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INSTRUMENT RESEARCH AND DEVELOPMENT DIVISION
QUARTERLY PROGRESS REPORT FOR
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INSTRUMENT RESEARCH AND DEVELOPMENT DIVISION

QUARTERLY PROGRESS REPORT FOR

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BETA-PARTICLE IONIZATION IN PURE GASES AND THE AVERAGE ENERGY TO MAKE AN ION PAIR - William P. Jesse

As has been noted in previous reports, careful measurements have been made of the total current produced in various gases in an ion chamber by a beta-source applied as a thin sheet to the collecting electrode. The beta-sources used are tritium, in the form of a thin layer of tritiated polystyrene coated with Aquadag, and Ni^{63} , plated electrolytically on a copper electrode. The maximum beta energy for the Ni^{63} is 67 kev.

It should be noted that this method of comparison of relative currents gives only the relative ionization produced in the various gases and hence only the ratios of the values of W , the energy required to produce an ion pair, not the absolute values. This is a distinct disadvantage, but any method for obtaining absolute values offers many additional difficulties.

The ratios of the W values for the various gases seem so far to be the same for the tritium and for the Ni^{63} sources within experimental error (1 to 2%). However, in some cases these ratios seem markedly different from those obtained for single polonium alpha-particles, and the pattern of the variation is somewhat difficult to understand.

In regard to a comparison with the alpha-particle ratios the gases investigated fall into three groups:

(1) For air, N_2 , O_2 , and CO_2 (all measured both for tritium and Ni^{63}), the ratios of ionization currents (and hence the inverse ratios for W values) agree within experimental error with the alpha-particle ratios.

(2) For A, Kr, and Xe the beta ionization currents, in comparison with that for air, are markedly less than for alpha-particles. Specifically, if the W for air is arbitrarily taken as 35.5 ev/ion pair (the absolute value obtained for polonium alpha-particles), then from the ratios in the beta-ray comparison the W for argon is 29.5 ev/ion pair for beta-particles. For alpha particles it was 26.4 ev/ion pair. Moreover, careful measurements with Ni^{63} show little difference between the currents obtained for A, Kr, and Xe, i.e. <5%, while maximum differences up to 20% were obtained in the alpha case.

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(3) For H_2 and the hydrocarbons CH_4 , C_2H_2 , C_2H_4 , and C_2H_6 , measurements for tritium beta-particles give ionization currents relative to air about 5% higher than in the alpha-particle case. Measurements with Ni^{63} for C_2H_4 agree well with the tritium values.

Since it seems improbable that the vagaries noted above are really characteristic of beta-ray ionization, every effort is being made to account for them by some condition of the experimental method.

In the noble gases of the purity here achieved, positive ion space charge effects can be quite marked and conceivably the ionization current may be limited by them.

This explanation does not seem likely to resolve the present difficulty because of three facts:

(1) When the beta-source is increased in strength by a factor of 10 the ionization current ratios in the various gases do not alter.

(2) When a grid work of copper wires is added to the central electrode, so that the collecting fields are greatly increased, no effect is observed on the current ratios.

(3) When oxygen is introduced into pure argon to the extent of a few tenths of a per cent, no effect is observed in the current relative to air as a standard. This is a rather crucial test for space-charge effects, since the negative ions formed on the oxygen molecules should neutralize to a great extent any positive space-charge.

In order to further test the validity of the experimental method, the beta-source on the electrode was replaced by an alpha-source which produces about the same total ionization current in the chamber. As much as possible all other conditions of the experiment were kept the same as for the beta-rays. The current ratios for various gases should be in accord with the ratios previously determined for single alpha-particles.

The ratios found for the relative currents from air, argon, krypton and ethylene were in excellent agreement with the previously determined ratios for single alpha-particles. From a count by measurement in a methane flow counter of the alpha-particles emitted from the source per minute and the absolute current produced by the source in a given gas, an estimate of W could be made for each gas. These absolute values were in agreement with the previously determined values within a few per cent.

It thus would seem that there is a distinct difference in the behavior of alpha- and beta-particles as measured in this particular chamber.

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One possibility for this difference may be in the fact that beta-particles are much more easily scattered than alpha-particles. Thus, a beta-particle emerging from the active surface on the electrode may strike a gas molecule and be scattered back to the electrode and so will not give up its full energy by ionization in the gas. It is suggestive that the deficiencies in ionization for the beta-particles, as compared with alpha-particles in the measurements above, increase continuously with the atomic number of the gas.

To test the possibility of such back-scattering a series of measurements is being made where the electrode consists of a network of very fine wires. These are electroplated in certain areas with a thin metallic film of Ni⁶³. The area of electrode thus exposed to the beta-particles which are back-scattered is greatly reduced, and hence the loss of energy in this way should be curtailed.

If back-scattering from the gas has played an important part in the measurements described, then the measurements in progress with the fine wire electrode should show a marked change in the ratios observed for the different gases.

PLASTIC SCINTILLATORS - Warren L. Buck and Louis J. Basile

Efforts to effect further improvements and innovations in plastic scintillators are continuing and may be grouped in the following categories: (1) investigation of plastics other than polystyrene and polyvinyltoluene in the hope of obtaining increased light output or other desirable properties, (2) incorporation of elements of high atomic number in the plastic so as to achieve better counting efficiency and pulse height resolution for gamma rays, and (3) production of boron-loaded plastic scintillators which will serve for detection of low-energy neutrons.

Scintillators in which the plastic is a polymer of vinylbiphenyl or of cyclohexylstyrene were prepared and tested but proved to give smaller pulses than scintillators of the polyvinyltoluene type, even when specially purified monomers were used. Further, these plastics were more difficult to fabricate.

To determine the effect of "cross-linking" upon the properties of polyvinyltoluene scintillators, samples have been prepared which contain various percentages of Dow Divinylbenzene Mixture copolymerized with the vinyltoluene. The former is a mixture of the three isomers of divinylbenzene and of ethylvinylbenzene, being 50% - 60% divinylbenzene. The monomers were purified by vacuum distillation to remove oxidation products; the pure materials were then mixed in the desired proportions, degassed and sealed off under vacuum in glass vials containing the standard amounts of p-terphenyl and tetraphenyl-butadiene, and placed in an oil bath at 125°C.

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Samples containing up to 2% of the divinylbenzene mixture polymerized readily to give a hard, colorless, transparent product. At higher divinylbenzene concentrations the product was not transparent and formed an expanded "foam." Copolymerization of divinylbenzene with styrene or related plastics is reported¹ to give greatly increased heat stability and chemical resistance to these plastics. It is hoped also that the resulting "cross-linking" of the polymer chains may facilitate energy migration within the plastic and yield more efficient scintillators. Pulse height measurements on these samples have not yet been made.

Attempts to produce a plastic containing an element of high atomic number by copolymerization of vinyltoluene and allyliodide have thus far been unsuccessful. Allyliodide appears to be quite unstable, readily decomposing with the release of free iodine. Before use the allyliodide monomer was washed with an aqueous solution of $\text{Na}_2\text{S}_2\text{O}_3$ to remove free iodine, dried over anhydrous MgSO_4 , and distilled under vacuum. This gave a light-yellow liquid which was mixed with purified vinyltoluene monomer in the desired proportions, degassed and sealed off under vacuum in glass vials, and placed in the polymerization bath at 125°C . After a short time in the bath all of the samples, even those containing as little as 1% allyliodide, developed a red color indicating the presence of free iodine; all such samples showed little, if any, evidence of polymerization after seven days in the bath. Free iodine is known to act as an inhibitor for the polymerization of styrene and related monomers.

The possibilities of forming copolymers of vinyltoluene and a more stable iodine-substituted monomer, of utilizing an iodine-substituted vinyltoluene, or of forming a solid solution of heavy metallo-organic compound in polyvinyltoluene are under investigation.

It was reported previously (ANL-5118) that at a temperature of 130°C dilute solutions of decaborane ($\text{B}_{10}\text{H}_{14}$) in vinyltoluene became discolored but did not polymerize satisfactorily. It was indicated that this effect did not appear to be due to impurities in either of the constituents. Investigation was continued to determine whether the discoloration was due to a reaction between the two constituents or to decomposition of the decaborane upon heating. The same behavior was observed when the polymerization temperature was held at $90 - 95^\circ\text{C}$. Since the decaborane used melts at $99 - 100^\circ\text{C}$, it seems unlikely that the discoloration of the solution is due to thermal decomposition of the decaborane.

It has been observed that when a small amount of gaseous boron trifluoride (BF_3) is condensed into a vial containing vinyltoluene and the contents are allowed to warm up, a rapid reaction occurs, accompanied by evolution

¹R. H. Boundy, R. F. Boyer, "Styrene: Its Polymers, Copolymers, and Derivatives" (Reinhold Publ. Corp., New York, 1952)

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of a gas and a large amount of heat, and resulting in polymerization of the vinyltoluene without externally applied heat. However, the product tends to be discolored.

More encouraging results were obtained using the methyl etherate of BF_3 (a liquid). It appears that a few drops of the etherate added to 20 ml of vinyltoluene substantially accelerates room-temperature polymerization of the vinyltoluene without discoloration of the product. Although the boron content obtained in this way is quite insignificant, the low-temperature polymerization should allow the use of solutes which become reactive or unstable at the high temperatures ordinarily employed for polymerization of polyvinyltoluene scintillators.

PHOTOELECTRIC COMPARATOR HEAD - H. Bruce Phillips

The photoelectric comparator head, used for accurately measuring coordinates of lines on photographs, has been completed and is now in operation. At present it is being used in the study of scintillation decay times.

The instrument is based on a Zeiss Measuring Microscope whose lateral and transverse table travels are calibrated in microns; the readings can be estimated to about ± 0.2 micron. The comparator head is interchangeable with the Zeiss Viewing Microscope, the change requiring only a few minutes.

Tests of the accuracy and sensitivity of the instrument are being made, and some results may now be reported. A photographic line (Eastman Kodak Panchromatic plates were used in the test) of about 0.020 in. width can be recentered to within about ± 0.5 micron, which represents a resettability of 0.001 line width. As an accuracy test, an oscillogram was made of an exponentially-decaying pulse of 1.8 mm amplitude, and its coordinates were measured with the instrument. The same pulse was then attenuated by a factor 0.5 and was similarly measured. When the latter set of data was multiplied by two, agreement with the initial data was obtained over a range of more than two decades, the maximum deviation being about 10%; however, the best smooth line drawn through the plotted points increased the accuracy to better than 1%. Thus the instrument is capable of measuring down to 6 microns with an accuracy of about 1%, provided that the photograph is sharp and dense. In this particular case 6 microns represents about 0.02 line width.

Most of the scatter in data plotted from photographs of oscilloscope tracer is probably due to (1) granularity and inhomogeneity of the cathode-ray tube phosphor, (2) flaws, scratches and smudges on the photographic negative, and (3) granularity of the developed image.

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Because of its ability to detect very small displacements, the instrument is quite sensitive to changes in ambient temperature. Therefore a warm-up period of at least one hour is required before the modulating motor warms the comparator head to equilibrium. A temperature change of 1°C produces a displacement of about 4 microns.

ELECTRON MOBILITY - Joseph C. Bowe

Voltage pulses have been obtained from a parallel plate chamber, filled with nitrogen at a pressure of 40 cmHg, by liberating a burst of photoelectrons from the cathode. The time of rise of the pulse was observed to decrease with increasing chamber voltages. No measurements were made of the electron transit time because (a) a spurious high frequency signal triggers the sweep and partially obscures the initial portion of the pulse, (b) at low chamber voltage, the amplitude of the signal is too small for measurement, and (c) of instability of the light source.

Several flash tubes have been delivered by the Kemlit Laboratory during the past quarter, but none are entirely satisfactory. Flash tubes from other manufacturers are being tested.

PHOTOMULTIPLIERS AND SCINTILLATION DECAY TIME - Robert K. Swank

Considerable effort has been devoted during this quarter to the measurement of scintillation decay times and, in particular, to an investigation of errors in the measurement procedure.

A minor source of error was discovered in the film transport which caused a rotation of the pulse relative to the reference baseline. This error has been completely eliminated by replacing the photographic film with glass plates. A special transport carriage has been constructed which translates the plate without rotation. Eight pulse waveforms and 2 to 4 time calibration traces can be recorded on each plate. By use of the photoelectric comparator (see p. 6), all the waveforms on a plate may be reduced to coordinate data in about 4 hours with an accuracy limited at present only by the granular nature of the oscilloscope screen.

Three new Type C-7164A photomultiplier tubes were received from RCA, and preliminary tests showed that these tubes had a very short transit time spread. Because of this, one of these tubes was incorporated into our decay time measuring apparatus. A number of scintillators that were previously measured with the H-4646 photomultiplier have been remeasured. Although good agreement was obtained in the measurement of anthracene (32.8 μs), large discrepancies were obtained with other scintillators. The magnitude of the discrepancy is larger the shorter the decay time. It appeared obvious from these observations that the photomultiplier was

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contributing significantly to the rate of decay. Previous calculations² had indicated that if the spread introduced by the photomultiplier had a Gaussian form, then the multiplier would not contribute significantly to the decay time as it is measured in these experiments. The large discrepancies observed can only be explained if the photomultiplier response is non-Gaussian. In fact, it must have a very gradual decay, resembling an inverse power law. A production model of the H-4646 (now designated as the C-7165A) has generously been supplied by Dr. R. W. Engstrom of the RCA Tube Division. Preliminary tests on this tube (described below) indicate that such a gradual decay is indeed characteristic in photomultipliers.

In addition to a gradual decay form, the photomultiplier response shows evidence of a pronounced "bump" which occurs, in the case of the C-7164A, at approximately 20 m μ s after the peak of the scintillation. This bump can only be observed with scintillators having a very short decay time. Such a bump (evident in Figure 3) can hardly arise from ordinary causes of straggling in the multiplier. It is very suggestive of a feed-back process such as that which gives rise to the afterpulsing normally observed in photomultipliers. It occurs about 40 times sooner, however, than the ordinary afterpulsing. Tests were made in which the shield plate in front of the first dynode was varied several hundred volts positive and negative with respect to the first dynode. Only a small effect was made on the appearance of the "bump," indicating that photoemission from the shield plate or the side walls of the envelope is not involved. One mechanism which could give rise to the bump, and which would give about the right amount of delay, is the feedback of photons from later dynodes to the photocathode. It has been known for some time that light is emitted from the dynodes during multiplication, although the process has never been investigated in detail. The construction of both the C-7164A and C-7165A photomultipliers is such that this light could reach the photocathode.

It is obvious that the photomultiplier response imposes a serious limitation on the measurement of very short decay times, a limitation that is not easily removed. It seems likely, however, that the decay times measured with the C-7164A are appreciably nearer the true values than those measured with the H-4646 or C-7165A.

An apparatus is under construction for the measurement of the decay time of a very thin film of pure polyvinyltoluene (one micron or less in thickness). This experiment is being performed for the purpose of determining experimentally the effect of re-absorption in the measured decay time. It has been suggested by Birks³ that the decay time of a thick sample of an organic scintillator may be many times longer than the true "molecular" decay time as a result of the fact that the radiation is repeatedly

²H. Bruce Phillips and Robert K. Swank, R.S.I. 24 611 (1953)

³J. B. Birks, "Scintillation Counters" McGraw-Hill, New York, 1953

re-absorbed and re-emitted. The discrepancy is greater the greater the overlapping of the absorption and emission spectra and the higher the fluorescence efficiency. From our measurements of absorption spectra this effect should be very small in polystyrene and probably also in polyvinyltoluene. However, should it be large, it could explain the behavior of decay time vs. concentration curves on the basis of radiative transfer of energy from solvent to solute without the need of a non-radiative mechanism. Although the possibility is remote, the importance of making certain of the nature of energy migration is so important that no such possibility may be overlooked. In the present experiment, the polyvinyltoluene film will be sealed inside an ordinary cathode-ray tube in place of the usual phosphor screen. The film will be pulsed with a short burst of electrons from the electron gun, and the decay will be observed with a photomultiplier in the usual way. The foregoing procedure is necessary for two reasons: (1) the plastic film must be sealed in vacuum to prevent oxidation processes associated with excitation; (2) low energy electrons are used for excitation because they can be stopped in the thin film.

A new experimental photomultiplier was received from the Allen B. DuMont Laboratories. This multiplier had the Farnsworth box type structure but incorporated special baffles between stages to reduce feedback effects. The manufacturer felt that this may have a bearing on the unusually high transit time spread observed in this tube. Our tests showed that the transit time spread was the same for this tube (20 μ s width at one half maximum) as for similar tubes without the baffles.

A seventeen-stage photomultiplier with a lithium-antimony cathode and beryllium copper dynodes was purchased from Dr. N. Schaetti of Zurich, Switzerland. The transit time spread of this tube was rather long. For example, at 4000 volts on the multiplier the width at half maximum of a single cathode electron pulse is approximately 10 μ s. However, the gain is very high ($\sim 5 \times 10^8$). The pulse height resolution with a sodium iodide crystal was about the same as an average type 5819 photomultiplier. The most interesting property of this tube is its low noise level. With a bias on our pulse height selector corresponding to one kilovolt in NaI(Tl) an integral counting rate of 280 counts per minute was obtained. This is significantly better than we have obtained with any photomultiplier have a cesium-antimony cathode.

A number of tests have been performed on two new photomultipliers manufactured at RCA, the C-7164A, and C-7165A. Figure 1 shows the output current as a function of input signal for both tubes. Figure 2 shows a curve of output current vs. time for a pulse resulting from amplification of a single cathode electron in the type C-7165A photomultiplier. This remarkable reproduction, made from a photograph on which the total pulse amplitude was 167 microns, was obtained through the use of the Zeiss Comparator with Dr. Phillips' new photoelectric indicator.

FIG. 1 AMPLITUDE RESPONSE OF TWO PHOTOMULTIPLIERS.

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FIG. 1
PHOTOMULTIPLIER ANODE CURRENT VS. TIME AFTER
EXCITATION BY THE LIGHT FROM A 2.5 mμs. X-RAY
PULSE ABSORBED IN A TERPHENYL-2-TOLUENE SCINTILLATOR.

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Figure 3 shows the response of both tubes to a terphenyl-toluene scintillator excited by a $2.5 \mu\text{s}$ X-ray pulse. Unfortunately, the sweep speed and transmission line used made it impossible to follow the decay curves much further than is shown, but visual observation indicated that the response of the C-7165A included a second maximum delayed by about $50 \mu\text{s}$ from the peak of the original pulse.

SCINTILLATION COUNTER TECHNIQUES - Robert K. Swank and John S. Moenich

Further progress on the measurement of signal-to-noise ratio of photomultipliers has been delayed by a rather large demand by various other Divisions for assistance in scintillation counter design and construction. We have been able in many cases to recommend commercially available components, but a large number of situations have arisen where the application of techniques developed in this Division was clearly required. The largest job has been the canning of special 2-1/2 in. cubical crystals for the DuMond-type gamma ray spectrometer under construction by the Physics Division. Three separate seals between the body of the welded aluminum can and the lid are now employed in this assembly. The innermost seal is made of R-313 (epoxy type polymer) for mechanical strength. The second seal is silicone high vacuum grease, for water resistance. The third, and outermost, seal is made with EC-801 (synthetic rubber polymer), which serves as a retainer for the silicone grease.

Altogether, during the quarter 14 scintillator assemblies and 12 light-tight photomultiplier assemblies were constructed.

FLUORESCENCE PHOTOMETER - Frank J. Lynch

The third instrument is in operation. The troublesome drift in the reading of these instruments was found to be due to change in fluorescence output of the uranium glass reference sample with temperature. When this reference sample was replaced by a U in NaF melt sealed in a transparent envelope, the drift was reduced to a negligible level. Figure 4 shows the variations of fluorescence light output with temperature for uranium glass and uranium in NaF melt. The desirability of using a reference sample of the same constitution as the measured sample is apparent in cases where the measured sample has a high temperature coefficient of fluorescence; the effect of a change in temperature will be eliminated if the reference sample has the same temperature coefficient and is maintained at the same temperature.

The performance of the instruments is now considered satisfactory. Within 3 minutes after the instrument is turned on the reading is within 1% of the equilibrium value. In an 8 hour period of operation changes in reading

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FIG. 4 FLUORESCENCE VS TEMPERATURE

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of a sealed standard sample are less than 1%. The noise in the input circuit produces fluctuations in reading equivalent to less than 2.5×10^{-12} g of uranium. The instrument has been calibrated to read 10 revolutions (1000 div.) for $5 \cdot 10^{-7}$, $5 \cdot 10^{-8}$, $5 \cdot 10^{-9}$, or $5 \cdot 10^{-10}$ g of uranium. When the sensitivity is set on the 2 least sensitive ranges, removal of the panels over the optical system cause less than 1% change in reading when the room is lighted by incandescent lamps.

In subsequent instruments a number of simplifications will be made. A transformer will be substituted for the electronic circuit which subtracts the attenuated reference signal from the unknown signal. A single 6N7 operated Class B amplifier will drive the field winding of the induction motor in the servo system, greatly reducing the power supply requirements. The power will be simplified and the regulator omitted.

A report on the instrument was delivered at the Chicago meeting of the American Physical Society. A written report for publication is nearly completed.

ROTATING CONDENSER ELECTROMETER - Frank J. Lynch

The design of a new rotating condenser is complete. It will use sapphire bearings, and electrical contact to the rotor will be made by means of a tungsten carbide thrust plate or a liquid metal (3 parts Gallium, 1 part Indium). The rotor and stator will have 10 plates. The rotor assembly will be driven by magnetic coupling at 10 rps.

The shaft will be constructed in the instrument shop and will be sent out to have sapphire bearings fitted to it.

INSULATORS - Raymond M. Munick

Electric current measurements on lucite as a function of time, temperature, voltage, and mechanical stress were continued. Measurements have been begun on polystyrene and teflon. For lucite graphs are given of polarization current versus time and of steady state versus temperatures.

Typical behavior of an insulator when a potential difference is produced across it is indicated in Figure 5, which gives representative data for lucite. Similar curves, but of a lower order of magnitude, have been obtained for polystyrene and teflon. The current flowing from one of the electrodes decreases in magnitude as a function of time elapsed since application of the voltage until a steady value is reached or the current is too small to measure. With the present experimental setup steady currents have been observed for lucite, but only transient currents from polystyrene and teflon.

The transient part of the current, which is the total current less the steady value, is called the polarization, absorption, or electrification current. If the voltage is removed after the polarization current has dried out, a reverse polarization current is obtained, but no steady current. As a function of time elapsed from application or removal of the voltage, the direct and reverse polarization currents are approximately equal in magnitude for short times.

For specimen IV of lucite, which was investigated at 25, 37, and 49°C as well as at room temperature, around 25°C, the polarization current was insensitive to temperature, but the steady current increased exponentially with increase in temperature, as indicated by the data of Figure 6, which represents the logarithm of steady current with 315 volts applied as a function of the reciprocal of the absolute temperature. The curves are numbered in chronological order. After the steady current seemed to have been reached at 49°C for curve 1, it was found that the steady current was actually decreasing at a very slow rate. A repetition of the measurements about a week later yielded the data for curve 2. Subsequent measurements several weeks later gave curves 3 and 4. Thus, the conductivity defined by the steady current appears to depend on the electrical and thermal history of the specimen. The data of Figure 6, interpreted as volume resistivity at room temperature, would indicate a variation between 10^{18} and 10^{19} ohm cm. The activation energy indicated is about 9×10^{-4} electron volt.

Generally Ohm's law appears to be obeyed, that is, the steady current through lucite is approximately proportional to the potential difference across the specimen. There are discrepancies in the data, however, which indicate the need for more careful checks.

The polarization current for lucite is approximately proportional to the change in voltage for short times but seems to depend upon the voltage history for long times. This is indicated by the curves of Figure 7, which show polarization current versus time after voltage change for changes of 140 volts from zero to 420 and back to zero with the attainment of steady current between changes. In Figure 8 are shown the three curves of total current obtained when the voltage was stepped down from 420 to 280, 280 to 140, and 140 to zero. It is of interest to note that for periods of a few days a current flowed from the specimen which was unrelated to the magnitude and opposite to the polarity of the potential difference across the specimen.

Some attempts were made to determine the relation between mechanical pressure upon and charge flowing from specimen II of lucite. The guarded electrode was left floating, while weights of from 1 to 5 kilograms were placed upon the specimen. In general, the insulated electrode becomes suddenly more positive when a weight is added, with a smaller, slower positive increase, and more negative when a weight is removed, with a smaller, slower positive decrease. The effect is greater with larger weights, but the measurements are inconclusive quantitatively because of poor reproducibility and some inconsistencies.

Fig. 6

Steady current through lucite (with potential difference of 315 volts) versus reciprocal of absolute temperature. Curves numbered chronologically.

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ARGONNE DOSIMETER - Francis R. Shonka

A total of 1604 Argonne dosimeters have been put into service and an additional 246 dosimeters are in process of being transferred to the Industrial Hygiene and Safety division, making a total of 1850 Argonne dosimeters completed on this work project to date.

A review of the progress on this work project indicates that the average production rate for the last six months has been 154 dosimeters per month. The production rate was maintained at a good level even during the vacation period. The average rate may have been higher had it not been for the fact that lack of some parts, especially the reflecting objective, retarded progress. Since further difficulties in the production of parts are not anticipated, the production rate in the next six months should be higher.

HIGH RANGE DOSIMETER

Several models of the High Range Dosimeter were made and tested in an attempt to develop a dosimeter with a range of at least 5 r. Ten prototypes of the latest design are under construction.