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INSTRUMENT RESEARCH AND DEVELOPMENT

QUARTERLY PROGRESS REPORT

FOR PERIOD ENDING JULY 20, 1952

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INSTRUMENT RESEARCH AND DEVELOPMENT REPORT

PHYSICS DIVISION

CRYSTAL DIODES

P. R. Bell C. Harris
M. Goodrich G. G. Kelley

Crystal diodes have been widely adopted in electronic circuits because of their low forward resistance and small capacitance. Recently some diode characteristics have been observed when a pulse of current (22 ma) is sent through the diode in the forward direction. The low forward resistance is not immediately obtained when the pulse begins, for most diodes the voltage required to produce the current is at first several volts higher than normal and reaches the equilibrium value in approximately 0.1 μsec. When the current pulse is shut off by applying a back voltage, the diode is quite conductive in the reverse direction. This abnormally large back current may persist for a microsecond. It has been found that most of the present-day diodes are inferior, in these respects, to diodes produced several years ago. The only satisfactory diodes available are recently produced CK 707's and old IN 34's

The discovery that both the forward and back resistance are very sensitive to light shining on the diode has caused dismay.

NEUTRON-SENSITIVE SCINTILLATION PHOSPHORS

J. Schenck

The search for better phosphors for detecting and measuring the energy of fast neutrons is continuing. It has recently been discovered that lithium iodide activated with europium (introduced into the mixture in the form of $EuCl_2$) performs much better than tin-activated lithium iodide. The light output is approximately 40% that of thallium-activated sodium iodide although the time constant for decay of the light flash is longer ($\sim$2.0 μsec). The light output is approximately a linear function of the particle energy. This can be seen from Fig. 1, which shows the pulse spectrum produced by a europium-activated lithium iodide crystal surrounded by paraffin and exposed to a polonium-beryllium source. The peak at 820 pulse-height divisions is the pair peak from the 4.45-Mev gamma ray in C^{12} and should have an energy of $4.45 - 2mc^2 = 3.43$ Mev. The peak at 1130 divisions is that due to the $Li^6(n,\alpha)H^3$ reaction, which has a Q value of 4.87 Mev.

The energies shown on the curve are the accepted values and exhibit some departure from linearity, the measured pulse height of the neutron peak is 5% less than that expected from a linear relation. The data for Fig. 1 were obtained by interposing some neutron absorber between the source and the detector in order to make the

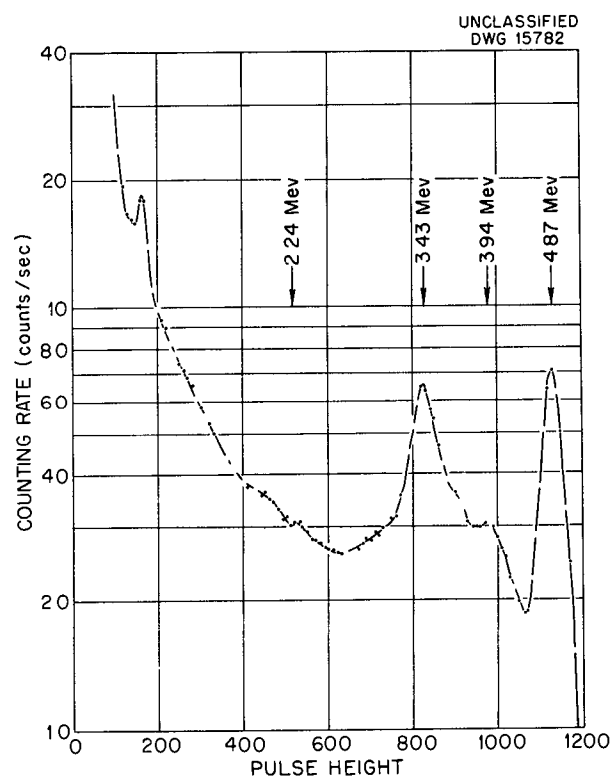

Fig. 1. Pulse Spectrum from a Europium-Activated Lithium Iodide Crystal When Exposed to a Moderated Polonium-Beryllium Neutron Source.

peaks nearly equal. If, instead, a lead absorber is interposed, the neutron peak will be about one hundred times larger than the gamma-ray peak.

The resolution (full width at half maximum) of the neutron peak is about 6%; this corresponds to a neutron energy resolution of about 300 kev.

The phosphor was irradiated with 3-Mev neutrons from the high-voltage Van de Graaff machine, and a time exposure photograph was taken of the pulses displayed on the face of a cathode-ray tube, Fig. 2. The top trace is due to 3-Mev neutrons and the center is due to thermal neutrons. The broad trace at the bottom is probably due to gamma rays. It appears the europium-activated lithium iodide phosphors will be very useful for measuring neutron energies and that interference from capture gamma rays from iodine is not a serious problem. Capture gamma rays may become more troublesome with larger crystals; this could be offset by the use of Li^6-enriched material.

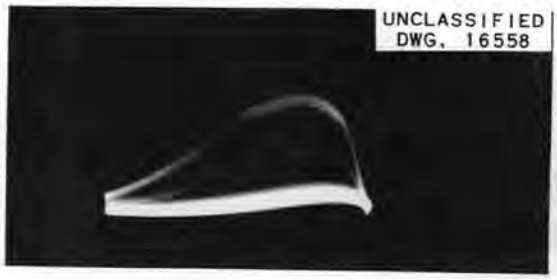

Fig. 2. Oscilloscope Photograph of Pulses from a Europium-Activated Lithium Iodide Phosphor Exposed to 3-Mev Neutrons.

HEALTH PHYSICS DIVISION

R. H. Dean
J. M. Garner
C. E. Graham
F. Kalil
B. Kahn
W. J. Lacy
R. L. Nichols

EVALUATION OF COMMERCIALLY AVAILABLE INSTRUMENTS FOR THE MEASUREMENT OF RADIOACTIVITY IN WATER

Several types of commercial, portable instruments are being studied to determine how useful and effective they are for the measurement of radioactive contamination in water, particularly for the routine monitoring of water supplies as well as for the detection of emergency levels of contamination that might result from laboratory accidents or atomic explosions. Electroscopes and G-M survey meters have been tested to date.

The responses of several types of portable G-M survey meters to various radioisotopes and to mixtures of fission products in water were observed by using volumes of standard solutions between 0.15 and 7.0 liters with concentrations of radioactivity between 10^{-4} and 10^{-1} μc/ml. Landsverk and Lauritzen electroscopes were investigated by using volumes of less than 0.5 liter and the same range of concentration. The responses of the instruments were obtained for the different standards and likewise for various energies of beta and gamma radiation. Knowledge of the range and sensitivity of the instruments studied will make possible recommendations concerning their use in water monitoring. In connection with this work a series of beta-emitting radioisotopes was studied to select standards covering a wide range of energies.[1]

Electroscopes. The electroscope may be read over a range of about 10,000 times the lowest detectable concentrations. As indicated in Fig. 3, for representative alpha-, beta-, and gamma-radiation emitters that had been deposited upon planchets, alpha radiation was detectable at an activity as low as 10^{-6} μc, beta radiation at 10^{-4} μc, and gamma radiation at approximately 10^{-2} μc. The concentrations in μc/ml can be calculated from the activity and volume of solution

[1] W. S. Lyon and B. Kahn, *Analytical Chemistry Division Quarterly Progress Report for Period Ending March 26, 1952*, ORNL-1276, p. 21 and 23.

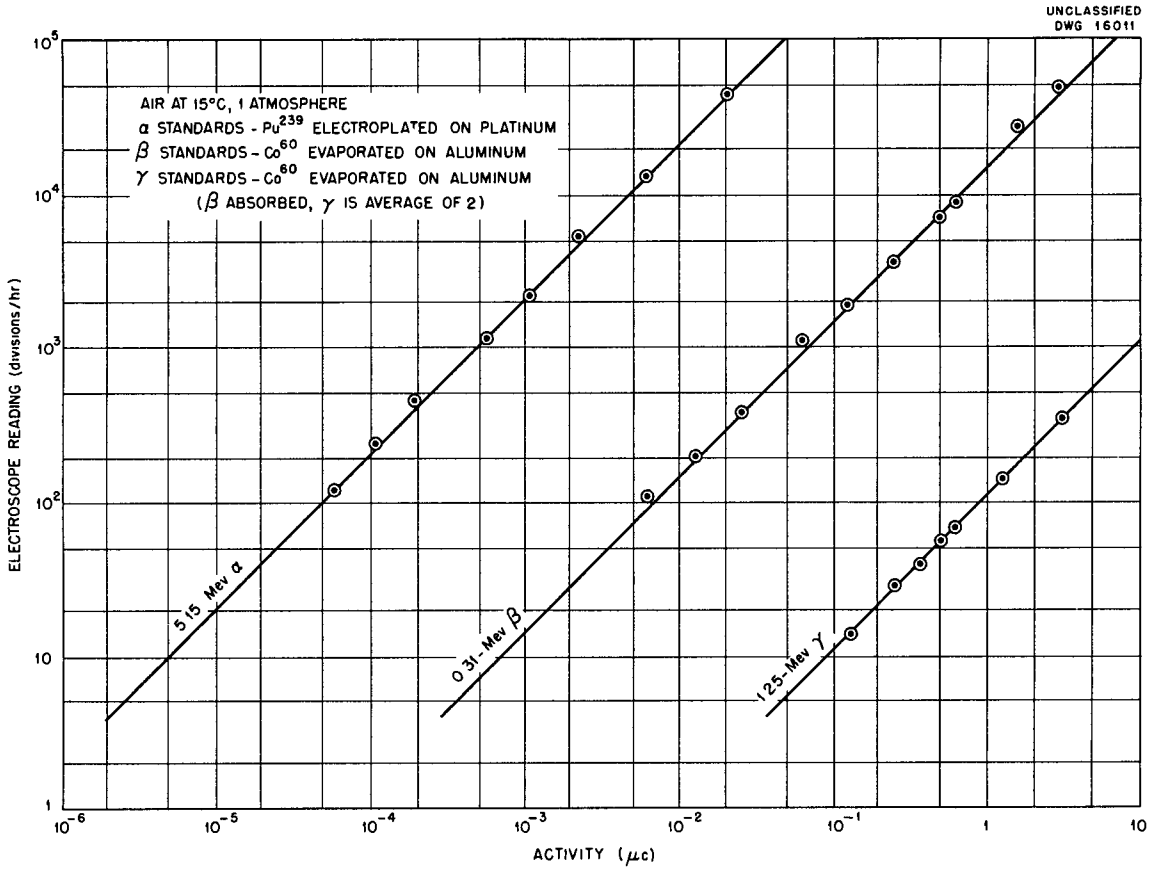

Fig. 3. Sensitivity of Landsverk Electroscope L-75.

evaporated. Whether these sensitivities are sufficient for routine use may be determined by comparison with the accepted values for the maximum permissible concentration of the various radioisotopes in water. The response of the electroscope is sufficient for determining the concentrations of fission products in drinking water that may be deemed safe for emergency use after an atomic explosion.

G-M Survey Meters. The use of sensitive beta-gamma G-M survey meters for the detection of emergency levels of radioactivity in drinking water has been suggested by various workers. The meter readings may be obtained by holding the probe of the instrument above the surface of the sample to be tested or by submerging it. A sample of unknown concentration of radioactive constituents can be monitored in terms of milliroentgens per hour, and such readings can then be converted by means of a calibration curve to concentrations in microcuries per milliliter. In these studies a variety of tests were made with three types of survey meters and with five interchangeable probes by using water solutions of various radioisotopes and of mixed fission products.

It was found that the response of different types of survey meters to the same solution varied considerably. There was a wide range in the response of any given meter to the solution of different radioisotopes. This range is indicated by the curves shown in Fig. 4. All the radioisotopes studied gave curves falling between those for Ru^{106}-Rh^{106} and Tl^{204} (see Fig. 4). It would

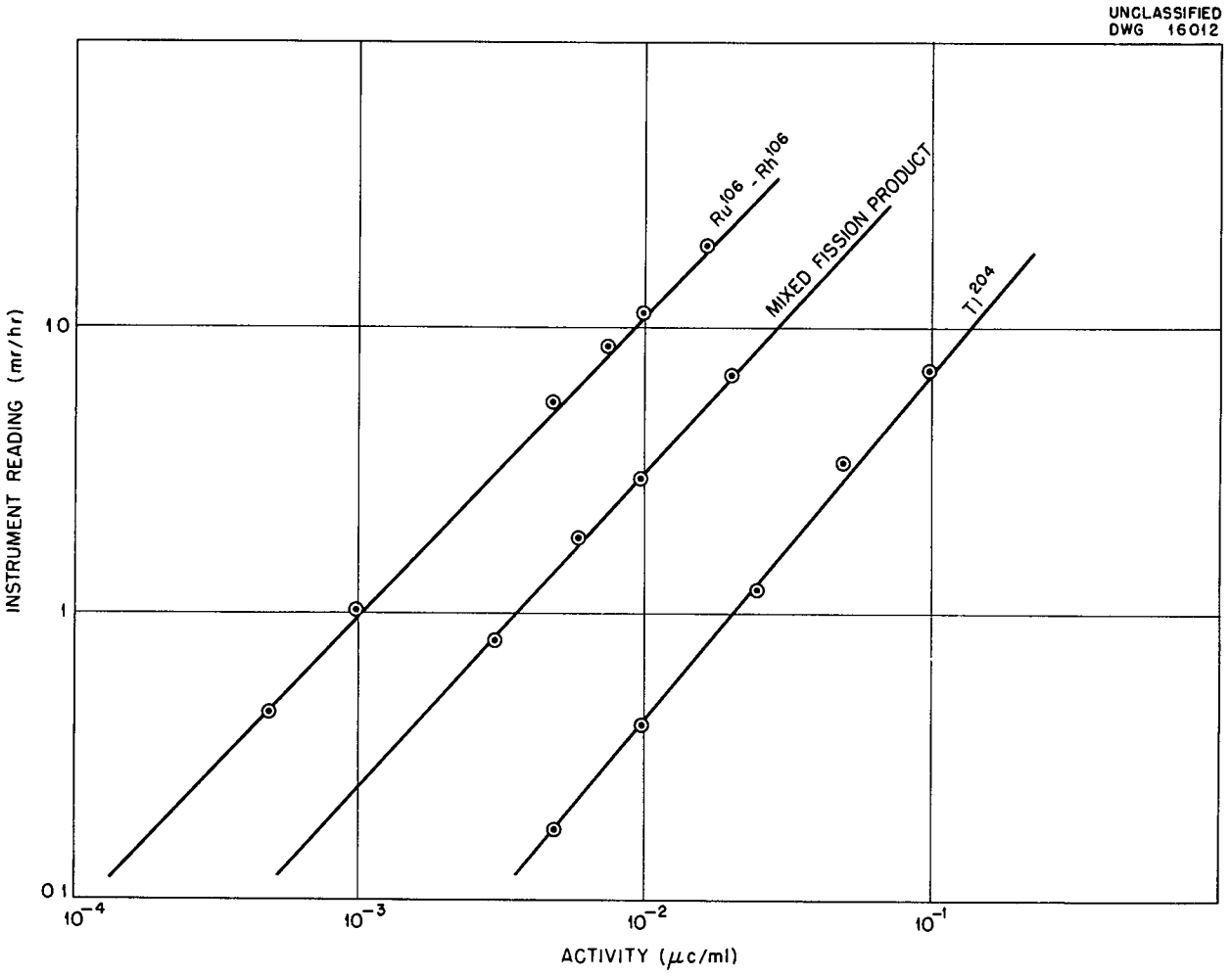

Fig. 4. Typical Readings of a Beta-Gamma Survey Meter with Probe Submerged in Radioactive Solutions of Known Concentrations.

be expected that a sample containing the usual diverse mixture of unknown radioisotopes probably would fall on a line in the central portion of the range and certainly between the extreme high and low values that are shown. The fission-product curve shown in Fig. 4 was obtained with a three-year-old fission product mixture.

MONITORING AND TELEMETERING AT WHITE OAK DAM

The installation of equipment for the measuring and recording water elevations and levels of radioactivity at White Oak Dam and telemetering the measurements to the X-10 area has been completed. Preliminary tests have been made and modifications are in progress. After calibration, this system will provide continuous records at the dam and at the Laboratory of the volume of water and the concentration of radioactivity in the water discharged from White Oak Lake.

WELL-LOGGING EQUIPMENT

Two new assemblies of equipment for making logs of the radioactivity in wells have been completed and put into service. Three of these trailer-mounted units are now available for routine observations and for special studies of the 55 test wells that have been drilled in the X-10 area.

INSTRUMENT DEPARTMENT

DIFFERENTIAL PULSE-HEIGHT DISCRIMINATOR, Q-1079

D. J. Knowles F. M. Glass

The differential pulse-height discriminator was designed for producing output pulses having a specific pulse height to be used to detect pulses that lie in a given section of a random distribution of input pulses between 10^2 and 10^5 counts/min. The input pulses come from a proportional counter through a linear amplifier such as the A-1, the output of which is limited to 100 v (max.) and has a rise time of 0.1 μsec or longer. The output of the pulse-height discriminator is coupled directly to a scaler that requires not more than 5-v signal for its operation.

The instrument consists of both upper- and lower-limit discriminator circuits, an anticoincidence circuit, a 2.52-μsec delay line, a cathode follower, and a regulated power supply. Input pulses coming from the proportional counter, amplified by the A-1 amplifier, are fed into the two identical discriminator stages simultaneously.

The upper-limit discriminator serves to stop all pulses above a given pulse height, whereas the lower-limit circuit stops all pulses below a certain limit, thus, a "window width" is established that will pass all pulses within the range of the window. The lower limit is set by adjusting the bias on the input discriminator tubes. The upper limit is set by applying additional bias to the upper discriminator pair. If the amplitude of the input pulse is below the desired height, the pulse is stopped in the lower-limit discriminator by adjusting the bias voltage so that the tubes will not trigger until a pulse of the proper pulse height is admitted. If the amplitude is high enough to pass the lower discriminator pair, it is passed on through the delay line to the first control grid of the dual-triode tube of the anticoincidence circuit. Simultaneously, the pulse is admitted to the upper discriminator pair.

The grid bias setting on the tubes in this circuit is of a different value than that of the lower discriminator, a higher amplitude pulse is required to trigger. If the amplitude of the pulse is within the window-width limits, the upper discriminator will not trigger, which will allow the pulse arriving at the anticoincidence tube from the lower discriminator pair to trigger the tube and produce a pulse that is fed to the cathode follower and on to the scaler. On the other hand, if a pulse enters the discriminators having an amplitude higher than the window-width adjustment (high enough to trigger the upper discriminator pair), it will arrive at the second control grid of the anticoincidence tube preceding the one from the lower discriminator and cause the second section of the tube to conduct more heavily. This tends to bias the first section more negatively and blocks the pulse that arrives from the delay line. In this manner, only pulses within the window-width range are allowed to pass through the instrument and out to the scaler to be counted. The window width may be adjusted by means of the window-width adjustment control, or the entire window may be moved up or down by the pulse-height selector control.

ALPHA MONITOR FOR AIRBORNE CONTAMINATION, Q-1263

D. J. Knowles

The alpha monitor for airborne contamination, Q-1263, is used when the possibility of air contamination exists to continuously monitor and record the alpha activity of air samples for radioactive dust particles that could be retained in the lungs.

The device is composed of

1. a differential count-rate meter, Q-1263,
2. a pair of scintillation counters,
3. a dual-channel precipitator,
4. a mechanical tape-drive mechanism,
5. an induced-draft type of blower for obtaining air samples,
6. a Brown Electronik, 10-mv potentiometer,

7. an alarm bell attached to the Brown potentiometer,

8. a mobile cabinet with specially built casters,

9. a combination power-supply unit consisting of a regulated supply for the scintillation counters and a nonregulated, high-voltage supply for the precipitator.

Air samples are picked up from two locations by the blower. One sample comes from the room and another from the air-conditioning system. Both samples of air are admitted to the dual precipitator through specially designed aperture slits and are blown across a $1\frac{1}{2}$-in.-wide aluminum tape, which moves between the slits at a rate of 1 ft/hr. The air is blown past the tape at right angles to its motion and in the same plane. In this manner, one air sample moves over the top of the tape and the other moves over the bottom. Since the tape is at ground potential and the precipitator points are at 8 kv negative, dust particles contained in the air are attracted to the tape.

As the tape moves through another aperture, it passes between the scintillation counters, which are mounted in the same manner as the precipitators. Counts are taken from both sides of the tape simultaneously and are fed into the differential count-rate meter. Owing to the function of this circuit, only the difference in counts between the air from the room and that from the air conditioner is indicated. Since the air gathered from the air conditioner is used as background, the instrument automatically records the activity level within the room above that of background. An alarm bell attached to the pen-drive mechanism of the recorder is set to be activated at roughly nine times tolerance. The monitor responds within 20 min. after an activity increase, the response time is a function of the rate of travel of the aluminum tape.

A new model of alpha monitor for health physics investigations is being considered, that will collect only one sample of air and take readings after 4- and 24-hr periods consecutively in order to separate the short-lived background activity from the longer-lived alpha contamination.

THERMISTOR TEMPERATURE RECORDER-CONTROLLER

G. Ritscher

A thermistor temperature recorder-controller has been designed to regulate the temperature in a calorimeter water jacket to an accuracy of 0.01°C. Although the temperatures desired are limited to a few degrees above room temperature, an over-all range in excess of 0 to 45°C is provided primarily for ease in checking the stability of the apparatus by making a calibration at the ice point.

A thermistor, Western Electric type 14-A, is used as the temperature-sensitive element in a Wheatstone bridge circuit. It has a resistance in the order of 100,000 ohm at room temperature and a negative temperature coefficient of approximately 5%/deg C. Since a high-resistance bridge circuit gives greater sensitivity with the comparatively high resistance of the thermistor, a Leeds and Northrup model S Speedomax was selected as the recorder-controller because of the higher input impedance of its amplifier. To provide the necessary control, full scale of the recorder was made in the order of 0.2°C. This value varies owing to nonlinearity of the thermistor element. To place the 0.2-deg band at the proper temperature, a manual control panel was mounted inside the instrument case in the upper left corner. The manual controls consist of a switch for changing range in steps and a ten-turn Helipot to provide coverage between steps.

An off-on contact was ganged to the slidewire of the instrument to control a heater in the water jacket of the bath. Tests in a trial bath with the completed apparatus showed deviations not exceeding 0.002°C. It was found that off-on control was quite satisfactory in a directly heated, well-stirred bath.

GAS METER FOR MEASURING LOW GAS-FLOW RATES

J. N. Baird

A gas meter has been developed to measure gas flow at rates of approximately 6 to 60 ml/min. The

device consists of a piece of stainless steel capillary tubing 6 ft long, 0.035 in. OD and 0.015 in. ID. The capillary tubing is connected between two pressure gages. Inserted in the line ahead of the upstream pressure gage is a porous stainless steel filter of the type commonly used as a snubber on pressure gages. The device was calibrated by forcing air through the system, reading the gages that indicated pressure drop across the primary measuring element, and collecting the air leaving the device over water at room temperature. The tube was calibrated with pressure drops from 35 psig down to 2 psig. These pressure drops produced flows of 137.0 and 7.46 ml/min, respectively. When plotted as a log-log graph the calibration data produced an excellent straight line that could be extrapolated to gas flows of 4 to 200 ml/min. Although calibrated with air, this device should be satisfactory for use with other gases having similar density and viscosity properties. The capillary tubing seems to make an excellent primary element and could be used in much greater lengths to measure still lower gas flows.

POND ACTIVITY MONITOR, Q-1200

H. N. Wilson F. M. Glass

A monitor for measuring the activity of the water at White Oak Dam has been constructed. The unit is composed of a detector, an amplifier, a linear count-rate meter, and a high-voltage supply. The detector is a scintillation counter that includes a type 5819 photomultiplier tube, an anthracene crystal, a cathode-follower preamplifier, and a lead shield with 2-in.-thick walls. The detector is designed so that the crystal detects radiation from the water but not from the bank of the pond, except through the 2-in.-thick lead shield. The detector is maintained at a constant distance above the water by a servomechanism.

The amplifier is stabilized and nonoverloading. The count-rate circuit and high-voltage supply are stable and drift free for long periods. The output of the count-rate meter can be read on a panel meter, or recorded on a 1 ma Esterline Angus recorder. The output of the unit also supplies a signal suitable for the telemetering equipment that has been set up by the Health Physics Division. The equipment, as originally designed, was excessively temperature-sensitive owing to the anthracene crystal, but fairly good compensation has been obtained by the addition of thermistors in the high-voltage RC filter.

VARIABLE-BEAT FREQUENCY OSCILLATOR, Q-1202

R. D. Sidnam B. M. Hildebrant

A request received for a stable frequency source with a range of 10 to 100 kc, with incremental control of ±15 cycles at any point within this range, to be used for an impedance bridge measurement of the Q of piezoelectric crystals.

The Q of a crystal may be defined as $f_0/\Delta f$, where f_0 is the resonant frequency, $\Delta f = f_1 - f_2$, and f_1 and f_2 are the frequencies above and below resonance at the half-power points. Since the Q of a crystal is relatively high, Δf is of the order of a few cycles, hence, a beat frequency oscillator capable of adjustment to a few cycles, must be employed.

The variable-beat frequency oscillator consists of two identical Clapp oscillators that are symmetrically constructed of components selected so that temperature changes will affect both oscillators in a similar manner. Each oscillator is separately shielded. The shields are of double construction, and the coils are wound on fused quartz forms to provide extremely low temperature coefficients. The high-frequency oscillator operates on a fixed frequency, and the low-frequency oscillator is variable. Both oscillators are stabilized by the use of a constant-voltage transformer.

The signal-to-noise ratio is of the order of 1600 to 1. The output amplitude of the signal is made continuously variable by the use of a gain control inserted in the output of the fixed-frequency oscillator. A ladder attenuator on the front panel provides for division of the output voltages into incremental steps with multipliers of 1, 25, 100, 500, and 2500, which give voltage ranges of 30 mv, 150 mv, 600 mv, 3 v, and 15 v, respectively.

DIRECT-CURRENT INTEGRATOR, Q-1259

F. M. Glass F. W. Manning

A current integrator has been completed and is in service. The instrument is designed primarily to integrate target current in the high-voltage accelerators for either positive or negative potential on the target. The usable range of the instrument is from 10^{-9} to 1.5×10^{-4} amp, with better than 1% accuracy. It will repeat to within 0.2% accuracy when a constant-current source is used for calibration.

The current integrator is composed of a regulated power supply, a storage capacitor, and a d-c amplifier that has a gain of 250 with an input impedance of approximately 10^{14} ohms feeding into a free-running multivibrator used as a pulse generator. Connected with the integrator is a Schmitt trigger pair that is used as a pulse shaper and is coupled to a binary scaler. The circuits are designed so that drift on the d-c amplifier has no effect on the calibration of the instrument. This is accomplished by allowing the target current to charge the integrating condenser to about 0.2 v, which is amplified by the d-c amplifier and causes the multivibrator to free-run. A metered pulse from the Schmitt trigger pair is rectified and used to remove the charge from the integrating condenser, which tends to return the multivibrator to its normal state. Each time the multivibrator triggers, a given charge is removed from the integrating condenser. The circuit is designed to contain sufficient dead-time to allow the amplifier to reset the multivibrator so that only one pulse at a time may pass through. If the condenser continues to be charged by the current, the rate of triggering in the multivibrator is proportional to the charging current. Since each pulse removes a known charge from the condenser, the current integral may be obtained for any given period of time by counting the number of pulses obtained.

A-C POPPY, Q-1306

O. Eason

The a-c poppy, Q-1306, is a redesign of the Q-669 instrument (revised poppy amplifier) constructed specifically for alpha surveys. The instrument uses an alpha proportional detector and provides an audible indication of radiation intensity.

The following changes have been made on the model Q-1306:

1. incorporation of the preamplifier in the probe, which consists of a triode-voltage amplifier and a cathode-follower circuit,
2. assembly of the components into a smaller cabinet (8 by 8 by 16 in.) to conserve laboratory bench space and provide a semiportable instrument,
3. elimination of the count-rate meter, since the instrument is used only as a radiation monitor that requires an audible indication,
4. redesign of the amplifier to use miniature tubes instead of conventional octal-base types and triodes instead of pentodes,
5. elimination of the complicated range switch used in the high-voltage supply of previous models.

PARALLEL-PLATE IONIZATION CHAMBER

R. E. Zedler

In order to determine the average energy lost in the production of an ion pair in a number of gases at low pressure, a parallel-plate ionization chamber to be used with alpha sources was designed and constructed according to specifications furnished by Hurst of the Health Physics Division.

The collector plate in the chamber, 25 cm in diameter, is surrounded by a guard-ring plate, 45.5 cm in diameter. The high-voltage plate is approximately 43 cm in diameter and is accurately located 10 cm from the collector guard-ring assembly by means of a post insulator arrangement. The plates are made of 24-S aluminum. The entire assembly is contained in a vacuum-tight steel tank with a flanged cover. The tank is 46 cm ID and 15.4 cm deep. It is fitted with two valves for admitting and expelling gases. Provision is made for the insertion of a nickel sample plate through a flanged opening at the bottom of the tank. The sample plate is securely fastened in the center of the high-voltage plate and is mounted even with its surface.