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INSTRUMENT RESEARCH AND DEVELOPMENT QUARTERLY PROGRESS REPORT

for Period Ending July 15, 1950

Compiled by

W. E. Thompson

DATE ISSUED OCT 20 1950

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PREFACE

This Instrument Research and Development Report covers the activities of instrument groups in the Chemistry, Health Physics, and Physics Divisions and the Instrument Department of the Engineering and Maintenance Division. Although the instrument groups report their work in division quarterly reports and will continue to do so, it is believed that some advantage will be gained by compiling the sections of these reports which cover instrument research and development with the quarterly report of the Instrument Department into a single unclassified document.

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CHEMISTRY DIVISION

DISCRIMINATION AGAINST BACKGROUND FOR C^{14} COUNTING

C. J. Borkowski and E. Fairstein

Work has begun on the counting of C^{14} when the C^{14} rate is close to the normal background rate of the proportional counter. The feasibility of discriminating between the C^{14} counts and the background counts by means of energy measurements is being examined. To date, no significant data have been obtained. The major difficulty at present is the drift in counting yield in the chamber for a given pulse-height selector setting. Since it is necessary to take data over a period of 48 hours for each set of conditions, the drift becomes important.

The data which have been taken seem to indicate that in this particular chamber, the pulse-height distribution of the background is close to that of the C^{14}. However, most of the background is due to local gamma radiation and not mesons. If the latter were the source of background counts, better discrimination could be obtained.

The present chamber is a hemisphere. A filling mixture of 90% argon and 10% methane is being used. The central wire configuration is such that a good peak is obtained for a 7 Kev X-ray emitter.

Ultimately gas counting of C^{14} will be done, whereas at present all data were obtained with a solid source.

ALPHA ENERGY ANALYZER

E. Fairstein

After being in operation for over a year, the alpha energy analyzer has been found to have the following faults:

1. The 6AG7 amplifier tubes and the 6BG6G high voltage regulator required replacement about twice as often as any of the other tubes.

2. The amplifier stability with respect to voltage disturbances at the input circuit was not as good as desired.

At present, there is no satisfactory substitute for the 6BG6G.

Both the main amplifier and preamplifier were redesigned in an attempt to remove the other shortcomings mentioned. The circuit of the new amplifier appears in Fig. 1.

The preamplifier has been simplified by using triodes where possible, and by using positive feedback between the second and third stages. The increase in gain which results from this application of feedback does away with the necessity for by-pass capacitors in these two stages. This represents an improvement in the reliability of operation since the limited space in the preamplifier box formerly required the use of miniature (and in this case poor quality) capacitors.

The positive feedback is especially easy to apply in a three-tube feedback loop. The basic requirements which must be met for stability are:

1. The positive feedback loop must be smaller than and be within the negative feedback loop.

2. The stages within the positive feedback loop must have a wider pass band than the stages external to the loop. The low frequency response is especially important (to prevent motorboating). When these conditions are met, the negative feedback controls the amplifier gain and frequency response, which is the desirable situation.

Where bandwidth requirements permit these conditions to be met, it appears that positive feedback can be used to advantage in many instrumentation problems.

The method of increasing the input signal size by feedback to a guard electrode was discontinued. Further consideration indicates that this practice represents the application of positive feedback in an undesirable fashion. The positive feedback loop here is as large as the negative feedback loop. Under this condition, the two feedback factors add algebraically. The effect is to decrease the net negative feedback and therefore the stability of the system. It is equivalent to breaking the positive feedback loop and simply decreasing the amount of negative feedback to restore the loss in signal height.

The main amplifier was redesigned to give greater gain without a loss in stability and without using feedback to the guard ring. The 6AG7 tubes were

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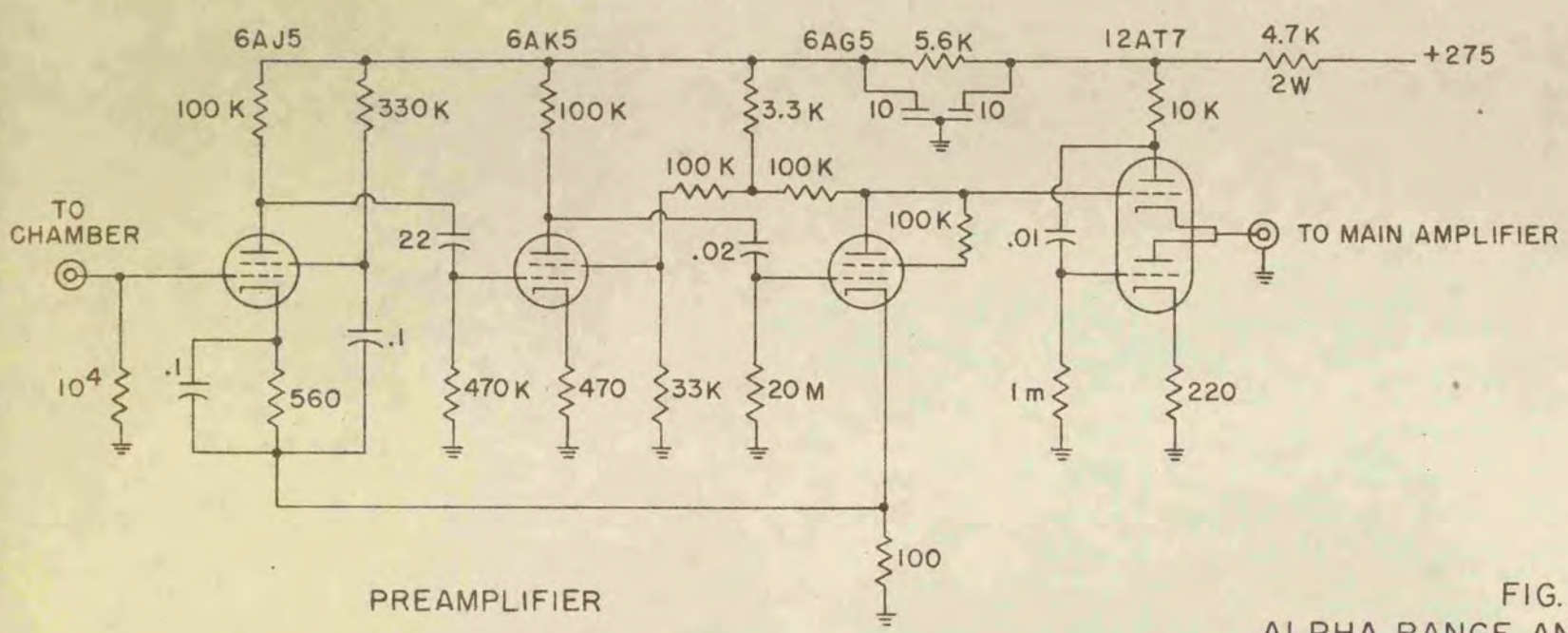
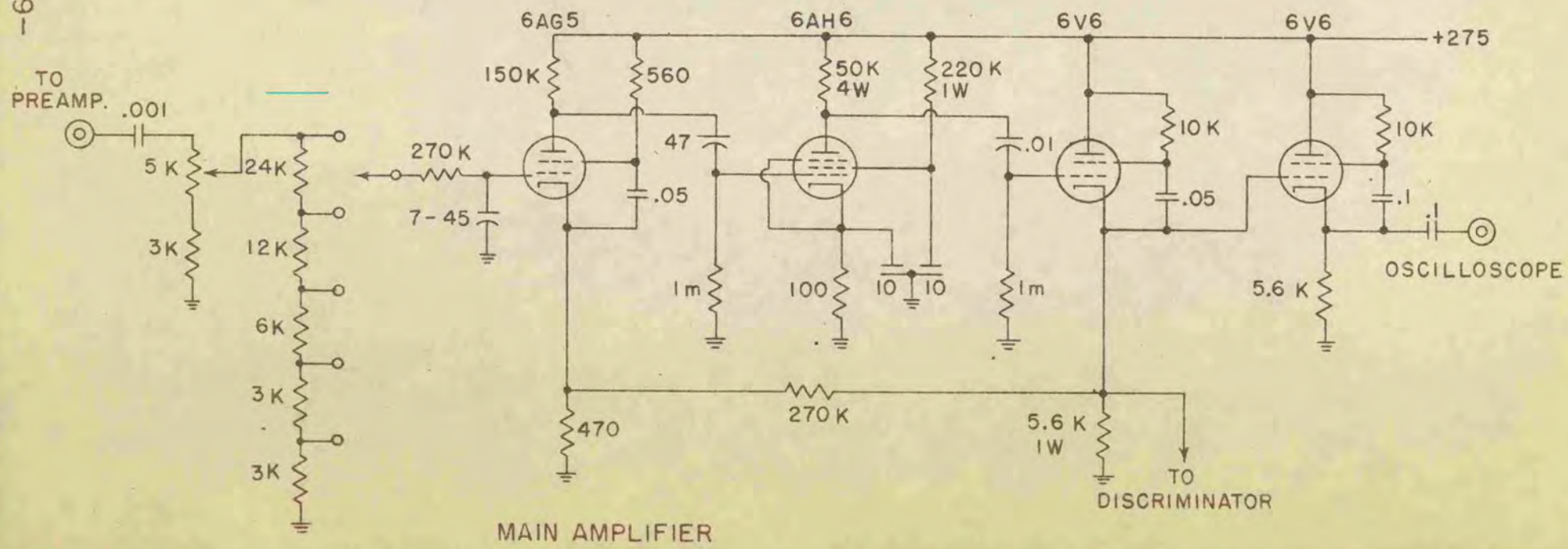


FIG. 1
ALPHA RANGE ANALYZER AMPLIFIER



also replaced by longer-life 6V6 tubes.

In the interest of stability the bandwidth of the system is controlled outside the feedback loops. The rise-time of the system is about eight microseconds, while the fall time is about 25. These are not the optimum for best signal-to-noise ratio, but are necessary for good resolution. The signal-to-noise ratio for a five Mev alpha pulse is still 1000 to one, and represents only one-third of the total peak spread.

The preamplifier gain is 1000. The feedback factor is 300 (50 db). The main amplifier gain is 500. The feedback factor is 50 (34 db). The "cathode-follower" coupling stage between the units has a feedback factor of at least 30 db.

A comparison between a pentode and triode connected input stage was made to determine which gave the higher signal-to-noise ratio. It was found that the triode stage was poorer by at least 50 percent. This is contrary to what appears in the literature, but the evidence is indisputable. Extreme care was taken to make the tube operating conditions identical in the two cases.

Feedback had no effect on the ratio, as is to be expected.

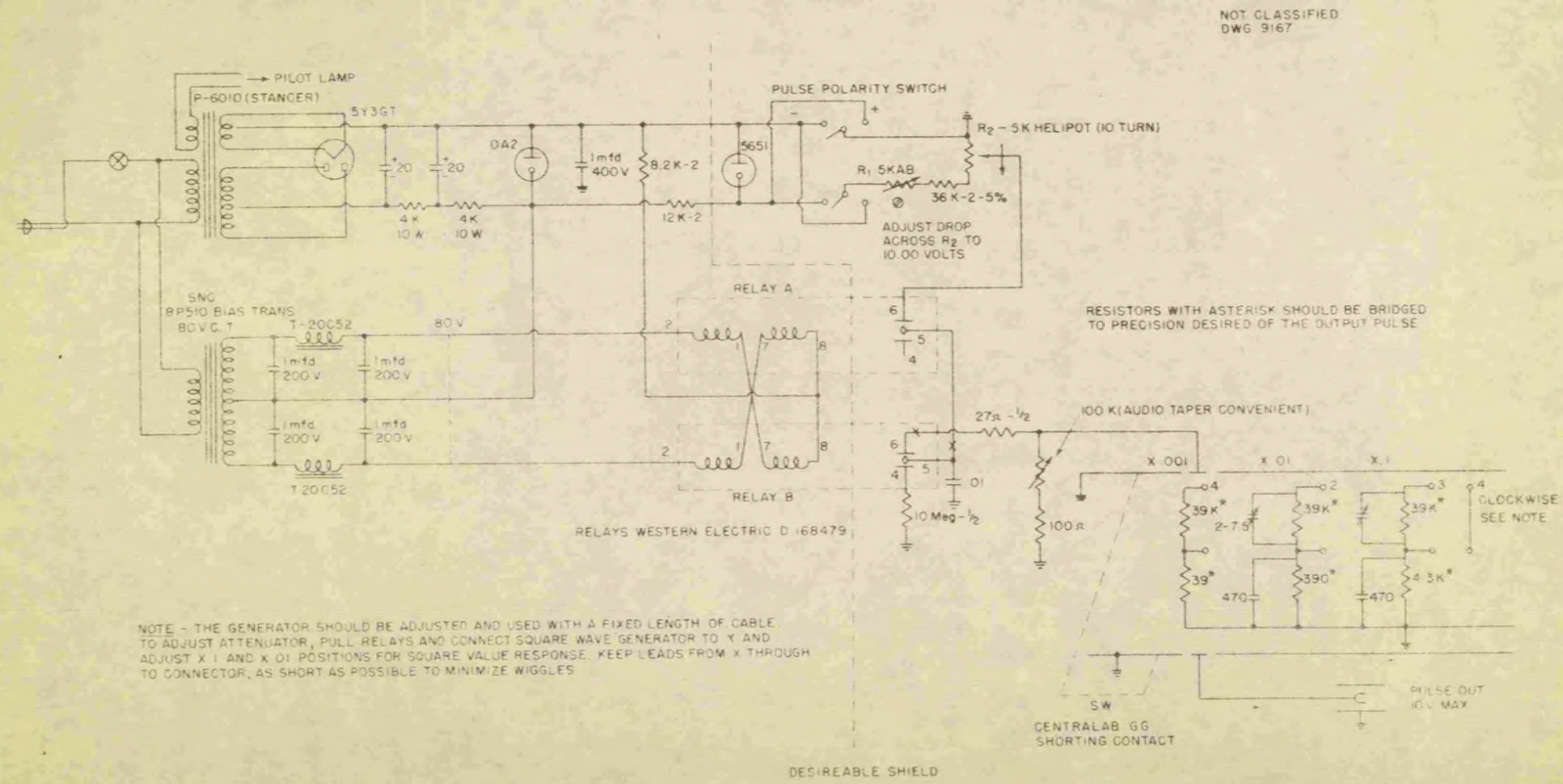
Some minor changes were made in the discriminator circuit; the plate current of the pulse-height selectors was decreased to increase their life, and RC differentiation was used in another part of the discriminator to eliminate a costly delay line.

The power supply requires redesign to take advantage of higher quality components now stocked at the laboratory. This is of importance, since one transformer has already burned out and at least one more is ready to burn out. Both are being operated at well within the manufacturer's ratings, but neither is hermetically sealed.

CONSTANT Q PULSER

R. A. Dandl

The pulse generator shown in the accompanying diagram was built to test high gain, wide-band amplifiers and differential discriminators. The generator



NOTE - THE GENERATOR SHOULD BE ADJUSTED AND USED WITH A FIXED LENGTH OF CABLE TO ADJUST ATTENUATOR, PULL RELAYS AND CONNECT SQUARE WAVE GENERATOR TO Y AND ADJUST X 1 AND X .01 POSITIONS FOR SQUARE VALUE RESPONSE. KEEP LEADS FROM X THROUGH TO CONNECTOR, AS SHORT AS POSSIBLE TO MINIMIZE WIGGLES

FIG. 2
CONSTANT Q PULSER

is especially useful for testing amplifiers because its pulse (+ or -) closely simulates a chamber pulse and it can be fed directly into a preamplifier. Its extremely high precision and stability make it a very useful instrument for the testing of amplifiers and differential discriminators either separately or in conjunction. The useful pulse output ranges from 50 microvolts to 10 volts at 60 cps. The rise time is approximately 10^{-8} seconds and fall time approximately 10^{-3} seconds. The stability is of the order of .1%.

An amplifier discriminator combination built by E. Fairstein and tested with the pulse generator, exhibited the following characteristics: with an amplifier gain of 10^5 the pulse distribution half width was .4 volt; with an amplifier gain of 500 the pulse distribution half width was .1 volt. (Pulse voltage into discriminator = 100 volts, discriminator slit width = 50 mv, rate meter time constant = 50 seconds, amplifier bandwidth approximately 100 kilocycles.)

It was necessary to use two D-168479 mercury relays (available on surplus for approximately $5.00). Because these are of the "make before break" variety, "break before make," single pole, double throw switching is needed. However, Western Electric manufactures "break before make" relays which could be used at a considerably higher cost. It is highly desirable to shield well the switching and attenuator circuits and to keep leads very short to prevent ringing. A connecting cable (8-20 ft of RG 7/U or equivalent) can be chosen and the attenuator peaked with a square wave generator.

MOVING FILM PULSE ANALYSIS

R. S. Stone and C. J. Borkowski

In taking energy distributions with conventional electronic pulse height analyzers, one has the choice between a multichannel device which simultaneously counts the number of pulses in each of a finite number of energy ranges, and a single channel instrument which sweeps through the energy distribution, counting only one size pulse at a time. At present, the first type has the disadvantage of excessive circuitry, and its resolution is limited at the outset by the number of channels available. The second type is obviously much slower, since a separate count must be taken for each energy increment it is desired

to resolve, and in the case of low counting rates this may be a serious drawback. For short lived samples this type of measurement may be out of the question. Moreover, reading only one pulse height at a time gives more chance for drifts in the calibration of the instrument to introduce errors in the final results.

One solution to this problem is to record on film every pulse which occurs, thus gaining the speed and accuracy of the multichannel analyzer, and then to extract the information from the film at leisure, giving as good resolution as is obtainable by sweeping the distribution with a single channel analyzer.

In our case, this film recording has been accomplished by feeding the pulses into an oscilloscope (Dumont 248) via an A-1 amplifier, and photographing the scope screen with a moving film camera (Fairchild Oscillo-Record Camera). The f 1.5 lens is used wide open, with Eastman Linagraph Ortho or Linagraph Pan recording film. The scope tube is a 5JP11, chosen for its highly photoactinic phosphor and relatively short persistence. The film is run at such a speed as to give about 10 counts per inch, so that a counting rate of 3000 c/m requires a film speed of about 5 in./sec. (The speed range of this camera is 1 in./min to 5 ft/sec; the General Radio Oscillograph Recorder runs from 5 ft/sec to 35 ft/sec.) The scope is used on driven sweep with the Z amplifier turned to full gain and its input paralleled with that of the Y amplifier. This permits blanking the spot on the tube face except when a pulse is being recorded. In the particular work done, a pulse ion chamber supplied the pulses, but the method is equally adaptable to other counting techniques.

Two variations of this method were tried. In one the X gain of the scope is cut to zero, so as to give a series of vertical lines with heights proportional to pulse energy. In the other method the X gain is left on so as to get shaped pulse traces, again with heights proportional to energy. The former type of record would doubtless be much easier to design an automatic photoelectric scanner around, but the latter lends itself more easily to visual counting. Moreover, the "blip" at the base and top of the one-dimensional pulses tends to introduce some uncertainty as to the exact end points. Both types of records were made, however, and both gave good results when measured visually.

Reading was done on an Eastman Recordak microfilm reader, with a magnification of about 13.5 X. Since the image on the scope face is reduced on

the film by a factor of 6, this sets the overall magnification between tube face and reader screen at around 2.25 X. The readings were made through a piece of waxed graphed paper to the nearest 1/20 inch.

The method was first tested by feeding a constant Q Pulser (a mercury relay type signal generator) into the scope, varying the input voltage from 0 to 10 volts. The film, when developed, indicated that the lower boundary of detectable voltage changes lay in the region of 1%-2%. Graphed, the deflection vs. input voltage curve gave excellent linearity up to 4 in. deflection on the microfilm reader, and good linearity to 5 in. Deflections up to 5 in. probably need not be corrected for scope nonlinearity, as at 5 in. deflection the departure is but 2%. This deflection corresponds to about a 2.25 in. trace on the 5 in. scope face.

Following this preliminary investigation, several actual energy measurements were made. The first was an attempt to separate the energy peaks from a composite sample in the alpha analyzer. These peaks lie at 4.82, 5.15, 5.50 and 5.75 Mev, respectively, or about 7% apart, and should furnish a measure of the resolving power of this method.

A graph was made of number of pulses vs. pulse height for a distribution of 349 points. This shows that the four energy peaks are readily separated. The curve obtained from the electronic differential discriminator (a single channel sweep type analyzer) was superimposed on the graph. Energy calibration of the film curve was obtained by assuming one of the peaks to be at the correct position, 5.15 Mev. With this assumption the other peaks are found to be in excellent agreement with the correct values. The largest error is only 0.5%, giving considerably better accuracy than had been hoped for. Of course, this is all relative to the chosen standard, a very close calibration point, and failures in linearity might be more serious over a greater range between calibration and measurement.

Points on the discriminator curve were taken from a Brown record, and plotted to scale. Comparisons of the resolution given by the two methods should probably not be made because of the vastly greater number of pulses evaluated by the discriminator. One evident difference between the two curves is the differential discriminator gives two of the peaks of practically indentical height, while the film curve shows one of these peaks lower than the other. However, integral areas under these two peaks on the film are

practically indentical, and hence the total number of counts in each peak is about same.

Another film was run on an Sn^{112} 24 Kv X-ray source, and the distribution of 244 pulses is plotted in Fig. 3. This source is seen to give a very pronounced peak, and would make a good calibration point for measurements in this region. There seems to be a secondary peak at about 25.8 Kv, which is about the right energy for the K β line, but there are really not enough pulses to be sure. (This secondary peak is only 10 pulses high.)

These data indicate that the film method gives good resolution and should be a useful tool in situations where either a quick count must be made or where an inordinately low counting rate precludes the use of a count rate meter. The principal objection to the method is the long and tedious process of reading the film. A projection system with a photoelectric scanner could be built to take care of this, the main obstacle being base line instability. Lateral shift in the film is probably negligible--sound recording practice holds this to 0.1 mm, or about 0.2% error for 4 in. on the microfilm reader—but d-c fluctuations in the scope cause the base line to change enough to vary results by several percent. Moreover, the intensity control must be set very carefully to yield a base line which is present but not heavily overexposed, particularly at the slower film speeds.

Film reading could be speeded up by using the time exposure type of pulse photography, wherein the film does not move, and successive pulses pile up to be read with a densitometer. Here one pass across the film with the densitometer would give the desired distribution. Moreover, one does away with processing long lengths of film. Disadvantages are messiness in absolute calibration of density--due to variables and non-linearities in film characteristics—and difficulty in resolving closely adjacent peaks because of film and tube phosphor halation. The first may be disregarded in a great number of cases, since in general we only wish to know the location of a given peak and to have a qualitative picture of its height relative to other portions of the energy spectrum. The second disadvantage may be eliminated by some sort of scale spectrum, but in general would tend to limit the method to cases where

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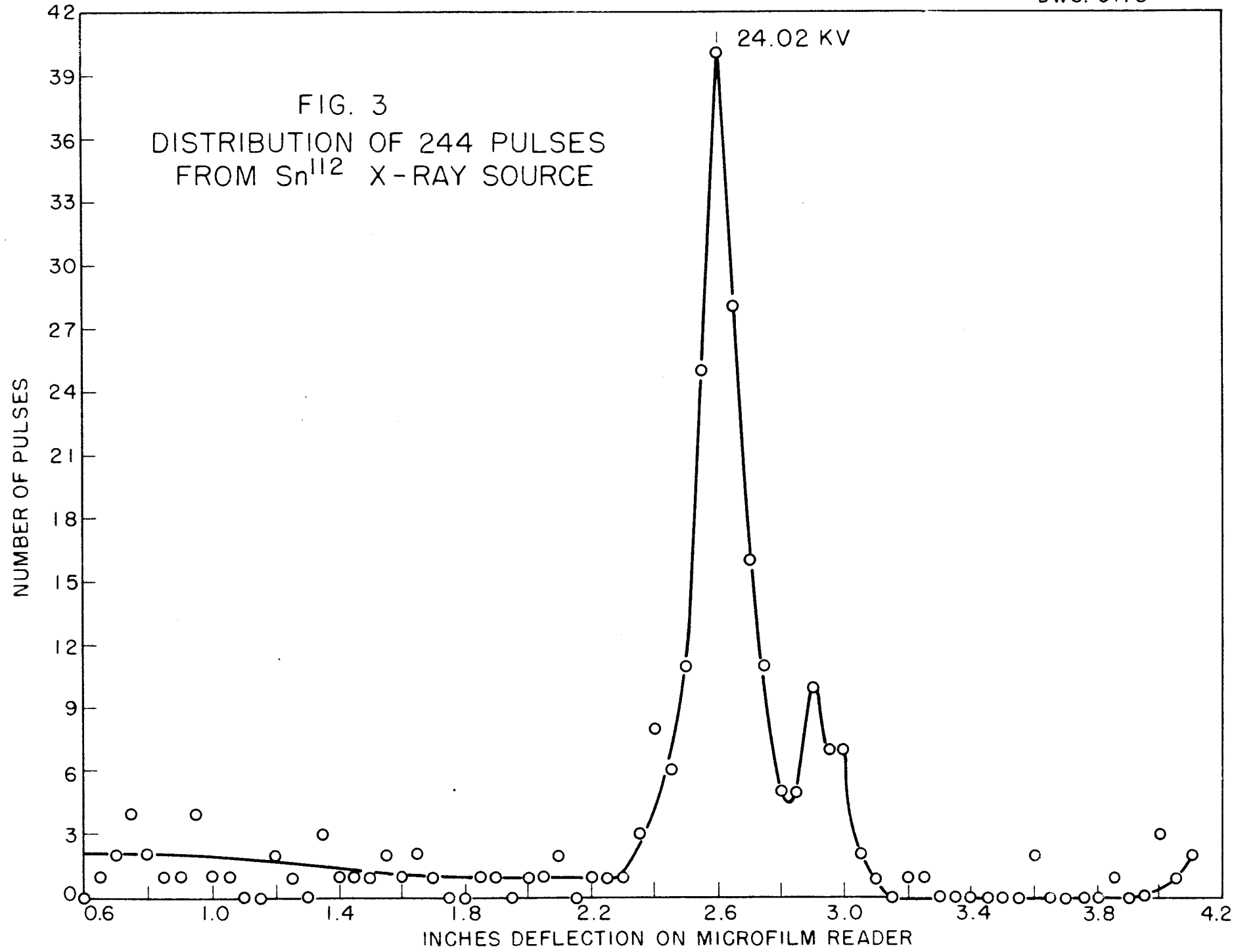

FIG. 3
DISTRIBUTION OF 244 PULSES
FROM Sn^{112} X-RAY SOURCE

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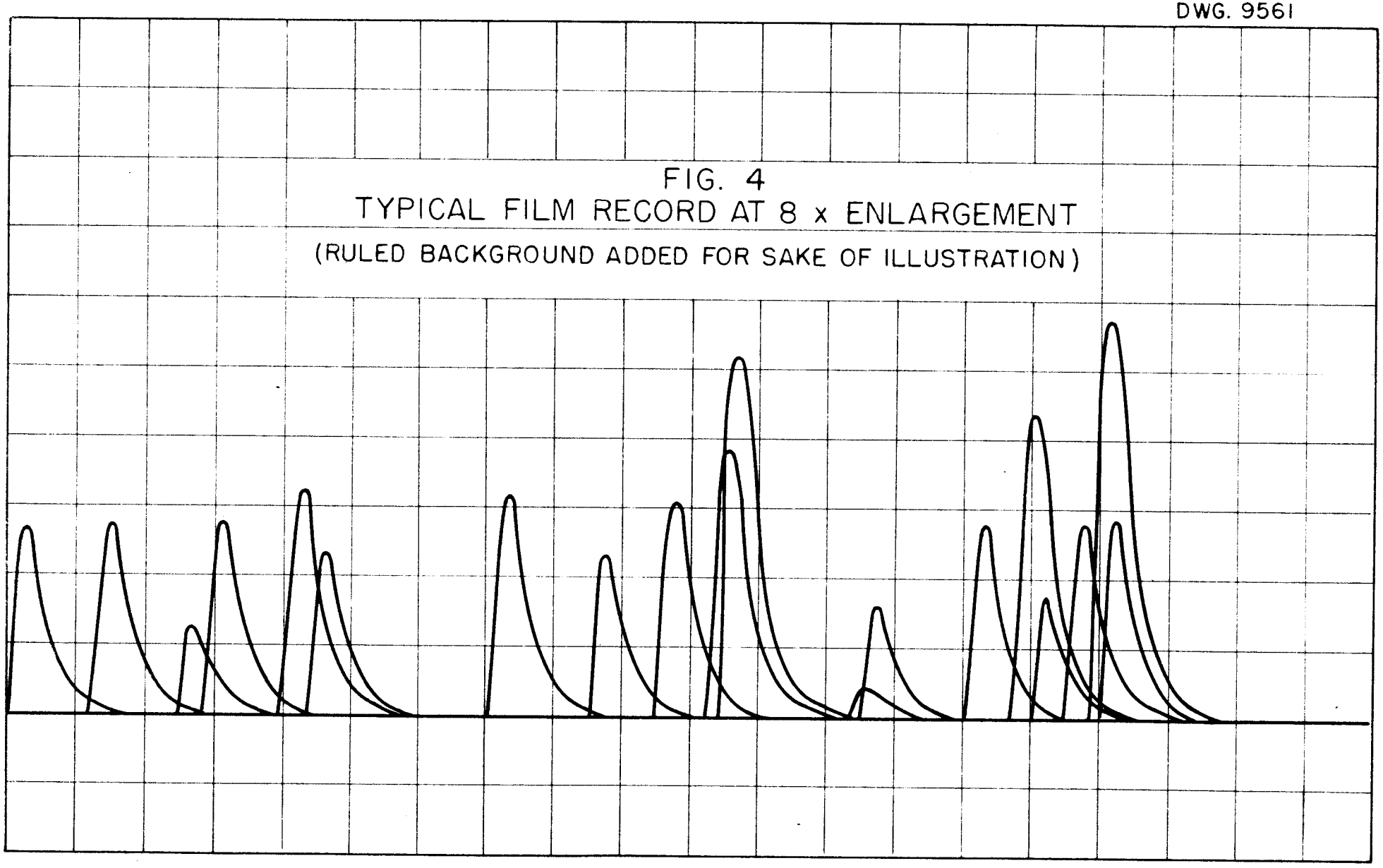

FIG. 4
TYPICAL FILM RECORD AT 8 x ENLARGEMENT
(RULED BACKGROUND ADDED FOR SAKE OF ILLUSTRATION)

energy peaks are not immediately adjacent. In other respects (speed of data gathering, large number of channels, etc.,) it has the advantages of the moving film.

Both techniques no doubt have their place, the moving film method being the more absolute and potentially more reliable, and the time exposure method faster and more convenient.

HEALTH PHYSICS DIVISION

PORTABLE FAST NEUTRON DOSIMETER

W. M. Hurst

The special design of a recoil proton proportional counter, applicable to a fast neutron dosimeter[1] where the neutron dosage is indicated directly by a counting rate, is confirmed in the neutron energy range of 0.3 to 2.5 Mev by experiments with monoenergetic neutron beams at Los Alamos. Measurements in the energy range of 2.5 to 6 Mev are scheduled for about July 12-16, 1950, at Carnegie Institute, Department of Terrestial Magnetism.

FAST NEUTRON FLUXMETER

W. M. Hurst

Two experimental proportional counters have been constructed, designed to have a uniform count rate response to fast neutrons in the energy range of 0.5 to 15 Mev. These counters will be tested in the energy range of 2.5 to 6 Mev at the Carnegie Institute, Department of Terrestial Magnetism.

NON-DIRECTIONAL PROPORTIONAL COUNTER

W. M. Hurst

One experimental, non-directional proportional counter is ready for testing and another is now being processed. In the near future these counters will be tested for non-directional characteristics relative to neutron energy absorption. These counters are for general monitoring, and special applications.

---

(1) Hurst, G. S., *Fast Neutron Count-Rate Dosimetry*, ORNL 589 (Feb. 17, 1950).

PORTABLE ALPHA SURVEY METER

W. M. Hurst

The modifications made have been largely in the probe of the survey meter described in ORNL-602,[2] and have resulted in an instrument operable in 98% relative humidity without the use of a desiccant Briefly, the probe insulator holding one end of the collector wire is removed from ground and is now supported by a guard ring which is a beam attached to the capacitor H. V. supply. This also results in a reduced leakage rate of the capacitor H. V. supply. A supplement to ORNL-602 is being prepared, describing the modifications in detail and listing all drawings required to manufacture the complete instrument.

CONTINUOUS WATER MONITORING

W. M. Hurst

In general, the water supply of a community is provided by a filtration and processing plant which receives its water from such sources as a river, mountain stream, spring, or water table. All types of sources are subject to the remote possibility of contamination by radioactive isotopes. We are concerned with the instrumentation problems of monitoring a municipal water supply so as to protect the community against over-exposure to a possibly dangerous radiation hazard in drinking water.

Preliminary specifications for the monitoring instrumentation include the following:

1. To be installed in the water processing plant, preferably at the raw water end so as to take advantage of the transit time of water through the processing.
2. The instrument is to detect beta and gamma radiation.
3. The instrument is to alarm at the permissible level of activity.

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(2) Hurst, W. M., Hurst, G. S., and McDonald, W. B., *A Portable Alpha Survey Meter*, ORNL 602 (Mar. 14, 1950).

4. A continuous record is to be made showing the water quality to be "safe" or "dangerous."

5. Alpha detection is not required.

6. Radiation energy measurements are not required.

First consideration has been given to the magnitude of the internal permissible level for various radioactivities. That tolerance is arrived at by considering such factors as: the relative biological effectiveness (R.B.E.), half-life, localization within the body, energy, and rate of elimination of the isotope from the body. As we are not concerned (by specifications) with neutrons, protons, or alpha rays, the R.B.E. factor is removed. Briefly, the various permissible levels range from the order of 10^{-7} microcuries/cc up to about a microcurie/cc, and these levels are for a long ingestion term of about 30 years. To alarm at the low-level of 10^{-7} microcuries/cc, the instrument would have to reliably detect activity of the order of 10^{-8} microcuries/cc, and that is considerably beyond the sensitivity of present day radiation detectors. For instance, activity of 10^{-8} microcuries/cc is about 0.02 dis/min/cc, and the background count of various beta detectors is of the order of 20 or 30 counts/min. To detect a low-level dose rate in water, concentration of the activity found in a gross quantity of water is mandatory.

A compromise is effected if we stipulate that the constant water monitoring is to detect a short-term high dose rate level or "surge" and the low-level activity is to be monitored by concentration of the activity.

A rough set of numbers, supporting such a design philosophy, may be prepared by using the following assumptions:

1. The transit time of water through the process plant and on to the consumer is longer than 30 minutes.

2. Direct measurement of the surge (high dose rate) may be a 15 minute integration.

3. The surge activity is to be approximately 5×10^{-5} microcuries/cc (or about 100 disintegrations/minute/cc).

Such an operating condition gives us two maximum permissible values (related to a short and a long term level) to monitor, and a single instrument may suffice for both measurements if the long-term activity level is concentrated from an appropriately large volume of water.

The design of a continuous water monitor is now thought of as consisting of the following components:

1. The radiation detector is to be an anthracene crystal followed by a "light piper" and the RCA 5819 photomultiplier tube. A light-tight housing for the detector is also to house a tray filled with running water to be monitored and possibly a pre-amplifier or cathode follower.

2. A differential pulse height selector is used to eliminate tube noise and reduce cosmic ray pulses.

3. An amplifier of extremely stable and reliable operation. To start with, an A1 linear amplifier would be used. A small amplifier is feasible, but will require engineering.

4. A recording counter with automatic reset to record a 15 minute integration of counts and then repeat.

The long-term tolerance activity is to be concentrated from a large volume of water by the use of a coagulent, collection of the floc and drying. Preliminary work by the Waste Disposal Research Section of the ORNL-Health Physics Division has disclosed attractive results relative to a single stage coagulation and the percentage of activity removed from a gross quantity of water. A desirable feature of this method of activity concentration is that the materials and process used are already present as a normal phase of water processing.

INSTRUMENT DEPARTMENT

COCKCROFT-WALTON GENERATOR

R. F. King

The behavior of the wood used in building the Cockcroft-Walton High Voltage Supply is being studied by keeping records of weights and electrical resistivity of a number of samples. Some of the samples are paraffin impregnated and ceresin coated, the same as used in the Cockcroft-Walton structure itself. Some are linseed oil impregnated. Some are subjected to the same temperature and humidity conditions as the Cockcroft-Walton structure, and others are kept in an air conditioned room at about 45% relative humidity. In addition to obtaining useful information, it is hoped that impending trouble can be anticipated by this system.

The 360 cycle motor-generator set for the Cockcroft-Walton has been delivered and is being installed at the present. The motor control for this set is now scheduled for shipment August 24.

Since radio frequency power requirements for the various ion sources tried have proved larger than at first thought, several radio frequency oscillators and their associated power supplies have been built—the latest one being capable of delivering about 350 watts at 27 megacycles. The same can be said of the d-c probe supply for the ion source. Already revised upward by a factor of seven in power, the indications at present are that another factor of two or three is needed.

Remote control for the four adjustments of the ion source to be made during operation was changed from purely mechanical to mechanical plus electrical. Five selsyn transmitters (one a spare for future needs) now do the job from a small portable control box.

Tests run on the new Van de Graaff pulley generator indicate that about 750 volt-amperes should be considered full load. At 750 volt-amperes continuous load the winding temperature rise is 51°C.

The general design, minus some details, for a 600 kilovolt metal and porcelain Cockcroft-Walton is ready for the new building.

HYDROGEN PUMPING WITH OIL DIFFUSION PUMPS

H. Reese

The study of oil diffusion vacuum pumps pumping hydrogen and air begun last quarter was continued and completed. This information is reported in ORNL 764.

MAGNETIC ANALYZERS

I. D. Groves

In order to analyze the by-products from material bombarded by 300 kv protons a double-focusing magnetic analyzer has been constructed. The analyzer has a mean radius of curvature of 10 cm and an air gap of one inch at this radius. This instrument is based on the principal, first established by Kerst and Serber, concerning the free oscillations of a charged particle moving in a magnetic field. The magnetic field has the form $H = H_0(r_0/r)^{1/4}$. A careful study of the field was made with a search coil and the field was found to agree with the ideal field very closely, the maximum deviation being 1.7% at 1/2 inch from the mean radius.

New pole pieces and pole adjustors were constructed for the mass separator magnet on the Cockcroft-Walton accelerator tube. The pole adjustors facilitate the focusing of the beam on the target. The mass separator vacuum chamber was designed to have five beam outlets, one straight through path, and outlets for mass one and mass two when bent through 15° and 10°33′ respectively. When the magnetic field is reversed, two identical outlets are provided on the other side.

ACCELERATOR TUBE STUDIES

I. D. Groves

A 16 section proton accelerator tube test section was constructed and tested. This section consisted of two types of glass insulators and two types of electrodes. Some of the glass sections will withstand 180 kv. Kovar rings were inserted between the stainless steel end plates and the glass insulators. This was done in order to lessen the stresses in the end glass insulators due to the expansion and contraction of the heavy stainless steel end plates.

RESONANCE ANALYZER

W. G. Stone

Two new analyzer heads have been tested. They were found to be unsatisfactory in regard to the filament mountings. Two new ones have been designed and one is ready for testing. This new one is of all glass construction, and it is believed that the filament will stand the magnetic field without difficulty. The amplifier which has been used with some success is not as stable either mechanically or electrically as it should be. A new amplifier is under construction.

The recent power failure did considerable damage to the vacuum system. This is being repaired and additional safety features are being incorporated.

During June Dr. Helmut Sommer from Dr. Hipple's laboratory at the National Bureau of Standards visited our laboratory to look over our equipment and compare notes with us. He seemed to be favorably impressed and expressed the opinion that we were on the right track to produce an inexpensive simple mass spectrometer.

LINE NOISE MONITOR

F. M. Glass

A line noise monitor (Q-1016) has been constructed making it possible to detect line transients caused by such things as faulty fluorescent lights, lightening, breaking inductive sources, and numerous others. It can be used in counting rooms to aid in obtaining more accurate data, or to detect noisy appliances in a laboratory. It may be set to detect single bursts of noise or continuous or frequent noise bursts. The monitor is simple, compact, and low in cost.

NEUTRON CHAMBERS

R. K. Abele

Four 3-in. and two 2-in. high-flux neutron chambers designed in collaboration with W. H. Jordan of the Physics Division have been assembled. These

chambers have enriched boron deposited on graphite in the active chamber volume. Materials used were graphite, magnesium, quartz and lead (Pb) wire. Two differential compensated neutron chambers designed by J. C. Gundlach of the Physics Division are now under construction.

RADIATION DETECTION ENGINEERING

During the period of this report approximately forty special ionization chambers and counters were designed, built, and delivered to the Research Divisions over and above the routine counter and chamber assembling and testing.

NEUTRON TIME-OF-FLIGHT SPECTROMETER—ELECTRONIC INSTRUMENTATION

W. T. Clary, Jr.

Assistance is being given to the Physics Division in the design and construction of a neutron spectrometer somewhat similar to the one in use at Argonne. At present a rough preliminary design of the electronic circuitry is nearly completed and construction has been started.

The electronic part of the instrument will consist of an impulse generator to indicate the instant of time the shutter opens, control circuits to provide the proper switching and timing pulse, eighty or slightly more scaling channels, power supplies, signal amplifier, and test circuits.

The control circuits are actuated by each impulse from the shutter and operate to turn on each scaling channel in turn.

The channel on time (determining range of neutron energies accepted) can be selected to be 4, 8, 12, 16, 20, or 24 microseconds, also the scaling channels operation can be electronically delayed behind the shutter impulse up to about 10,000 microseconds in three ranges. Thus the instrument can be used over a wide range of energies.

The impulse which indicates the instant of shutter opening will be generated by either a magnetic or an optical system. Both methods will be further investigated. An Al amplifier and preamp will be used as signal circuits. All controls, except power switches, will be mounted on a main central panel. A method of rapid overall testing will be incorporated. Considerable care is being taken to reduce maintenance problems and insure greatest realiability.

LIQUID LEVEL TELEMETER

K. H. Kline

A new oscillator, constructed and installed in model instrument, appears to have a range of tuning, without discontinuities, necessary to indicate liquid level changes of the order of 15 inches. Special teflon-insulated R-F cable necessary to connect the detector head with the oscillator is now on hand (RG 87/U).

Final design of the instrument and the associated probes will now proceed unhampered.

REGULATED POWER SUPPLIES FOR MAGNETS

K. H. Kline

Two magnets and power supplies are being constructed for the Physics Division. Each one is to furnish a maximum flux of 20,000 gauss across a two inch air gap, 10,000 gauss across a four inch air gap. The power supply furnishes a maximum current of 1.25 at 4000 volts continuous duty. The current to the magnet coils will be regulated to at least one part in 1000. This is accomplished by means of vacuum tube comparator amplifier controlling an amplidyne generator which in turn furnishes the control current to a saturable reactor in the primary of the rectifier circuit transformer.

One magnet has the requirement that the direction of the field be reversible in a maximum ten seconds, without incurring an error of more than 100 gauss. This will be attempted by paralleling the magnet coil with a large capacitor, this permitting opening of the circuit without danger of switch arcing, and the ensuing damped oscillations will reduce the residual flux to a tolerable minimum. This particular magnet and power supply are not scheduled for early completion. The other magnet supply has been completed but as yet has not been tested.

ELECTROMAGNETIC FLOW METER

P. E. Brown

Development has been undertaken on a flow metering system based upon the measurement of the emf generated by a conducting fluid moving through a

magnetic field. To use the system with aqueous solutions, an alternating magnetic field has been adopted. Ranges of flow of 0 - 100 to 0 - 1000 cc/min are contemplated. Several designs of electrodes and non-conducting flow channels have been tested. An amplifier has been designed to produce a d-c output which may be recorded by a Brown or L&N potentiometer controller. Tests to determine accuracy, reproducibility, stability, and basic limitations are underway.

MULTI-CHANNEL REMOTE INDICATING COMPARATOR

W. H. Brand

An eight element measuring array for under water dimensional survey has been completed. A selector switch successively connects the eight elements to a single point recorder and the variation from a reference is recorded. Atcotran linear differential transformers, canned and sealed, are held in a fixed array. The core motion produced by movement of the specimen is reproduced by movement of the core in an instrument mounted Atcotran. Repeatability of .001 in. in a .300 in. span was obtained. Variation of lead length up to fifty feet produced no effect in the signal or record.

HIGH SPEED MOTION PICTURE STUDIES

S. A. Hluchan

A Western Electric Company high speed (150 to 5000 pictures per second) motion picture camera with accessories has been purchased and used on two different problems. The first problem was the measurement of instantaneous velocity and size of gas bubbles in a rapidly changing fluid stream. The second was the study of globular formations at obstructions in pipes carrying flowing mixtures of immiscible liquids. The optical problems presented are more formidable than that of stopping the motion.

CHANGES IN DESIGN AND FABRICATION OF ELECTRONIC CHASSIS

J. R. Tallackson

The Instrument Department is now stocking three larger sizes of chassis as flat sheets, cadmium plated and containing all holes and notches required

for bending and assembly. The chassis, as flat sheets, allow the use of of turret punch presses to punch tube socket holes, transformer cut-outs, etc. Two turret presses are used: (1) 7-1/2 ton, 12 station press, manually powered, and (2) a 15 ton motor driven 16 station press equipped with a gage table. The mounting of sockets and AN connectors is facilitated by group punches which punch all holes required in one pass. After punching, the chassis is bent on a small press brake. This requires only one or two minutes. The foregoing, which is being used for both experimental and routine construction, has virtually eliminated the use of Greenlee type punches in our sheet metal and electronic shop.

Cost savings are such that the equipment will pay for itself in two to four years.

DEMONSTRATION PILE SIMULATOR

J. R. Tallackson

At the request of E. C. Campbell of the Physics Division, an electro-mechanical pile simulator for classroom demonstration has been built. A manually operated rod changes the "K" and controls the direction of a variable speed d-c motor which operates the pile power indicator. Delayed neutron effect is simulated by a weighted bellows which actuates microswitches. The bellows are linked to the control rod through racks and gears. The pile is "scrammed" by a limit switch energizing a solenoid. Values of "K" and pile power are indicated on legible, vertical scales. Simulation is only quantitative, and it is not designed for any measurements whatsoever.

REVISED A1 AMPLIFIER AND A1B PREAMP

J. De Lorenzo

Revisions were made in the A1 amplifier and A1B preamplifier for beta proportional counting using sealed-off end window tubes. To prevent the A1 amplifier from overloading and double pulsing with large input pulses, feedback in the first section of the amplifier was automatically increased for pulses exceeding a certain level.

This was accomplished by placing a germanium diode and resistor in parallel with the feedback resistor. This scheme, however, will work only for positive pulses; hence conversion of the AlB preamplifier to a plate loaded stage was necessary.

The change was not quite sufficient to prevent the second section from overloading. By inserting a positive and negative pulse clipping network between the first and second sections of the amplifier, it was found that the amplifier was linear to about 60 volts output. An input pulse as large as five volts would not double pulse the amplifier.

RECORDING MANOMETER FOR PHYSIOLOGICAL PRESSURES

E. W. Burdette J. B. Davidson

An automatic method for estimating gas exchange in biological and chemical reactions has been developed to be used in lieu of the Warburg manometer. The same procedures and techniques adaptable to the Warburg instrument can be used with the automatic apparatus. This apparatus consists of a Statham transducer (Model P5C, Range 0-.2 to 0-.4 psi cost $135.00) used as the pressure detecting device, a transmitter and controller designed by C. A. Mossman of ORNL and a Brown Electronic Recorder. This equipment has been used successfully in photosynthesis to measure the respiration of chlorella by Dr. W. A. Arnold of the Biology Division of ORNL.

RE-DESIGN OF ORNL 64 SCALER

F. M. Porter

Re-design of the existing 64 Scaler was attempted for the purpose of incorporating features which would decrease the number of failures and increase the versatility of an instrument that is widely used at the Laboratory.

Re-design includes the following: A high voltage supply capable of operating in the proportional region with good regulation, increased voltage ratings on filter condensers, a reliable high voltage delay for protection of G-M tubes, all hermetically sealed transformers and chokes, 110 v neon pilot lights instead of the 6.3 v pilot lights, increased intensity of interpolation lights by reducing the associated series resistor, improved stability

of scaling stages by slight adjustments of cathode and grid resistors, the count-stop-reset switch replaced with a DPDT wiping action toggle switch for the count-stop switch and a push-button reset, a d-c count-stop relay for remote control of the scaler, a $6AL_5$ coupling stage with associated input and output connectors for cascading scalers, a calibration potentiometer for H.V. meter adjustments, the 1N-34 biasing diode changed to a 1N-58A, .001 mfd mica condensers shunted across the VR tubes to improve the stability of the shunt regulator tube's cathode voltage, the plate voltage for the preamplifier taken from the 8.5 Hy. choke and condenser tie point and dropped through a separate resistor and additional filtering used, all 5% resistors in the input and scaling stages, a shock mounting for the .01 glassmike condenser, a relay-out of the chassis mounting components so as to facilitate construction and improve heat dissipation, .01 mfd by-pass condensers mounted in spring clips and secured to the chassis.

Considerable effort was spent in the selection of high quality components for the new scaler, and it is believed that the recommended components will result in greater stability and fewer failures.

MODIFICATION OF HAND AND FOOT COUNTERS

K. N. Forrestal

ORNL foot and hand counters were modified to insure standardization of geometry and to improve scaler performance. The geometry standarization was provided in the foot counter section and consisted of installing 12 inch long glass G-M counters and placing the counters at a distance of 3-1/2 in. from the center line of the tube to the protective paper covers. This required redesigning the bases of the units. In addition, all foot counter scalers were standardized at scales of 64. In the case of seven Kele-Ket counters this was done by building a scale of eight with a cascade circuit input to the original scale of eight.

This standardization of hand and foot counters has helped to improve operation considerably by providing a definite comparison of performance values on a plantwide basis.

USE OF THE LAURITSEN ELECTROSCOPE

G. M. Toffell O. K. Neville
J. B. Davidson

A simple inexpensive instrument for the determination of the ion current produced by C^{14} beta disintegrations has been developed using a Borkowski type ionization chamber connected in parallel with a Lauritsen electroscope. The advantage of the present design over previous modifications of the electroscope lie in the lower cost and ease of conversion of the commercial model.

Although extensive tests have not been made, the following results may be noted:

1. The scale is linear over 3/4 of the range.
2. The background time for full scale leakage is approximately 24 hours.
3. The instrument has been used successfully for measuring activities in the 1 to .001 microcurie range. It is used most conveniently in the .01 - .1 microcurie range. Drift rates in this range are reproducible within .1%.

TEN CELL COUNTING PLANCHET ELECTROPLATING APPARATUS

J. B. Davidson

Designed and constructed for Mr. Leon Wish of the Biology Division to speed up production of counting planchets which are copper disks plated with radioactive iron, the apparatus consists of ten stirring motors mounted in two rows above a wooden base board. The cells are of 1 in. glass tubing approximately 6 in. long and are cemented to a brass base which supports the cell and serves as the cathode. The platinum stirring rod which is chucked to the stirring motor shaft serves as the anode with connection to the six volt plating voltage being made through the motor frame. A control panel provides individual switching for each of the cells and a selector switch with a 0 - .5 amp meter enables the operator to determine the plating current in any of the ten cells.

INSTRUMENT CONSTRUCTION AND MAINTENANCE

W. J. Ladniak

The following instruments were built in the Instrument Fabrication Shop for use in research work:

A-1 Amplifiers	9
Logarithmic Count Rate Meter	3
Linear Count Rate Meter	12
Differential Discriminator	3
a-c Electrometer	1
Alpha Range Analyzer	1
High Meg Bridge	1
	30

Beside the above work there were 78 instruments built and 54 auxiliary parts made for various jobs throughout the plant.

In the Instrument Service Group, the number of instruments serviced is as follows:

	NO. INSTRUMENTS SERVICED	NO. OF FAILURES
April	247	564
May	214	489
June	200	512
	661	1565

A percentage of instrument failures is as follows:

Transformers replaced	2.36%
Number of G-M tubes replaced	8.69%
Number of filter condensers replaced	2.30%
Number of by-pass condensers replaced	1.36%
Number of resistors replaced	2.90%
Number of vacuum tubes replaced	33.83%
Number of instruments calibrated	3.35%
Miscellaneous failures	45.11%

The majority of our transformers replaced were in scaler instruments. In our new scaler design we are replacing these transformers with hermetically

sealed transformers. Therefore, the future scalers should show little trouble with transformer failure.

The majority of our vacuum tubes replaced are in scalers. Whenever a scaler is brought in for any reason, the tubes are checked and if the Gm is low in any tube, it is replaced. If one tube is replaced, the second tube in the scaling pair is then matched with a tube of the same Gm. This increases the tube replacement.

Miscellaneous failures are due to mechanical failures of allied parts which are necessary for proper usage of the instrument.

PHYSICS DIVISION

SCINTILLATION SPECTROMETRY

P. R. Bell R. C. Davis
J. M. Cassidy W. H. Jordan

The energy resolution and accuracy of measurement of energy have been considerably improved both for beta and gamma rays.

Energy Resolution. It has been shown by the measurements of Hopkins[1] that the resolution now obtained is near the maximum possible with phosphors known today. The width of peaks produced in anthracene by monoenergetic electrons (~ 12% full width at ½ maximum for 626 Kev) can be accounted for by the statistical variation of the number of photoelectrons produced at the photocathode, including the effects of the multiplication process.[2] The photo efficiency of RCA-5819 tubes often is within a factor of two of theoretical perfection so that little improvement in resolution can be expected from this direction. The light emission from anthracene and NaI-TlI is in the region of the maximum sensitivity of the antimony-cesium photosurface and is also largely transmitted by the tube envelope and by the lucite used as a diffusive light piper.

Measurement, both by Hopkins and Bell, of the number of photoelectrons emitted from the photocathode of a good 5819 tube with good optical conditions by a light flash in anthracene produced by a known energy electron gives the apparent efficiency of the phosphor. It was found that between 400 and 500 photoelectrons are produced per Mev of energy loss in anthracene. The pulse size for commercially available sodium iodide-thallium (Harshaw is very nearly the same although some specimens of NaI-TlI have been produced by R. C. Davis and by R. Hofstadter that give a pulse nearly double this size.

If the optical efficiency of the scintillation counter is assumed to be about unity and the efficiency of the phototube about 0.1 (one photoelectron released for 10 incident photons), the anthracene and NaI-TlI energy efficiency from beta ray to photoelectron is about 1%. An interesting side result is

(1) Hopkins, J. I., Forthcoming in *Rev. Sci. Inst.*

(2) Morton, G. A., *Pulse Size Distribution from a Secondary Emission Multiplier*, MonP 333 (July 10, 1947); Morton, G. A. and Mitchell, J. A., "Performance of 931-A Type Multiplier as a Scintillation Counter," *Nucleonics* 4, No. 1, 16 (1949).

that the efficiency of good ZnS-Ag (Patterson D) phosphor for alpha particles is nearly the same as that of anthracene for electrons, when considered on a photoelectrons out to particle energy in basis.

Phosphors

a. *Anthracene.* Anthracene from several sources has been tested. University of Rochester anthracene, very recent Harshaw anthracene and our own give very nearly identical pulse sizes. Earlier Harshaw anthracene (late '49) gave somewhat smaller pulses (70%). A number of samples prepared by the Chemistry Division of ORNL were tested. Some early samples gave wide low peaks for mono-energetic electrons; later samples grown by the reflux method gave better results but even the latest gave pulses somewhat too small although the samples were extremely clear and free from cracks and quite colorless. A method for improving the performance of very large anthracene crystals which always have a number of cracks has been long in use although it has not been reported before. The crystal is suspended over a container of Canada balsam dissolved in xylene or toluene inside a vacuum desiccator. The desiccator is pumped with a fore pump until the solution boils vigorously for four or five minutes. The crystal is then tilted into the solution and after a short time air is let into the desiccator. The crystal is removed from the solution and the outside cleaned off with toluene. Crystals so treated give much better pulse distributions, probably due to the better optical transmission.

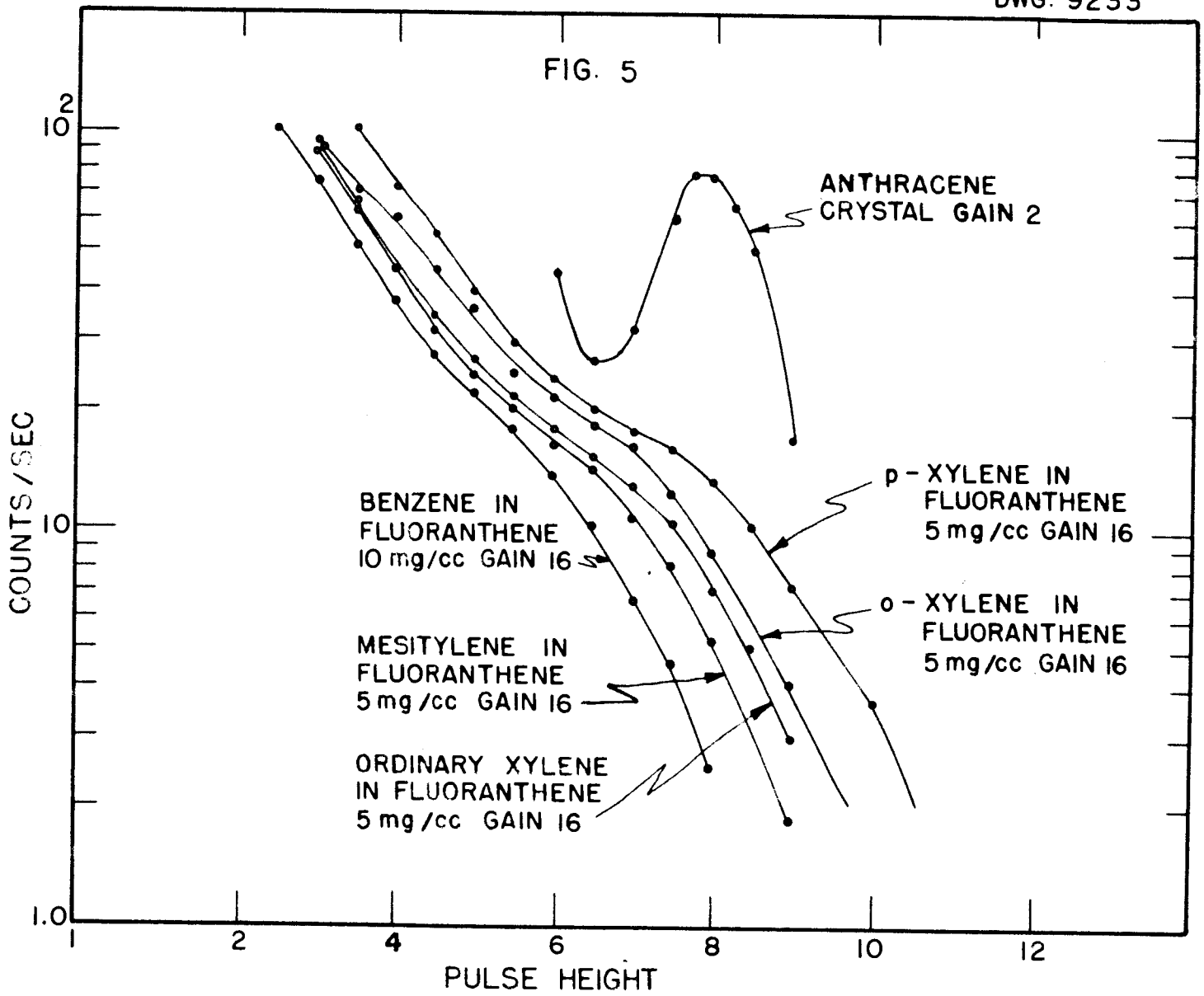
b. *Solution Phosphors.* Certain substances do not follow the general behavior of fluorescent substances in solution. A fluorescent substance generally yields less and less light as its solution becomes more and more concentrated, giving little or no fluorescence in the pure liquid substance (this explains the sudden cessation of fluorescence in anthracene when it melts). This self quenching of fluorescence is very slight for fluoranthene and terphenyl. Solutions of these substances give moderately large pulses in dilute solutions in organic solvents.[3] Figures 5 & 6 show the curves given by various substances in various solutions. Note the amplifier gain is different for various solutions. The exciting radiation is Cs^{137} beta rays. For comparison, part of a curve for solid anthracene is given. Complete results are listed in Table I. The best solution, terphenyl in m-xylene (0.5 g/100 cc), gives pulses three or four times smaller than anthracene.

A solution phosphor 2-1/4 in. in diameter and 7 in. long was tested. The resolution obtained was similar to that of smaller volumes of solution. This counter gave a background count of

(3) Reynolds, G. T., "Liquid Scintillation Counters," *Nucleonics* 6, No. 5, 68 (1950).

UNCLASSIFIED
DWG. 9233

FIG. 5



UNCLASSIFIED
DWG. 9191

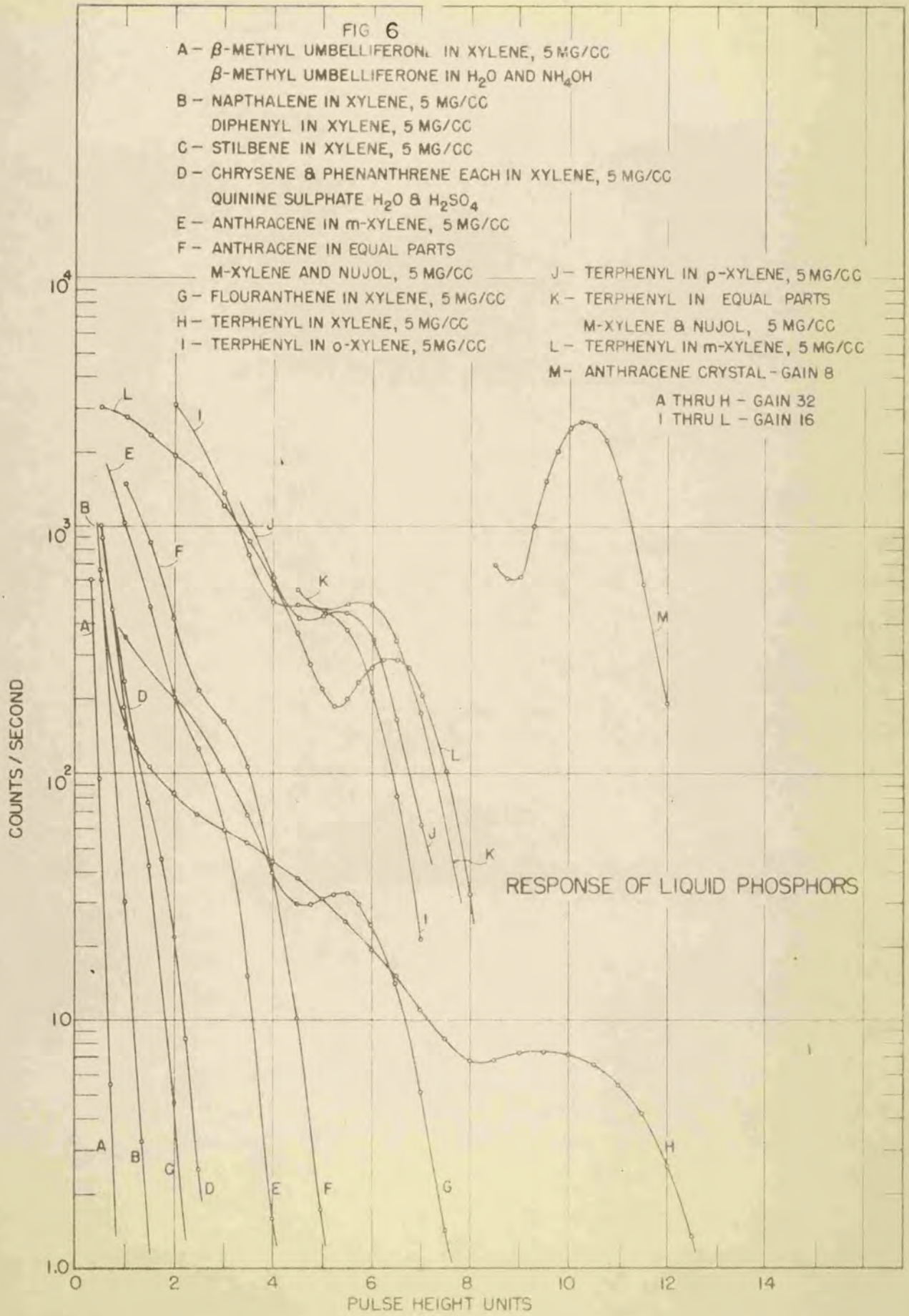


TABLE I

Phosphor	Pulse Height
Anthracene crystal	1.00
M-xylene and terphenyl	.34
M-xylene, nujol and terphenyl	.32
P-xylene and terphenyl	.30
O-xylene and terphenyl	.28
Ordinary xylene and terphenyl	.27
Xylene and fluoranthene	.15
Anthracene with equal parts m-xylene and nujol	.093
M-xylene and anthracene	.075
Quinine sulphate, H_2O and H_2SO_4	.053
Ordinary xylene and chrysene	.053
Ordinary xylene and phenanthrene	.053
Ordinary xylene and stilbene	.040
Ordinary xylene and naphthalene	.029
Ordinary xylene and diphenyl	.029
Ordinary xylene and β-methyl umbelliferone	.016
β-methyl umbelliferone, H_2O and NH_4OH	.016
P-xylene and fluoranthene	.15*
O-xylene and fluoranthene	.13*
Mesitylene and fluoranthene	.125*
Benzene and fluoranthene	.110*
Ordinary xylene and fluoranthene	.128*

* Measured with ultra-violet photomultiplier type C-7140.

50 counts per second in the physics counter room shielded with 2-1/2 feet of concrete. None of these counts were due to the phototube, of course, since the discriminator was set to count pulses of 100 Kev and greater (equivalent electron energy in the solution).

c. *Solution phosphors with solvents containing high Z substituents.* Tests were made with chloroform and ethyl iodide as solvents and extremely small pulse sizes were observed. Examination of other solvents is in progress.

d. *Anthracene mixtures.* Mixtures of anthracene and about 1% of various other organic phosphors were made and crystals grown from them by R. C. Davis. These crystals were all good and transparent but all of them gave smaller pulse height than anthracene. Table II gives the results compared with pure anthracene whose pulse height is taken at 1.00.

TABLE II

Anthracene +	Pulse Height
Anthracene	1.00
1% trans-stilbene	.63
1% Pyrene	.88
1% Fluoranthene	.88
1% Fluorene	.52
1% Phenanthrene	.84
1% Naphthalene	.75
1% Terphenyl	.78

e. *Sodium iodide, thallium activated.* After the stimulating letter by S. E. A. Johansson,[4] further study of the sodium iodide phosphors was begun after a long lapse. A single crystal of NaI with about 1/2 to 1% thallium impurity, made by the Harshaw Chemical Company, was obtained. A cylinder 1-1/2 in. diameter and 1 in. high was ground with carborundum paper and finished with metallographic emery paper. The crystal was inserted into

(4) Johansson, S. A. E., "Measurements of the Energy of Beta- and Gamma-Rays with a Scintillation Counter," *Nature* 165, 396 (1950).

a fitting lucite box with 1/16 in. thick sides and the box end filled with the standard 1-1/2 in. diameter, 3/4 in. high lucite light piper and the two parts joined with ethylene dichloride. The space between the crystal and the lucite box was filled with dry mineral oil. All of the work had to be done in the dry box since the NaI-TlI is extremely hygroscopic. This crystal assembly was attached to a 5819 photomultiplier with Canada balsam and covered by an aluminum reflector. The results obtained appear in Figs. 7 to 12. Samples of various substances were placed close to the crystal with sufficient absorber between sample and crystal to remove the beta rays, if any, that were emitted. Peaks arising from the photoelectric process are observed from 22.2 Kev (Ag Kα X-ray) to 4.44 Mev (excited state of C^{12}). These peaks are at a pulse height corresponding to the gamma ray energy since the X-rays or Auger electrons from the iodine atom from which the photoelectrons come are detected with substantially 100% efficiency and are, for all practical purposes, simultaneous with the photoelectron. The sum of all the pulses is thus recorded by the amplifier.

Figure 7 shows the response to the radiations from 330 d cadmium. The Ag K X-rays give a good peak despite their low energy. The gamma ray energy is not too well known but is reported at 88.4 Kev. This gamma ray is largely internally converted accounting for the small intensity of this peak. Another weak gamma ray can be seen between the two peaks.

Figure 8 is the pulse spectrum produced by 51.5 d Hg^{203}; the well known gamma ray at 279 Kev and the Hg K X-rays produce good peaks. The turn up at low pulse size is due to the L X-rays. The Compton electron distribution can be seen below the X-ray line breaking off at 450-550 pulse height divisions. The gamma ray of Cs^{137} at 0.661 Mev gives the curve of Fig. 9. Here the curve is plotted on linear paper rather than the usual semi-log. The full width at half maximum for the peak is about 11%, approximately the same as for anthracene. The broad peak at 350 pulse height is due to gamma rays leaving source (near the crystal) and producing a Compton scattered photon in the surrounding lead shield. Those scattered photons that reach the crystal must proceed almost directly backward, and hence are almost monoenergetic and near the minimum energy (0.184 Mev) for a single Compton scattering for the .661 Mev initial energy. The turn up at low pulse height is largely due to Ba K X-rays.

The effect of collimation on the detected pulse spectrum can be seen in Fig. 10. Curve 1 produced by a 1/2 mc source of Co^{60} at several feet shows many degenerate gamma rays produced by back scattering, making the curve rise at low energies. The two gamma rays (1.17 and 1.33 Mev) are clearly resolved however.

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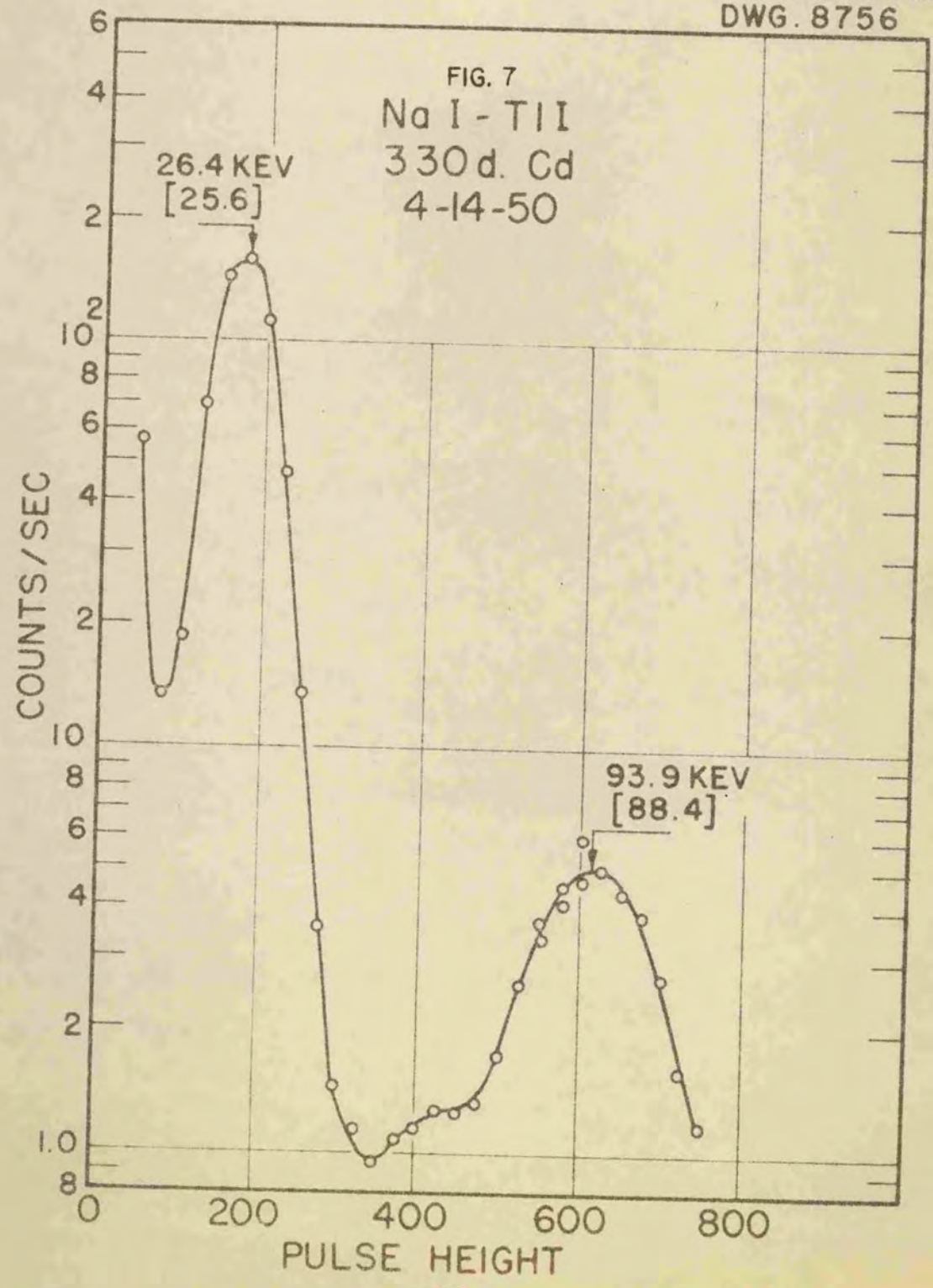

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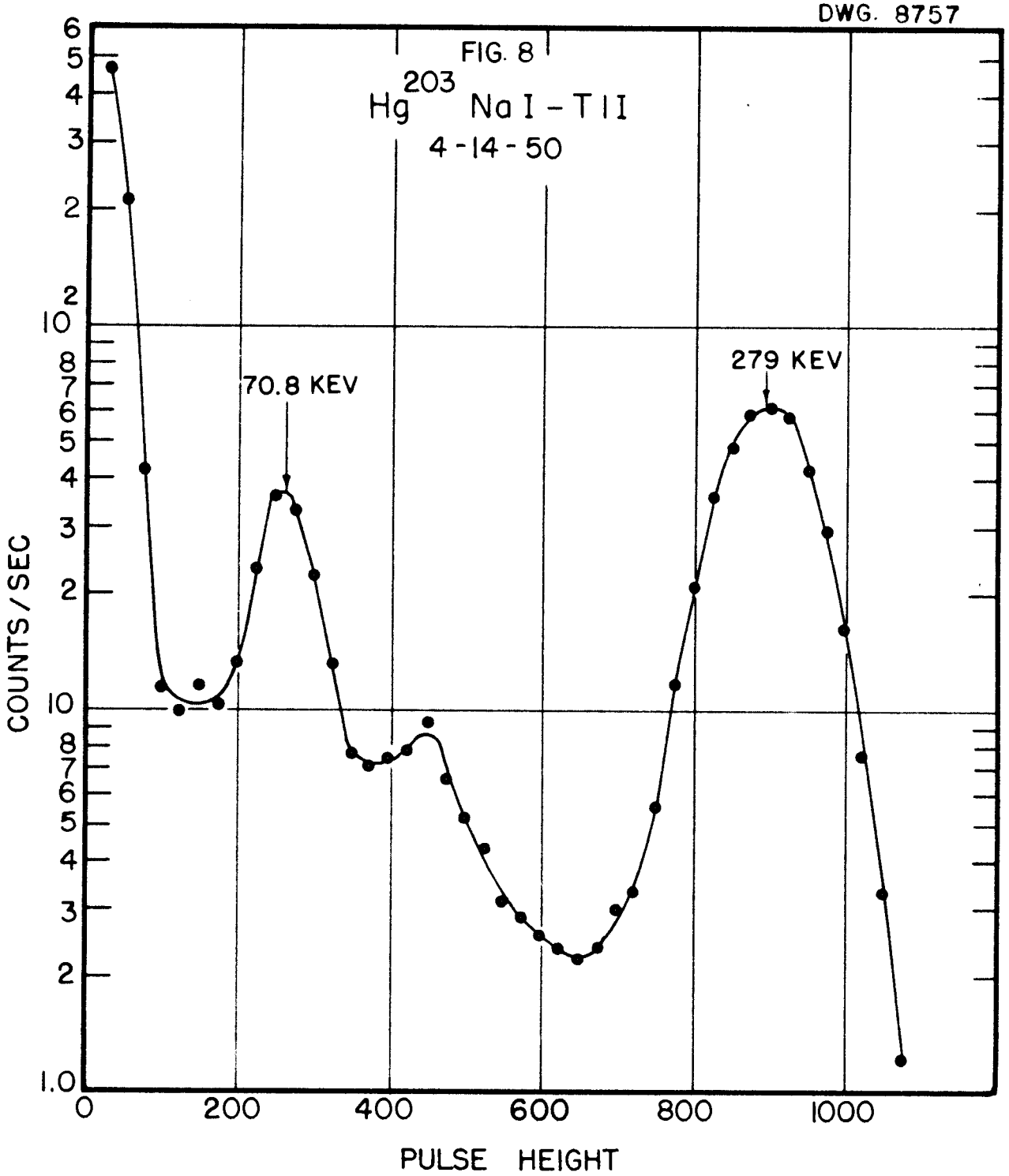

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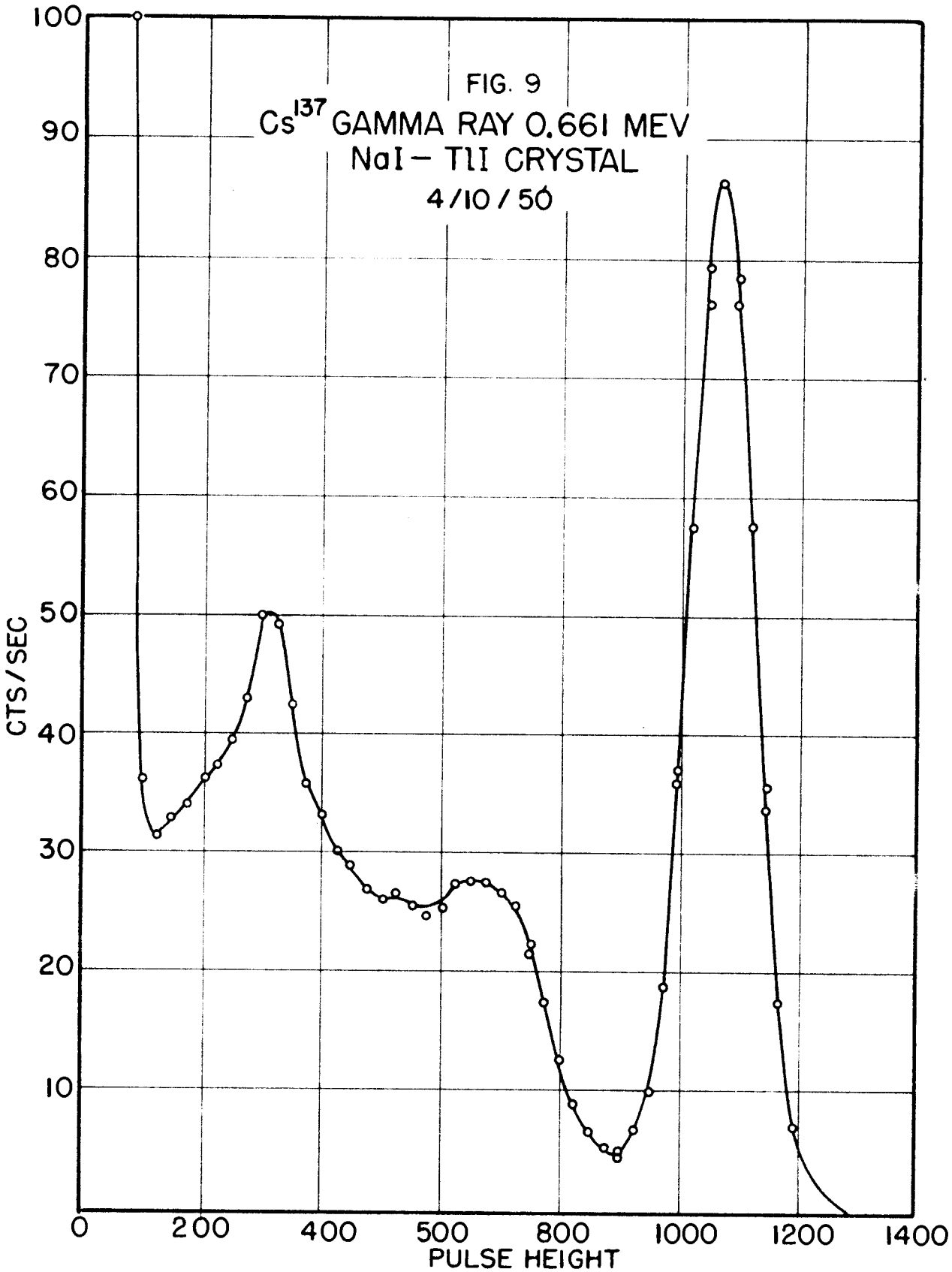

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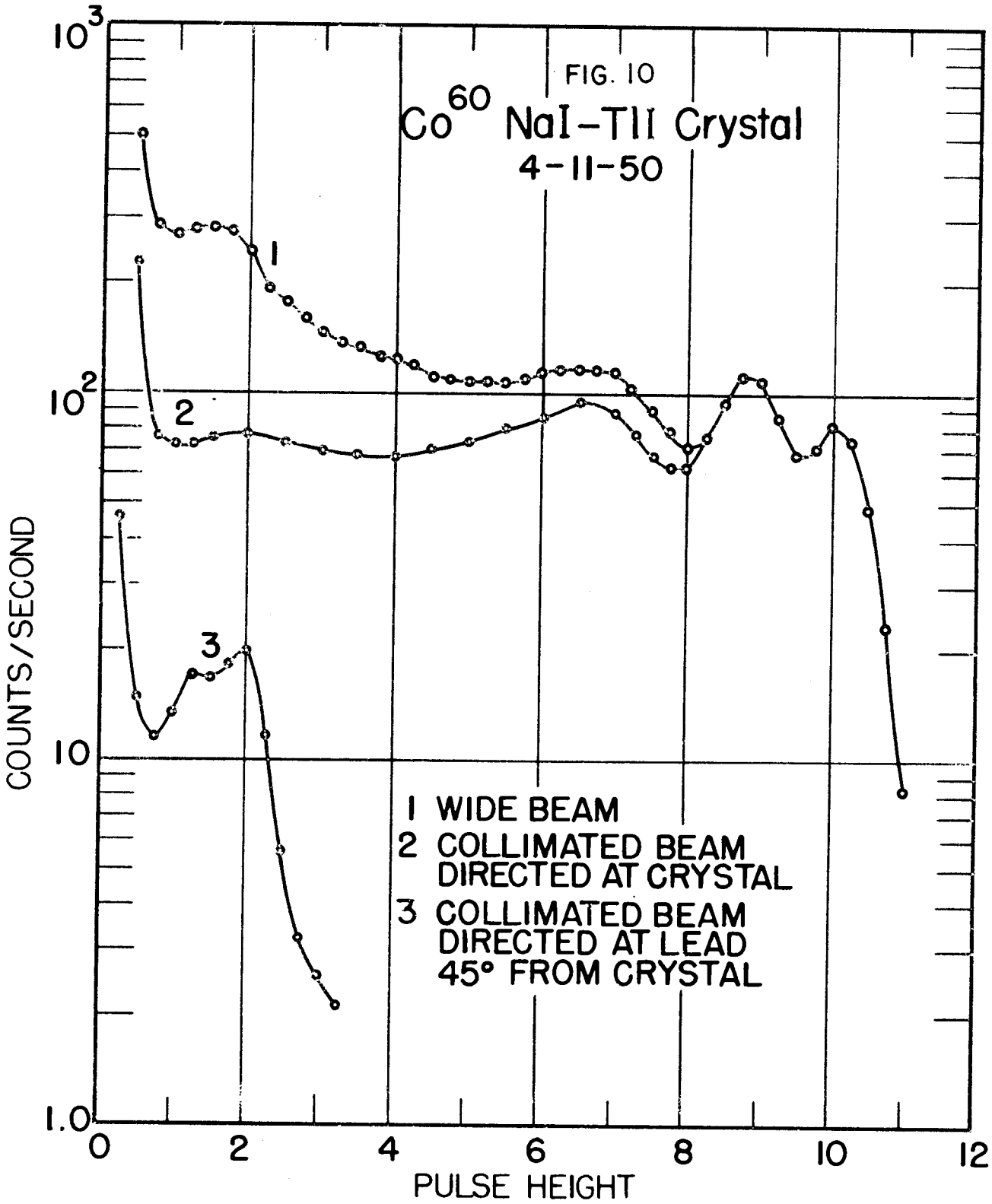

Fig. 11

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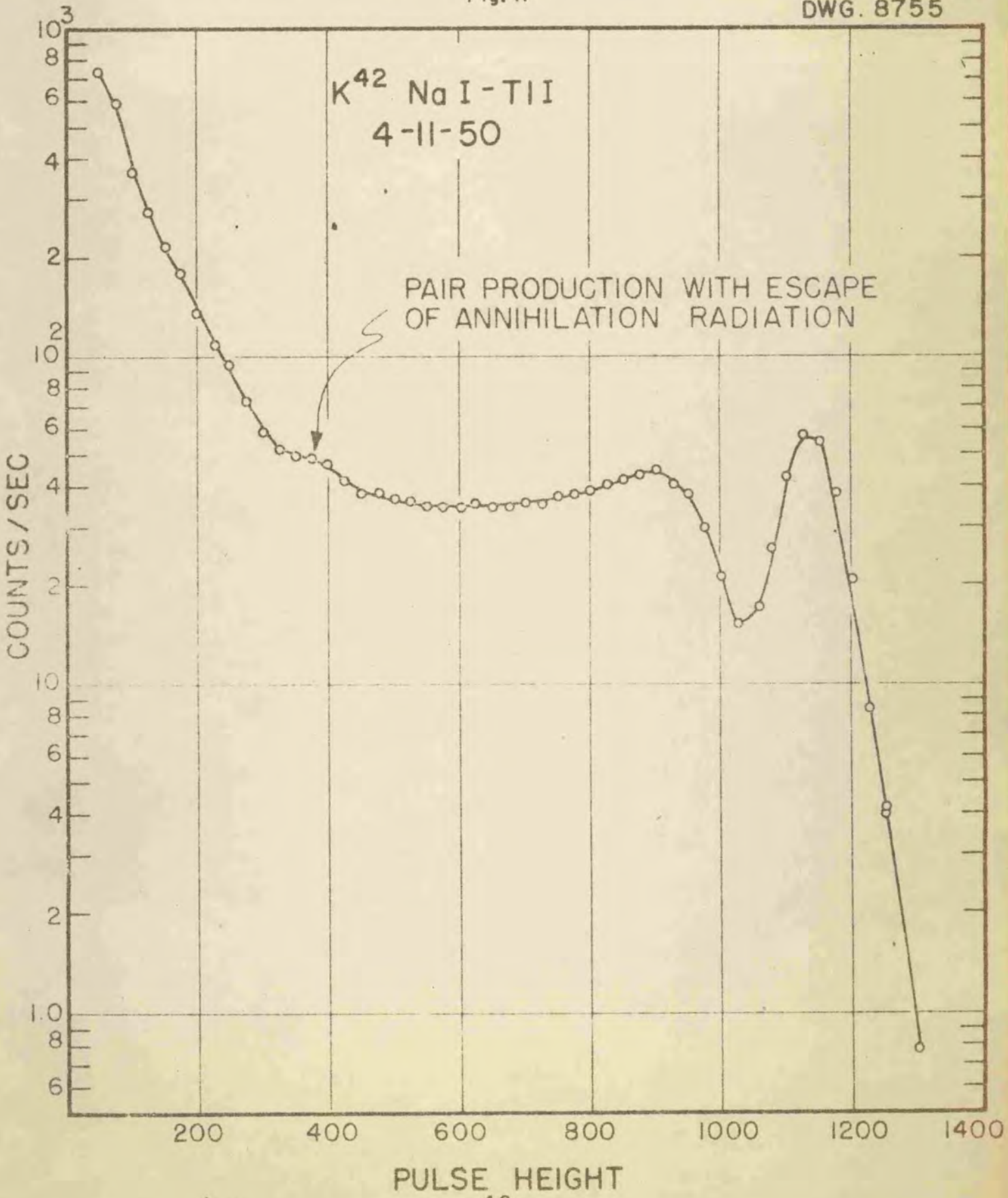

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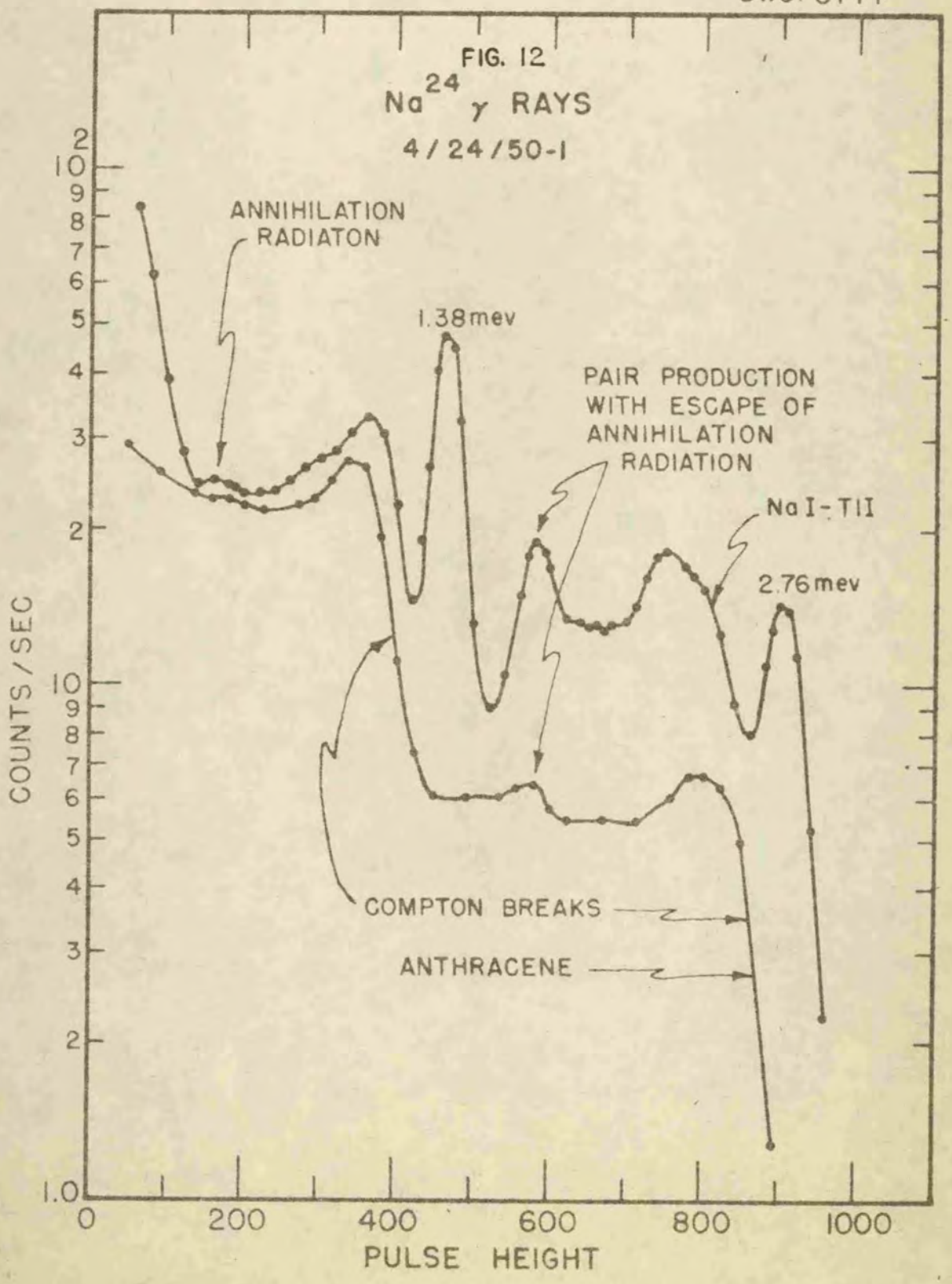

When a 3/8 in. diameter hole 4 in. long in a thick lead block is used to collimate the beam from this source (closer to give same number of counts per second at the peak) the low energy excess is largely removed (curve 2). When a collimated beam is turned so that it misses the crystal and strikes the lead shield wall nearby, the lower curve 3 is obtained. This consists almost entirely of Compton scattered photons. The counting statistics were not sufficient to make the double humped peak shape significant.

A higher energy gamma ray (K^{42} 1.51 Mev) gives a smaller photo peak compared with the Compton response (Fig. 11). The source was at a considerable distance and required a thick absorber to stop the beta rays (3.5 Mev) so that degenerate radiation is fairly strong. At this energy a new process begins to appear with appreciable strength. Pair production within the phosphor is responsible for the peak at 0.5 Mev. The pairs stop in the crystal giving a pulse equal to their total kinetic energy, 1.02 Mev less than the gamma ray energy. The positron annihilates and if the two 0.511 Mev annihilation photons chance to escape, the lower energy peak is produced. If one or both photons are completely or partially detected a pulse lying between this peak and the photoelectron peak results.

Pair production becomes quite prominent for the high energy gamma ray from Na^{24} (2.76 Mev). Figure 12 shows the response both for anthracene and NaI-TlI, to the gamma rays of Na^{24}. The sodium iodide responds in a complicated way to the 2.76 Mev ray. The peak at 1.7 Mev is the response to the pairs when the annihilation radiation photons chance to escape completely. The lower energy hump of the broad peak at 2.2-2.4 Mev is produced by the chance complete detection of one annihilation photon with escape of the other. When both photons are absorbed completely the pulse produced falls on the peak produced by the photo effect. The whole region between 1.7 and 2.7 Mev is considerably elevated due to pulses of intermediate size due to partial detection of one or both annihilation protons. Pairs are also produced in the shield by gamma rays that do not reach the crystal; some of the annihilation radiation from these pairs reaches the crystal and produces the peak at 0.51 Mev.

The lower curve in Fig. 12 for the same radiation on an anthracene crystal shows of course only the Compton distribution for the two gamma rays and a very weak pair production peak as would be expected from the low Z elements of the crystal.

As the gamma ray energy increases, the photoelectric process becomes less efficient and the pair production more efficient so that the triple peaked response for a single gamma ray becomes lopsided with the upper energy peak weakest.

Measurements with NaI-TlI Phosphors. Figure 13 is the pulse distribution produced by a polonium-beryllium neutron source. The five curie source was inserted in an 8 in. cubical block of paraffin and the block covered with 1/4 in. of B_4C plastic. The shield was used to prevent activation of the NaI crystal. As can be seen from Fig. 13 only one gamma ray is emitted by the source. From the three peaks this gamma ray energy appears to be 4.44 ± .03 Mev. There appear also several other weak peaks. The peak at 2.24 Mev and the Compton distribution beginning shortly below it are due to the capture gamma ray of hydrogen in the paraffin; the energy agrees well with the 2.23 Mev reported by Chalk River. The next lower peak is that of the nuclear gamma ray of Po and the lowest peak is that from the excited state of Li^7 from the boron reaction. The lower two are very inaccurate due to their crowdedness and being on a steep slope. The calibration for these measurements was obtained from the well known gamma ray of ThC'' at 2.62 Mev. A sample of ordinary thorium was used to obtain this line.

This measurement of the excited state of C^{12} is of some interest and has been sent as a Letter to the *Physical Review* to appear in the July 15 issue. Shortly after this result was obtained, Pringle, Standil and Roulston reported a similar measurement.(5) There is quite a remarkable coincidence here since the same calibration radiation is used as well and their reported energy of 4.40 ± .05 Mev agrees well with ours. They found a weak higher energy gamma ray which we do not confirm. Figure 14 shows the pulse spectrum from 4.4 to 8 Mev. Two very weak peaks exist but are probably due to capture gamma rays from neutron leakage. When part of the boron shield was removed the strong peak at 6.4 Mev on the upper branch of this figure is found; this is the lower pair peak from a gamma ray at 7.4 Mev. The gamma ray appears to be produced by capture in the iron magnetic shield of the spectrometer. No appreciable number of pulses appear above an equivalent energy of 8 Mev.

The excited state of C^{12} has been measured also by measuring the neutron groups emitted in the $Be^9(\alpha,n)C^{12}$ reaction by Bradford and Bennett(6) who obtain 4.44 to 4.46 Mev for the gamma emitting level depending upon the method of calculation used.

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(5) Pringle, R. W., Standil, S., and Rouston, K. I., "The Gamma-Rays from $Be^9(\alpha,n)$," *Phys. Rev.* 78, 627 (1950).

(6) Bradford, C. E. and Bennett, W. E., "Neutron Groups from $Be^9(\alpha,n)C^{12}$," *Phys. Rev.* 78, 302 (1950).

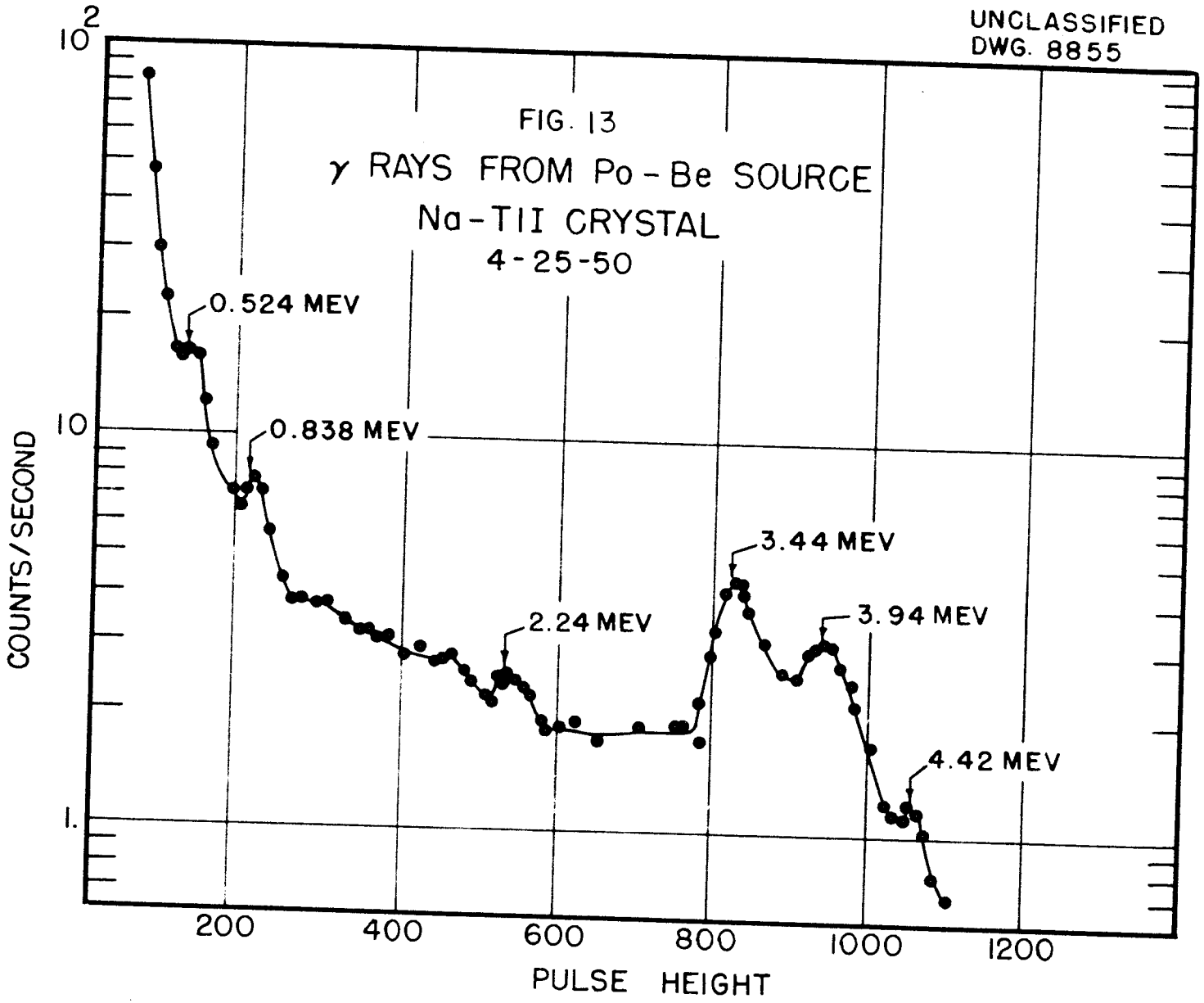
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FIG. 13
γ RAYS FROM Po-Be SOURCE
Na-TII CRYSTAL
4-25-50
0.524 MEV
0.838 MEV
2.24 MEV
3.44 MEV
3.94 MEV
4.42 MEV
COUNTS/SECOND
10^2
10
1.
200
400
600
800
1000
1200
PULSE HEIGHT

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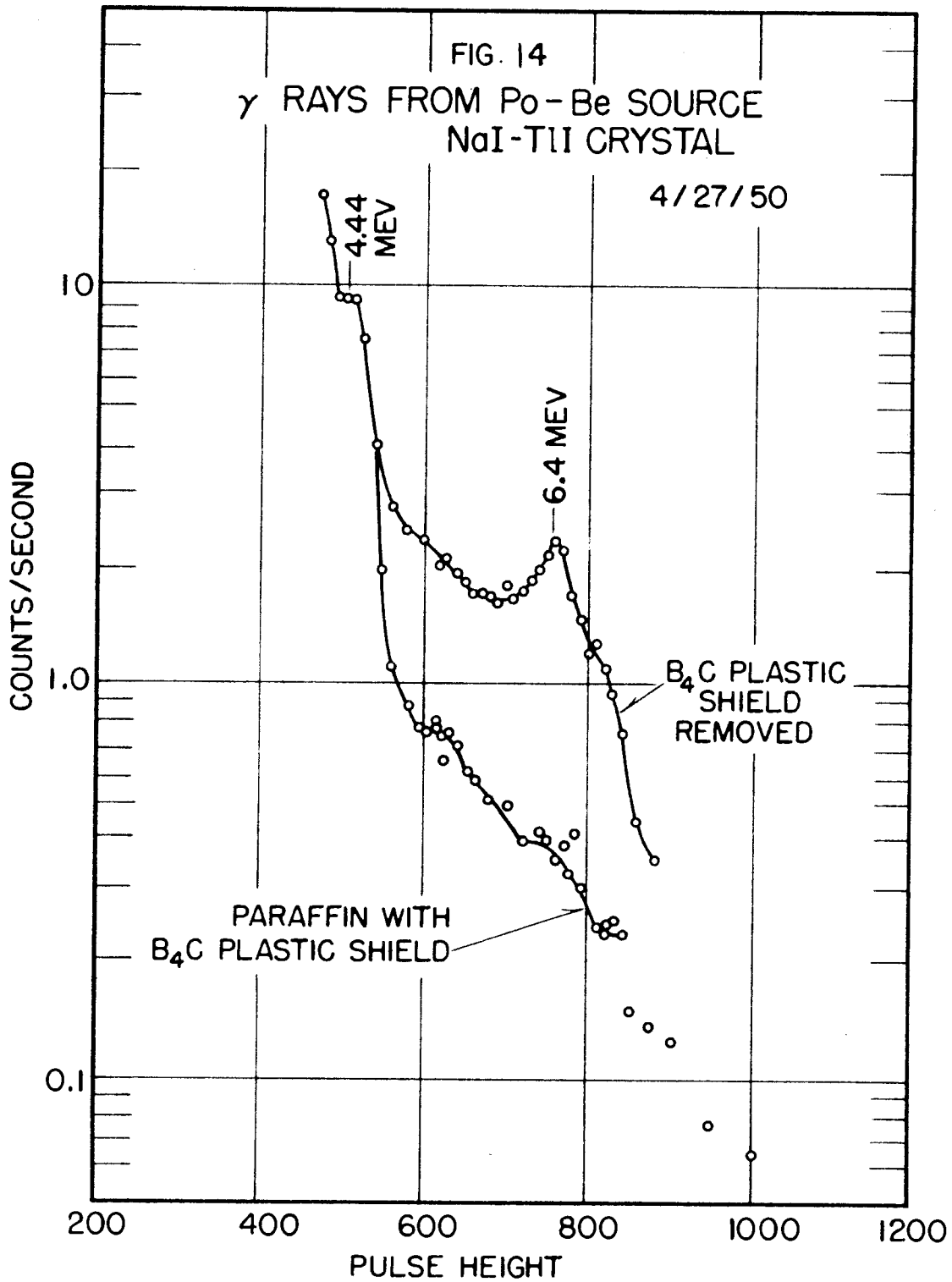

K^{40} Gamma Rays. The gamma rays of K^{40} are of unusual interest so they were rerun with the NaI crystal. They had previously been run on anthracene and reported in the *Physical Review* [Vol. 77, 409 (1950)]. Figure 15 shows the pulse distribution found for ordinary KCl. By careful comparison with the gamma rays of K^{42}, Na^{24} and Zn^{65} the gamma ray of K^{40} seems to be 1.462 ± 0.01 Mev. Careful examination of the curve in the low energy region discloses a pair of weak and overlapping peaks. As in the case of K^{42} which is near in energy, a peak (somewhat weaker and lower in energy in this case) is to be expected from pair production. After an appropriate size and shape of peak is substracted, a peak about 0.2 counts per second high remains at 0.5 Mev. This seems to be due to annihilation radiation and is probably all due to pairs produced outside the phosphor as in the case of Na^{24} (Fig. 12).

If one assumes this peak is entirely due to positrons emitted by K^{40} by transition to the ground state of A^{40}, one obtains an upper limit for the occurrence of this process. By using appropriate values of the efficiency it is found that not more than two positrons are emitted for 10^5 beta rays from the K^{40} - Ca^{40} transition.

From our previous work(7) the beta ray transition has been shown to have the unique third forbidden shape and a maximum energy of 1.36 ± 0.05 Mev. This has since been confirmed by Alburger(8) who gets 1.36 ± .03 Mev and the same shape. The shape combined with the known spin change of four units shows that the transition is parity allowed. The mass difference between the ground states (neutral atoms) of Ca^{40} and A^{40} have been measured by several groups. Sailor(9) finds 0.27 ± 0.21 millimass units while Roberts and Nier(10) get a difference of 0.32 ± 0.08 millimass units, both finding Ca^{40} heavier.

Combining these with our gamma ray measurement the decay scheme shown in Fig. 16 results. The absence of any considerable amount of positron transitions to the ground stage of A^{40} with 640 Kev of kinetic energy available makes it extremely improbable that there are any K captures to the ground state of A^{40}.

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(7) Bell, P. R., Weaver, B., and Cassidy, J. M., "The Beta-Rays of K^{40}," *Phys. Rev.* 77, 399 (1950).

(8) Alburger, D. E., "Beta-Ray Spectrum of K^{40}," *Phys. Rev.* 78, 629 (1950).

(9) Sailor, V. L., "Energy Levels in Ca^{41} and the Mass Difference Between A^{40} and Ca^{40}," *Phys. Rev.* 75, 1836 (1949).

(10) Roberts, T. R. and Nier, A. O., "The Ca^{40} - A^{40} Mass Difference and the Radioacity of K^{40}," *Amer. Phys. Soc. Bull.* V 25, No. 3, p. 7 (1950).

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Fig. 15

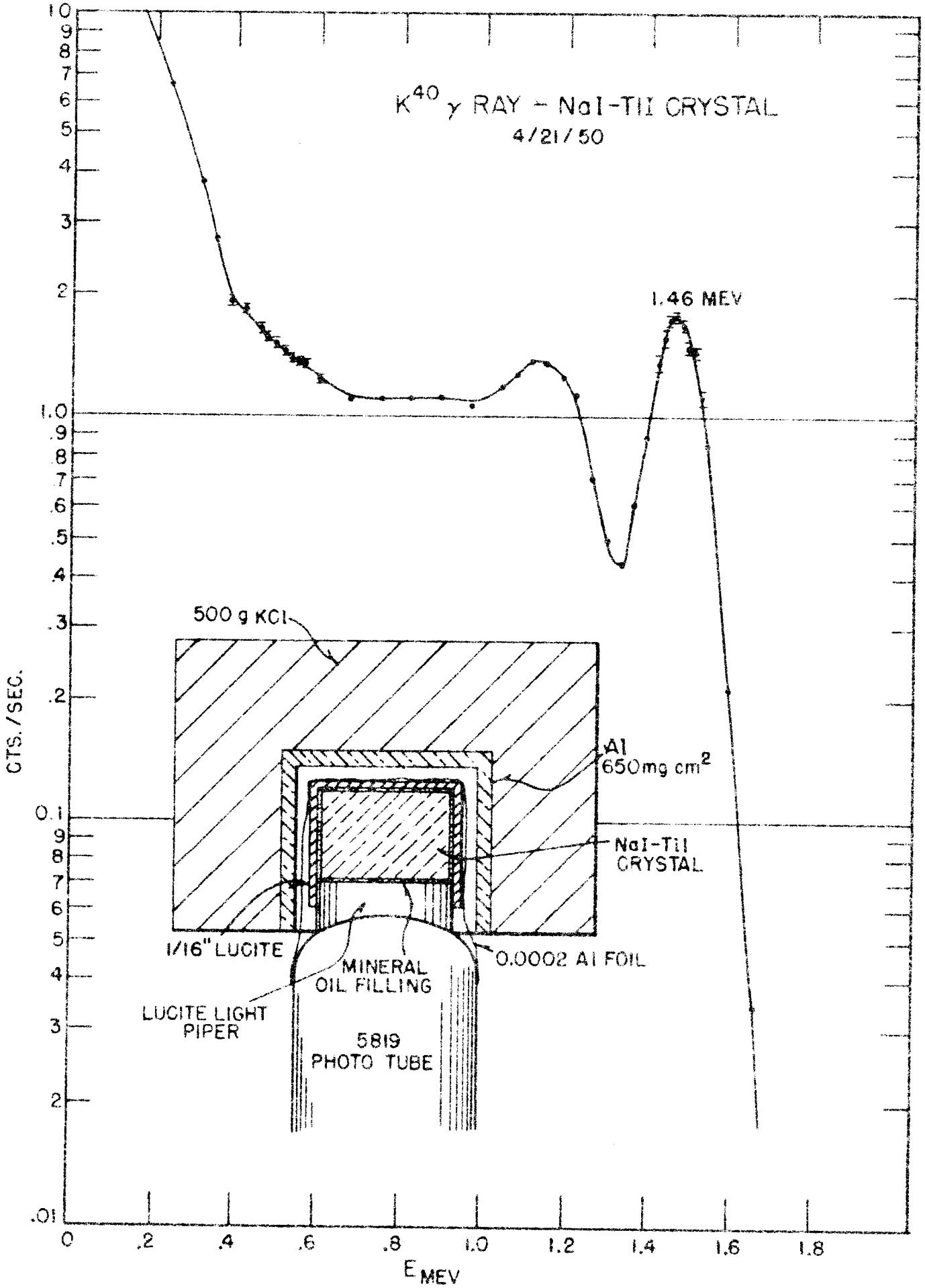

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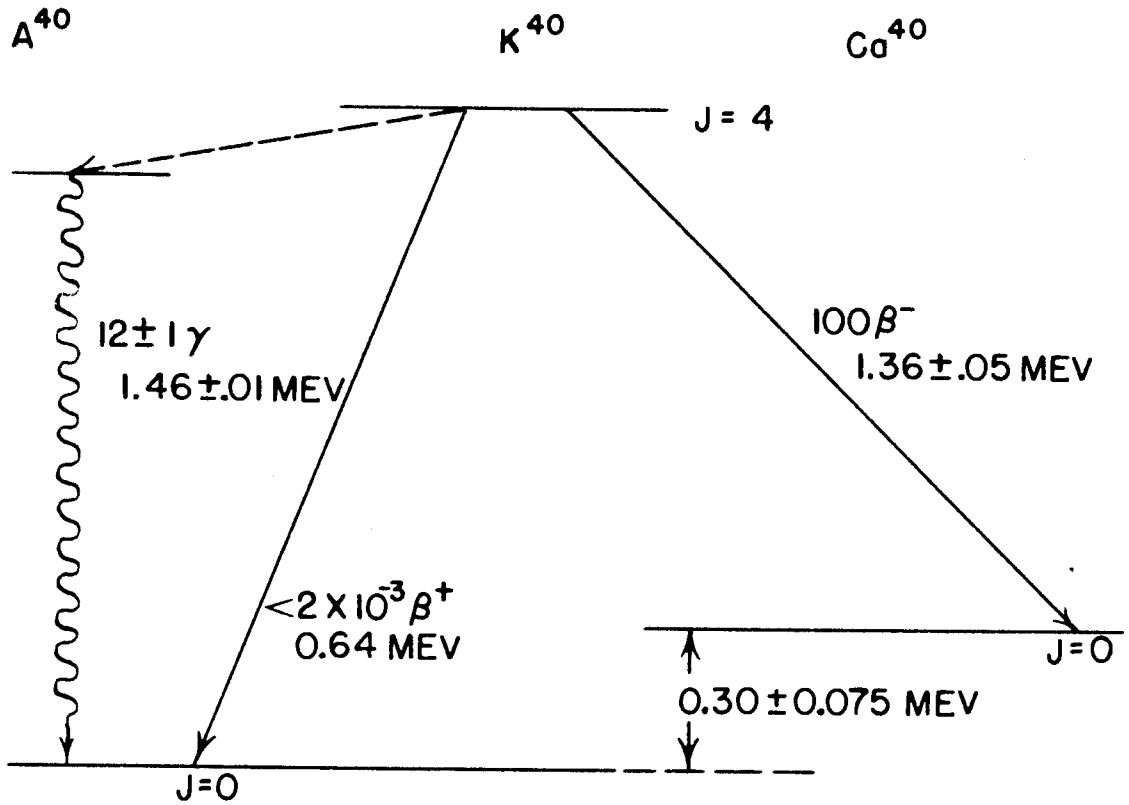
Fig. 16



It is somewhat surprising to find so few positrons since the degree of forbiddenness was expected to be the same as for the beta ray.

Activities in the Rare Earths. An attempt was made to find gamma ray activities among the rare earths. The reported activity of lanthanum[11] was found but the two prominent gamma rays at 1.0 and 0.54 Mev correspond moderately well with the two prominent lines in the spectrum produced by a carnotite sample which presumably contained largely the uranium series in equilibrium (Fig. 17). The two peaks similar to the lanthanum peaks occur at 0.63 and 1.2 Mev. The energies are sufficiently different that they are probably not identical. The extremely pure lanthanum was produced by D. H. Harris in the Chemistry Division.

A ten gram sample of Nd_2O_3 produced by Spedding and five grams of praseodymium nitrate (City Chemical Company) were run and no high energy gamma rays were found in either sample. A large sample (92 g) of CeO_2 produced by Harris was measured and a very weak complex spectrum was found. This spectrum coincides with that of thorium. Figure 18 shows both curves. The peak near 1 Mev does not appear in the cerium curve probably as an accident of the spacing of the points. The characteristic 2.62 Mev triad of peaks is conclusive evidence. Probably there is no gamma radiation from cerium above 100 Kev. Samples of several other rare earths are on hand and are being measured.

Annihilation of Fast Positrons. The ability of the scintillation spectrometer to measure a weak high energy gamma ray in the presence of a strong low energy one makes possible the measurement of the annihilation of fast positrons. The probability of annihilation of fast positrons is quite low so that a large number of 0.51 Mev quanta are found for every one of higher energy. Part of the fast annihilation spectrum lies below 0.51 Mev and is hidden. Copper 64 is the best positron emitter available to us and its use is limited by the presence of a weak nuclear gamma ray at 1.35 Mev.[12] Figure 19 shows the spectrum obtained with samples of Cu^{64} enclosed in a positron absorber of lucite and of lead. The nuclear gamma ray is quite clear. We find 1.33 ± 0.03 Mev for the energy of this gamma ray.

The region between the Compton break for the gamma ray and the foot of the 0.51 Mev annihilation peak is filled by a pulse distribution that seems to

(11) Pringle, R. W., Standil, S., and Roulston, K. I., "The Natural Activity of Lanthanum," *Phys. Rev.* 78, 303 (1950).

(12) Deutsch, M., "Gamma-Rays from Cu^{64}, Annihilation of Swift Positrons, and Experiments on Orbital-Electron Capture," *Phys. Rev.* 72, 729 (1947).

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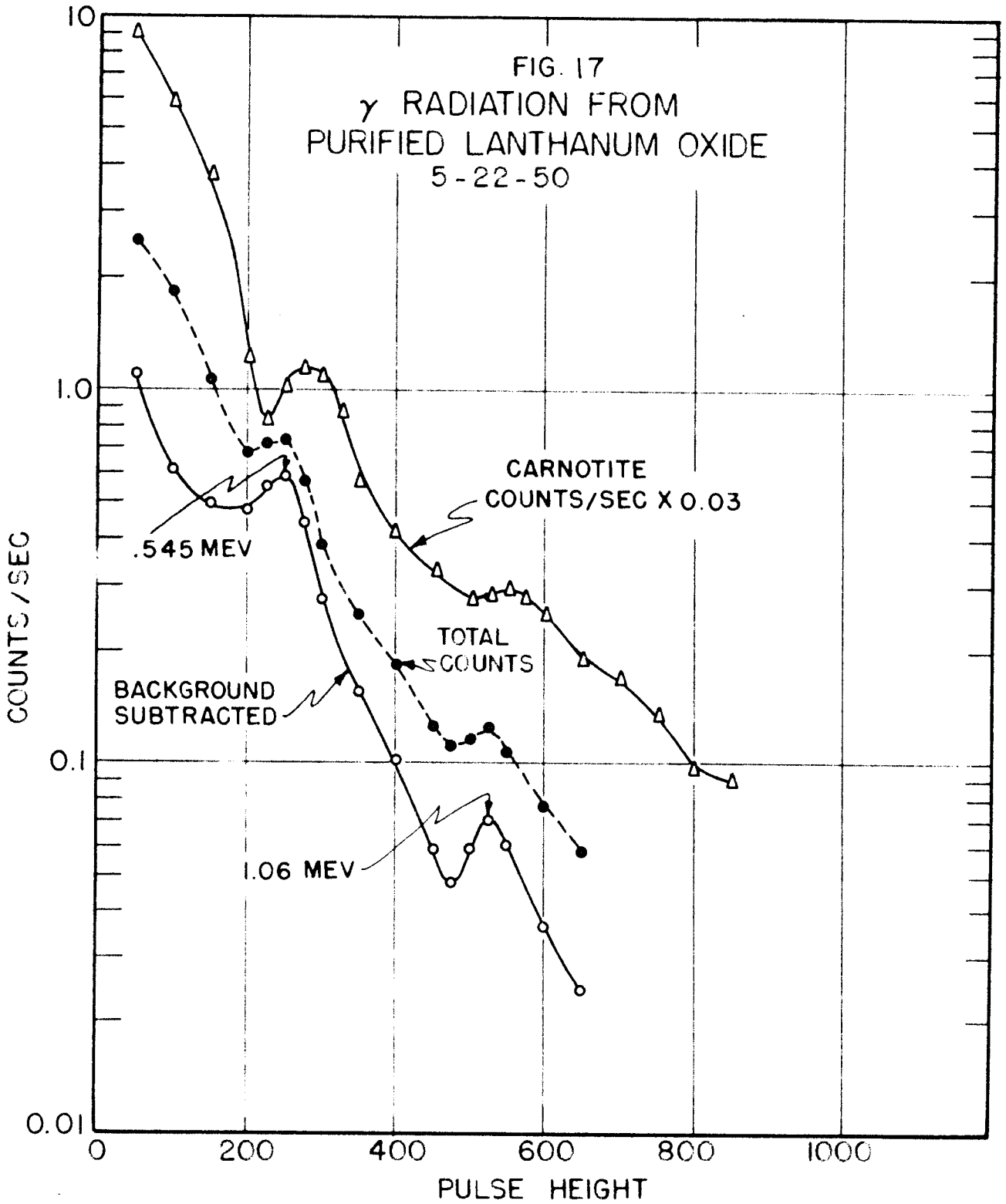

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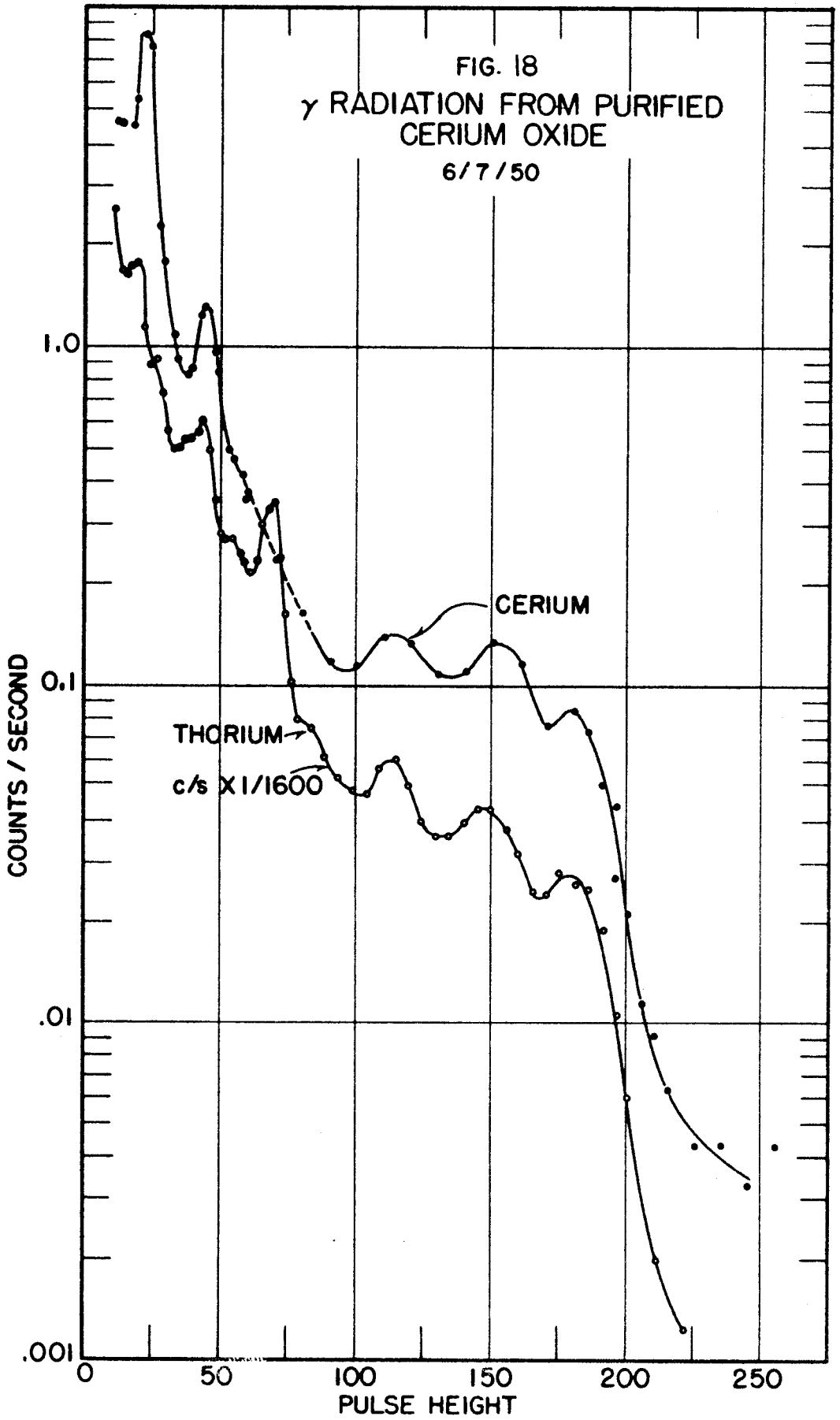

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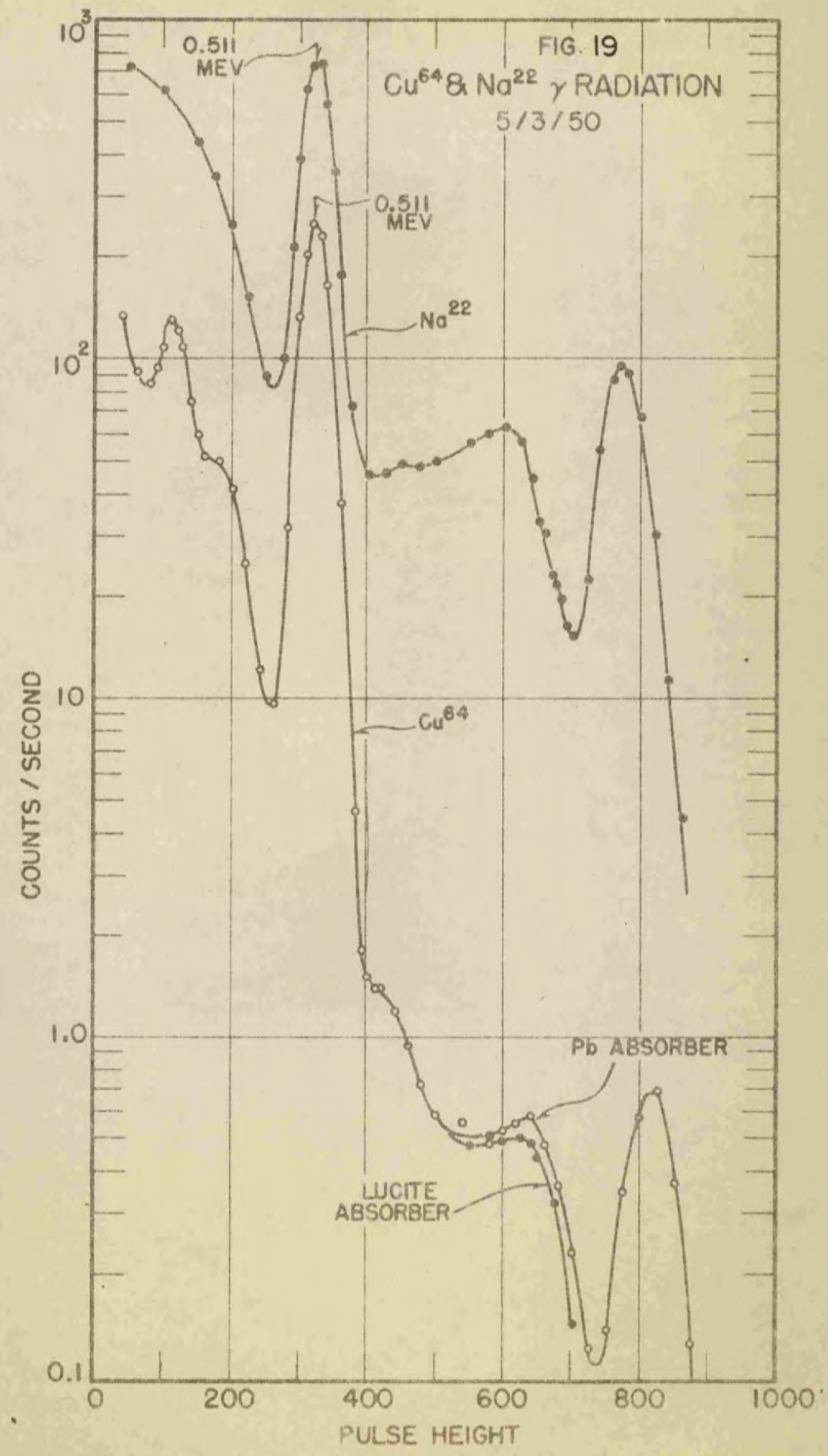

be due to a gamma ray continuum such as would be given by fast annihilation. Also shown in Fig. 19 is the spectrum given by Na^{22}. This substance emits positrons followed by a gamma ray of 1.277 Mev in cascade. The weak effect of fast annihilation cannot be seen on this curve but the shape of the gamma ray response is nearly that which should be found for the copper gamma ray if no fast annihilation were present.

The curve with the lead absorber shows a slight peak near 1.0 Mev. It is unfortunate that the peak of the Compton curve of the 1.35 Mev gamma ray is also almost at this same place, but the curves for the lead and lucite absorbers seem to be significantly different. Single quantum annihiliation of the positrons would be highly Z dependent and should give a broad peak near this energy. Further work on fast annihilation is under way with the source shielded from the detector so that the nuclear gamma ray is suppressed.

Temperature Dependence of Scintillation Pulses in Anthracene (J. E. Francis). The temperature dependence of the size of the pulses from an anthracene crystal has been investigated using a single channel analyzer. In order to eliminate any effects from the cooling of the phototube, a quartz light piper was placed between the phototube and the crystal, The crystal was cooled with liquid nitrogen and its temperature measured by a thermocouple in contact with the crystal. Figure 20 shows the results obtained with a 1P21 and a 1P28 phototube using first a Cs^{137} source than a Po α source on each tube. The pulse height which is plotted on the graph is the pulse height of the peak in the spectrum for the Po α source and the peak for the conversion of the 630 Kev β-ray for the Cs^{137}. The curves have been normalized to the pulse height for the Po α source on the 1P28 at room temperature. The pulse height is increased approximately thirty-six per cent by cooling to liquid nitrogen temperature.

Figure 21 is the curve obtained when both the 1P28 and the crystal are cooled. When the temperature is lowered rapidly the upper curve is obtained and is in agreement with the results obtained by Kelley and Goodrich. When the tube is cooled slowly the lower curve is obtained.

Figure 22 is the curve obtained when both the 1P21 and the crystal are cooled. The pulse height for the 1P21 is increased approximately 65% at liquid nitrogen temperature over its value at room temperature. Part of this increase is probably due to a change in the transmission characteristics of the envelope. Some spectrographic evidence of this change was obtained by Kelley

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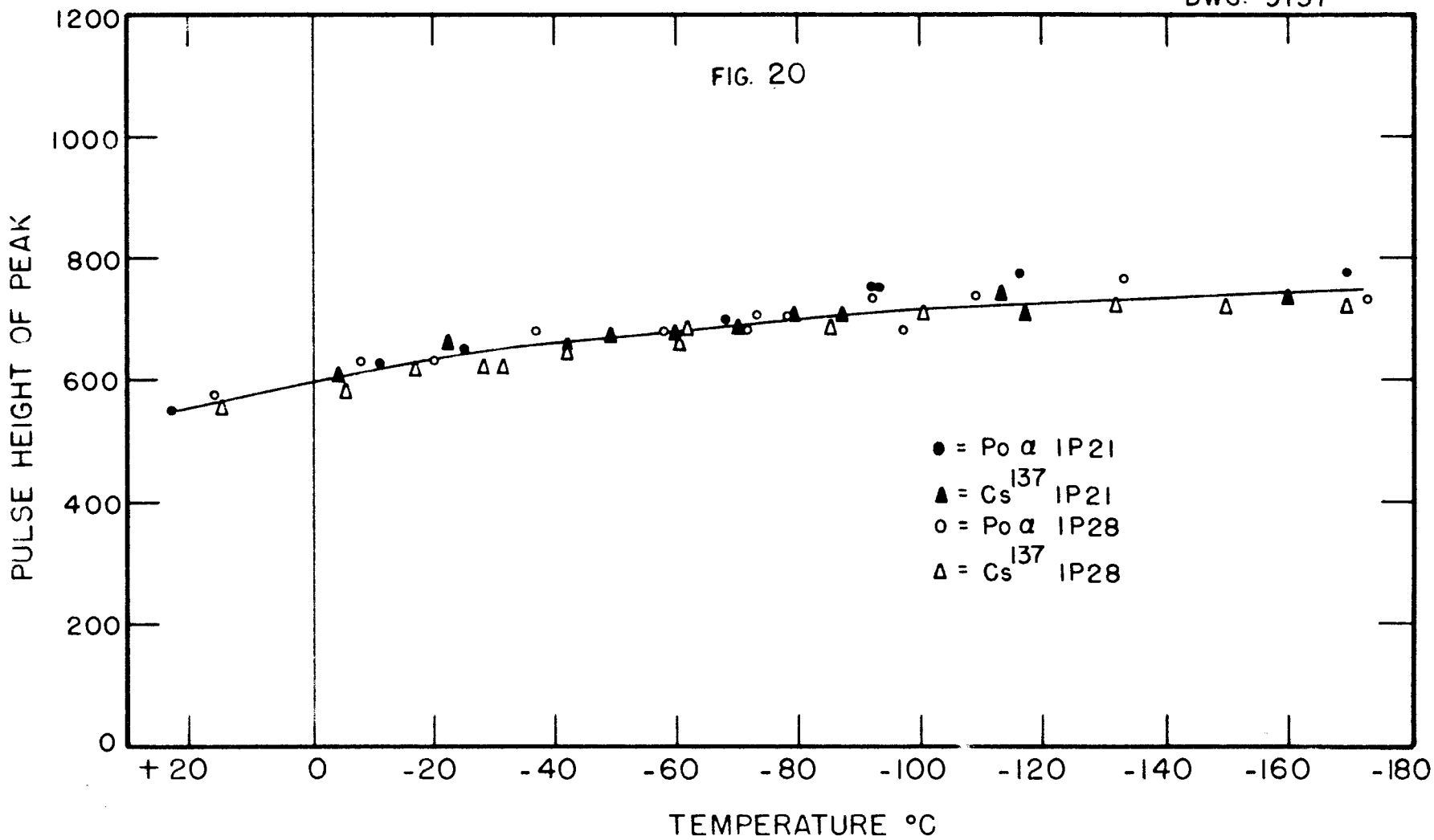

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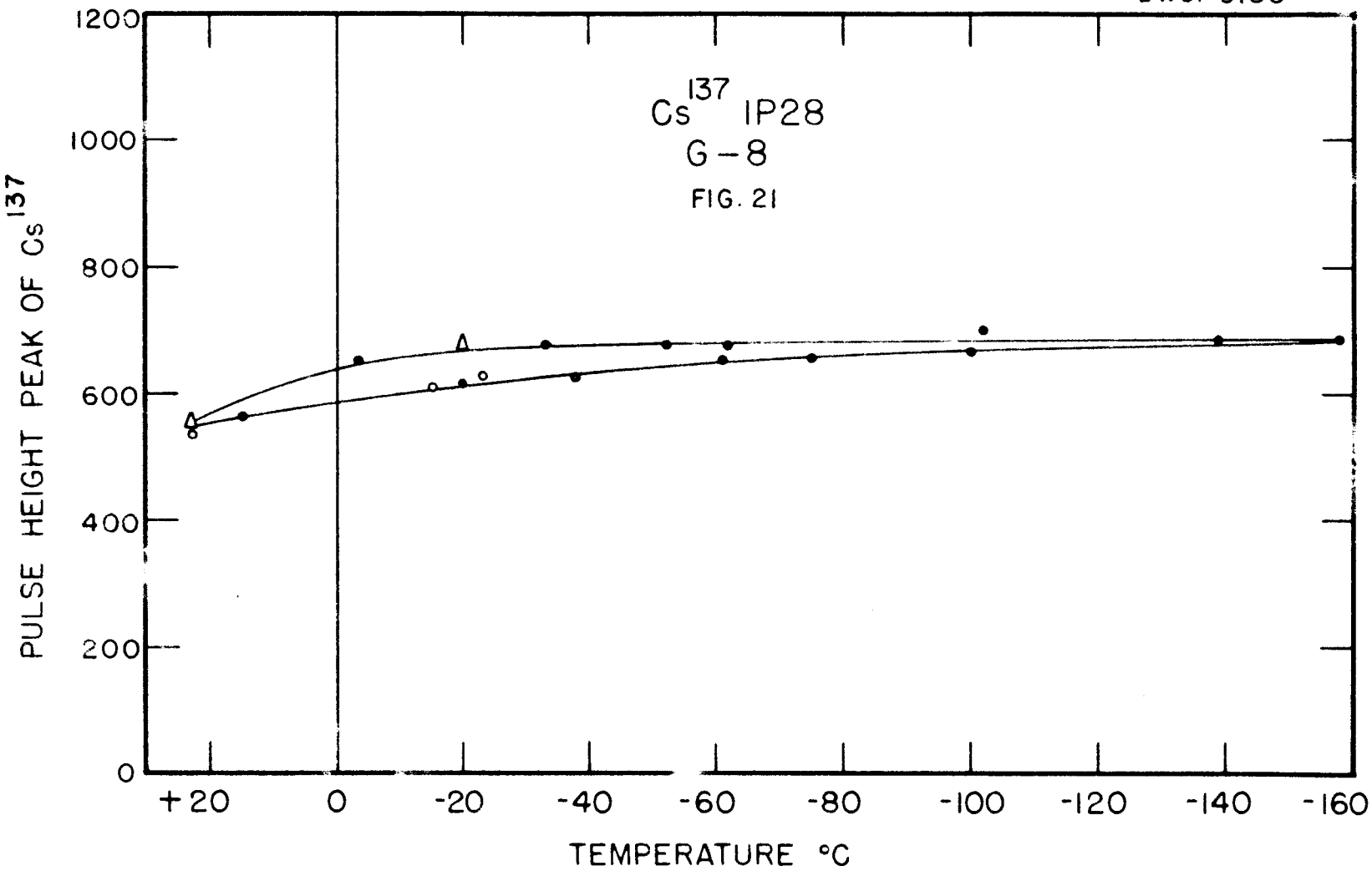

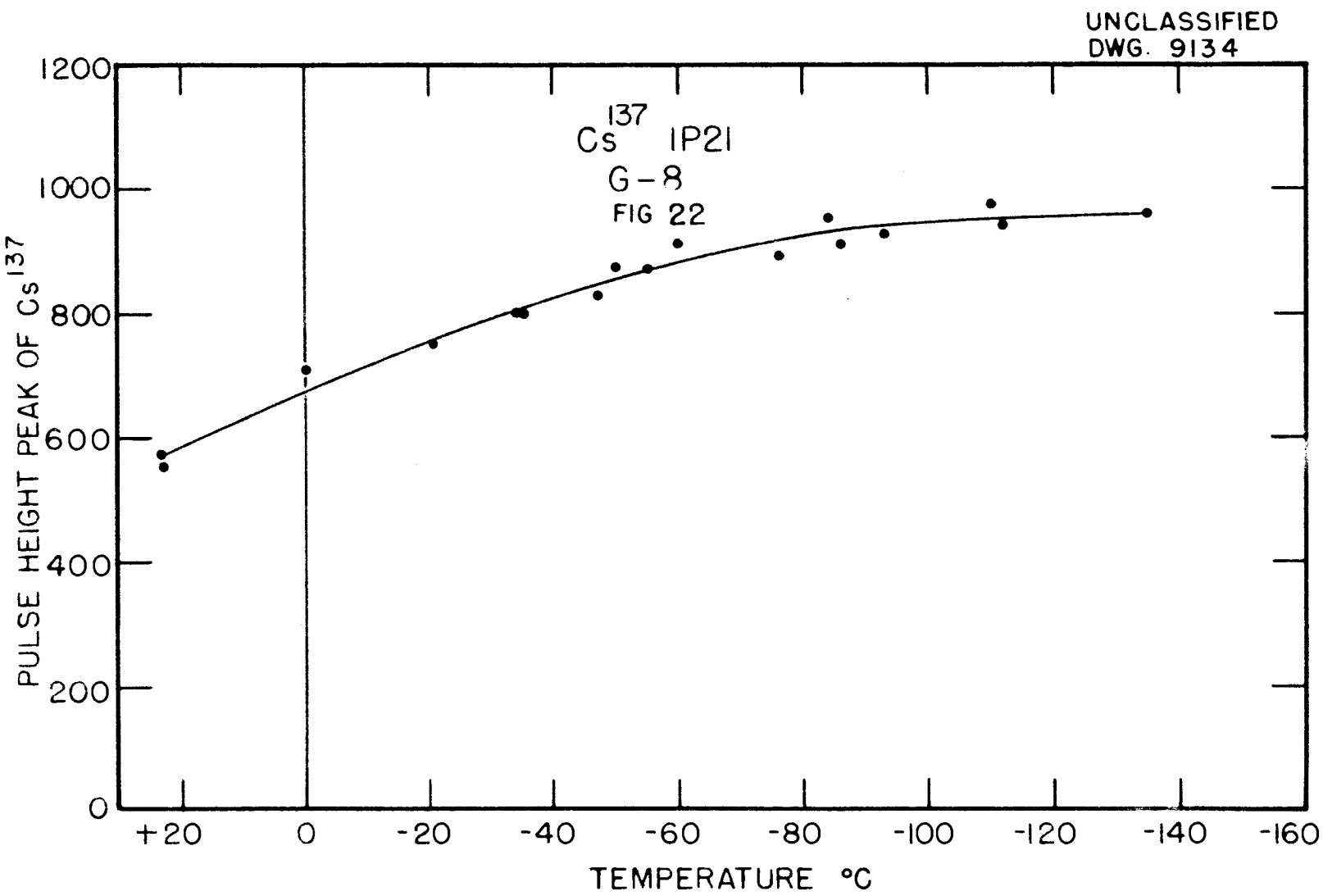
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Cs^{137} 1P21
G-8
FIG 22
PULSE HEIGHT PEAK OF Cs^{137}
1200
1000
800
600
400
200
0
+20
0
-20
-40
-60
-80
-100
-120
-140
-160
TEMPERATURE °C

and Goodrich.[13] The curve for the 1P28 does not show this large increase probably because the transmission characteristics of its envelope are not changed.

PROPORTIONAL COUNTERS

J. E. Francis and J. I. Hopkins

As a preliminary step to measuring coincidences between soft radiations and hard radiations it was desirable to study the characteristics of proportional counters. To do this two Eck-Kreb shells were filled with proportional counter fillings. One was filled with 60 cm of argon and 6 cm of methane; the other was filled with 60 cm of xenon and 6 cm of methane. They have proved satisfactory as proportional counters.

Figure 23 shows the curve obtained for the 8.6 Kev X ray from Zn^{65}. The width at half maximum is approximately 18 percent.

MULTI-CHANNEL ANALYZER

G. G. Kelley

The multi-channel pulse height analyzer described in the last report[14] has been completed and is in operation. Circuits have been included to make the amplifier inoperative during the time a pulse is being measured. Figure 24 is a schematic diagram of the pulse sorter chassis. Window widths may be maintained to better than 2% very easily. Resolving time is between 1.5 and 7 μ-sec depending on the size of a pulse.

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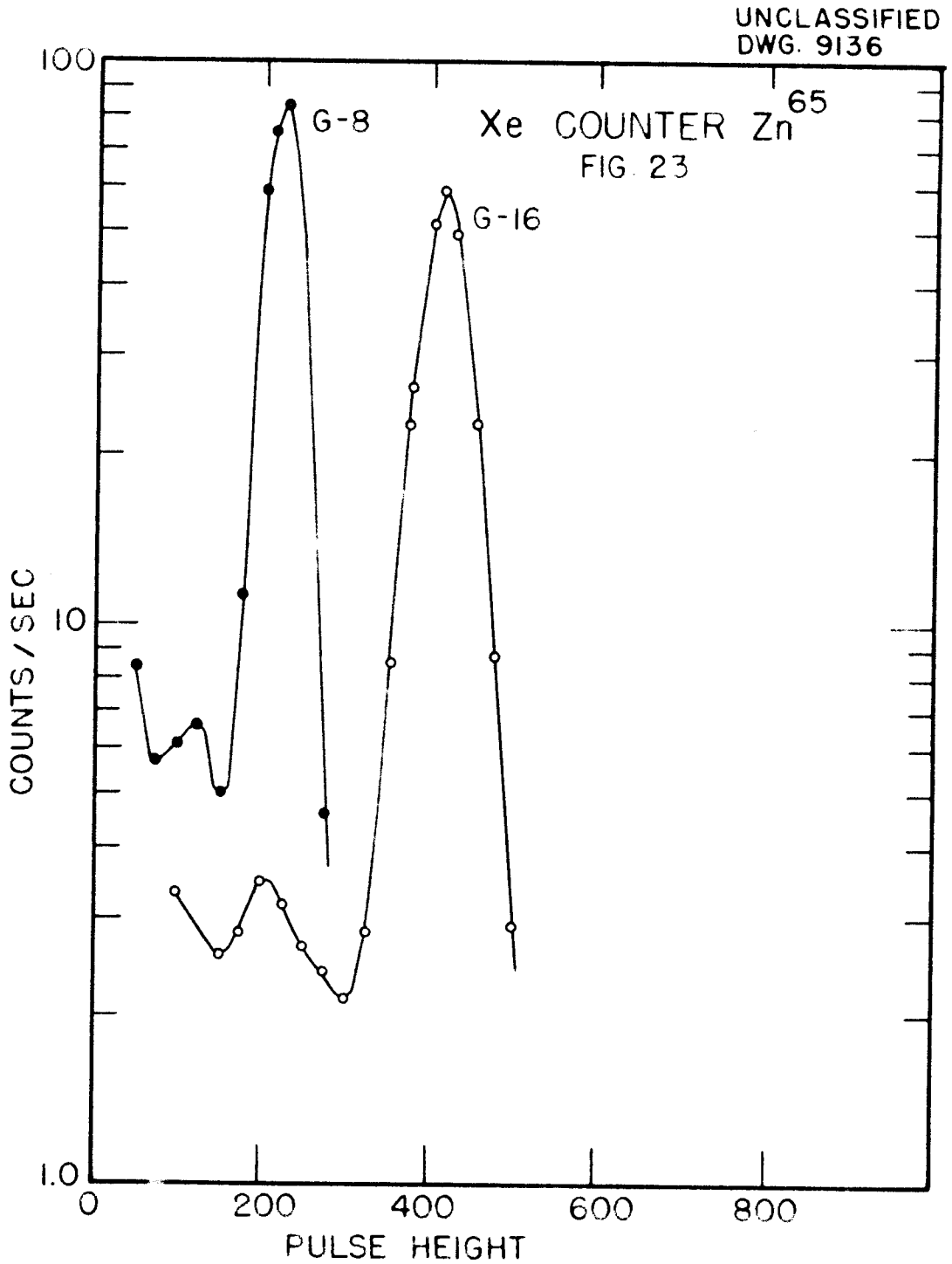
(13) Kelley, G. G. and Goodrich, M., "Temperature Dependence of Scintillation Pulses in Anthracene," *Phys. Rev.* 77, 138 (1950).

(14) Kelley, G. G., "A Multi-Channel Pulse Sorter," *Instrument Research and Development Quarterly Progress Report for Period Ending April 15, 1950*, ORNL 714, 29 (June 19, 1950).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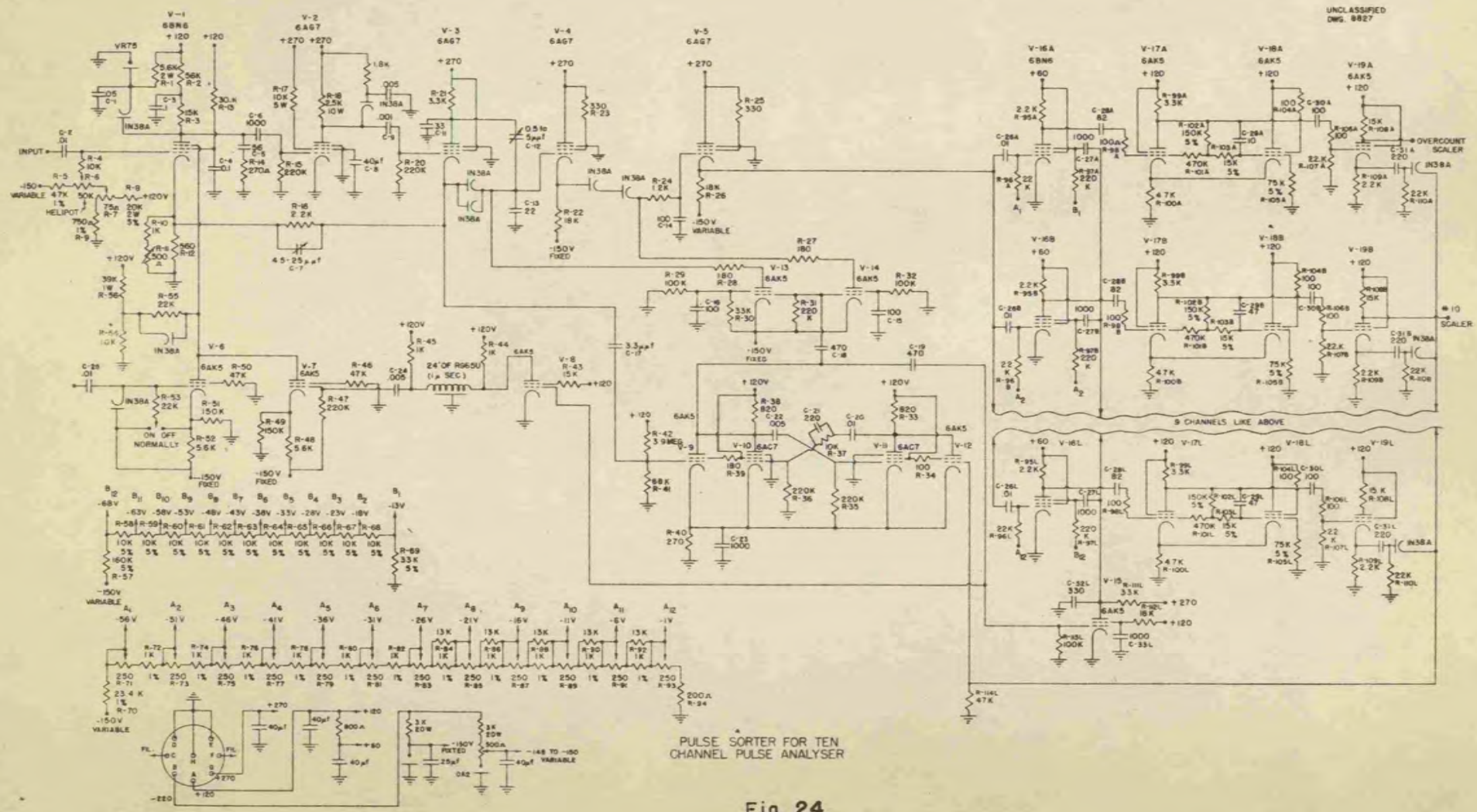
Xe COUNTER Zn^{65}
FIG. 23
G-8
G-16
100
10
1.0
COUNTS / SEC
0
200
400
600
800
PULSE HEIGHT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INPUT
OVERCOUNT SCALER
10 SCALER
9 CHANNELS LIKE ABOVE
PULSE SORTER FOR TEN
CHANNEL PULSE ANALYSER

Fig. 24