ANL-4828

Argonne National Laboratory

QUARTERLY REPORT

MARCH, APRIL AND MAY, 1952

INSTRUMENT RESEARCH AND DEVELOPMENT DIVISION

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ANL-4828
Instrumentation

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INSTRUMENT RESEARCH AND DEVELOPMENT DIVISION QUARTERLY REPORT MARCH, APRIL AND MAY, 1952

F. R. Shonka, Division Director

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QUARTERLY PROGRESS REPORT FOR MARCH, APRIL AND MAY, 1952

Instrument Research and Development

Francis R. Shonka, Director

THE AVERAGE ENERGY TO MAKE AN ION PAIR IN VARIOUS GASES BY ALPHA PARTICLES FROM POLONIUM - William P. Jesse

As previously reported, the experimental fact has been established that the addition of very small amounts of argon to pure helium or neon greatly increases the ionization observed under alpha particle bombardment. According to a suggestion by Dr. Roland E. Meyerott, a tenable explanation is that this increase results from a discharge of the metastable states in helium (or neon) when an excited atom of helium strikes an argon atom. In the process an argon atom is ionized, and a pair of ions is collected in the chamber. Thus, for helium we have,

$$He^* + A \longrightarrow He + A^+ + e^-$$

Any additional energy imparted by the metastable helium atom He* to the argon atom A, above that energy to produce an ion pair, is carried off as kinetic energy in the ejected electron e^-.

During the past few months a number of experiments have been devised in an attempt to prove or disprove such an hypothesis and to gather more information as to the behavior of the gas mixtures in question.

A typical curve representing the result of successive additions of argon to helium is shown in Fig. 1. On the ordinate axis is plotted the number of ion pairs collected per alpha particle, while the abscissa represents the concentration of argon in the gas mixture in parts per 10,000. The data for three alpha runs are plotted on the graph.

The curve is seen to resemble very closely those for the growth of radioactive substances. In fact, the curve actually drawn on the plot is that represented by the empirical expression

$$I = A(1 - e^{-\mu t}) + C$$

Here I = number of ion pairs collected per alpha particle;
t = concentration of argon in parts per 10,000.
A, C, and μ are constants which, to fit the experimental data, have been given the values

$\mu = 0.538$, $A = 48{,}400$, $C = 128{,}400$

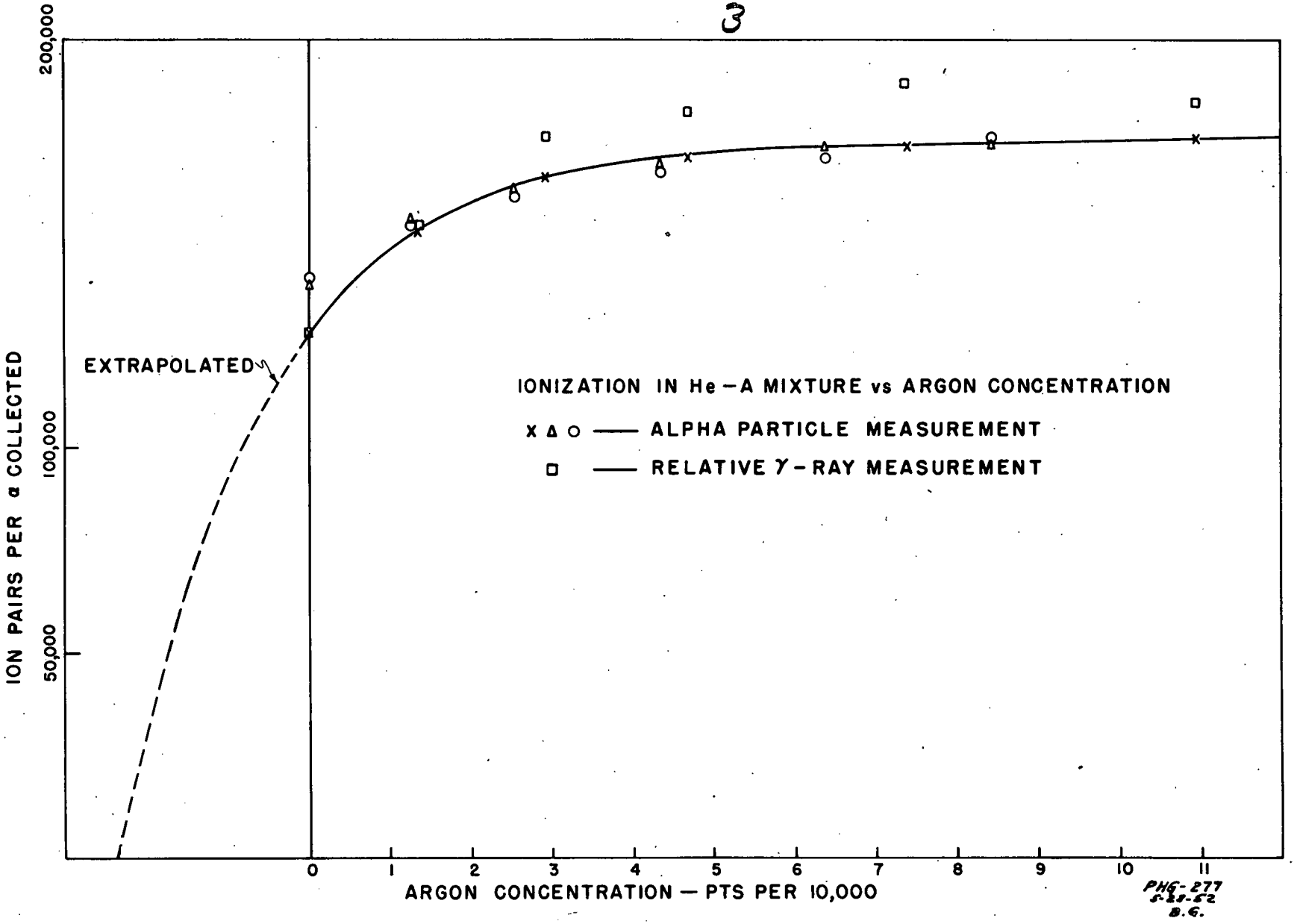
3
200,000
100,000
50,000
ION PAIRS PER α COLLECTED
EXTRAPOLATED
IONIZATION IN He – A MIXTURE vs ARGON CONCENTRATION
X Δ O —— ALPHA PARTICLE MEASUREMENT
□ —— RELATIVE γ – RAY MEASUREMENT
0
1
2
3
4
5
6
7
8
9
10
11
ARGON CONCENTRATION — PTS PER 10,000
PHC-277
8-29-62
B.G.

Figure 1

It should be noted that for zero argon concentration the runs ⊙ and △ give higher values than the run marked X. This seems reasonable, since the first two runs were made with commercially pure helium put into the ion chambers directly from the breaker flasks, while in the last run the gas was further purified by passage over cocoanut charcoal at liquid air temperature. The reduction of impurities in the helium no doubt causes the drop in ionization observed, since the ionization values are quite sensitive to very small impurities in this region. This is shown quite well by the steep slope of the curve near the origin.

The addition of small quantities of argon to neon gives a curve of a very similar nature, though the ionization in this case is somewhat larger throughout. Summarized values for neon and helium plus argon are as follows:

	Ion Pairs per Alpha	W ev/ion pair
Purest helium used	126,900	41.3
Helium + 0.11% argon	176,400	29.7
Purest neon	144,000	36.3
Neon + 0.10% argon	201,300	26.1

It is interesting to note that the values given in the literature for W for helium, i.e., about 30 ev/ion pair, agree very well with the value above for helium saturated with argon as an impurity. Also, the value of W for helium, theoretically calculated by Fano (Phy. Rev., 70, 44 (1946)) to be about 38 ev/ion pair, is in much better agreement with the experimental value found here for very pure helium.

In order to observe whether the increased ionization could be observed for ionizing agents other than alpha particles, a brief run was made, where for each argon concentration the chamber was irradiated by gamma rays from a radium source in a standard position. Drift measurements were made with the source present, and then the background was taken with the source removed. Such measurements do not, of course, give the ionization from single events, as in the case of the alpha particles, but each drift measurement is proportional to the average current produced in the chamber by the gamma rays for a given argon concentration.

The relative ionization currents so derived are plotted as ⊡ on the same plot as the alpha values. The gamma measurement for zero argon concentration was arbitrarily made to coincide with the alpha measurement here, and the succeeding gamma points were put in from the measured ratios. Thus, only the relative values for the gamma points have any significance. Although the data for the gamma rays are not very accurate, it can be seen that a rise in ionization accompanies an increase in the argon concentration, just as in the case for the alpha particles.

A further test of the hypothesis that the increased ionization is due to metastable atoms was made by measurements where neon, instead of argon, was introduced into helium. Since the energy of the metastable state in helium is 19.8 ev above the ground state, and the ionization potential of neon is 21.5 ev, there is not enough energy available to ionize the neon atoms when they suffer collision with helium atoms in the metastable state. Hence, in this mixture, there should be no increase in ionization with increasing neon concentration.

No increase was observed by experiment at all comparable to that observed with argon. An increase of a few per cent was sometimes observed, but this was attributed to accumulated impurities in the chamber. The more rapidly the readings were taken after the introduction of neon, the smaller the observed change.

It would seem of interest to try the effect of impurities in argon, the gas which is most commonly used in nuclear experiments. Since the energy of the metastable state in argon is low (11.6 ev), one must search for a contaminant with an ionization potential lower than this. Vapors of the organic liquids benzene, xylene, and toluene would seem most suitable.

PLASTIC SCINTILLATORS - Warren L. Buck, Robert K. Swank and John S. Moenich

During this quarter our work on plastic scintillators has involved mainly an investigation of the dependence of scintillation efficiency upon fluor concentration in several polystyrene solid solutions. In addition, several improvements in the technique of preparing and testing these scintillators have been effected. The information should be of interest to persons desiring to prepare useful plastic scintillators. The investigation has also yielded certain information on the physical processes involved in the scintillations, particularly how excitation energy may be transferred from the solvent (polystyrene) to the dissolved fluor.

In the method of preparation which we are presently using commercial-grade styrene monomer is purified by distillation at 30-35°C and a pressure of 10-13 mm of Hg. The desired amount of organic fluor plus 0.2 % (by weight) of benzoyl peroxide to serve as a polymerization initiator is dissolved in this purified styrene. Twenty ml of the resulting solution is placed in a tightly stoppered Pyrex test tube (20 mm O.D. by 150 mm long) and polymerized by heating in a constant-temperature water bath at 70°C for four days.

The polymerized sample is removed from the test tube (by cracking the glass) and is then machined into the form of a solid cylinder 13/16 in. in diameter and 1/2 in. long. One face of this cylinder is given a high optical polish while the other face is "frosted" by grinding with # 200 emery powder in mineral oil. The sides of the cylinder are allowed to retain the smooth lathe-cut acquired during the machining operation.

For determining the relative scintillation efficiencies we use an RCA-5819 photomultiplier working into a linear pulse amplifier and an integral bias discriminator circuit. Scintillations are excited by the beta particles from a natural uranium foil; these betas have a maximum energy of about 2.3 Mev. Alpha particles and very low energy betas from the uranium are filtered out by a thin polished aluminum reflector between the source and the scintillator. A Lucite "light pipe," 1/4 in. long, separates the scintillator from the window of the photomultiplier tube. The physical arrangement of source, reflector, scintillator, and phototube is carefully duplicated for each measurement.

For each scintillator tested, we determine the value of discriminator bias which gives a certain standard, arbitrarily chosen, counting rate; the over-all gain of the photomultiplier and amplifier are held constant at all times. When this standard counting rate is attained, the system is counting all scintillations produced by beta particles having energies above a certain standard value (about 1 Mev in our standard procedure). The value of discriminator bias which gives the standard counting rate is then taken as a measure of the scintillation efficiency or "pulse height" of the scintillator being tested. We have expressed these values as fractions relative to the value obtained using a high-quality anthracene crystal of approximately the same dimensions. Determinations of the pulse heights produced by the 5.2-Mev alpha particles from Pu^{239} have been made for some of these scintillators by a similar procedure.

Our method does not measure the absolute scintillation efficiency, since for any given type of scintillator the pulse height obtained depends also upon the relation between the spectral distribution of light in the scintillations and the spectral sensitivity of the photomultiplier. However, since the RCA-5819 is probably the most widely used photomultiplier, the results are of practical significance. Also, the question of spectral distribution does not enter in when comparing the efficiencies of different samples of the same type of scintillator. The integrating time of our photomultiplier-amplifier system is of the order of a microsecond while the scintillation decay times for all the plastic scintillators tested are considerably less than a microsecond, so that differences in decay time of the various scintillators have no bearing on our efficiency measurements.

Rather extensive data on the dependence of scintillation efficiency upon fluor concentration have been obtained for polystyrene solid solutions of each of the following organic fluors: (1) trans-stilbene, (2) 1,1′, 4,4′-tetraphenyl-1,3-butadiene, and (3) para-terphenyl. In each case the efficiency increases rapidly with increasing fluor concentration at low concentrations, reaches a maximum at a concentration of the order of 1 %, and then falls off at higher concentrations. Results for the stilbene and the tetraphenylbutadiene solid solutions are shown in Figs. 2 and 3.

The comparatively large scintillation light outputs obtained with fluor concentrations of the order of 1 % or less make it seem most probable

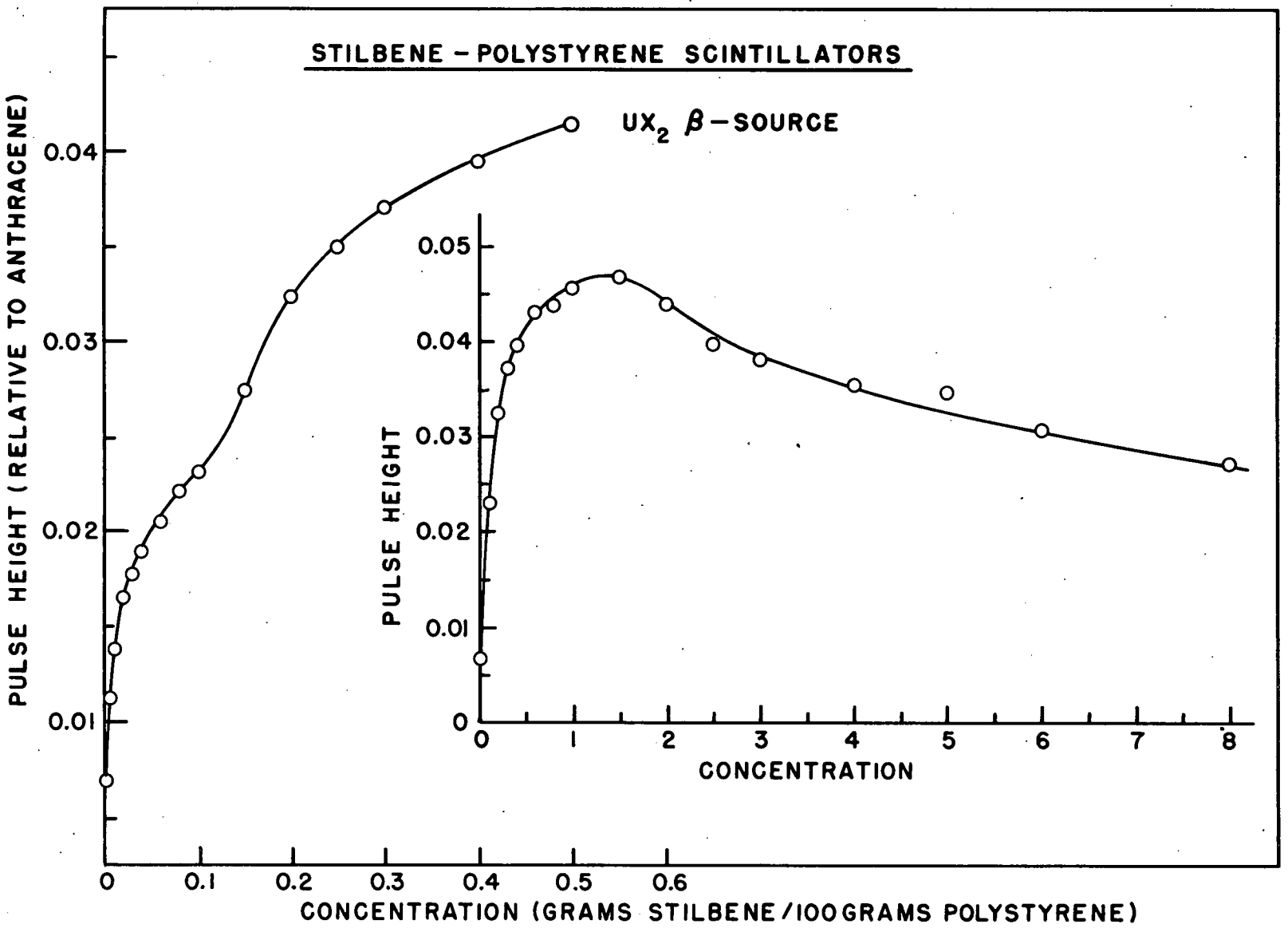

Figure 2

PNG-260
4-25-52
B.G.

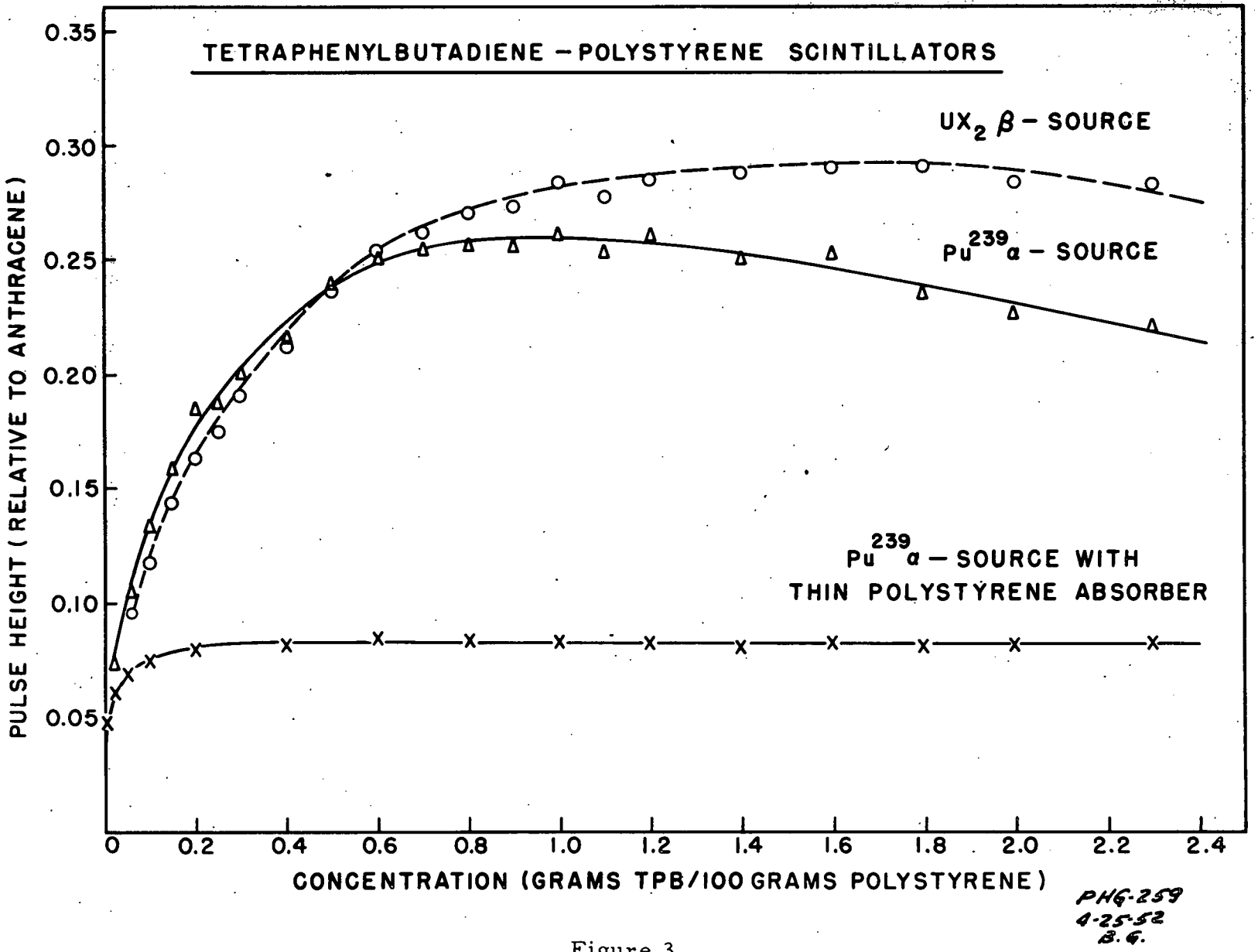
TETRAPHENYLBUTADIENE – POLYSTYRENE SCINTILLATORS
UX2 β – SOURCE
Pu239 α – SOURCE
Pu239 α – SOURCE WITH
THIN POLYSTYRENE ABSORBER
PULSE HEIGHT (RELATIVE TO ANTHRACENE)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
CONCENTRATION (GRAMS TPB/100 GRAMS POLYSTYRENE)
PHG-259
4-25-52
B.G.

Figure 3

that some process is involved here by which excitation energy is transferred from the ploystyrene to the dissolved fluor. For example, a polystyrene solid solution containing only 1.7 % of dissolved tetraphenylbutadiene gives pulse heights (for betas) about 29% as large as those obtained with an anthracene crystal, and it is reported that a pure tetraphenylbutadiene crystal gives pulse heights only about 50% as large as those from anthracene.(1)

The two upper curves in Fig. 3 show pulse height relative to the anthracene crystal as a function of concentration for solid solutions of 1,1',4,4'-tetraphenyl-1,3-butadiene in polystyrene for both beta and alpha particle excitation. The curve for betas shows a peak relative efficiency of about 0.29 at a concentration of about 1.7%, while the curve for alphas shows a peak relative efficiency of about 0.26 at a concentration of about 1.0%. This type of plastic scintillator, which is the best we have obtained to date, has a scintillation decay time of about 8 millimicroseconds and a fluorescence spectrum with a broad peak in the neighborhood of 4600 A, which makes it well suited to the spectral response characteristic of the RCA-5819 photomultiplier.

The lower curve in Fig. 3 was obtained with a thin sheet of pure polystyrene (containing no fluor) approximately 7.5 mils thick interposed between the alpha source and the plastic scintillators. This polystyrene sheet is thick enough to stop the alpha particles yet thin enough to be quite transparent to any light of wave lengths above 3000 A. From this curve we draw two conclusions:

> First: Since the scintillation light output from the plastic scintillators under these conditions is essentially constant for all concentrations above about 0.2%, the falling off of the two upper curves at high concentrations can hardly be due to self-absorption of the tetraphenylbutadiene fluorescence within the plastic scintillator.
>
> Second: It is observed that the light output does increase with fluor concentration at low concentrations, approaching saturation at a concentration of about 0.2%. Since the plastic scintillators were physically separate from the thin polystyrene film and were shielded by it from the alpha particles, we infer that the effect here must be due to alpha-excited fluorescence in the pure polystyrene film, and that this fluorescence is then absorbed in the plastic scintillator and excites tetraphenylbutadiene fluorescence therein.

An attempt by us to measure the fluorescence spectrum of polystyrene was unsuccessful, but it has been reported that pure polystyrene excited by copper X rays does fluoresce in the region of 3100-3350 A, and it

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(1) L. Pichat and Y. Koechlin, J. chim. phys. 48 225-228, May-June, 1951.

has been proposed that the transfer of excitation energy from solvent to solute in polystyrene solid solution scintillators may be accomplished through absorption of the polystyrene fluorescence by the dissolved fluor.[2]

However, our results in this case seem to indicate that while this type of energy transfer could take place it should reach a maximum efficiency at fluor concentrations well below the observed optimum concentration for direct particle excitation of the plastic scintillators. Hence we infer that there must be another mechanism by which excitation energy is transferred directly (i.e., non-radiatively) from the polystyrene to the dissolved fluor and which accounts for the observed values of optimum concentration.

Figure 2 shows scintillation pulse height relative to anthracene vs. concentration for solid solutions of trans-stilbene in polystyrene, using the uranium beta source. A peak relative pulse height of about 0.05 is obtained at a concentration of about 1.5%. This appears to disagree with the earlier results of Koski,[2] who found that a 10% concentration of trans-stilbene in polystyrene was slightly more efficient than a 2% concentration.

Because of the relatively low efficiency of the stilbene-polystyrene scintillators we have not repeated the experiment involving the alpha source and the thin polystyrene film, but we have obtained somewhat more complete data on the pulse heights for beta particle excitation at very low fluor concentrations.

The low-concentration portion of this curve is shown in detail on the left portion of Fig. 2, and it will be noted that there appears to be a sort of shoulder with a point of inflection at a concentration of about 0.12%.

Optical absorption measurements on pure polystyrene and on a stilbene-polystyrene solid solution in the region of 3100-3350 A indicate that although at very low stilbene concentrations part of the reported polystyrene fluorescence would be reabsorbed by the polystyrene itself, the fraction of this light which would be absorbed by the dissolved stilbene should increase with increasing stilbene concentration and approach saturation for concentrations of the order of 0.1%. Hence we feel that the observed shape of the curves in Fig. 2 may be interpreted on the assumption of a radiative (fluorescent) transfer of excitation energy from the polystyrene to the dissolved stilbene at quite low concentrations and a competing direct energy transfer process which is effective at higher concentrations.

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[2] W. S. Koski, Phys. Rev., 82, 230-232 (1951).

The results for the terphenyl-polystyrene solid solutions will not be described in detail except to state that the peak pulse height, relative to the anthracene crystal, appeared to be about 0.06 at an optimum concentration of about 1%, and that the curve of relative pulse height vs. terphenyl concentration showed evidence of a shape in the low-concentration region similar to that observed for the stilbene-polystyrene scintillators.

HIGH RESISTANCE TESTER - Frank J. Lynch

High value resistors around 10^{12} ohms were measured using the rate of drift method, with a vibrating reed electrometer, and the induction current method, with the new resistance tester. (The coupling air condenser of the Applied Physics Corporation vibrating reed was found to have a capacitance of 13 mmf, using a coaxial condenser calibrated by the Bureau of Standards.) Readings on the new tester were approximately 5% lower than those obtained by the rate of drift method. These discrepancies are probably due to errors in the voltage dividers and will be corrected.

Preliminary measurements with a few millivolts to a few volts applied to the resistor gave variations in resistance of less than 1%.

ROTATING CONDENSER ELECTROMETER

Work has started in the Instrument Research and Development Shop on the construction of the rotating condenser electrometer. All materials are on hand, including the small ball bearings. Work has also started on the associated electronic circuits which involve a high gain 100 c.p.s. amplifier and synchronous detector.

URANIUM FLUORESCENCE PHOTOMETER

Considerable difficulty has been experienced in decoupling plate supply in the various amplifier stages owing to the good low frequency response and the high over-all gain of approximately 109. The attenuators are being wired, and the entire instrument will be tested soon.

RECORDING DYNAMIC CONDENSER ELECTROMETER AND CHAMBER

A second recording electrometer, having scales of 10, 100, and 1000 mv, with automatic scale changing at the extremes of record, has been delivered to N. J. Scully of the Biology Division. Also included was a 1-liter chamber for monitoring air in a closed system.

FAST PREAMPLIFIER

A preamplifier capable of 40 V rms output has been constructed. The gain is varied from 10 to 100 by varying the negative feedback. It uses one 12AT7, one 6AH6, one-half 12AT7, one 6K6. The probe clamps on the chassis under test and uses a 6K6.

PROPORTIONAL COUNTER SPECTROMETER - Joseph Bowe

A gas-filled proportional counter X-ray spectrometer and the associated electronic equipment are now in satisfactory operation. The counter is constructed of a brass cylinder, 20 in. in length and 4-1/2 in. in diameter. The end seals, which contain the guard ring and central wire support, are soft soldered to the end plates, which, in turn, are rigidly bolted onto the cylinder. An O-ring, lead gasket arrangement keeps the chamber airtight. Photons are admitted into the counter through a beryllium window, 1 in. in diameter and 0.034 in. thick. A 0.005 in. Kovar wire is used as the anode. The gas filling consists of a 9-1 mixture of argon and methane at atmospheric pressure. Prior to filling, the chamber was pumped and baked at about 100°C for several days. The original gas filling is still being used with no apparent deterioration after a 3-month period. The upper limit to the energy that can be measured is determined by the physical dimensions and the gas pressure. It is required that the range in the chamber of the most energetic particle be of the order of the length of the radius. In the present counter, the radius corresponds to the range of an 80-kev electron. The smallest energy that can be measured is limited by the useful electronic and gas multiplication that can be employed. In addition, there are limitations imposed by the poorer resolution at low energies.

The counter has been used primarily as an aid in testing the operation and performance of the electronic equipment. For this purpose, the six-kilovolt X rays of manganese, which result from the decay of Fe^{55} by K capture, were used to activate the counter. The spectrum, which shows a line at six kilovolts and one of weaker intensity at three kilovolts, was plotted for a number of different values of counter voltage and amplifier gain. The best resolution, defined as the ratio of the full width at half maximum to the location of the peak, was obtained with a low amplifier gain and a correspondingly high gas multiplication. The X-ray peak was amplified to 50 volts and had a resolution of 21%. With reduced gas multiplication but increased amplifier gain, a resolution of 23.5% was obtained. A resolution of 30% was obtained when the output pulse was amplified to 15 volts.

The Atomic Instrument Company linear amplifier was modified so as to operate only on negative input pulses. With this modification, the large pulses which become limited do not have an under-short or over-short at the base line. This eliminates the "background" at low bias voltages and extends the usefulness of the spectrometer in the low energy region.

In the course of the present work, it is estimated that gas multiplications between 600 and 10,000 have been employed. A 6-kev photon liberates about 365×10^{-19} coulomb of change. If this is collected on a capacity of 50 mmf, a pulse amplitude of 0.73 microvolt is obtained. The rms value of the amplifier noise was measured to be 12 microvolts.

URANIUM CHAMBERS - Alwyn C. Lapsley

An analysis has been made on transient and polarity effects that have been noted on cylindrical uranium fission chambers. The transient effect is one whereby at any voltage below saturation, the collection efficiency increases with time. The polarity effect is one of more voltage being required for saturation when the central electrode is at a negative potential.

The transient effect is believed to be a result of a heavy oxide coating which builds up on the uranium and acts as a very high DC resistance in the electrical circuit. (In addition to serving as the source of fission fragments, the uranium constitutes the outer chamber electrode.) The indications are that under the influence of the pile radiation, the insulating features of the oxide layer are destroyed. The voltage drop across the layer is thus reduced, and a given externally applied potential more efficiently collects the ions in the chamber. This hypothesis is supported by experiments on chambers from which the oxide layer has been largely removed. With them, the transient effect is, at least to a great extent, eliminated.

The polarity effect may be the result of positive ion space charge in the chamber. The carriers of negative charge will be predominantly electrons, and their greater mobility will result in their being removed from the chamber faster than the positive ions. It is thus probable that there will be a positive ion space charge through the major volume of the chamber. A mathematical approach which assumes that there are no electrons or negative ions in the chamber shows more voltage is required to collect the positive ions on the inner electrode. Also, the calculated voltage ratios for the two collection polarities are in rough agreement with the experimental values. This hypothesis is treated in detail in ANL-4806.

THERMOPILES

A promising candidate for measuring neutron flux is a thermopile designed by the Brown Instrument Division of the Minneapolis-Honeywell Regulator Company. The complete unit as designed by them is rather bulky, however, and a more compactly packaged assembly has been designed and built. Its versatility was further increased by making it watertight.

INSULATORS

Plans are under way to test the performance of insulators when exposed to a reactor flux. The hope is to carry out simultaneous checks on various candidates.

ARGONNE REFLECTING MICROSCOPE DOSIMETER - Francis R. Shonka

During the month of April, final assembly of the Argonne reflecting microscope dosimeter was begun. A serious difficulty was encountered in molding the cases. It was found that the cases did not withstand the mechanical shock that the sample dosimeter cases withstood in earlier tests. The cases which were strong enough to withstand the impact were found to fail generally on the hermetical seal. It was also found that the plastic which would adhere well to the reticle was structurally too weak. Considerable time was spent in solving these problems, and successful cases have been molded recently.

At this time, no further difficulties in the dosimeter pilot line operation are anticipated, although an attempt will be made to develop an improved case which will involve one molding operation rather than the molding of the reticle separately from the dosimeter case.

Approximately 75 dosimeters are being delivered to the Radiological Physics Division at this time. It is planned that these dosimeters be put into immediate service. Careful checks will be made on the performance of the dosimeters in the field so that rapid determinations can be made of their performance.

POCKET AND FINGER CHAMBERS

The pocket and finger chambers, put into field use by the Radiological Physics Division several months ago, have proven very satisfactory. It was discovered that the chief cause for incorrect chamber readings was the operators' inexperience in handling and reading the chambers; instructions for proper handling of the chambers were given to the operators.

The chamber clip has proven unsatisfactory and will be replaced shortly by another (safety-pin type) fastening device.

DIFFERENTIAL ION CHAMBER

A small cylindrical differential chamber has been designed and four have been built for Samuel Untermyer's use in E.B.R. This chamber consists of parallel plates of enriched uranium, stainless steel, and depleted uranium. The plates are 0.010 in. thick, the active area width is 0.250 in., and the active length 1.750 in. These plates are mounted rigidly into teflon. The teflon insulator does not withstand pile radiation too well, but since it is a rather intricately shaped insulator, it would be difficult to use other nonhydrogenous insulating materials such as lavite which would expand and become distorted during the heat-treating.

ELLIPSE GENERATOR

A fixture for generating ellipses has been designed and built. If this fixture is used with the Gorton Pantograph, any size or eccentricity ellipse, up to a maximum of 4 in. semi-major or semi-minor axes, can be generated. Although there are quite a few uses for generating ellipses in our work, the chief incentive for designing and building this accessory is for application of ellipses to the field of reflecting optics.

CONTEMPLATED WORK

Work has not been done on the following list of projects up to the present time only because so much effort has been expended on other work, especially on the Argonne dosimeter pilot line operation. It is hoped that during this coming quarter, work will be done on at least some of these projects.

ZAMBONI PILE

It is planned to test the sample Zamboni Pile sent to us by the Bureau of Standards. The development work of this type of voltage supply represents a considerable amount of effort on the part of the Bureau of Standards, and since their decision to go into this project was due, in part, to our interest, it is our intention to test the Zamboni Pile thoroughly. This voltage supply should be suitable for the dosage rate survey meter and other portable counting equipment.

DOSAGE RATE SURVEY METER

The principle of a quartz fiber dosage rate survey meter has proven to be not only feasible but promises to be almost the ultimate answer to a survey meter which would require little maintenance and which could be always dependable as far as calibration is concerned. In its present state, the meter could be very much improved by incorporating reflecting optics, similar to those used in the Argonne dosimeter, and by some other minor engineering changes.

REFLECTING OPTICS

The field of reflecting optics shows such good promise that it would warrant a great deal of our effort. It is quite obvious that some of the greatest difficulties encountered in the use of reflecting optics could be eliminated by using proper molding techniques, and hence this work could be accomplished more effectively at the Argonne National Laboratory than at any other organization interested in this field.

METAL TO CERAMIC SEALS

In addition to the usual problems encountered in the use of insulators in gas-type systems, we are interested in extending this work to include insulators used inside reactors.

CONDUCTING PLASTICS

Through cooperation with several companies, we have been able to obtain materials such as conducting Bakelite from the Formica Company and conducting ebonite from the Dryden Rubber Company. There is an acute need for a greater variety of these materials. The most pressing need is for a conducting plastic which could be both compression and injection molded.

PILE CONTROL CHAMBER

A fission chamber was constructed for a control chamber in the Naval Reactor. The chamber consists of 14 circular disks, 2-1/2 in. in diameter with a spacing of 0.100 in. between the disks. The coating on the disks is enriched uranium. The chamber is almost complete, except for the final coating of the disks and final assembly.

MEASUREMENT OF SCINTILLATION DECAY TIMES - Robert K. Swank and H. Bruce Phillips

A system for measuring the decay time of scintillation materials would be desirable. Measurements have already been made elsewhere on many of the most commonly used scintillators. In the case of the inorganic scintillators, conventional oscilloscope measuring techniques are applicable. However, for organic scintillators, very high speed techniques are necessary. The measurements which have been previously presented are in considerable disagreement. It is desirable not only to check these results but to have facilities available so that newly discovered scintillators may be measured promptly. Furthermore, measurements of scintillation decay time in activated crystals as a function of activator concentration, measurements of decay time as a function of temperature, and other physical parameters are of considerable theoretical importance in understanding the scintillation mechanism. Also of interest is the measurement of the decay rate of different parts of the luminescence spectrum. To understand the difficulties of such measurements, consider the case of anthracene, perhaps the easiest organic material to measure. If anthracene is excited to luminescence by a 1-Mev beta particle, it will emit approximately 10,000 luminescent photons. The emission will begin at the rate of approximately 300 photons per millimicrosecond and decrease exponentially thereafter. The photomultiplier cathode will emit about one photoelectron for each 10 photons received. Therefore, if all the anthracene light is collected by the photocathode, the initial rate of emission of photoelectrons will be 30 per millimicrosecond.

Thus, if the time resolution of the oscilloscope system is approximately one millimicrosecond, the number of photoelectrons received in that interval will be 30, so that the fractional variance is 18%. If many pulses are averaged, the accuracy of measurement can be much better than 18%. However, this calculation is based on the initial rate of emission. For accurate data on scintillators it may be necessary to follow the decay for two or more mean lives, at which time the measuring accuracy will be substantially reduced. Furthermore, the above estimate is for the most efficient known organic scintillator. For less efficient scintillators the measurement will be still more difficult. Finally, if experiments are performed wherein the maximum output of the scintillator is not available, this will still further reduce the accuracy of measurement.

In view of the above limitations with nuclear particle excitation, it was decided to attempt to use artificial excitation. Electron acceleration seems to be most promising but would require very high voltages in order that the electrons be brought out through a vacuum-tight window. A calculation for a copper target X-ray tube indicated that with a 1-ma beam current and 30-kv accelerating potential the rate of X-ray bombardment of a test crystal could be about 8 Mev per millimicrosecond. Thus, when the crystal is bombarded to "saturation" and the tube cut off, the initial decay rate will correspond to 8 Mev per millimicrosecond. In the case of anthracene, this gives a light intensity of 240 times as high as when 1-Mev β particle excitation is used. A tube was designed which would incorporate these features. It has a transmission type target window; the crystal is located outside the tube less than 0.001 in. from the point of X-ray generation. The target window is 0.006-in. copper foil, silver soldered to a steel subassembly, which is in turn welded to a standard Kovar glass tube. The electron gun was designed and the tube, exclusive of the target, was constructed by the Multitron Laboratories of Chicago, Illinois. The tube is permanently sealed. The gun is designed to produce a spot of approximately 1/16 in. diameter, to give a maximum beam current of 1 ma, and to be gated from cutoff by approximately 50 volts.

A tube has been completed and is now in operation. Owing to internal leakage, it cannot be operated above 20 kv. A second tube is under construction which, it is believed, will overcome this difficulty. In addition, the second tube will have a nickel target window instead of copper. This enables a slightly thinner target window to be used with somewhat greater strength.

The first tube, up to the voltage used, is performing pretty close to expectations. At 16 kv its output is 1 Mev per millimicrosecond. In addition to the much brighter scintillations obtained, two other important advantages are observed: (1) The scintillations are all of identical magnitude, so that averaging of statistical fluctuations can be done very nicely by simply using a long photographic exposure and reading the position of the trace with a microphotometer. Thus, 1000 or more independent scintillations can be

averaged in one measurement. (2) Since the scintillation is artificially produced as a result of the pulse delivered to the grid of the X-ray tube by the mercury relay pulse generator, the oscilloscope trace can be triggered directly from the pulse generator, thus avoiding statistical time jitter of the trace.

In use, the X-ray tube is housed in an oil-filled container, the target window protruding through a rubber oil seal. The target is operated at ground potential, and the cathode ray gun assembly is adjustable to 30 kv below ground; the high voltage and pulser leads enter the oil housing through insulated bushings.

X-RAY TUBE PULSER

In order to gate the X-ray tube with short pulses (e.g., 10^{-8} seconds duration) a mercury switch is used to discharge a length of delay cable into its surge impedance. This type pulse generator has been described by Garwin, (Rev. Sci. Instruments, 21, 903 (1950)).

A mercury switch capsule taken from a Western Electric relay type 275B is mounted coaxially inside a length of 9/16 in. I.D. brass tubing and is supported by 0.244 in. diameter rods soldered to the switch terminals. These rods, forming the center conductors of a coaxial line, are in turn attached to General Radio coaxial connectors, type 874-B. The pulse forming line and output cable are made from 50-ohm cables which plug into the mercury switch connectors. The switch is driven by means of a coil of wire surrounding the switch unit; when energized by 60-cycle current the pulser produces 120 c.p.s.

When 10^{-8} second pulses were viewed on a high voltage cathode ray tube, type 5XP11, it was found that there was sufficient mismatch through the switch to produce noticeable reflections. This has been remedied by reducing the outer conductor to 3/8 in. I.D. over the length of the switch capsule; this appears to maintain the impedance through the switch at 50 ohms.

Two outputs are taken from the pulse generator. One output feeds directly into a terminated 50-ohm transmission line which leads to the X-ray tube, while the second output drives a 4700-ohm resistor in series with a 50-ohm transmission line, giving a signal attenuated by about 40 db in the second line. The attenuated signal is used to trigger the sweep of a Tektronix type 517 oscilloscope.

The pulse generator can produce 100-volt pulses into a terminated 50-ohm line, and 200-volt pulses into an open line. In order to drive the grid of the X-ray tube, which may be below ground by as much as 30 kv, the output of the pulser is fed into the oil-filled X-ray tube housing and through a 30-kv, 500 mmf condenser connected to the grid; the transmission line is terminated by a 50-ohm resistor inside the oil housing.

SCINTILLATION DETECTOR

The scintillations produced in the fluor by the X-ray pulses are detected by a high current photomultiplier, R.C.A. developmental type H-4646. The output of the photomultiplier is used to drive a 200-ohm transmission line which is connected directly to the vertical deflection plates of a 5XP11 cathode-ray tube in a Tektronix type 517 oscilloscope. The length of the 200-ohm line is chosen to give a time delay of about 150 millimicroseconds in order to compensate for the delay in the oscilloscope sweep generator.

Because of the current saturation in the photomultiplier for large light pulses, together with the nonlinearity of the cathode-ray tube deflection, it was necessary to calibrate the system. This was done by interposing a series of X-ray absorbers of known attenuation between the X-ray window and the fluor under investigation. A series of photographs was made of the oscilloscope display with the various absorbers in place, allowing pulse height to be correlated with light intensity.

Although a number of scintillators have been observed, no measurements can be reported until the system is calibrated. Besides the vertical calibration, a horizontal (time base) calibration is being made, using reflections in an air dielectric coaxial cable.

INSULATORS - Raymond J. Munick

A new apparatus for measuring the resistance of good insulators has been designed and built, which combines some of the features of both methods described in the last report. Adjustments are being made to get the mechanical electrometer part in better working order. In connection with this work, since it was necessary to analyze the operation of the electrometer, a report was written on the theory of mechanical electrometers.

The essential elements of the instrument are shown schematically in Fig. 4. The test insulator is in the shape of a disk onto which are evaporated the insulated electrode A_1, the guard ring A_2, and the high voltage electrode A_3. The diameters of A_1 and A_3 are 7/8 and 3 in. respectively; the gap between A_1 and A_2 is 3/64 in. wide; and disks from 3/32 to 1/2 in. thick can be used. Contact to A_1 can be made by means of a fine wire, which is moved by a relay arm. A brass disk A_5 7/8 in. in diameter faces A_1. The electrode A_4 is a 5-micron platinized quartz fiber and a brass supporting rod, which are shown in finer detail in a side view in Fig. 5. These elements are enclosed in an evacuated brass case, and the quartz fiber is viewed through a window with a microscope.

By means of the circuit V_5 is constrained to follow the relation

$$V_5 = -rV_4 + V_o, \qquad (1)$$

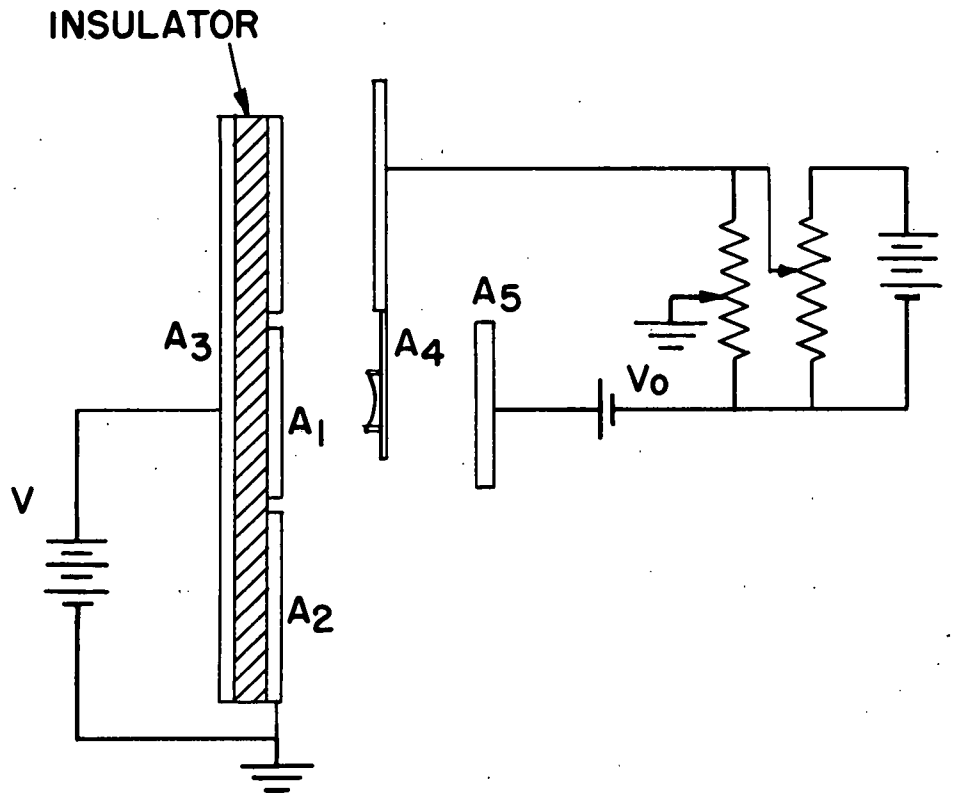

Figure 4. Essential Elements of Resistance Apparatus

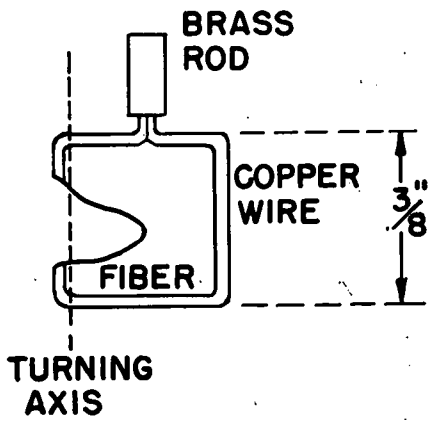

Figure 5. Details of Fiber Mounting

where r is a positive number and V_O is a fixed voltage. With A_1 grounded, r and V_O are adjusted until A_4 remains at the zero point irrespective of the magnitude of polarity of V_4, except that V_4 must not exceed a critical value. If V_4 exceeds the critical value, unstable equilibrium results, and the fiber snaps abruptly from the zero point to contact with one of the disks.

When r and V_O are set to satisfactory values, the voltage V is placed on A_3, and then A_1 is ungrounded. As charge leaks to A_1, its potential rises, which causes A_4 to deflect. Then V_4 is adjusted to bring A_4 back to zero, which indicates that A_1 has returned to ground potential. Under these conditions it can be shown that

$$R = \frac{-V \Delta t}{(C_{14} - r C_{15}) \Delta V_4} , \qquad (2)$$

where R is the resistance through the body of the insulator from A_3 to A_1, Δt is the time that elapsed before an adjustment ΔV_4 in V_4, and C_{14} and C_{15} are the direct capacitances between A_1 and A_4 and between A_1 and A_5.

The more promising of the quartz fibers which have been tried have a conductivity of at least 100 divisions per volt. A change in potential of A_1, corresponding to 1/5 division, about 2×10^{-3} volts, can be detected. The change in charge ΔQ_1 which gives rise to this change in V_1 in time Δt is $2 \times 10^{-3} \times C_1$, where C_1 is the total capacitance of A_1, about 6×10^{-12} farads, or ΔQ_1 is about 1.2×10^{-14} coulomb. Also, Q_1 equals $V \Delta t / R$ where R is anticipated to be of the order of 10^{18} ohms. Therefore, the time required for one adjustment, which gives a measurement is about

$$\Delta t = \frac{1.2 \times 10^4}{V} \ \frac{\text{seconds}}{\text{volt}} . \qquad (3)$$

Therefore, the instrument promises to be relatively rapid for measuring 10^{18} ohms: 2 minutes for 100 volts, 20 minutes for 10 volts, and for 1 volt about 3-1/3 hours. Because it is so promising in this respect, the alternative method involving an electronic potential indicator has been abandoned.