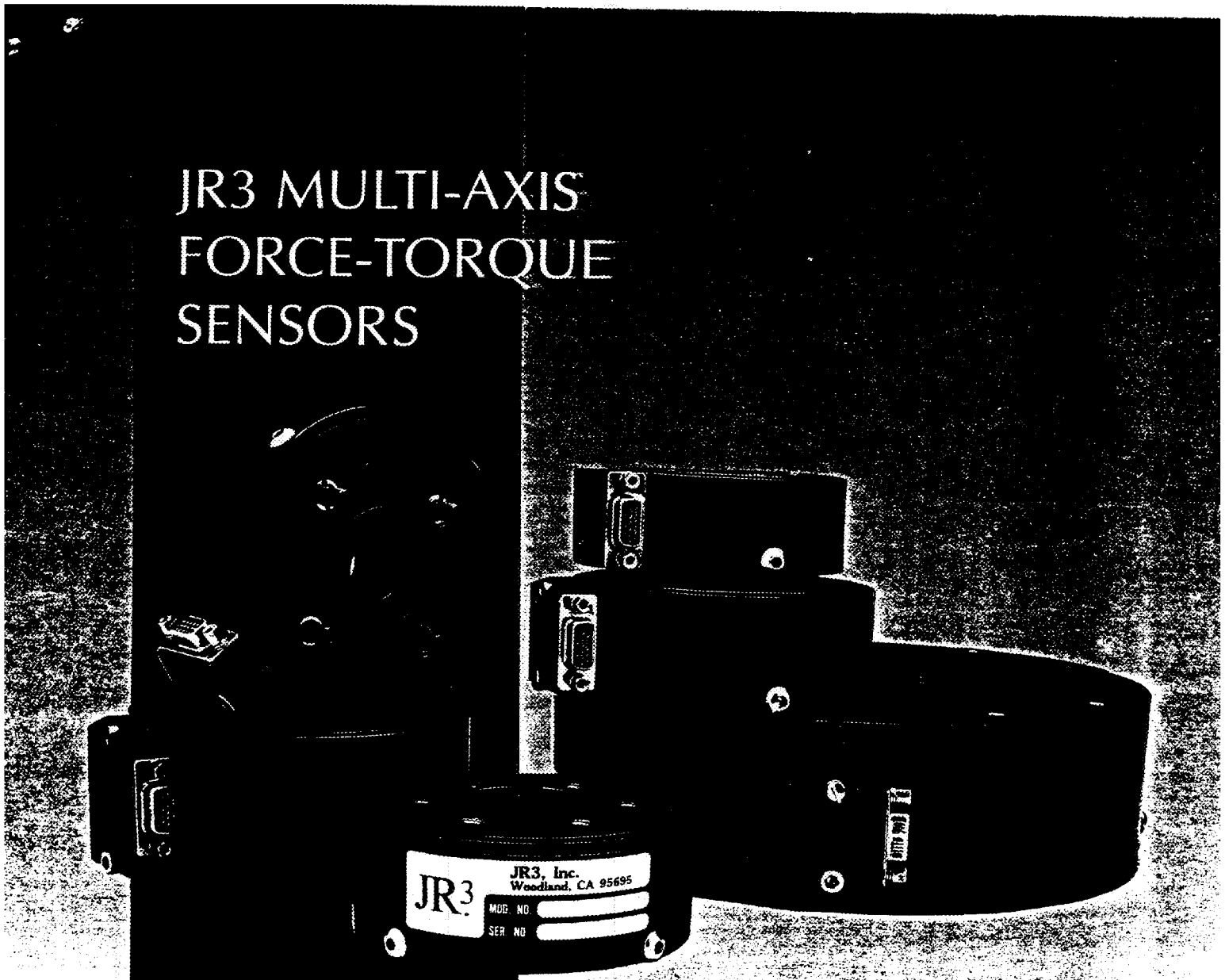
March 31, 1993

JR3, Inc.
22 Harter Avenue
Woodland, CA 95776

(916) 661-3677
Fax (916) 661-3701

| PRODUCT | QTY 1-4 | QTY 5-9 |
|---|---|---|
| **SENSORS** (specify load capacity and bolt pattern when ordering) | | |
| MODEL<br>67M25 25 or 50 lb<br>BOLT PATTERNS:<br>ISO 40mm, UNIMATION PUMA 560 | 4,485 | 4,150 |
| MODEL<br>90M31 25 or 50 lb.<br>BOLT PATTERNS:<br>ISO-50mm | 4,485 | 4,150 |
| MODEL<br>100M40 25, 50 and 100 lb<br>BOLT PATTERNS:<br>ISO-63mm, UNIMATION PUMA 760 | 4,485 | 4,150 |
| MODEL<br>50M31 25 lb<br>BOLT PATTERNS:<br>ISO-25mm | 4,735 | 4,380 |
| **RECEIVER/PROCESSORS** | | |
| ISA (IBM-AT) bus | 920 | 886 |
| VMEbus | 1,280 | 1,232 |
| UNIMATION UNIVAL CONTROLLER<br>(modified VMEbus) | 1,280 | 1,232 |
| UFS Receiver System for Serial Sensors<br>(Stand Alone) | 1,725 | 1,650 |
| **EXAMPLE SYSTEM PRICES** | | |
| 67M25 sensor with an ISA bus receiver | 5,405 | 5,036 |
| 67M25 sensor with a VMEbus receiver | 5,765 | 5,382 |

# JR3 MULTI-AXIS FORCE-TORQUE SENSORS




- *3, 4, and 6-axis configurations*
- *Variety of sizes, capacities and bolt patterns*
- *Digital and analog support electronics*

JR3

JR³ force-torque sensor bodies are of a stiff monolithic design with an integral safety factor of 600%. Optional mechanical overload protection is available for the lowest capacity units.

The sensor bodies need not contain electronic components; this permits the sensor to be used in harsh environments.

The top and bottom sides of the sensor body are manufactured to duplicate the user's desired bolt pattern. Captive bolts in the sensor allow easy installation without the need for adapter plates.

Foil gage wheatstone bridges ensure temperature stability and linearity.

**Moment Capacities (inch - lbs.) of standard sensor models**

| Thickness | Load Rating (Fx, Fy) | DIAMETER (inches) 3 | 3.5 | 4 | 4.5 | 6.5 | 7.5 | 13 |
|---|---|---|---|---|---|---|---|---|
| 1.25: | 15 lbs. | 45 | 52 | 60 | 68 | | | |
| | 25 | 75 | 88 | 100 | 112 | | | |
| | 50 | 150 | 175 | 200 | 225 | | | |
| 1.5" | 75 | 225 | 262 | 300 | 338 | 488 | 562 | |
| | 100 | 300 | 350 | 400 | 450 | 650 | 750 | |
| | 150 | | | | 675 | 975 | 1125 | |
| 2.0" | 250 | | | | 1125 | 1625 | 1875 | |
| | 400 | | | | | 2600 | 3000 | |
| | 500 | | | | | 3250 | 3750 | |
| 3.5" | 5,000 | | | | | | | 42500 |
| | 25,000 | | | | | | | 212500 |

(Fz: 2X the above)

- JR3's family of 3, 4 and 6-axis sensor bodies are available in a wide variety of sizes, capacities and bolt patterns. Some of the bolt patterns available fit these industrial robots:

Unimation PUMA 560
Unimation PUMA 760
Unimation PUMA 860
ASEA IRB 6
ASEA IRB 90
ASEA IRB 2000/3000
Seiko RT 3000/5000
Cincinatti Milacron T3-776
IBM 7576
American Robot MR 6260
Manutech R2
ADEPT
GMF S10/200
GMF S400
GMF A500
Panasonic

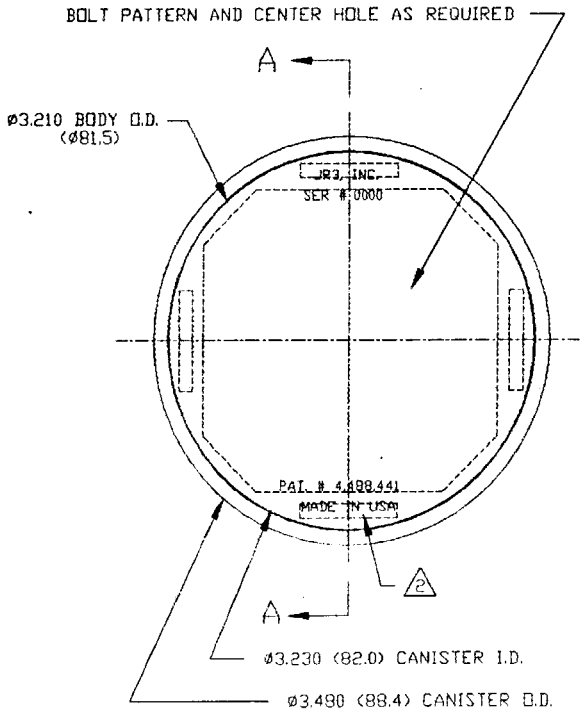
- JR3 manufactures a variety of digital and analog support electronics which provide many types of data transmission and interfaces.

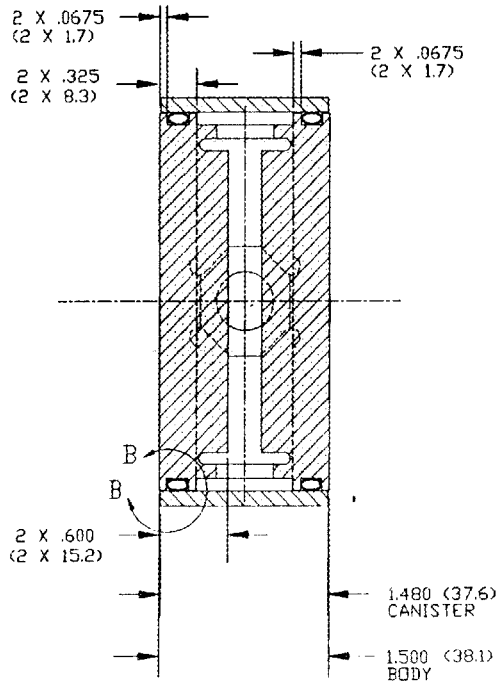
Sensor body model # definition:

UFS - 30 12 A 50 - U560

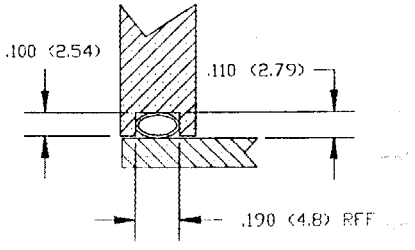
- U560: Bolt Pattern
- 50: Fx & Fy load rating (lbs) (Fz load rating is 2 times Fx) (Torque rating is diameter times Fx rating)
- A: Material (A=Aluminum)
- 12: Thickness 12=1.25", 15=1.5", etc.
- 30: Diameter 30=3.0", 35=3.5", etc.
- UFS: Type (no. of axes) UFS= 6 axes, TFS= 3 axes, QFS= 4 axes

JR3 Inc.
22 Harter Avenue
Woodland, CA 95695 USA
Phone: (916) 661-3677
FAX: (916) 661-3701




SECTION A-A




DETAIL B-B

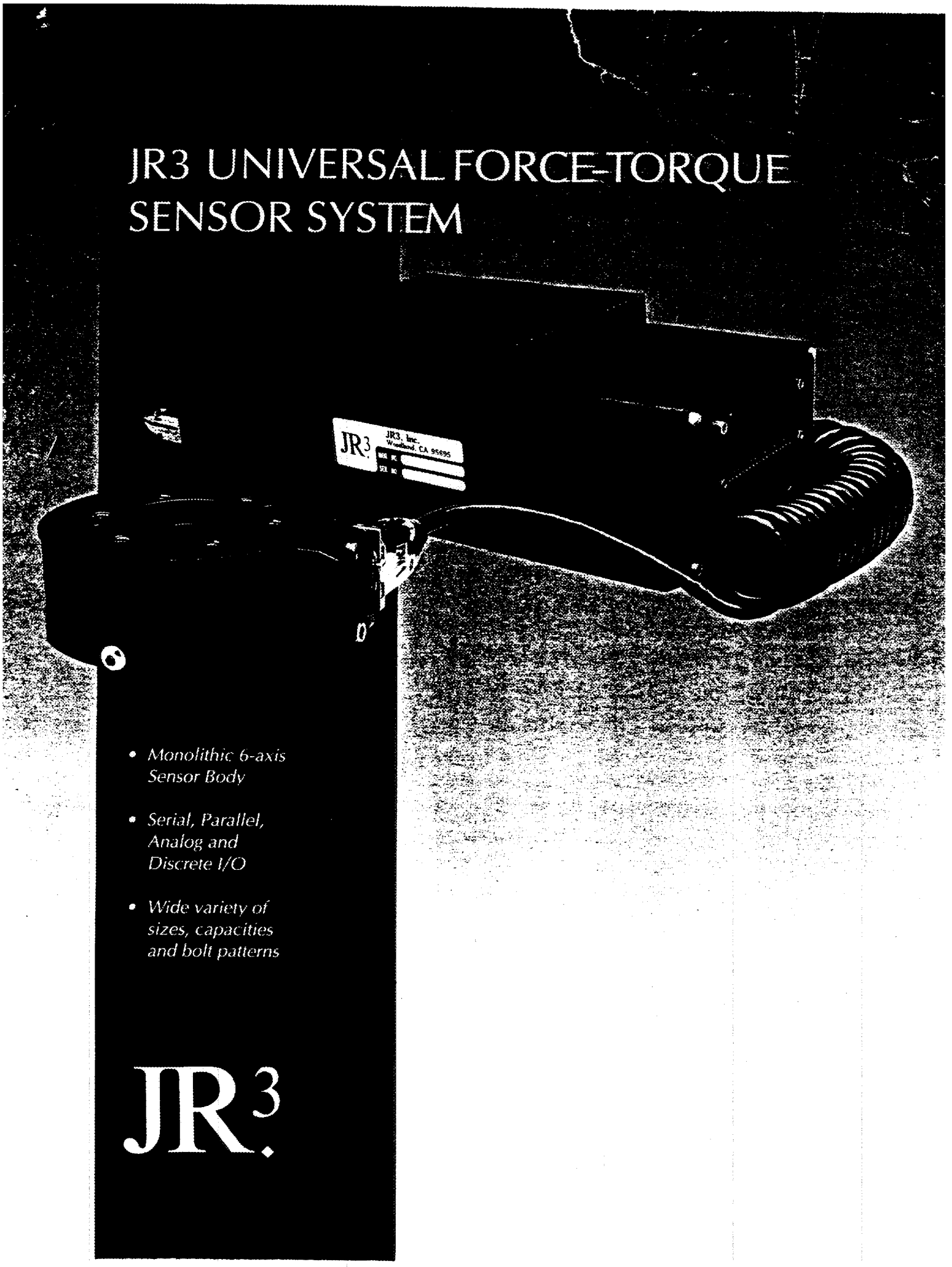
NOTES:

1. ALL DIMENSIONS ARE IN INCHES (mm).

2. ENGRAVE IN APPROXIMATE LOCATION SHOWN IN .10-INCH (2.5mm) HIGH BY .007-INCH (.2mm) DEEP CHARACTERS PER JR3-015.

| | | |
|---|---|---|
| TITLE: O-RING DESIGN CONCEPT, TYPICAL | | |
| SCALE: 1/1 | MODEL: 3515XXXXXXX (SHOWN) | DRAWN: GCS |
| MAT'L: | | DATE: 6-15-92 |
| TOLERANCES: XX = ±.010 (±.25) XXX = ±.005 (±.13) | | REV DATE: |
| JR3, INC. | | |

# JR3 UNIVERSAL FORCE-TORQUE SENSOR SYSTEM




- *Monolithic 6-axis Sensor Body*
- *Serial, Parallel, Analog and Discrete I/O*
- *Wide variety of sizes, capacities and bolt patterns*

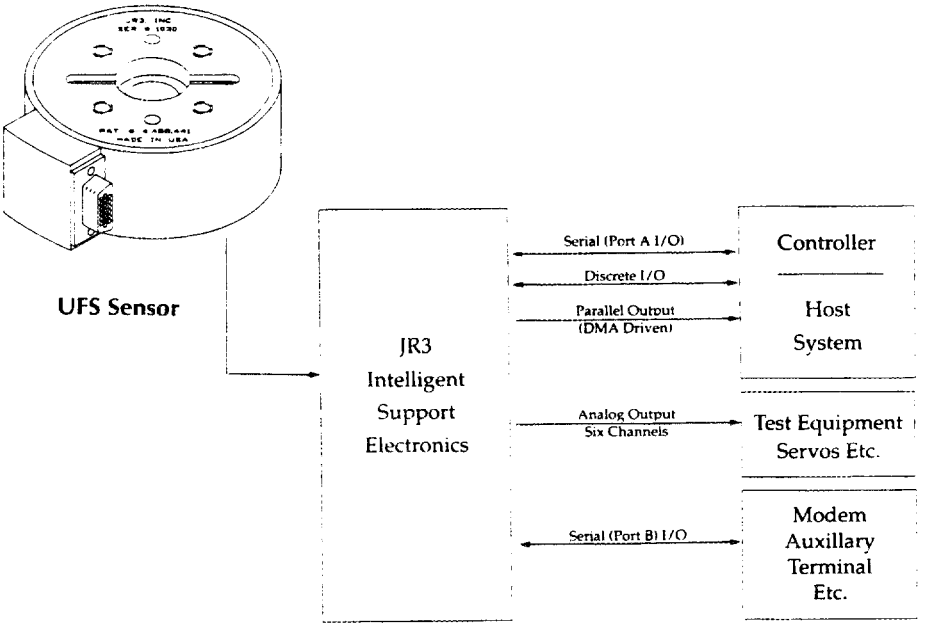
JR3

The JR3 UFS System consists of a six degree-of-freedom sensor body, an interconnecting sensor cable and the UFS intellegent support electronics. The system measures forces and torques along and about all three cartesian axes.

The six-axis sensor bodies are available in a wide variety of sizes, capacities and bolt patterns.

The 16-bit microprocessor-based intelligent support electronics [illegible]

- Two serial ports can be set up for either RS232 or RS422.
- DMA driven parallel interface provides a high speed data output path.
- Discrete I/O port has a variety of input and output signals.
- Analog output is available as six channels of direct output from the signal conditioning board. The JR3 DAC option provides eight channels of filtered and de-coupled processed analog data (6 axes plus 2 global vectors).
- Filters: analog: 4th order, user-settable
  digital: 4th order, user-programmable
- Load threshold monitoring is done via user-definable load envelopes. Up to 16 load envelopes can be stored in EEPROM and activated with simple signals or commands.
- User-definable tool frames allow coordinate transforms and rotations.
- User-defined parameters can be stored in EEPROM (such as communication parameters, time base rate, active load envelope and toolframe, active axes, filter coefficients).

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JR3 COMMERCIAL TRANSDUCER STIFFNESSES: 9 August 1990

| | | | | | |
|---|---|---|---|---|---|
| (1) | Type: | Model No. | | | 3012A25-U560 |
| | | Diameter | | | 3.0 in |
| | | Thickness | | | 1.25 in |
| | | Load Rating | | | 25 lb |
| | Measured Stiffness | Shear | $K_{FY}$ | = | 37 K lb/in |
| | | Axial | $K_{FZ}$ | = | 330 K lb/in |
| | | Bending | $K_{MX}$ | = | 240 K in-lb/rad |
| | | Torsion | $K_{MZ}$ | = | 72 K in-lb/rad |

| | | | | | |
|---|---|---|---|---|---|
| (2) | Type: | Model No. | | | 4012A50-U760 |
| | | Diameter | | | 4.0 in |
| | | Thickness | | | 1.25 in |
| | | Load Rating | | | 50 lb |
| | Measured Stiffness | Shear | $K_{FY}$ | = | 66 K lb/in. |
| | | Axial | $K_{FZ}$ | = | 710 K lb/in. |
| | | Bending | $K_{MX}$ | = | 649 K in-lb/rad |
| | | Torsion | $K_{MZ}$ | = | 244 K in-lb/rad |

| | | | | | |
|---|---|---|---|---|---|
| (3) | Type: | Model No. | | | 6019A100-FTT1 |
| | | Diameter | | | 6.0 in |
| | | Thickness | | | 1.9 in |
| | | Load Rating | | | 100 lb |
| | Measured Stiffness | Shear | $K_{FY}$ | = | 74.4 K lb/in |
| | | Axial | $K_{FZ}$ | = | 468 K lb/in |
| | | Bending | $K_{MX}$ | = | 2180 K in-lb/rad |
| | | Torsion | $K_{MZ}$ | = | 929 K in-lb/rad |

| | | | | | |
|---|---|---|---|---|---|
| (4) | Type: | Model No. | | | 6024A100-FTT1 |
| | | Diameter | | | 6.0 in |
| | | Thickness | | | 2.4 in |
| | | Load Rating | | | 100 lb |
| | Measured Stiffness | Shear | $K_{FY}$ | = | 77.5 K lb/in |
| | | Axial | $K_{FZ}$ | = | 769 K lb/in |
| | | Bending | $K_{MX}$ | = | 2630 K in-lb/rad |
| | | Torsion | $K_{MZ}$ | = | 976 K in-lb/rad |

# JR3

# FORCE-MOMENT SENSORS

## Moment capacities of standard sensor models:

| Thick-ness | Load rating (Fx, Fy) | DIAMETER (inches) 3 | 3.5 | 4 | 4.5 | 6.5 | 7.5 | 13 |
|---|---|---|---|---|---|---|---|---|
| 1.25" | 15 lbs. | 45 | 52 | 60 | 68 | | | |
| | 25 | 75 | 88 | 100 | 112 | | | |
| | 50 | 150 | 175 | 200 | 225 | | | |
| 1.5" | 75 | 225 | 262 | 300 | 338 | 488 | 562 | |
| | 100 | 300 | 350 | 400 | 450 | 650 | 750 | |
| | 150 | | | | 675 | 975 | 1125 | |
| 2.0" | 250 | | | | 1125 | 1625 | 1875 | |
| | 400 | | | | | 2600 | 3000 | |
| | 500 | | | | | 3250 | 3750 | |
| 3.5" | 5,000 | | | | | | | 42500 |
| | 25,000 | | | | | | | 212500 |

(Fz:2X the above)

## Standard bolt patterns currently available for these robots:

Unimation PUMA 560
Unimation PUMA 760
Unimation PUMA 860

ASEA IRB 6
ASEA IRB 90

GE A 40
GE P 50

Seiko RT3000/5000

Cincinatti Milacron T3-776

IBM 7576

American Robot MR 6260

Manutech R2

ADEPT

GMF S100/200
GMF S400
GMF A500

Panasonic

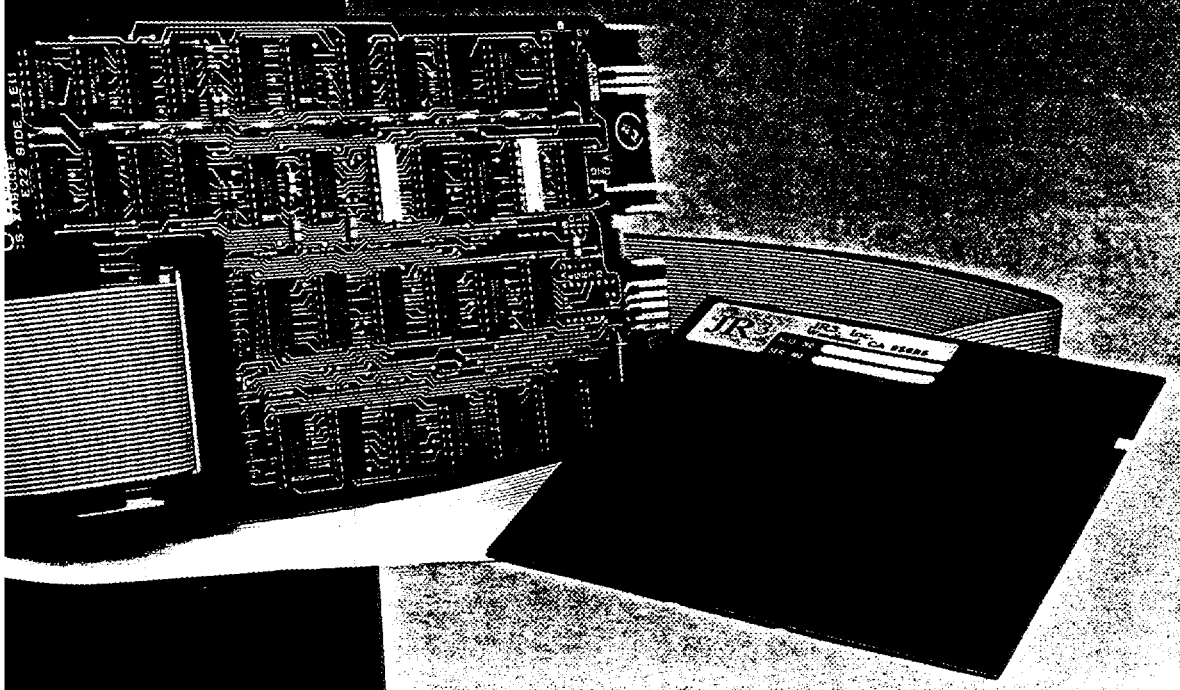
Maker 110

JR3

Custom designs available

JR3, Inc.
22 Harter Ave.
Woodland, CA 95695
(916) 661-3677

# S-VAL II
# TERFACE



*Quick and Easy*
*nterface between*
*R3 UFS system*
*and Unimation*
*VAL II* controller*

*Kit consists of:*

- *DRV11 card***
- *JR3 DRV-DMA cable*
- *Sample VAL II program*

JR3

* VAL is a trademark of Unimation Incorporated.
** The DRV11 card is a product of Digital Equipment Corporation.

JR3

# JR3 SENSOR SYSTEMS PRICE SCHEDULE

**Effective June 1, 1991**

Prices subject to change without notice

JR3, Inc.
22 Harter Ave.
Woodland, CA 95695
(916) 661-3677
Fax (916) 661-3701

## Universal 6-Axis Force-Moment Sensor System

| | Quantity 1 - 2 | Quantity 3 - 9 |
|---|---|---|
| **Standard UFS System** | **$6,650** | **6,320** |
| Standard aluminium sensor, up to 4 inches diameter, up to 100 lb capacity<br>Standard intelligent support electronics system<br>20 foot sensor cable (add $2.00 per foot for each foot over 20 feet)<br>For sensor diameters over 4 inches, add $200.00 per inch over 4 inches<br>For load ratings over 100 lbs, add $1.00 per lb over 100 lbs | | |
| **Partial System** | **5,850** | **5,550** |
| Standard aluminium sensor, up to 4 inches diameter, up to 100 lb capacity<br>Amplifier/signal conditioning electronics (analog output only)<br>20 foot sensor cable (add $2.00 per foot for each foot over 20 feet)<br>For sensor diameters over 4 inches, add $200.00 per inch over 4 inches<br>For load ratings over 100 lbs, add $1.00 per lb over 100 lbs | | |
| **Sensor Only** | **4,390** | **4,160** |
| Standard aluminium sensor, up to 4 inches diameter, up to 100 lb capacity<br>Calibration matrix<br>For sensor diameters over 4 inches, add $200.00 per inch over 4 inches<br>For load ratings over 100 lbs, add $1.00 per lb over 100 lbs | | |

### Options

| | | |
|---|---|---|
| UFS Power supply 120 VAC (240 VAC optional) | **475** | **450** |
| Processed analog output (DACs) | **620** | **590** |
| 15 bit A/D | **620** | **590** |
| Val II interface kit (DEC DRV-11 & cable) | **490** | **470** |
| Unival interface kit (Data Translation DT-1417 & cable) | **895** | **850** |
| IBM PC/compatible interface kit (Metrabyte PIO-12 & cable) | **260** | **250** |
| Stainless steel sensor construction<br>Load capacities above 500 lbs.<br>Modified sensors, cables, electronics, software | Contact JR3 for prices | |

### Components

| | | |
|---|---|---|
| Standard 20 foot sensor cable (add $2.00 per foot for each foot over 20 feet) | **200** | **190** |
| Complete standard UFS intelligent support electronics system | **2,550** | **2,390** |
| UFS Electronic system enclosure with end panels and harness - no PC boards | **370** | **350** |
| UFS Signal conditioning PC board | **925** | **880** |
| UFS A/D PC board | **410** | **390** |
| UFS Processor PC board | **1,250** | **1,180** |

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# UFS SYSTEM OVERVIEW

By measuring the forces on three orthagonal axes, and the moment or torque about each of the axes, the JR$^3$ UFS system can completely define the loading at the sensor. The system consists of the six degree of freedom sensor body, the intelligent electronics support system, interconnecting cables and, optionally, a power supply. Along with the three forces and moments, the output data can include the calculated magnitude of the combined (global) force and moment vectors of loads applied to the sensor, the rate of change of the load on each axis, and stored values of the maximum and minimum loads encountered. The data can be displayed in different units and a variety of formats.

The system has several communication options. There are two independent serial I/O ports, a high speed parallel output port, 8 bits of discrete TTL level input and output, and 6 channels of amplified raw analog output. The system can receive commands from, and send data to, terminals, or a variety of computers using the serial I/O ports. The parallel output port can transfer data at high speed to computers or directly to robotic or industrial controllers. The discrete I/O port allows a simple interface for control and monitoring of load envelope setpoints.

## Sensor

JR$^3$ sensors are produced in a wide variety of load ratings and bolt patterns. The physical size of the sensor varies, depending on factors such as force and moment ratings and required mounting dimensions. The JR$^3$ sensor is a monolithic design containing no electronic components. Inherently temperature compensated full bridge metal foil gauge Wheatstone bridges are employed. The Wheatstone bridges receive excitation from the electronics unit and sense the forces and moments. The low level analog signals are returned to the electronics unit through the sensor cable.

The reference point for all loading data is the geometric center of the sensor. The axes on the JR$^3$ sensor are oriented with the X and Y axis in the plane of the sensor body, and the Z axis perpendicular to the X and Y axes. The standard JR$^3$ point of view is "robot view, applied load." The forces and moments are related by the Right Hand Rule. Software commands can translate the reference point along the axes, rotate its angle, and negate all axes to change the loading reference point orientation and point of view.

## Intelligent Electronics Support System

The microprocessor based JR$^3$ intelligent electronic support system consists of an enclosure housing three circuit boards. They provide strain gauge excitation voltage and amplify and filter the low level analog gauge output, convert the signals to digital data and process the digital data in a variety of ways. The standard system represents data with 12 bits of resolution, 15 bit resolution is optional.

In addition to computations and data processing, the micro processor also handles serial and parallel communications and controls the discrete I/O port. An optional DAC (Digital to Analog Converter) can convert the processed digital data to analog signals, providing processed analog output.

# UNIVERSAL FORCE-MOMENT SENSOR SYSTEM

JR3, Inc.
22 Harter Ave.
Woodland, CA 95695
(916) 661-3677
Fax (916) 661-3701

SAMPLE CHART OF CAPACITIES WITH RESOLUTION

| SENSOR LOAD RATING | DIAMETER (INCHES) | LOAD COMPONENT | | 100% OF MECHANICAL LOAD RATING | RESOLUTION WITH 12 BIT A/D |
|---|---|---|---|---|---|
| 15 lb | 3.0" | FORCES | Fx, Fy | 15 lb | 0.12 oz |
| | | | Fz | 30 lb | 0.24 oz |
| | | MOMENTS | Mx, My, Mz | 45 in-lb | 0.35 in-oz |
| 25 lb | 3.0" | FORCES | Fx, Fy | 25 lb | 0.20 oz |
| | | | Fz | 50 lb | 0.39 oz |
| | | MOMENTS | Mx, My, Mz | 75 in-lb | 0.59 in-oz |
| 50 lb | 3.0" | FORCES | Fx, Fy | 50 lb | 0.39 oz |
| | | | Fz | 100 lb | 0.78 oz |
| | | MOMENTS | Mx, My, Mz | 150 in-lb | 1.17 in-oz |
| 100 lb | 6.5" | FORCE | Fx, Fy | 100 lb | 0.78 oz |
| | | | Fz | 200 lb | 1.56 oz |
| | | MOMENTS | Mx, My, Mz | 650 in-lb | 5.08 in-oz |
| 500 lb | 7.5" | FORCES | Fx, Fy | 500 lb | 3.91 oz |
| | | | Fz | 1000 lb | 7.81 oz |
| | | MOMENTS | Mx, My, Mz | 3750 in-lb | 29.30 in-oz |

NOTES: 100% of the mechanical load rating is the fatigue limit. The sensor can be subjected to single axis loadings up to 400% without experiencing damage. At loadings beyond this point the sensor may experience plastic deformation. This will cause offset shift and may require an adjustment of offset trimpots in the support electronics. Overloading of a single axis beyond 700% or damage from overloading due to impacts may require factory rework of the sensor. Contact JR3 for details of overload ratings with multi axis loading.

100% mechanical load rating for moments is computed by multiplying sensor diameter by sensor load rating.

Stiffness: deflection under 100% rated load on a single axis is 0.001 inches or less.
JR3's 12 bit A/D gives a resolution of one part in 2048 parts of electrical full scale. Electrical full scale can be set by the user to between 40% and 200% of the sensor's mechanical load rating. Setting the electrical full scale to a smaller range enhances the resolution. Setting to a larger range allows overload quantification.

$$\text{12 bit resolution} = \frac{1}{+/-\,2048} \qquad \text{15 bit resolution} = \frac{1}{+/-16384}$$

With 12 bit resolution 1 to 4 counts of noise is typical

Band width:

Low pass filters (fourth order Butterworth) in the analog electronics may be set by the user for a cutoff frequency in the range of 8 Hz to 160 Hz. The filters may be bypassed, providing a bandwidth in excess of 5 kHz at the analog output.

The digital sample rate (all 6 axes) may be set from 35 Hz to a maximum of about 350 Hz.

# JR3

## UFS PARALLEL PORT INTERFACE KITS

JR3, Inc.
22 Harter Ave.
Woodland, CA 95695
(916) 661-3677
Fax (916) 661-3701

In most applications, the JR3 parallel port offers the fastest means to transfer data between the JR3 UFS system and a robot controller or computer. The JR3 UFS parallel output port is driven internally via a DMA (Direct Memory Access) channel to allow rapid response to a request for Raw or processed data.

JR3 offers several kits to interface with specific robot controllers or computers. Each kit consists of a parallel port board to match a specific computer or bus, and a JR3 cable to interconnect the UFS system and the parallel port board.

- VAL II Interface Kit

  A quick and easy interface between the JR3 UFS system and Unimation VAL II robot controllers. The kit consists of a DRV11 parallel port card and a JR3 DRV-DMA cable.

  This kit can also be used with DEC Q-Bus computers.

- IBM PC/Compatible Interface kit

  IBM PCs and true compatibles can easily read data from the JR3 UFS system using this kit. The kit consists of a metrabyte PIO12 parallel I/O card, a JR3 PIO12-DMA cable and sample program routines in Turbo Pascal.

- Unival Interface Kit

  The Unival Kit offers easy connection to Unimation Unival robot controllers. The kit consists of a Data Translation DT-1417 parallel card and a JR3 DT1417-DMA cable.

  This kit can also be used with many VME Bus computers and controllers.

# FAX TRANSMISSION

**Assurance Technologies, Inc.**
**503-D Highway 70 East**
**Garner, NC 27529**
**Phone: 919-772-0115**
**Fax: 919-772-8259**

Business Hours: Monday - Friday 8:00AM-5:00PM

| | | | |
|---|---|---|---|
| **TO:** | **David Holcomb** | **FROM:** | **Cathy Knight (extension 134)**<br>**Sales Manager** |
| **Company:** | **Oak Ridge National Labs** | | |
| **Fax Number:** | **615-574-4058** | **Date:** | **January 28, 1994** |
| **Phone Number:** | **615-576-7889** | **Total Pages, Including Header:** | 6 |

**Reference: Specs for Force/Torque Sensors in Nuclear Environments**

Dear David:

We are pleased to be involved in the writing of specifications for the use of multi-axis force/torque sensors in nuclear environments. As I mentioned over the phone, we are working with Harwell Laboratories, Atomic Energy Authority, in Oxford, England to develop a sensor which can be used in a radiation environment up to 1MGy. They have re-designed, and re-built a Stæubli robot which is called "Neater" to function in radiation environments up to 1MGy. I understand there are about 10 of these being used to date.

To date, our standard stainless steel sensor body with silicon strain gages and standard resident electronics has been exposed to a cumulative gamma radiation dosage of 300 MGy. No effort was made to operate the sensor during the radiation exposure. Following each exposure, the sensor was connected to the controller and terminal to observe the output of the raw strain gages. At the 300 KGy level, only two small changes have been observed: 1) the accuracy may be up to 1% less than our factory standard, and 2) there seems to be a few hours required for self annealing of the electronics for the system to function normally.

Harwell has at least one of our standard sensors now functioning in a "hot cell" with a radiation level of 200 Gy which has not experienced any abnormalities.

Our temperature compensation option for our standard sensors corrects the gain shift error to the range of -40°C to 76°C, and we have located components which can increase the range to 125°C. We have not tested any of these components in a radiation environment.

We have protected a number of sensors with special coatings and water-tight connectors to function immersed in shallow water. Except for our Nano and Mini models, our standard models have resident electronics. These electronics can also be located in a separate box up to 6 feet from the sensor without loss of signal integrity.

To protect the sensor during the washdown, it may be necessary to encase it. Some of the concerns about the spray wash of pelletized carbon dioxide include:

1) The storage temperature for our standard sensors is -65°C. How cold do you expect the carbon dioxide to make the sensor?

2) Is it expected that the sensor will be subject to the full 250 psi pressure or some lesser force? What is the duration of the spray wash expected to be?

3) We do not have any test data readily available concerning the affect of alkaline solutions on the sensor, strain gages, or electronic components Our preliminary design for encasing the sensor should withstand a pH of 12, but some elastomers may need to be replaced eventually. How *low* might the pH be?

I have attached a price list for our standard products. Waterproofing a standard sensor can add $500 to $4000 depending on the method used, i.e. whether the electronics remain on the sensor or are in a separate box, whether water-tight connectors are needed, etc. If the sensor is encased to protect during washdown, separate waterproofing of the sensor would not be necessary.

A ball park figure for one system to meet all specifications discussed above would be around $15,000. More information would be required for a formal quotation. Delivery is expected to be six to twelve weeks. Delivery for standard systems is normally 3 weeks.

I will mail you a packet of information including articles and technical reports and a general price list.. If you wish to contact Harwell Laboratories, I suggest you speak with Paul Elosequi at 011-44-235-434727, or fax him at 011-44-235-434803. I'm sure he will be glad to talk with you about our sensors and their work in this field.

Please call me on extension 134 if I can be of further assistance.

Sincerely,

Cathy Knight

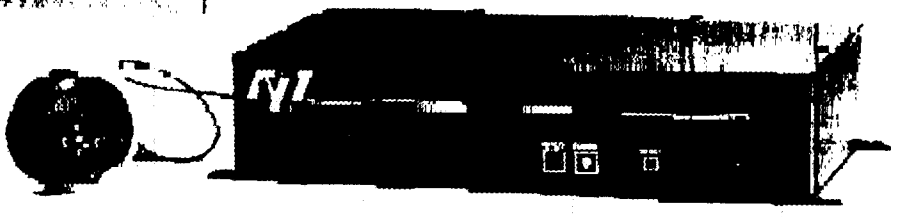
Cathy Knight

# F/T Sensor System

## Measures 6-axis forces and torques

## Product Description

The F/T sensor system measures the full 6 components of force and torque. It consists of a transducer, shielded high-flex cable and intelligent controller.



### Transducer

The compact and rugged monolithic transducer converts force and torque into amplified analog strain-gage signals. Silicon strain gages provide high noise [illegible] in standard or hard models.

### Controller

The controller uses a 12 bit A/D converter to digitize the amplified analog strain-gage signals. These digitized strain values are converted into forces and torques (F/T values). The digitized F/T and strain-gage values can be output via the standard RS-232 serial port at a variety of baud rates.

Digital discrete I/O capability is available for signalling user programmed F/T thresholds, monitoring system health and biasing F/T values.

An analog and/or parallel board option is available for high speed output. Serial and parallel communication software and boards are available for IBM PC compatible computers.

### Built-in Capabilities

Internal software provides a variety of powerful functions:

- **Tool transformations** translate and/or rotate the F/T reference frame.
- **Bias** [illegible] F/T [illegible] to be detected and stored.
- **Biasing** provides a convenient way to offset and weight [illegible]
- **Minimum update transition** possible by reducing the number of axes output.
- **Communicate** through the serial and/or optional parallel port.
- **Start-up buffer** issues commands automatically when the F/T system is powered up.
- **Programmable F/T thresholds** provide fast-response F/T condition monitoring.
- **Temperature compensation** option corrects for errors due to changes in temperature.

Assurance Technologies, Inc.
503D Highway 70 East
Garner, North Carolina 27529
Tel.919.772.0115 Fax.919.772.8259

## Key Features and Benefits

- **Overload protection**
  Mechanical overload protection of up to 2000% of range protects the transducer from inadvertent crashes. No F/T transducer has ever been returned for calibration or repair due to a crash.
- **High signal-to-noise ratio**
  Silicon gages provide an output 75 times stronger than conventional foil gages. The signal is then amplified in the transducer resulting in near zero noise distortion.
- **High resolution** of 1:4096 with 12-bit A/D
  **High speed output** of over 1200 Hz with optional parallel board exceeds requirements for robotic applications.
- **Prompt delivery** of standard F/T models
- **Custom F/T sensors** can be designed and built to your specifications
- **Application assistance** by experienced engineers.

## Applications

Assurance Technologies is the largest supplier of multi axis force/torque sensors in the world. Over 1000 F/T sensors are being used in a variety of applications such as:

- **Robotic part insertion** verification for mechanical and electrical component assembly
- **Deburring, polishing, grinding** where robot is required to apply a constant force
- **Force/torque feedback** for manipulators in nuclear environments.
- **Physical rehabilitation** and prosthetics research.
- **Force and torque limit** verification.

The F/T sensor system has been integrated with a variety of robots —please call for more information.

[redacted]

## Transducer

| Models, lb/in-lb | 15/50 | 30/100 | 75/300 | 150/600 | 200/1000 | 350/2100 | |
|---|---|---|---|---|---|---|---|
| **Sensing Ranges** | | | | | | | |
| Force range, ± lb (N) | 15 (66.7) | 30 (133) | 75 (334) | 150 (667) | 200(890) | 350(1557) | Custom calibrations and transducers available |
| Torque range, ± in-lb (N-m) | 50 (5.65) | 100 (11.3) | 300 (33.9) | 600 (67.8) | 1000(113) | 2100(237) | |
| **Resolution** | | | | | | | |
| Fx, Fy, oz (N) | 0.20 (0.05) | 0.40 (0.11) | 1.0 (0.28) | 2.0 (0.56) | 2.0 (0.56) | 4.0 (1.1) | |
| Fz, oz (N) | 0.40 (0.11) | 0.80 (0.22) | 2.0 (0.56) | 4.0 (1.1) | 4.0 (1.1) | 8.0 (2.2) | |
| Tx, Ty, Tz, in-oz (N-mm) | 0.40 (2.8) | 0.80 (5.6) | 2.0 (14) | 4.0 (28) | 8.0 (56) | 16 (113) | |
| **Overload Protection** | | | | | | | Mechanical overload protection standard |
| Max. Fxy allowable, lb (N) | 150 (670) | | 800 (3.6k) | | 2250 (10k) | | |
| Max. Fz allowable, lb (N) | 300 (1.3k) | | 2250 (10k) | | 6650 (30k) | | |
| Max. Txyz allowable, in-lb (N-m) | 500 (56) | | 3000 (340) | | 12600 (1.4k) | | |
| **Dimensions**, diameter x length, in (mm) | | | | | | | |
| Transducer with standard tool adaptor plate | 2.9 x 1.10 (74 x 29) | | 3.6 x 1.10 (92 x 29) | | 6.1 x 1.80 (155 x 45.7) | | Drawings available upon request |
| Standard rear end-plate | 3.0 x 0.19 (75 x 4.7) | | 3.7 x 0.17 (94 x 4.7) | | 6.1 x 0.40 (155 x 10.2) | | |
| Optional rear ring/plug assembly | 3.6 x 0.28 (93 x 7.1) | | 4.4 x 0.41 (110 x 10) | | Not available | | |
| Optional front ring/plug assembly | 3.1 x 0.31 (80 x 7.9) | | 3.8 x 0.35 (97 x 8.9) | | 6.1 x 0.70 (155 x 17.8) | | |
| **Weight**, lb (g) | | | | | | | |
| Transducer with standard tool adaptor plate | 0.4 (180) | | 1.79 (810) | | 9.4 (810) | | |
| Standard rear end-plate | 0.1 (50) | | 0.23 (100) | | 1.0 (450) | | |
| Optional rear ring/plug assembly | 0.3 (150) | | 0.66 (300) | | | | |
| Optional front ring/plug assembly | 0.25 (110) | | 0.52 (240) | | 2.0 (900) | | |
| **Transducer Cable**, length, ft (m) | Standard 25 (7.5), optional lengths 50 (15) or 75 (22.5) | | | | | | |

**New small transducers available** — **Nano** dim's: 17mm *dia.* x 12mm *t*; **Mini** dim's: 45mm *l* x 32mm *w* x 11.25mm *t*

## Controller

**Serial Communication** — RS-232 (9-pin connector); 1200, 9600, 19.2k, 38.4k baud (higher baud rates available)

**Optically Isolated Digital Discrete I/O (10 VDC - 24 VDC)**

- 4 force monitor inputs (selects threshold conditions to be monitored)
- 4 force monitor outputs (reports results of monitored threshold conditions)
- 2 handshake signals
- 1 sensor bias input signal
- 1 sensor fail output signal

**Serial F/T Data Output Rates**

| **ASCII** (6 axes enabled) | **Binary** (6 axes enabled) | **Binary** (3 axes enabled) |
|---|---|---|
| 9600 baud: 21 Hz | 9600 baud: 72 Hz | 9600 baud: 143 Hz |
| 19.2k baud: 54 Hz | 19.2k baud: 143 Hz | 19.2k baud: 286 Hz |
| 38.4k baud: 87 Hz | 38.4k baud: 150 Hz | 38.4k baud: 300 Hz |
| | *38.4k baud: 286 Hz | *38.4k baud: 572 Hz |
| | *76.8k baud: 572 Hz | *76.8k baud: 1144 Hz |

* force condition monitoring disabled

**Force Condition Monitor Response Time** — 2 milliseconds or better depending on software setup

## Analog and Parallel Board (Optional)

**Parallel Communications (LSTTL)**

- 16-bit word input
- 16-bit word output
- 4 handshake signals

Software utilities and parallel I/O board for IBM PC-compatibles available.

**Analog Outputs (±5 volts)** — 6 axes or 6 raw strain gage bridge data

**Parallel and Analog F/T Data and Raw Gage Output Rates**

Resolved data rates** accurate to <±5%
- 1 axis: 2953 Hz
- 2 axes: 2345 Hz
- 3 axes: 1944 Hz
- 4 axes: 1660 Hz
- 5 axes: 1449 Hz
- 6 axes: 1285 Hz

Raw gage data rate of approximately 3450Hz (6 bridges)

Since product improvement is a continuing effort at ATI, we reserve the right to make changes in specifications without notice.

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# PRICE LIST — General

**July 1993**

## Force/Torque Sensing Systems

System Includes: Transducer, controller, standard endplates, 25' cable, 10 amp power cord, software and documentation. Mini and Nano systems include mux box which contains sensor electronics.

| Part Number | Description | Price |
|---|---|---|
| 9105-NANO-3/1 | Nano F/T 3/1 System | $5,950 |
| 9105-NANO-6/2 | Nano F/T 6/2 System | $5,950 |
| 9105-NANO-12/4 | Nano F/T 12/4 System | $5,950 |
| 9105-MINI-5/10 | Mini F/T 5/10 System | $5,300 |
| 9105-MINI-10/20 | Mini F/T 10/20 System | $5,300 |
| 9105-MINI-20/40 | Mini F/T 20/40 System | $5,300 |
| 9105-3X-F15T50 | F/T 15/50 System | $5,300 |
| 9105-3X-F30T100 | F/T 30/100 System | $5,500 |
| 9105-3X-F75T300 | F/T 75/300 System | $6,000 |
| 9105-3X-F150T600 | F/T 150/600 System | $6,500 |
| 9105-3X200/1000 | F/T 200/1000 System | $7,200 |
| 9105-3X350/2100 | F/T 350/2100 System | $7,500 |

### Options—general

| Part Number | Description | Price |
|---|---|---|
| 9105-3X-BPARALL | Parallel Board | $600 |
| 9105-3X-BANALOG | Analog Board | $800 |
| 9105-3X-BAN/PAR | Analog/Parallel Board | $1,000 |
| 9105-TEMPCOMP | Temperature Compensation | $350 |
| No Part Number | Special Calibration | $300 |

### Optional Ring/Plug Assemblies

Ring/Plug assemblies available as substitutions for standard plates.
(Include flanged adaptor plate, ring and plug)

| Part Number | Description | Price |
|---|---|---|
| For aluminum models—F/T 15/50 and F/T 30/100: | | |
| 9105-3XPFEPFA-S | Front Ring/Plug Assembly | $250 |
| 9105-3XPREPFA-S | Rear Ring/Plug Assembly | $250 |
| 9105-3XPF/RFA-S | Front & Rear Ring/Plug Assemblies | $400 |
| For stainless steel models—F/T 75/300 and F/T 150/600: | | |
| 9105-3XPFEPFA-M | Front Ring/Plug Assembly | $250 |
| 9105-3XPREPFA-M | Rear Ring/Plug Assembly | $350 |

## PRICE LIST — General - Continued

### Optional Plugs

Plugs available as replacements or extras

| Part Number | Description | Price |
|---|---|---|
| 9105-3XPFPLUG-S | Front Plug | $75 |
| 9105-3XPRPLUG-S | Rear Plug | $75 |

### Optional Communication Software

Utilities software for communication with IBM-compatible PC.

| Part Number | Description | Price |
|---|---|---|
| 9105-LIBRY-SER | Serial Utilities Library Files | $175 |
| 9105-SOURC-SER | Serial Utilities Source Files | $195 |
| 9105-LIBRY-PAR | Parallel Utilities Library Files | $175 |
| 9105-SOURC-PAR | Parallel Utilities Source Files | $195 |

### Optional Communication Hardware

Hardware required to use parallel utilities software for communication with IBM-compatible PC

| Part Number | Description | Price |
|---|---|---|
| 9105-3XBPARALL | Parallel Board for F/T Controller | $600 |
| 9105-PARBOARD-PC | Parallel I/O Board for IBM-PC Compatible | $395 |
| 9105-PARCABLE | Parallel I/O cable F/T controller-to-PC | $50 |
| 9105-PAR-PC-KIT | Parallel Interface Kit (Includes Parallel Board for F/T controller, Parallel Board for PC, and Parallel Interface Cable) | $1045 |

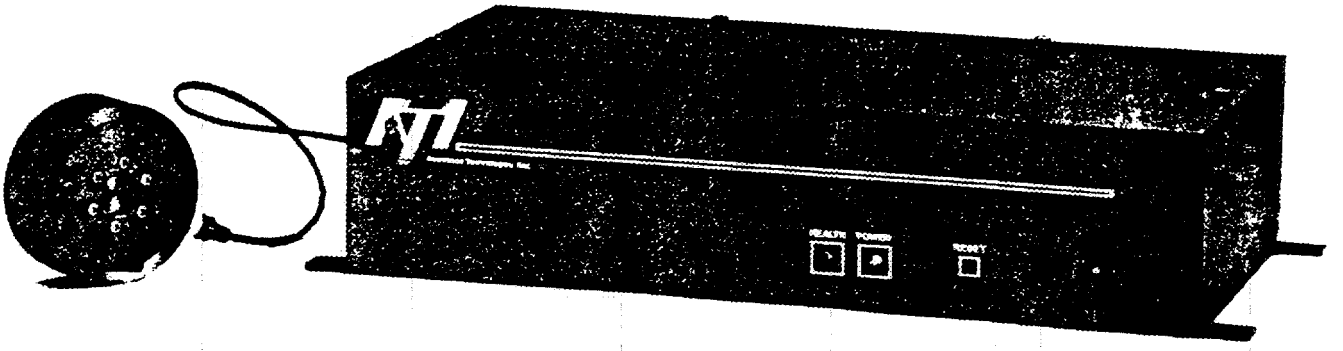
### Optional Cable Lengths

Cable lengths available as substitution for standard length or spare

| Part Number | Description | As Substitution | As Separate Cable |
|---|---|---|---|
| 9105-C3-25 | 25' cable | | $300 |
| 9105-C3-50 | 50' cable | $155 | $460 |
| 9105-C3-75 | 75' cable | $310 | $615 |

Terms: Net 30 days, US dollars, FOB Garner, NC, USA.

# Force/Torque Sensing System



## New ATI F/T Sensor Is Smaller, Faster and More Economical

*Tested at Beta sites in Japan, the new force/torque sensing system from Assurance Technologies, Inc. has been qualified for production and is now available to manufacturers in the United States and throughout the world. ATI has modified its established sensing system, with input from Japanese users, to produce a system that offers smaller size, faster data rates and a more economical price.*

## 250+ Hz Serial, 1000-2500 Hz Parallel/Analog

*The U.S.-made F/T sensing system now provides 250+ Hz serial data output, and 1000-2500 Hz parallel/analog output with an optional card. ATI has also simplified system design, not only reducing size and cost, but also making the product easier to use. The new design also features optically isolated input/output circuits for interface protection.*

## Multi-Axis Configurations

*Transducers can be configured with 1 to 6 user-selected axes of sensing — up to three axes of force and three axes of torque. Silicon strain gauges yield maximum voltage output, minimizing the risk of noise interference.*

## Applications

*ATI F/T sensing systems provide verification, inspection and control functions for parts assembly, press fitting or any automated process where force feedback can improve quality. The user can establish a number of force and/or torque conditions for load monitoring. When any of those conditions are met, the F/T sensor informs the host controller, allowing it to initiate the appropriate response, such as "reject," "start search routine," etc.*

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# Specifications

## Transducer

| **Models,** lbs/in-lbs | 15/50 | 30/100 | 75/300 | 150/600 | |
|---|---|---|---|---|---|
| **Sensing Ranges** | | | | | |
| Force range, ± lbs (N) | 15 (66.7) | 30 (133) | 75 (334) | 150 (667) | Custom calibrations are available |
| Torque range, ± in-lbs (m-N) | 50 (5.65) | 100 (11.3) | 300 (33.9) | 600 (67.8) | upon request |
| **Resolution** | | | | | |
| Fx, Fy, oz (N) | .20 (.05) | .40 (0.11) | 1.0 (0.28) | 2.0 (0.56) | |
| Fz, oz (N) | .40 (.11) | .80 (0.22) | 2.0 (0.56) | 4.0 (1.1) | |
| Tx, Ty, Tz, in-oz (mm-N) | .40 (2.8) | .80 (5.6) | 2.4 (17) | 4.8 (34) | |
| **Overload Protection** | | | | | |
| Max. Fxy allowable, lb (N) | 150 (670) | | 750 (3.3k) | | |
| Max. Fz allowable, lb (N) | 300 (1.3k) | | 1500 (6.7k) | | |
| Max. Txyz allowable, lb-in (m-N) | 500 (2.2k) | | 3000 (13k) | | |
| **Dimensions,** diameter x length, in (mm) | | | | | |
| Transducer with standard tool adaptor plate | 2.9 x 1.1 (74 x 29) | | 3.6 x 1.1 (92 x 29) | | |
| Optional rear end-plate | 3.0 x 0.19 (75 x 4.7) | | 3.7 x 0.17 (94 x 4.7) | | Drawings available upon request |
| Optional rear ring/plug assembly | 3.6 x 0.28 (93 x 7.1) | | Not available | | |
| Optional front ring/plug assembly | 3.1 x 0.31 (80 x 7.9) | | 3.8 x 0.35 (95.5 x 8.9) | | |
| **Weight,** lbs (g) | | | | | |
| Transducer with standard tool adaptor plate | 0.4 (180) | | 2.2 (1000) | | |
| Optional rear end-plate | 0.1 (50) | | 0.3 (150) | | |
| Optional rear ring/plug assembly | 0.3 (150) | | Not available | | For quick disconnection of sensor |
| Optional front ring/plug assembly | 0.25 (110) | | 0.75 (340) | | For quick disconnection of tooling |
| **Axes of Sensing** | Fx, Fy, Fz, Tx, Ty, Tz | | | | Combinations of any 1 or more axes available |
| **Transducer Cable,** length, ft (m) | 25 (7.5) | | | | |

## Controller

| | | |
|---|---|---|
| **Communications** | RS-232C (9-pin connector) | 1200, 9600, 19.2k, 38.4k baud |
| **Optically Isolated Discrete I/O** (10 VDC - 24 VDC) | 4 force monitor inputs<br>4 force monitor outputs<br>2 handshake signals<br>1 sensor bias input signal<br>1 sensor fail output signal | |
| **Serial Data Output Rates for Any Combination of 3 Force and Torque Vectors** | **ASCII**<br>9600 baud: 42 Hz<br>19.2k baud: 108 Hz<br>38.4k baud: 174 Hz | **Binary**<br>9600 baud: 143 Hz<br>19.2k baud: 286 Hz<br>38.4k baud: 300 Hz<br>38.4k baud: 572 Hz (when not using force condition monitoring statements) |
| **Force Monitor Response Time** | 10 milliseconds | |

## Analog/Parallel Board (Optional)

| | |
|---|---|
| **Parallel Communications (TTL)** | 16 inputs<br>16 outputs<br>4 handshake signals |
| **Analog Outputs (±5 volts)** | 6 axes or 6 outputs of raw strain-gauge data |
| **Force Processing and Data Output Rates** | Resolved data rates accurate to ±10%<br>1 axis: 2500 Hz<br>2 axes: 2200 Hz<br>3 axes: 1900 Hz<br>4 axes: 1600 Hz<br>5 axes: 1300 Hz<br>6 axes: 1000 Hz<br>Raw gauge data rate of approx. 2500 Hz (6 bridges) |

*Since product improvement is a continuing effort at ATI, we reserve the right to make changes in specifications without notice.*

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9205-05-1001-01 April 1991

# Mini-F/T and Nano-F/T Specifications

## Mini-F/T

Dimensions: 1.76" x 1.25" x .14" (44.7mm x 31.8mm x 3.6mm)

Interface plates required.

Recommended calibration: (Other calibrations are possible.)

| Axis | Range | Resolution |
|---|---|---|
| Fxy | 50 lb | 0.025 lb |
| Fz | 145 lb | 0.075 lb |
| Txyz | 50 in-lb | 0.025 in-lb |

Maximum loads before yielding:

| | |
|---|---|
| Fxy | 300 lb |
| Fz | 650 lb |
| Txy | 210 in-lb |
| Tz | 280 in-lb |

## Nano-F/T

Dimensions: 0.63"diameter x 0.06" thickness (16mm x 1.5mm)

Interface plates required.

Recommended calibrations:

Calibration A

| Axis | Range | Resolution |
|---|---|---|
| Fxy | 12 kg | 0.006 kg |
| Fz | 25 kg | 0.012 kg |
| Txyz | 10 kg-cm | 0.005 kg-cm |

Calibration B

| Axis | Range | Resolution |
|---|---|---|
| Fxy | 5 kg | 0.0025 kg |
| Fz | 10 kg | 0.005 kg |
| Txyz | 4 kg-cm | 0.002 kg-cm |

Maximum loads before yielding:

| | |
|---|---|
| Fxy | 25 kg |
| Fz | 50 kg |
| Txyz | 20 kg-cm |

*Assurance Technologies, Inc.*
*503D Highway 70 East*
*Garner, North Carolina 27529*
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# APPENDIX K
# TACTILE SENSORS

BSi BONNEVILLE SCIENTIFIC, INC.

David Holcomb
Oakridge National Labs
Contracts Division, Bldg. 3500
P.O. Box 2008
Oak Ridge, TN 37831-6010

Dear Mr. Holcomb:

Enclosed is the information you requested regarding our tactile sensor system.

Bonneville Scientific was founded in 1981 to research, develop and commercialize robotic products. The development of the tactile sensing technology has been supported by seven government agencies over a 12-year period. Those sponsoring agencies are NASA, NSF, DOE, DARPA, USAF, VA and the Department of Education.

The versatility of Bonneville's sensing technology has opened the door to a variety of applications in areas outside of robotic tactile sensing. These range from simple switches to sophisticated force-measuring devices for the medical industry.

The price of the system is $7,000. (This amount does not include the price of the computer.) For an additional cost, the sensor can be custom designed to fit specific applications. The additional cost would be determined by the shape, size and element density needed. Orders for multiple sensors may qualify for a discount.

Also available are single-element sensors without electronic support. If purchased in quantities of less than ten, the cost is $42.00 per sensor. In quantities of ten, they sell for $19.00 each, and in quantities of 100 the price drops to $11.00 each.

If you have any questions regarding Bonneville's tactile sensor system or would like to discuss other applications, please feel free to call me at (801) 359-0402.

Sincerely,

BONNEVILLE SCIENTIFIC, INC.

G. Bruce Felix
Marketing

GBF:arb

Enclosure

1849 W. North Temple, Bldg. E • Salt Lake City, Utah 84116 • 801-359-0402 • Fax 801-359-0416

BONNEVILLE SCIENTIFIC INC.

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# FOREWORD

There is no perfect tactile sensor system. Even our human perception of tactile sensation, which uses information from a variety of sensors, employs an extraordinarily powerful computer, and incorporates the knowledge gained from a lifetime of experience, is easily fooled.

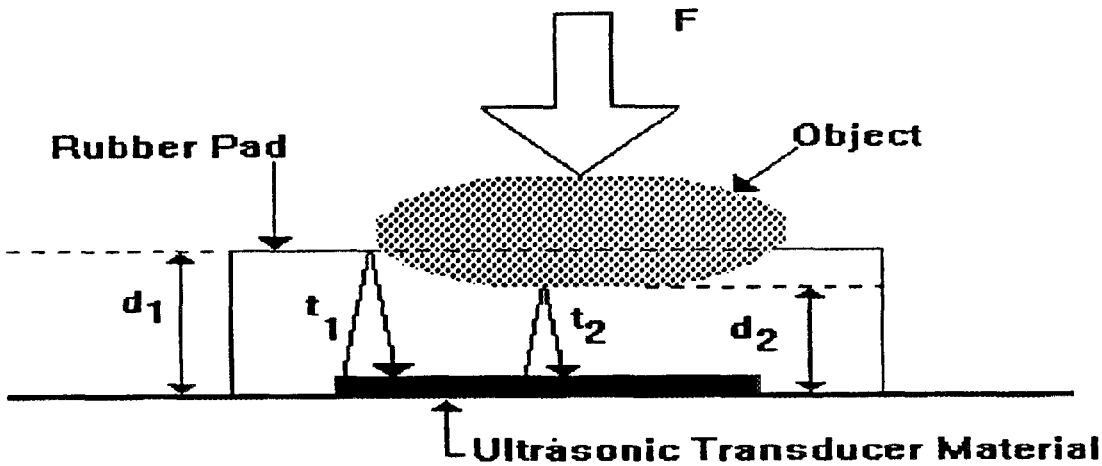
All artificial tactile sensor systems behave differently. Each one has its advantages and disadvantages, and what may be an advantage in one application can be a disadvantage in another application. Bonneville Scientific believes it is important to divulge as much information as possible about the performance of these systems so the potential user can make an informed decision about the suitability of a particular tactile sensor for his or her application.

Presenting this information to the user is a particularly difficult task for Bonneville Scientific because the technology allows for so many options that, to be all-encompassing, one has to speak in generalities. For example, since sensors can be produced with almost any shape array elements using almost any type and stiffness of rubber, possible force sensitivity is extremely high and force range extremely large, but not necessarily in the same sensor.

Therefore, we will first explain the principle of operation for Bonneville's tactile sensor so that the features of the technology can be better understood. This is followed by the specifications for the Model 200-16X16A Tactile Sensor System. This is a general purpose system and represents only one example of the many possible system configurations. Finally, the technological advantages of Bonneville's tactile sensors are listed.

## TACTILE SENSOR PRINCIPLE OF OPERATION

Bonneville Scientific's tactile sensors use a two-dimensional array of ultrasound transmitters and receivers to measure the thickness of an overlying rubber pad. When objects contact the sensor's pad, the rubber is compressed. The amount of this compression depends upon the magnitude of the force applied by the object and the stiffness of the rubber. The thickness measurement principle used in the sensor is ultrasonic pulse-echo ranging or SONAR. Figure 1 shows the construction of one element of the tactile sensor array and illustrates the principle of operation.




$d_1 - d_2 = \frac{1}{2}c(t_1 - t_2)$ $\quad$ $F = k(d_1 - d_2) = \frac{1}{2}kc(t_1 - t_2)$

where F is the compressive force
c is the speed of sound in the rubber and
k is the rubber stiffness.

**Figure 1. Tactile Sensor Construction and Principle of Operation**

Each element of the sensor array transmits an ultrasonic pulse which travels through the rubber pad, is reflected off the top surface of the rubber, and returns to the element. The time interval ($t_1$) for this travel, or Time of Flight (TOF) is measured for each array element. When a contacted object applies a normal force (F) to the rubber pad, the pad is compressed and the TOF is reduced ($t_2$). The difference in TOF is proportional to the compression of the pad ($d_1$ - $d_2$) which, in turn, is proportional to the applied force.

# MODEL 200-16X16A SENSOR SYSTEM

The tactile sensor system consists of four main components: 1) the sensor array, 2) a small electronics module, 3) signal detection and computer interface circuit boards, and 4) a remote microcomputer. These four components would be used in any customized system. With the appropriate interface board and software, a different personal computer or an engineering workstation can be used to operate the sensor.

## Sensor Array and Specifications

The sensor array is a laminated, rigid, flat structure with 256 square tactile elements. It is comprised of the ultrasonic transducer material, an elastomeric pad, and an integral flex-circuit cable.

### *Ultrasonic Transducer Material*

The transducer material is PVDF (Polyvinylidene Fluoride) film having 256 elements arranged in 16 columns by 16 rows. Each element is a square, 0.060" on an edge, with 0.010" separation between elements. Overall size of the array's force-sensitive area is 1.11" by 1.11".

### *Elastomer Pad*

The sensor's elastomer pad consists of two parts. Directly over the transducer material is a silicone rubber sheet which determines the force characteristics of the sensor. On top of the silicone rubber is a thin foam layer which provides a controlled interface for reflecting the ultrasonic pulse.

*Silicone Rubber*--The entire array is covered with a 1/8" thick silicone sheet. This rubber material is available in differing formulations, ranging from very soft to firm, depending upon the required force sensitivity and force range. The silicone rubber sheet is replaceable.

*Foam Layer*--On top of the rubber sheet is a 1/32" thick layer of closed-cell urethane foam. This foam layer, unlike most compliant materials, provides a surface with a relatively constant coefficient of friction that changes little with normal (grasping) force or with contamination. When worn or damaged, the foam layer can be replaced.

### *Sensor Dimensions*

The outline of the sensor and its dimensions are shown in Figure 2. The entire sensor assembly is 1.53" x 1.53" x 0.19" thick.

*Sensor Cable*

An integral flexible circuit cable 0.375" wide by 0.025" thick and 12" long emanates from the sensor and connects to the electronics module with miniature edge connectors. (Custom-length cables are available.)

## Electronics Module

The electronics module has been miniaturized (2½" X 2½" X ⅞") to facilitate mounting on or within a robot arm. This module performs the array element pulsing, multiplexing and echo signal amplification. The electronics module is connected to the system microcomputer through two ten-foot miniature cables (longer or shorter cables are available).

## Computer Interface and Signal Detection Boards

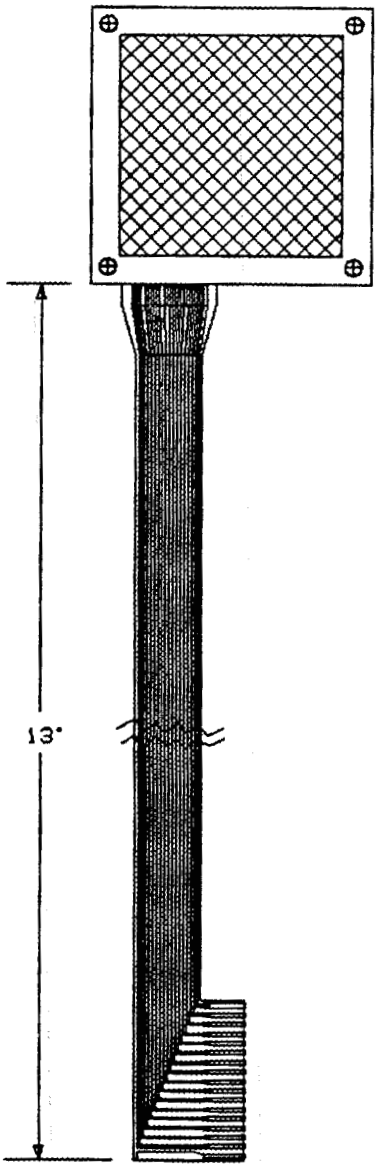
The tactile sensor system has two circuit boards which plug into the microcomputer. One board contains the signal detection circuitry and an 80 MHz clock and counter for measuring the Time-of-Flight (TOF) of the ultrasonic pulse. This board, under computer direction, addresses sensor elements and sends sensor data to the microcomputer. The binary data word generated by the electronics contains both error and TOF information. This information is passed to the interface board for further processing by the computer.

The tactile sensor system computer digital interface board controls data transfers between the sensor electronics and the microcomputer.

## System Microcomputer

The Model 200-16X16A Tactile Sensor System requires, at a minimum, a 33 MHz, 386-based, IBM PC-compatible microcomputer having 128 kbyte of cache memory and a mouse. Faster performance can be obtained by using a 486-based microcomputer. The computer runs under Windows 3.1® to provide the user with a convenient graphical interface with the tactile sensor. The computer performs all data processing tasks: sensor zeroing and calibrating; data formatting; tactile image recording, playback and display.

# TACTILE SENSOR DIMENSIONS



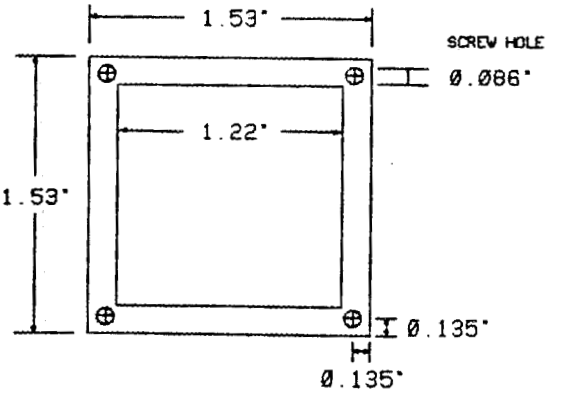




Figure 2

## Sensor Operation

The tactile sensor system is operated through software which runs under Windows 3.1®. Operation of the system has been simplified by using a graphical user interface with push-buttons, pull-down menus and dialogue boxes. Figure 3 shows the monitor screen when the Tactile Sensor System software is running. Various menu options are displayed across the top of the screen and sensor controls are located in a box at the lower left side of the screen. The control symbols for operating the sensor are modeled after those found on a video cassette recorder (VCR). They include buttons for Stop ([]), Play or Run (>), Fast Forward (>>), Rewind (<<), Pause (| |), Record (O), and Zero (#). Located directly above these controls is a scroll bar which allows the operator to move quickly through all of the frames in a recorded tactile data file and stop at any frame of interest. (A frame is the data from one full scan of all of the sensor elements.) A box next to the controls displays information related to the data acquisition rate, frame (i.e. scan) number, and location of a user selected taxel and its value.

Sensor operation and control is described below.

*Zeroing* (# Push-Button)

Prior to using the tactile sensor, a "zeroing" procedure is performed so that the change in the sensor's elastomer sheet thickness can be calculated when the sensor contacts an object. When the zeroing button on the screen is clicked, 100 TOF values are recorded and the average value is calculated for each tactile element. These averages are stored in memory. Then an additional 100 samples are taken and individually compared to the previously computed average. Any TOF values which differ more than 5% from the average are discarded, and the remaining values are used to calculate a new average TOF. This new average for each element is then stored in memory. Zeroing takes less than two seconds for the 256 element sensor.

*File Menu* (Figure 4)

The file menu allows the user to open, close, and save the data file as well as exiting the tactile sensor program.

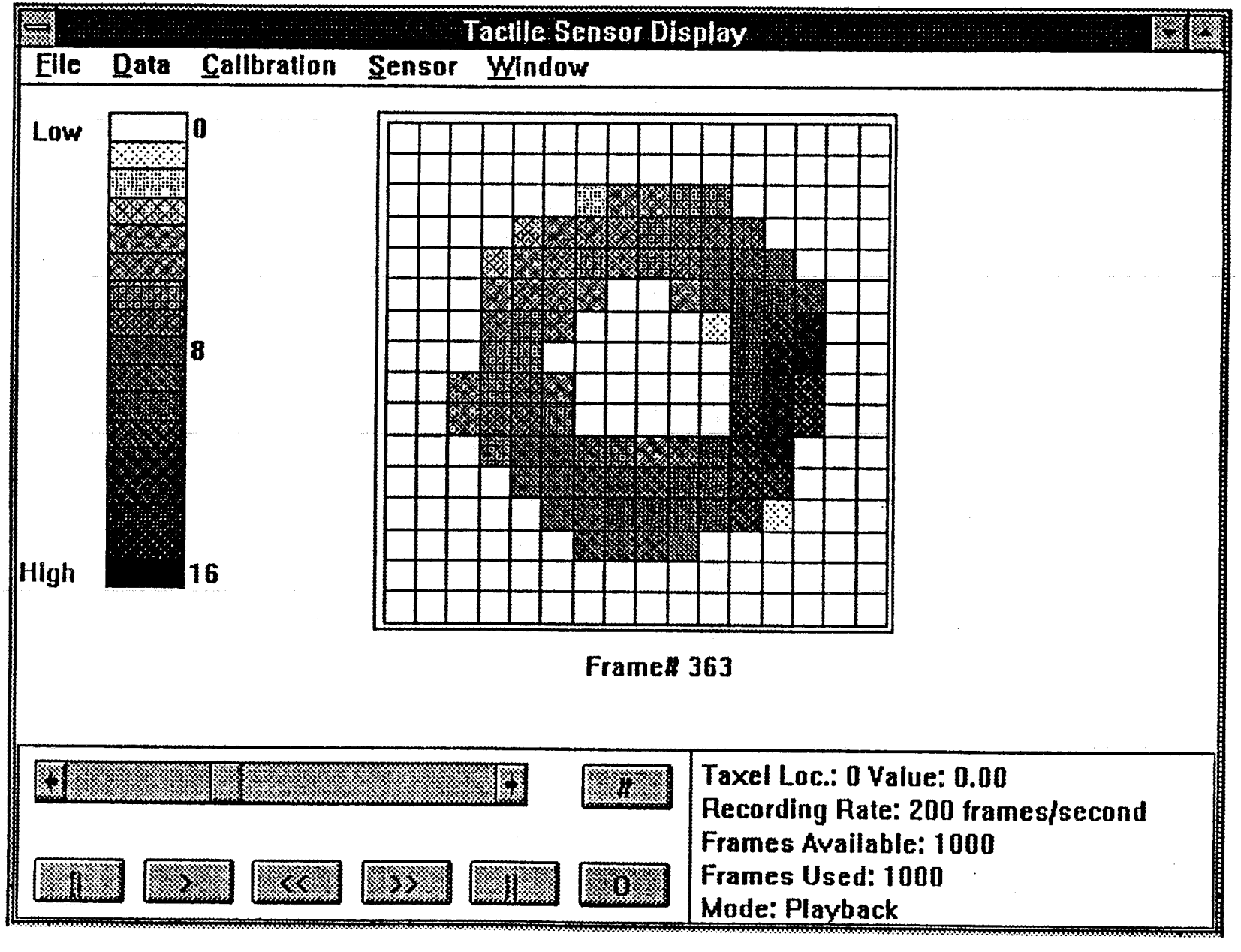



Figure 3. Tactile Sensor System Main Display

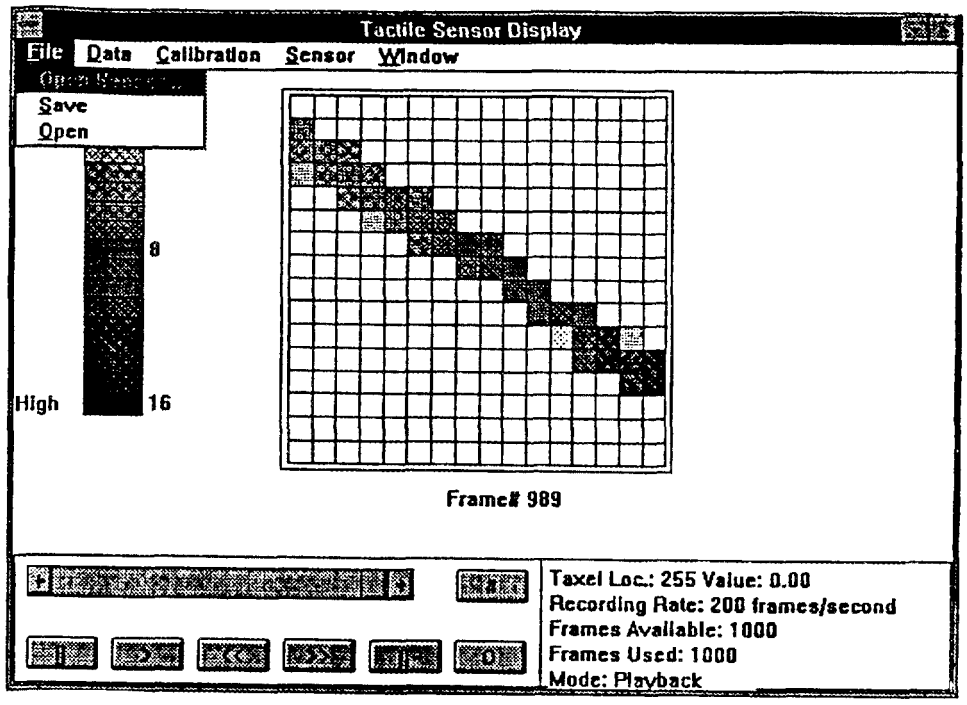



Figure 4.
File Menu
Selections

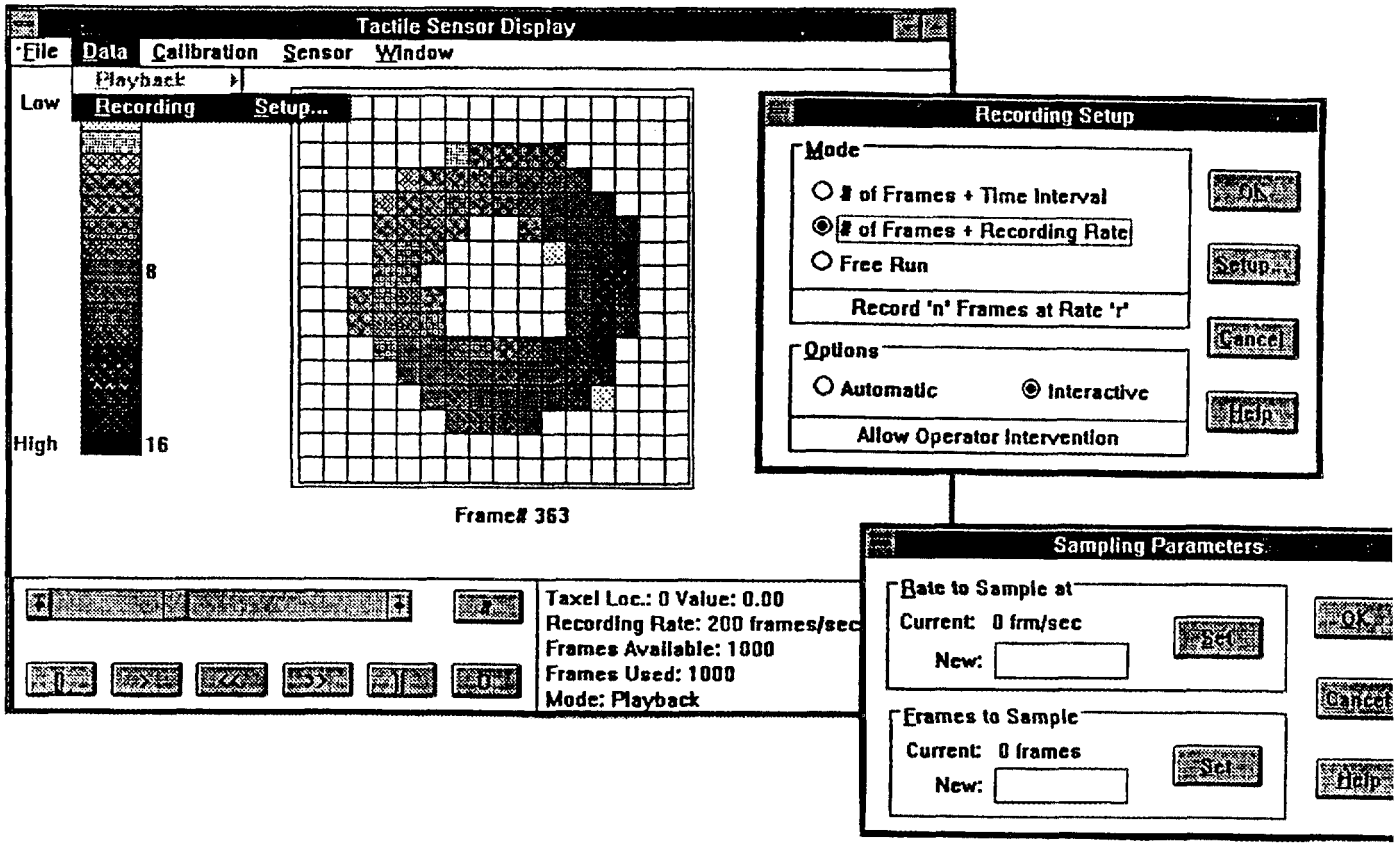



Figure 5.
Data Menu and Dialogue Boxes for
Recording and Sampling Parameters

*Data Menu* (Figure 5)

This menu allows setting of the recording parameters for the sensor when operating in Record/Playback Mode. By clicking on Data / Recording / Setup, a dialogue box, called Recording Setup, is reached. In this box, the operator can set the number of frames per second (between 50 and 240 for the 256-element sensor) and the total number of frames to be recorded. (The number of frames that can be recorded is limited only by the amount of available RAM. 1000 frames for the 256-element sensor will take 1/2 MB of RAM.) Alternatively, the operator may choose to set the time period over which a chosen number of frames would be recorded. The maximum time period (in seconds) is 1/50th times the number of frames chosen. The operator may also choose to allow (or disallow) intervention during recording. Allowing operator intervention enables the recording process to be halted (or "paused"), but may introduce a correlation error between time and sensor activity.

*Calibration Menu* (Figure 6)

Through this menu, the sensor is calibrated for force by entering the appropriate value (or constant) for the stiffness of the elastomer sheet. The constant is used in converting the calculated sheet thickness change into force.

*Sensor Menu* (Figure 7)

This menu allows choices to be made for displaying the tactile image. Gray scale or color displays can be chosen, and the sensor element grid can either be displayed or hidden from view. This menu also contains a search feature which allows the operator to go directly to specific frames or time periods in the recorded data.

*Window Menu* (Figure 8)

The mode of sensor operation is chosen through this menu. The operator can choose between Realtime, Playback, or Auto-Playback Modes. In the Realtime Mode, the forces acting on the sensor will be computed and displayed at a rate of 30 to 50 frames per second. In Playback Mode, the forces acting on the sensor will be recorded at rates set in the Data / Recording / Setup dialogue box and played back at an average of 30 to 50 frames per second. (The number of frames displayed per second is directly related to the number of taxels changing value from one frame to the next. If every taxel was changing value in every frame, the data display rate would be significantly reduced.) In the Auto-Playback mode, the contents of a chosen tactile data file can be set to be played back in an endless loop.

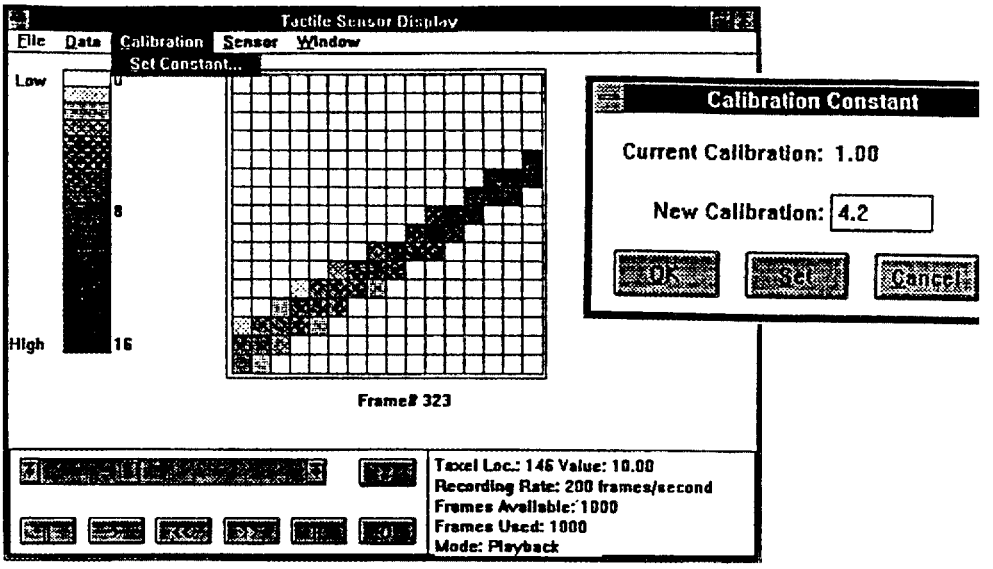



Figure 6.
Calibration Menu and
Dialog Box

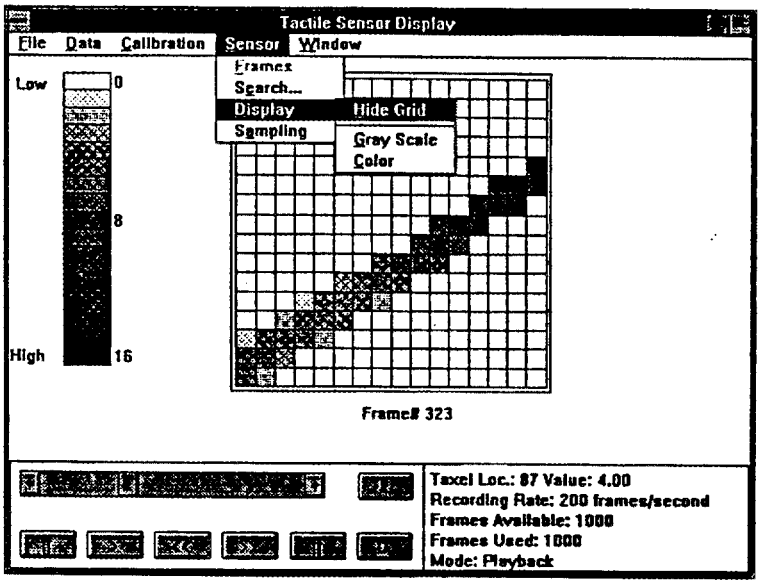



Figure 7.
Sensor Menu
Selections

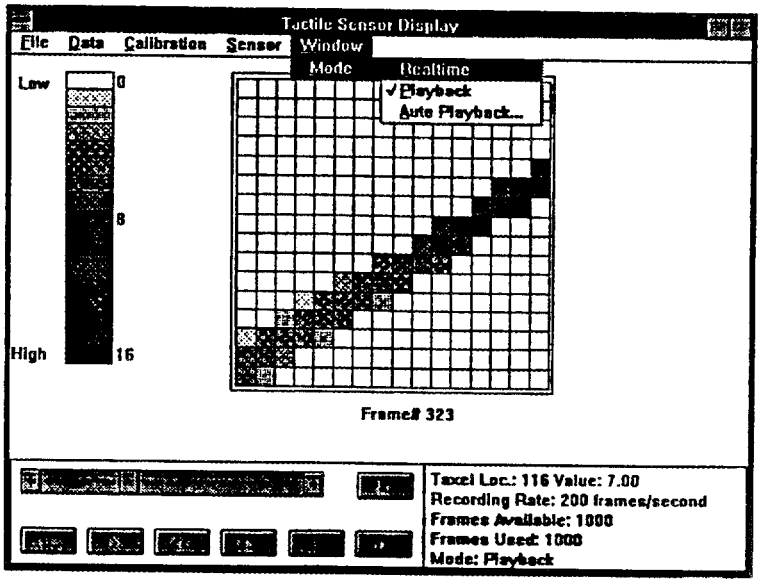



Figure 8.
Window Menu
Selections

Another feature of the software is the Taxel Force Value Readout. In Playback Mode, the numerical value of each tactile element (taxel) in the displayed tactile image can be displayed. This is achieved by first moving the cursor onto the tactile image to "freeze" the image. The cursor is then positioned onto the desired taxel. The mouse button is clicked and the taxel value, along with its row and column position, appears at the top of the readout area.

## Tactile Information

Figure 9 shows the sensor for a Model 200-8X32A Tactile Sensor System. The sensor is mounted on the gripper or end-effector of an industrial robot and the "tactile image", resulting from a metal ring being grasped by the robot, is displayed. The pictured tactile sensor is also comprised of an array of 256 individual tactile elements. However, the tactile elements in this sensor are arranged in a grid of eight columns and 32 rows. Each rectangle in the image represents a tactile element. The image is portrayed using a gray-scale format with the higher forces indicated by the darker shading.

In addition to detecting whether an object is being grasped with too much or too little force, the force distribution on the sensor also provides information as to the shape and location of the grasped object. Oftentimes, shape and location are more useful than actual force values.

In many industrial applications, detection of object slippage is vital. With the Bonneville system, object slippage is easily detected by a change or shift in the tactile image. Examples of tactile images, from an object being properly grasped by the robot and in various "slipped" positions, are shown in Figure 10. Other tactile images, obtained from common objects, are presented in Figure 11.

BONNEVILLE

SCIENTIFIC

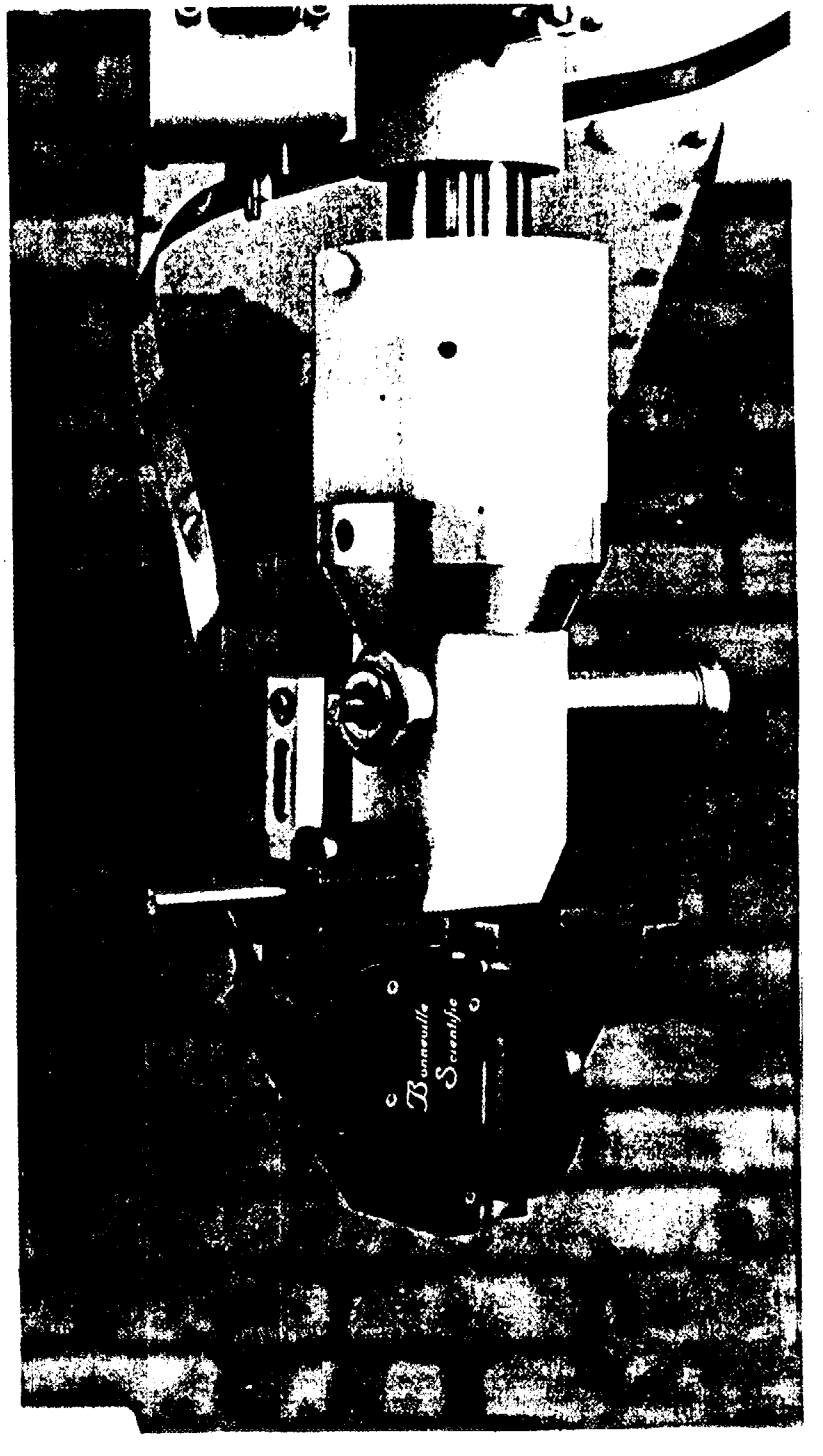
## Tactile Sensor System

- Rugged
- Accurate
- Repeatable
- Rapid Response
- No Moving Parts
- Easily Customized:

  Rubber Characteristics

  Array Pattern

  Size
- Broad Applications



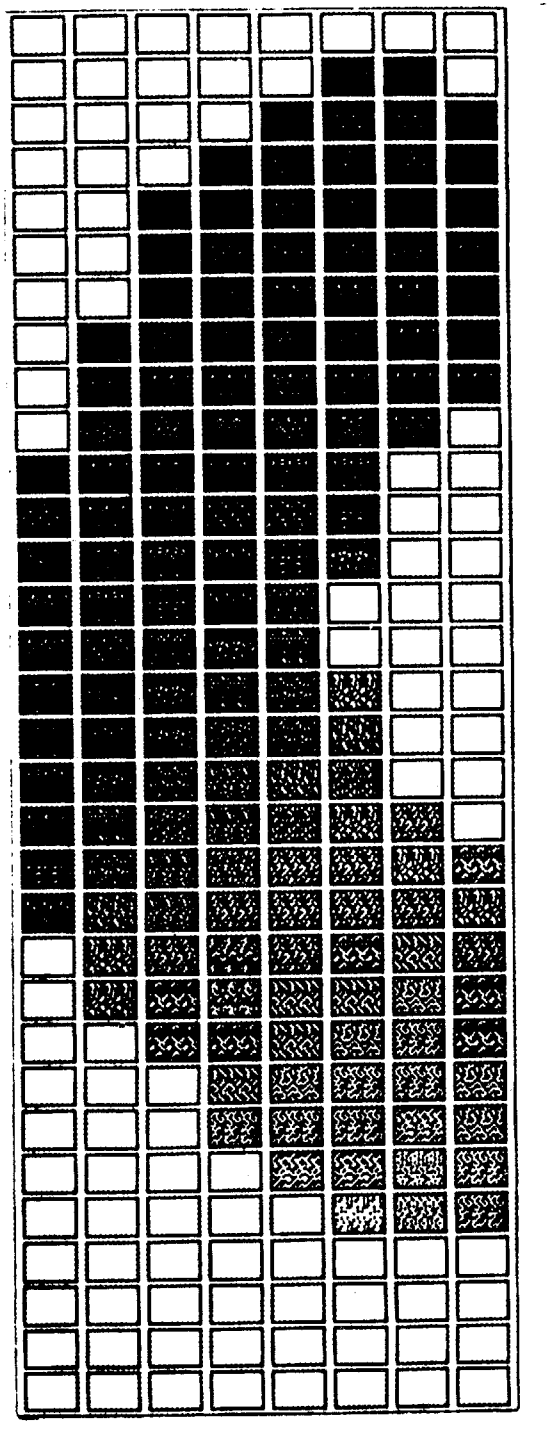
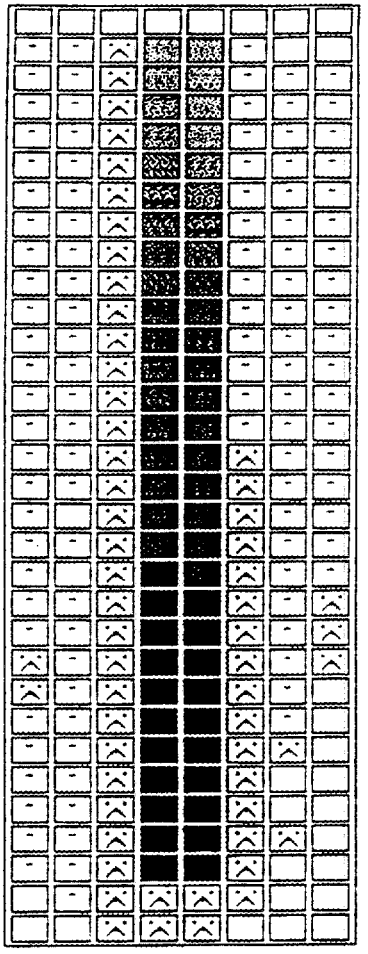



Figure 9. Sensorized finger contacting a metal ring and the resulting image.



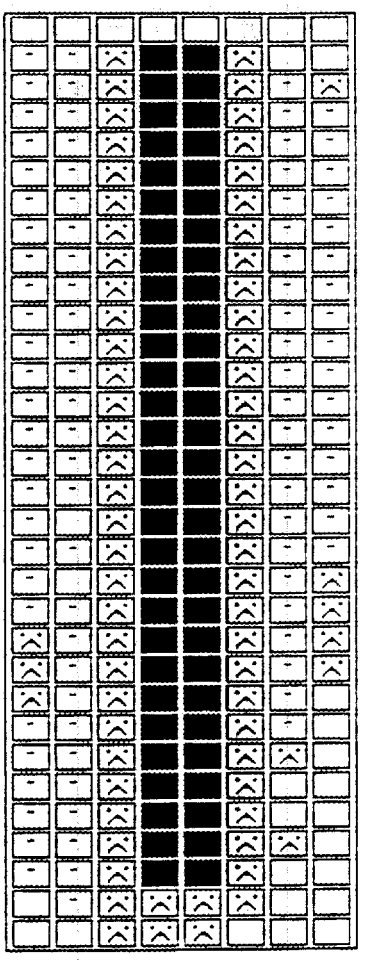
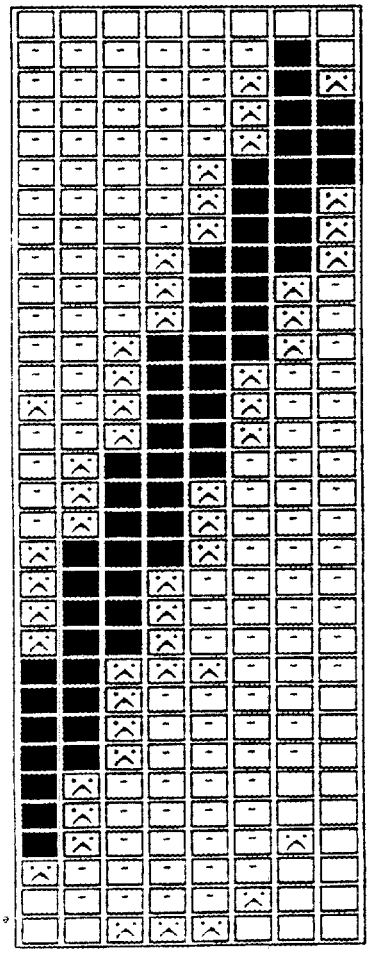
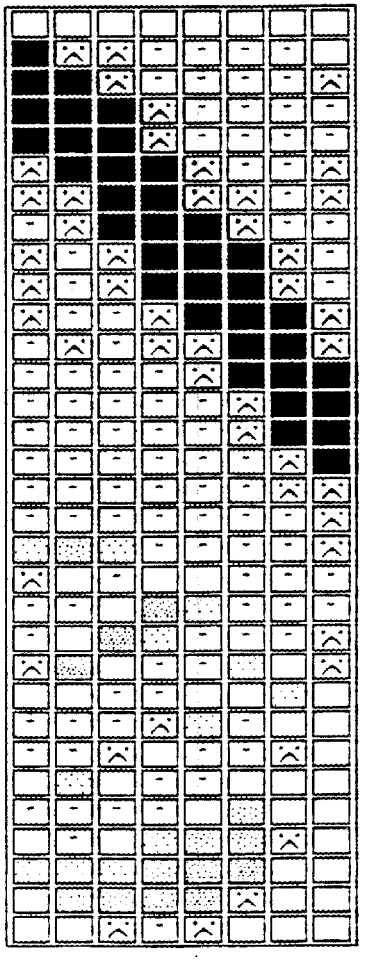
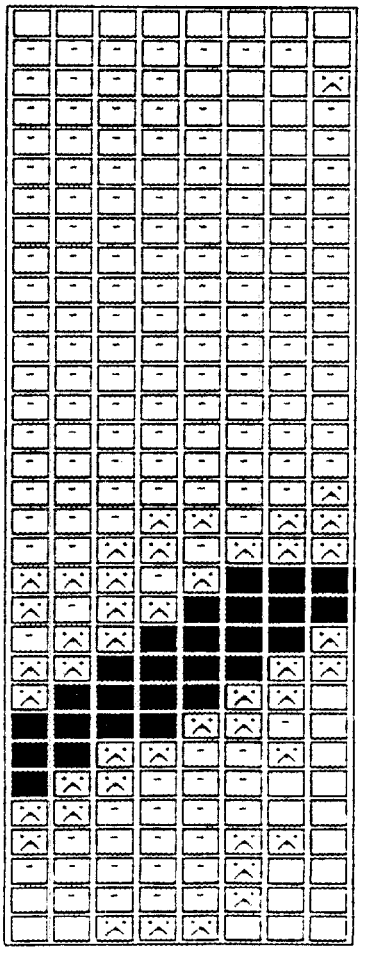


Figure 10.

Top left corner shows uneven force distribution of a gripper as it grasps flat metal bar (shown at the far left). Clockwise from this image, same bar shown with uniform force distribution, and images of the bar at different rotations.







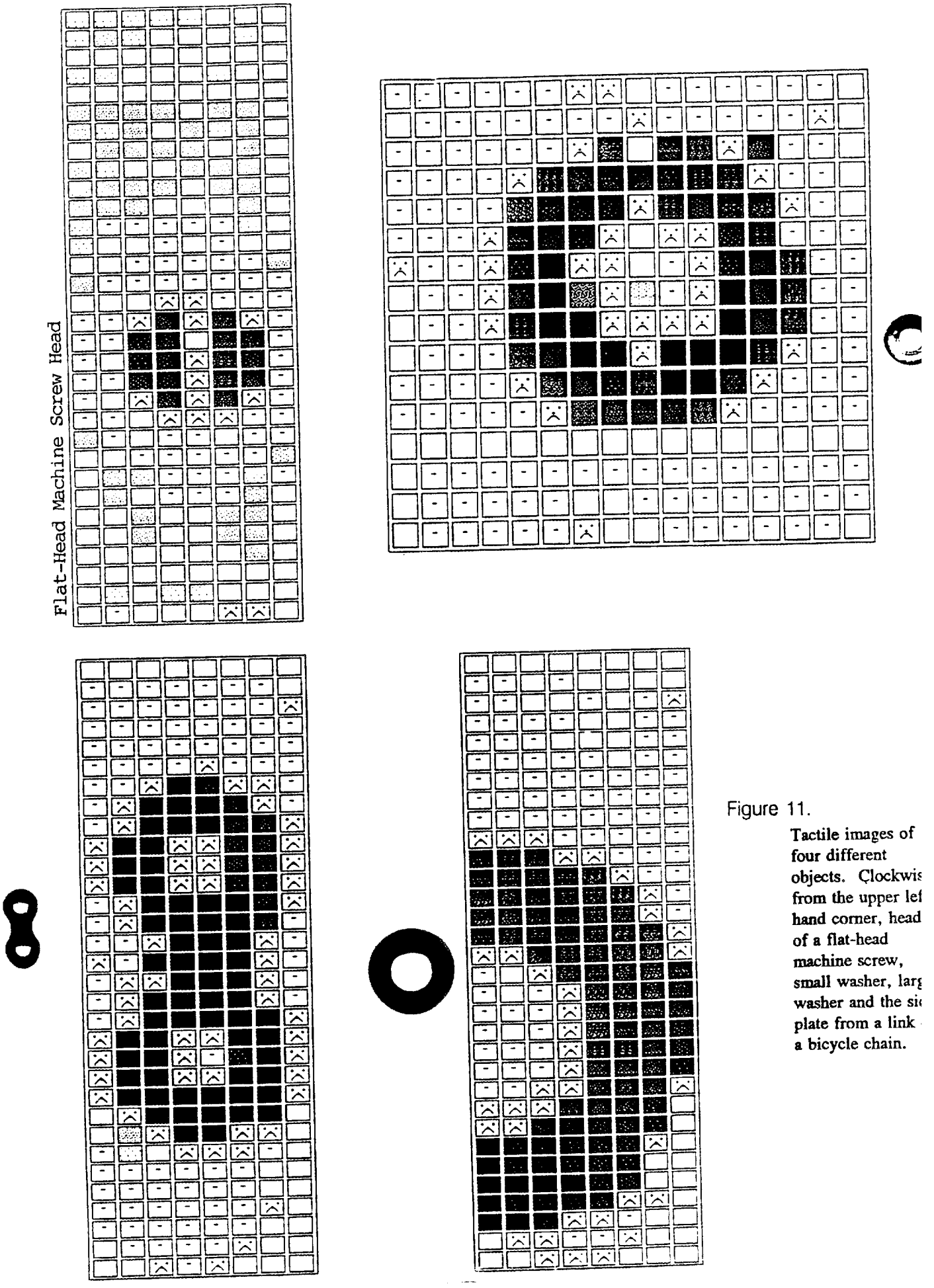



Figure 11.

Tactile images of four different objects. Clockwis from the upper lef hand corner, head of a flat-head machine screw, small washer, larg washer and the si plate from a link a bicycle chain.

# DETAILED SPECIFICATIONS FOR MODEL 200-16X16A TACTILE SENSOR SYSTEM

Presented below are the specifications for the Model 200-16X16A Tactile Sensor System and an explanation of their significance.

## Time-of-Flight (TOF) Resolution--12.5 ns

The TOF measurement for the ultrasonic echo pulse has a resolution of 12.5 ns. This parameter directly determines force resolution and dynamic range of the sensor system. The greater this resolution is (i.e., the smaller the time interval), the greater the force resolution and dynamic range.

## Sheet Thickness Resolution--6 microns

The minimum change in thickness of the sensor's rubber sheet that can be measured depends upon TOF resolution and the speed of sound in the rubber. For the silicone rubber used in the sensor, sheet thickness can be resolved to about 6 microns. (For urethane rubbers, this resolution would be about 10 microns.)

## Pressure Resolution--0.5 PSI

The sensor's pressure resolution depends upon sheet thickness resolution and rubber stiffness. For the rubber type and thickness used in the 16 x 16 element sensor previously described, a 6 micron change in sheet thickness corresponds to a pressure of about 0.5 PSI. Therefore, the pressure resolution is about 0.5 PSI. This parameter will be lower (i.e., greater resolution) for softer rubbers, or for a thicker rubber sheet, and higher for stiffer rubbers or for a thinner sheet.

## Force Resolution or Sensitivity--1 gram

The force sensitivity depends upon the pressure resolution and the area of the array elements. For the 0.060" x 0.060" elements used in the 16 x 16 sensor array, the corresponding force sensitivity is about 1 gram. The smaller the area of the individual elements, the greater the force sensitivity. Softer or harder rubber compounds can provide force sensitivities from less than 0.5 grams to beyond 5.0 grams. However, extremely soft rubbers are usually weak.

## Dynamic Range–1 to 250

Dynamic range is determined by the sheet thickness resolution and the maximum amount of compression of the rubber sheet. For the Model 200-16X16A System (i.e., 12.5 ns TOF resolution and 1/8" thick silicone sheet) and for a maximum elastomer compression of 50%, there are about 250 force values. Therefore, the dynamic force range would extend from approximately 1 to 250 times the minimum force or pressure resolution. Due to the much higher speed of sound in urethane rubber, there would be about 150 force levels for a 1/8" sheet, which would reduce the dynamic range by about 60% compared to silicone. Doubling the rubber sheet thickness would also double the dynamic range (and double the force sensitivity). Accurate sheet thickness measurements can be made beyond 50% compression, but rubber hysteresis becomes more significant when calculating the corresponding forces.

## Rubber Characteristics

Almost any kind of rubber can be used in the tactile sensor. However, for applications requiring very high force sensitivity, soft rubbers must be used. Bonneville Scientific recommends the use of silicone rubber in these applications because silicones can be made very soft, they have a lower speed of sound, and are highly stable. Urethane rubbers can be used in the sensor when less force sensing is acceptable and their superior strength is important. However, very soft urethanes are less stable than silicones. Natural or neoprene rubber can also be used when less force sensitivity is needed.

### *Linearity*

This is an important parameter if force measurement needs to be accurate. Over modest ranges of pad compression (e.g. 10-20%), deviations from linearity are typically 5-15%, mostly due to hysteresis in the rubber. The amount of hysteresis depends upon the type of rubber and the area of the object compressing the pad.

*Environmental Characteristics*

Different rubbers better withstand different environmental factors. For example, the silicones last longer in oxidizing environments, the neoprenes withstand exposure to oil, while the urethanes are quite abrasion-resistant.

*Temperature Effects*

*The main affect of temperature on the tactile sensor is expansion of the rubber sheet as the temperature increases. This is easily compensated for by periodically rezeroing the sensor when it is unloaded. Rezeroing takes less than two seconds and can be done whenever the sensor is not contacting an object.*

## Overload Limit–Greater than 1000 PSI

Destructive tests on tactile sensors showed that, when uniform loads were applied, the rubber sheet material ruptured without damaging the underlying transducer material. This occurred at pressures in excess of 1000 PSI. When new rubber sheets were applied, sensor performance was unchanged.

## Sensor Signal Detection

Currently, only the arrival time of the initial portion of the ultrasonic echo signal is measured. As a consequence, when the sensor's pad is non-uniformly compressed over a particular tactile element, only the maximum compression of the pad is measured and the corresponding force is calculated. The result is that the maximum force at a tactile element is calculated and displayed as though it were covering the entire tactile element. For tactile elements that are small relative to object feature size, the maximum force is close to the average force.

## Sensor Response to Sharp Edges

Sharp objects, such as edges and points pressed deeply into the sensor pad, may distort the rubber surface such that an insufficient amount of ultrasonic energy is reflected back to the tactile element. Consequently, no signal is detected for that tactile element. When this occurs, the "Abort" bit is set in the binary data word. The "frowny face," which can be seen in Figures 10 and 11, is the abort symbol. (This feature is not yet

available on the Model 200-16X16A. Also, the improved electronics in the Model 200-16X16A system detects much weaker echo signals so that "aborts" occur much less frequently.) Although the pattern of abort symbols can be very useful in inferring location of sharp objects on the pad and their extent, no force information is available without *a priori* knowledge of the object.

## Spatial Resolution—0.070"

The spatial resolution of the tactile sensor may be simply given as the element-to-element spacing. Since the ultrasonic beam from each element has such small divergence, echo signals arise from the pad surface directly over each tactile element. For the 16x16 sensor array, the spatial resolution is 0.070".

## Maximum Sensor Scanning Rate—240 scans/second

The scan rate of the 256-element sensor is about 240 scans (or frames)/second. If the tactile data are displayed while the sensor is being scanned, the scan rate decreases.

## Data Display Rate—30 to 50 scans/second

The display rate of the tactile image is roughly 30 to 50 scans/second. The display rate varies, depending on the number of taxels that change value between scans.

## Other

The above description is for a specific tactile sensor system configured to meet generic robotic applications. Different array geometries for different end-effectors and systems having different performance parameters are available.

## SPECIFICATIONS SUMMARY FOR MODEL 200-16X16A

| | |
|---|---|
| Time-of-Flight (TOF) Resolution | 12.5 ns |
| Sheet Thickness Resolution | 6 microns |
| Pressure Resolution | 0.5 psi |
| Force Resolution or Sensitivity | 1 gram |
| Dynamic Range | 1 to 250 |
| Rubber/Linearity | 5-15% deviation |
| Rubber/Environmental | Rubber dependent |
| Rubber/Temperature Effects | Rubber dependent |
| Overload Limit | Greater than 1000 PSI |
| Sensor Signal Detection | Maximum force on taxel |
| Sharp Edge Response | May not give force values |
| Spatial Resolution | 0.070" |
| Maximum Sensor Scanning Rate | 240 scans/sec |
| Data Display Rate | 30-50 scans/sec |

NOTE: The above specifications are for a specific tactile sensor system configured to meet generic robotic applications. Many of the specifications above are dependent on the type of sensor being constructed. Please refer to the Detailed Specifications section in this material for descriptions of materials, limitations, and other specification information.

# COMPETITIVE TECHNOLOGICAL ADVANTAGES

Bonneville's tactile sensor systems combine several important advantages:

## Ruggedness

The sensors are extremely rugged and able to withstand severe overloads. Unlike mechanical and some optical transduction methods, Bonneville's laminated sensor employs no moving parts and is able to withstand overloads in excess of 1000 PSI, depending upon rubber type.

## Range of Options for Rubber Pad

A wide variety of elastomers may be used for the rubber pad, and damaged, worn, or contaminated pads can be replaced inexpensively. The sensitivity, or force range of the sensor, can be altered simply by changing pads. For example, softer rubber might be used for delicate objects while pads made of different rubber compounds could be substituted to withstand different agents or chemicals in the robot's operating environment. No other tactile sensor offers such efficient, economical versatility. On the contrary, increasing the sensitivity or changing the environmental characteristics of those sensors using resistive inks or conductive rubbers requires the purchase of new sensors.

## Versatile Technology

Sensors can be made to incorporate different sizes, shapes and/or number of elements. Sensors can also incorporate non-uniform arrays, arrays featuring elements of varying size and shape, and arrays featuring varying force sensitivity and range at different regions of the sensor.

## Rapid Force Measurements

Force measurements can be made every 4 to 6 microseconds/sensor element.

## Miniaturization

Tactile elements can be miniaturized. To date, elements have been made as small as 0.020".

## Adaptable to Curved Surfaces

The sensors can be made to fit the curved surfaces of end-effectors.

## Accurate and Repeatable

This is achieved through the use of "first principles" in the sensing technique and the fact that drift in element or amplifier sensitivity is unimportant since time, not amplitude, is measured. Unlike the piezoelectric and pyroelectric-based tactile sensors, Bonneville's sensors can continually measure a steady force.

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