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HEALTH PHYSICS DIVISION

K. Z. Morgan, Director
F. Western, Associate Director

QUARTERLY PROGRESS REPORT

for Period Ending January 20, 1951

DATE ISSUED MAR 21 1951

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1. INSTRUMENT DEVELOPMENT SECTION

Constant Water Monitor. An increase in sensitivity of the system being designed has been obtained by surrounding a thin-walled beta counter with a vertical cylindrical wall of water having about 1/8 in. air gap between the water wall and the counter. The wall of water is almost 1/2 in. thick, and there is no spray or splashing to contaminate the counter.

The continuous gas flow discharge counter 0.75 in. in diameter and about 2 in. in length was constructed largely of 0.0005-in. sheet aluminum so as to have a beta window area about 90 per cent of the total area of the counter. The counter, operated in the Geiger region, has a background counting rate of 11 c/min when shielded with 3 in. of lead. The beta window area is approximately 4.8 in.^{2}

A sample solution of Sr^{90} having an activity of 20 dis/cc/min was measured with the above apparatus with the following results: total counting rate, 32 c/min; background, 11 c/min; and net counting rate 21 c/min. In this case the activity counting rate is closely equal to the dis/cc/min of the activity. A test of activity measurement for 8 hr resulted in no increase of background counting rate although some water vapor did condense into a fine film on the lower part of the counter and thereby forcibly demonstrate the lack of carry-over of activity.

In brief, the work accomplished to date, although incomplete in fine detail, does indicate that a continuous water monitor can be constructed to have a significant reading (twice the background) where the activity of energetic betas is 11 dis/cc/min or more.

A modification of the instrument will permit rapid (10-min) measurements of beta activity in liquid solution of about 50 cc volume where the lower limit of activity is about 10 dis/cc/min. A desirable feature is in not having to reduce the activity to a solid. A disadvantage of the instrument is the counter shell which requires a beta energy of at least 45 Kev for penetration.

Fast-neutron Survey Meter. In collaboration with the Physics of Radiation Dosimetry Section, design information is being assembled so that commerical production of this instrument may be discussed.

2. RADIOACTIVE WASTE DISPOSAL RESEARCH

Physical facilities for research on problems of radioactive waste disposal will be expanded by construction of a laboratory and pilot plant building especially designed for this purpose. A contract for the construction of this building was awarded in December, 1950, and construction was begun early in January, 1951. Under the cooperative program with the U. S. Public Health Service and other agencies, this facility is being provided primarily for water decontamination research on both civilian and military problems, but it will also be an advantage in related waste disposal studies. Completion is expected in the middle or latter part of the summer of 1951.

The principal change of program during this period has been in the reorganization and intensification of the laboratory and small pilot plant studies on various methods of water treatment for the removal of particular isotopes and mixed fission products. There is a greatly increased demand for information and advice regarding the problems of possible contamination of community water supplies with radioactive materials, particularly from water works and sanitation officials who are responsible for emergency water-supply protection in connection with civil defense programs. Considerable time and effort have been devoted to the assembly of available data on water decontamination and to discussions of these problems with various groups.

Water and Liquid-waste Decontamination Processes. Two types of fission product mixtures were used in experimental studies to obtain further data on removal by water-treatment procedures. In one series, radioisotopes were mixed in proportions estimated to approximate the contamination of water that might result from an atomic explosion. In the experimental water-treatment plant this radioisotope mixture was fed to tap water containing 100 ppm of clay turbidity and was treated by coagulation with alum, lime, and sodium silicate; sedimentation; and passage through gravity filter columns containing standard sand and Anthrafilt media. Efficiencies in the removal of individual radioisotopes varied widely, but overall removals for the mixture were 70 to 73 percent In the laboratory a specially developed jar test unit was used in a series of studies to determine the reduction in activity in an aged and previously treated tank waste by variable amounts of clay turbidity. For clay additions ranging from zero to 4400 ppm followed by stirring and clarification, reductions up to 88% were obtained.

No further experimental work has been done on the calcium phosphate precipitation process for the decontamination of waters and liquid wastes mentioned in a previous progress report (ORNL-877). A report on these studies has been prepared and released, *Studies on the Removal of Radioisotopes from Liquid Wastes by Coagulation*, by R. A. Lauderdale, Jr., ORNL-932.

A special progress report and summary of data obtained thus far from the water-decontamination studies at ORNL are being prepared and are to be completed during January, 1951. The purpose is to indicate, as definitely as present data will permit, the efficacy of normal and modified water purification procedures in the removal of radioactive contaminants from water. Considerable information concerning methods of water decontamination was reviewed in an article and in a paper prepared during this period: (1) "Observations on the Removal of Radioactive Materials from Waste Solutions" by Conrad P. Straub, scheduled for publication in *Sewage and Industrial Wastes*, February, 1951; and (2) "Recent Developments in the Treatment and Disposal of Radioactive Waste Liquors," by Conrad P. Straub, a paper presented at the 117th Meeting of the American Association for the Advancement of Science in Cleveland, Ohio, Dec. 29, 1950.

In an effort to meet the needs of civil defense agencies and others for a reliable method of decontaminating small quantities of drinking water, two workers of this section have developed and tested a small water-decontamination unit for this purpose. Numerous tests have indicated that by passage through this unit, quite large concentrations of mixed fission products can be reduced by a factor of 10^4 or greater. A preliminary report is to be completed soon describing the details of this unit and the results of evaluation tests that have been completed up to that time.

Some work on sewage-treatment processes has been continued. The graduate student of the Georgia Institute of Technology assigned to this section completed his thesis work on the removal of I^{131} from sewage by laboratory trickling filters, prepared a preliminary draft of his findings, and is compiling a final report and thesis on this project. In other series of experiments, the efficacy of activated sludge in the removal of mixed contaminants from a diluted waste-tank solution using jar tests with various periods of stirring and also the removal of I^{131} from raw sewage mixtures by contact during stirring were given further study.

Survey Studies and Ecological Study of White Oak Creek Drainage System. This category includes studies and installations that are of particular interest to the ORNL program and also those concerned specifically with the special Ecological Study being executed by TVA.

The weir installation below the settling basin has been completed, and the entire flow from the settling basin is now passed through the weir box. A continuous water-level recorder and a continuous sampler have been installed. Continuous records of outflow and facilities for proportional sampling of the effluent are therefore available.

The trailer-mounted automatic cable reel for the logging of radioactivity in the test wells previously installed at various points in the X-10 area was constructed, used for making about thirty logging records, and corrected for improved operation. Two new reels designed for operation by gravity instead of by motor drive are being constructed. When the development of these is completed it is expected that periodic logging of the fifty test wells will be adopted as a routine survey operation.

Studies by the staff of the Ecological Study program include physical studies, fisheries biology, botany, and limnology. A summary of progress in these studies includes the following:

1. The study of the time of water travel from the X-10 area through White Oak Lake was repeated using fluorescein dye instead of salt as the indicator of water movement.
2. A "Preliminary Study of the Fish Population of White Oak Creek, September - October, 1950" was completed, and a report of this study has been prepared for early distribution.
3. A detailed study of the level and distribution of radioactivity in fish of White Oak Lake is in progress and about 20% complete. This involves dissection and radioassay of specimens of each species of fish present in the lake and the calibration of the fish probes against the radioactivity found in the sacrificed fish.
4. The relation of vegetation to soil activity in the lake area is being studied by sampling and analysis, and an improved method of preparing soil samples for gross beta counting through the use of a graduated set of sieves has been developed.
5. Limnological investigations were directed particularly toward a survey of the plankton flora and fauna of White Oak Lake. These have included observations and appraisal of related conditions such as temperature, oxygen content, nitrogenous compounds, carbonates, and turbidity and the collection, classification, and quantitative estimation of plankton specimens at numerous selected points in the lake.

Instrumentation and Techniques. Progress in instrumentation for waste disposal studies has included redesign and shop work orders of the well-logging equipment mentioned above and further work and calibration on the several Ecological Study instruments mentioned in previous quarterly reports. A source of concentric tubing was located, and with improved shop techniques this permits construction of G-M tubes for beta probes with walls approximately 0.001 in. thick without strengthening ribs.

As a part of the project to measure and record water levels and radioactivity at White Oak Dam with telemetering to the X-10 Area, the float-operated water-level recorder was installed at White Oak Dam and has been in operation for some time. However, changes of the design for alterations and further construction at the dam may necessitate gauging and monitoring at a different location from that originally selected, and, therefore, the installation of telemetering and monitoring facilities has been deferred until the final design for these alterations has been adopted.

For the measurement of radioactivity in live fish, improved gamma probes have been constructed using copper tubes lined with bismuth instead of the stainless steel tubes. Also a scintillation type gamma detector using sodium iodide crystals has been designed and is being constructed in an effort to attain the desired gamma sensitivity in the fish probe instrument.

3. THEORETICAL PHYSICS

Fast-neutron Tolerance Calculations. Collision densities and energy losses from a 10-Mev beam of neutrons normally incident on a 30-cm slab of tissue have been obtained by a Monte Carlo procedure. A preliminary report summarizing the data, together with the resulting tolerance determination, is being prepared. As soon as machine time is available, the data will be used to obtain information concerning beams of lower energies.

Empirical Evaluation of Effective Atomic Number. A report on the determination and use of an effective atomic number for compounds is being written. It is found that while the gamma-ray mass absorption coefficient can, in general, be determined within 10 per cent by using such formulas for the range $6 \leqslant Z \leqslant 20$ and for 0.01 Mev $\leqslant E \leqslant 0.25$ Mev, the error in some few cases may be as much as 20%.

Calculation of Stopping Power at Intermediate Energies. The problem has been completed and the details are published in ORNL-884.

Stopping Power of Ions in Tissue. The problem consists in evaluating the relative damage caused by recoil H, C, N, and O ions in tissue due to fast-neutron radiation. The contribution due to atomic collisions has been evaluated. The ranges of energy considered are 0.25 Kev to 2.5 Mev for hydrogen ions and 2.5 Kev to 25 Mev for heavier ions.

4. PHYSICS OF NUCLEAR RADIATION

Measurements of Neutron Dosage. (*a*) *Piezoelectric frequencies.* Previously mentioned (ORNL-786) 5- and 1-megacycle quartz crystals were further tested. One 5-megacycle crystal, 5-A, showed a frequency variation of 15 cycles in the course of several days of observation. Another specimen, 5-B, on being washed with distilled water and dried with hot air, showed a drop in frequency of about 100 cycles, after which there was a fluctuation of about 13 cycles. Crystal 1-A, activated at its second harmonic (approximately 2 megacycles), also showed a frequency range of about 15 cycles. Crystal 1-C, on being washed with distilled water, showed an immediate drop in frequency of about 30 cycles and an additional drop of approximately 20 cycles in the course of two weeks, after which its frequency varied within a range of about 5 cycles.

The cooperation of R. S. Livingston and his group was obtained to make exposures of these crystals to a beam of 1-Mev protons in their 22-in. cyclotron. Crystal 5-B was exposed to 10 μa-sec at 1 μa of the proton current. A drop in frequency of 320 cycles occurred, but the exposed face of the crystal was somewhat discolored, and it appeared possible that the frequency change was due to loading by some foreign material carried by the beam. After the crystal was washed with HCl, the frequency increased by about 25 cycles. Crystal 5-A was then exposed to 30 μa-sec at 1.5 μa, but it was shattered by this current. Crystal 5-B was accidentally chipped. Other exposures are planned, the crystal to be screened with aluminum foil, but these are to be sandwiched in as convenient to both parties.

Through the kind cooperation of V. W. Siebs of Western Electric Company, who are the only producers at present, we secured a few specimens of EDT (ethylenediamine tartrate) piezoelectric crystals. Since half the atoms of this material are hydrogen, any effects due to recoil protons from fast neutrons were expected to be maximum. The crystals had a fundamental frequency of 55.950 kilocycles, and an oscillator with multiplier stages was therefore constructed, giving the 18th harmonic of about 1 megacycle. These specimens were of zero cut at 26°C and were very stable, varying only about 2 cycles per megacycle in the course of two days. One specimen was exposed to 4.8×10^9 n_f/cm^2 (Po-Be), 8.1×10^9 n_f/cm^2 (Po-Be), about 3×10^{12} n_f/cm^2 (fission), and 2.4×10^{13} n_f/cm^2 (fission). At the end of this series there was a drop

in frequency of 1.7 ± 0.9 — an insignificant change. Since this series of fast-neutron exposures comprises about 9×10^5 weeks of tolerable exposure, it is evident that the material is not suitable for neutron monitoring.

(*b*) *Modification of conventional gamma pocket meters.* Work was begun on the modification of pocket meters to try to determine fast-neutron exposures. Calculations had indicated that, by modification of materials, differential response to n_f and γ radiation should be obtainable. While the response was not expected to correspond to rem, it was expected to be measurable.

The first test consisted in filling a group of the tenite II—walled Victoreen pocket meters with propane gas (C_3H_8). On an average, seven of these chambers responded only 2 per cent more to Po-Be neutrons than eight air-filled chambers. At the same time, γ (Ra) response was increased by 34 per cent. From this it appeared that wall effects would have to be used.

In a second test 12 Victoreen pocket meters were used. Half had sleeves of 2S aluminum, sufficient to stop 10-Mev protons, inserted to shield the tenite walls. The other half had sleeves of an equivalent thickness of aquadag-coated polyethylene inserted. This latter had the dual purpose of both equalizing the collecting volume and enriching the walls in hydrogen content. Exposures to Ra γ gave a 24 per cent drop in average readings by the polyethylene-lined group, and a 20 per cent drop in the aluminum-lined group when compared to a control group of 20 unmodified chambers. Exposure to Po-Be neutrons gave an 18 per cent rise in the polyethylene-lined group, and a 49 per cent drop in the aluminum-lined group as compared to the control group.

Four chambers were then fabricated; two of them had aluminum walls and teflon insulators, to eliminate hydrogen, and the other two had polyethylene walls and insulators to maximize the hydrogen content of the walls. Preliminary tests indicate that the gamma response of the two groups is approximately the same, and the neutron response of the hydrogenous chambers is about 2.5 times that of the nonhydrogenous group. However, there has been considerable irregularity of leakage stability and the chambers are too few for conclusive tests. Six more of each type have been constructed and are about to undergo further tests. With some modification and refinement, this project shows promise of feasibility.

(*c*) *Particle film microscopy.* A rotating azimuthal dark-field condenser developed by E. H. Land, and described in AECU-700, has been fabricated at our shop. This device causes nuclear tracks, which consist of aligned silver

grains, to fluctuate in intensity of illumination as the beam rotates, while leaving random grains relatively constant. As a consequence, tracks are recognizable at lower magnification, and the area scanned by a microscope field is larger.

It was observed that at 100× the effectively illuminated area was 20 times that of one microscope field at about 900×. It was further noted that while a three-grain track can be distinguished at 900×, it cannot be distinguished at 100× even with the rotating dark-field. In fact, counting efficiency was about 35 per cent. Thus the effective improvement is by a factor of about 7. There is the further drawback that personal judgment of the observer is more significant than with 900× standard dark-field observation. A few films, counted by three observers, showed counts varying by about 30 per cent. On the other hand, the statistics of the counts are improved considerably, since tolerable exposure is indicated by about 150 tracks per 12 fields rather than 22 tracks per 10 fields as by the present method. Further practice may bring about more consistency.

Beta Scattering. Experiments discussed in ORNL-877 were continued. A modification of the design of the extrapolation chamber previously used permitted measurements in gases other than air and in vacuo. The modified chamber is described in ORNL-905. The purpose of the investigation in vacuo was to determine the actual electron backscattering. Most of the investigation was made with beta radiation from S^{35}.

The first part of the investigation consisted in the evaluation of the backscatter from the collector material. It was noted that the reversal of the collecting voltage, about 90 volts, between the source carrier and the collector produced a considerable change in intensity. Therefore, using a beryllium collector, the collecting voltage was varied from zero to about 14 volts between the source carrier and collector, keeping first the collector positive, later negative relative to the carrier. The change of intensity amounted to an increase of about 30 per cent for positive collection (positive collector), and a decrease of the same order for negative collection, taking the intensity at collector voltage zero as 100 per cent. The major portion of the variation occurred between zero and 3 volts in either direction.

Repeating these experiments with cadmium and lead collectors, the percentage variations increased up to 85 per cent while the actual intensities

decreased. This decrease of the total intensity with Z was expected and looked for owing to previous theoretical considerations. Extending the variation of the collector voltage up to 1500 volts, it was found that only a very slow, 5 to 10 per cent, gradual increase for positive collection and a still smaller decrease occurred for negative collection beyond 10 to 14 volts. These observations are in qualitative agreement with the report of I. J. Trump and R. J. Van de Graaff in *Physical Review* **75**, 44-45 (1949). However, a preliminary evaluation will be given here pending further investigation.

The very large intensity variations between zero and 10 volts (Fig. 1) and the very small changes from 15 to 1500 volts (Fig. 2) indicate that two different processes have to be considered. The slowly varying intensity above 15 volts is apparently due to the effect of the battery voltage between source and collector on the primary and backscattered particles of comparatively high energy. Since S^{35} has an energy distribution varying from zero to 168 Kev, it is quite understandable that the effect of 1.5 Kev should be small.

The comparatively large effect of the very low potential from zero to 10 volts is apparently not due to real backscattering but to the production of actual secondary electrons of properties similar to those produced in a vacuum tube. Consider a high-velocity particle, primary or backscattered, moving through matter. The particle will produce ionization along its path and, therefore, electrons with energies up to a few volts. Inside the material these electrons will be stopped within some few atomic layers, but at the boundary between the material and the vacuum they can enter the vacuum if their energy exceeds the work function of the material. Let

I_+ = the current measured with the collecting electrode positive

I_- = the current measured with the collecting electrode negative

I_β = the current carried by the primary beta particles emitted from the source

α_Z = the fraction of I_β backscattered from the collector

S_p = the number of secondary electrons emitted from the source carrier per primary beta particle

S_Z = the number of secondary electrons emitted from the collector material, of atomic number Z, per backscattered beta particle

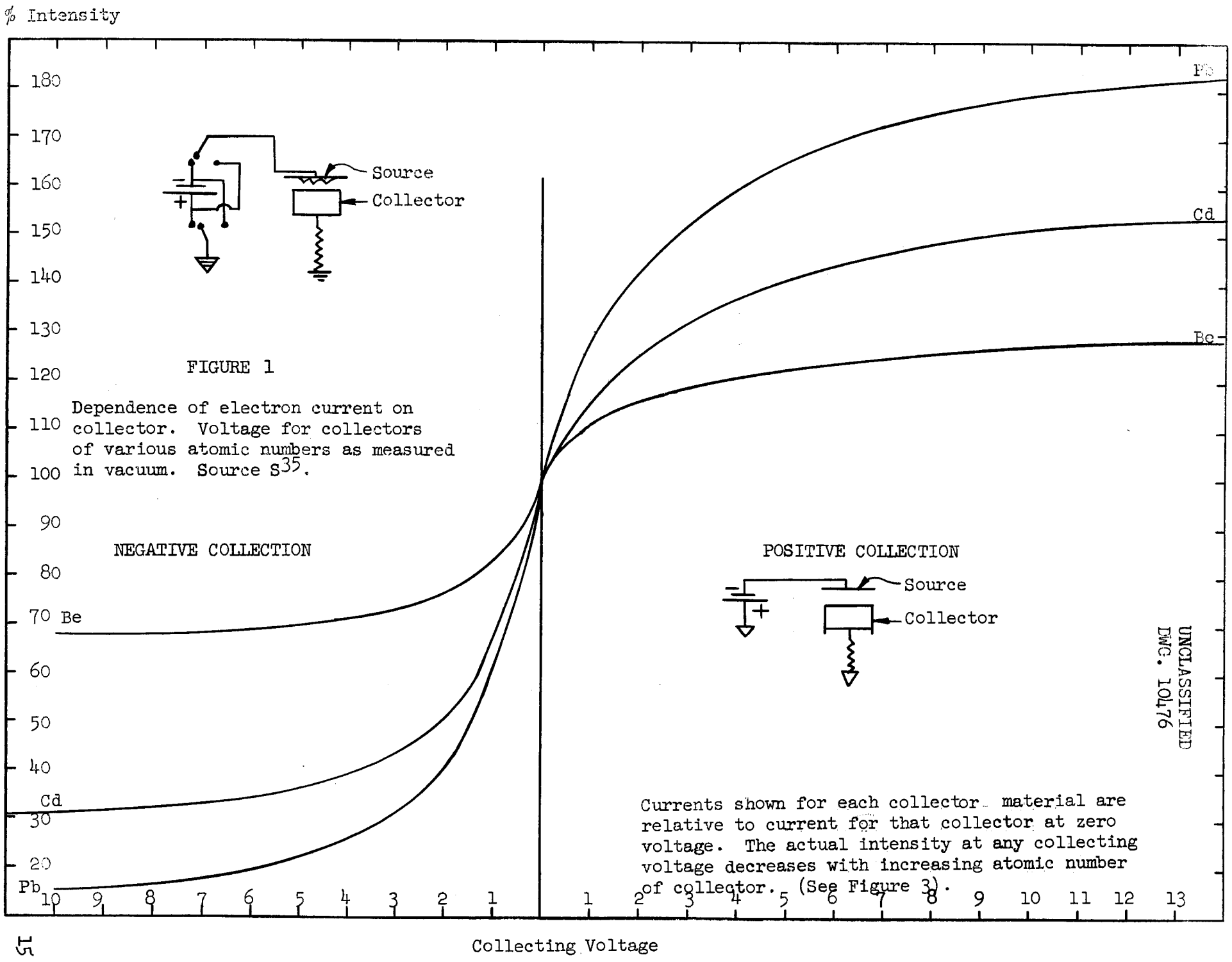

FIGURE 1

Dependence of electron current on collector. Voltage for collectors of various atomic numbers as measured in vacuum. Source S^{35}.

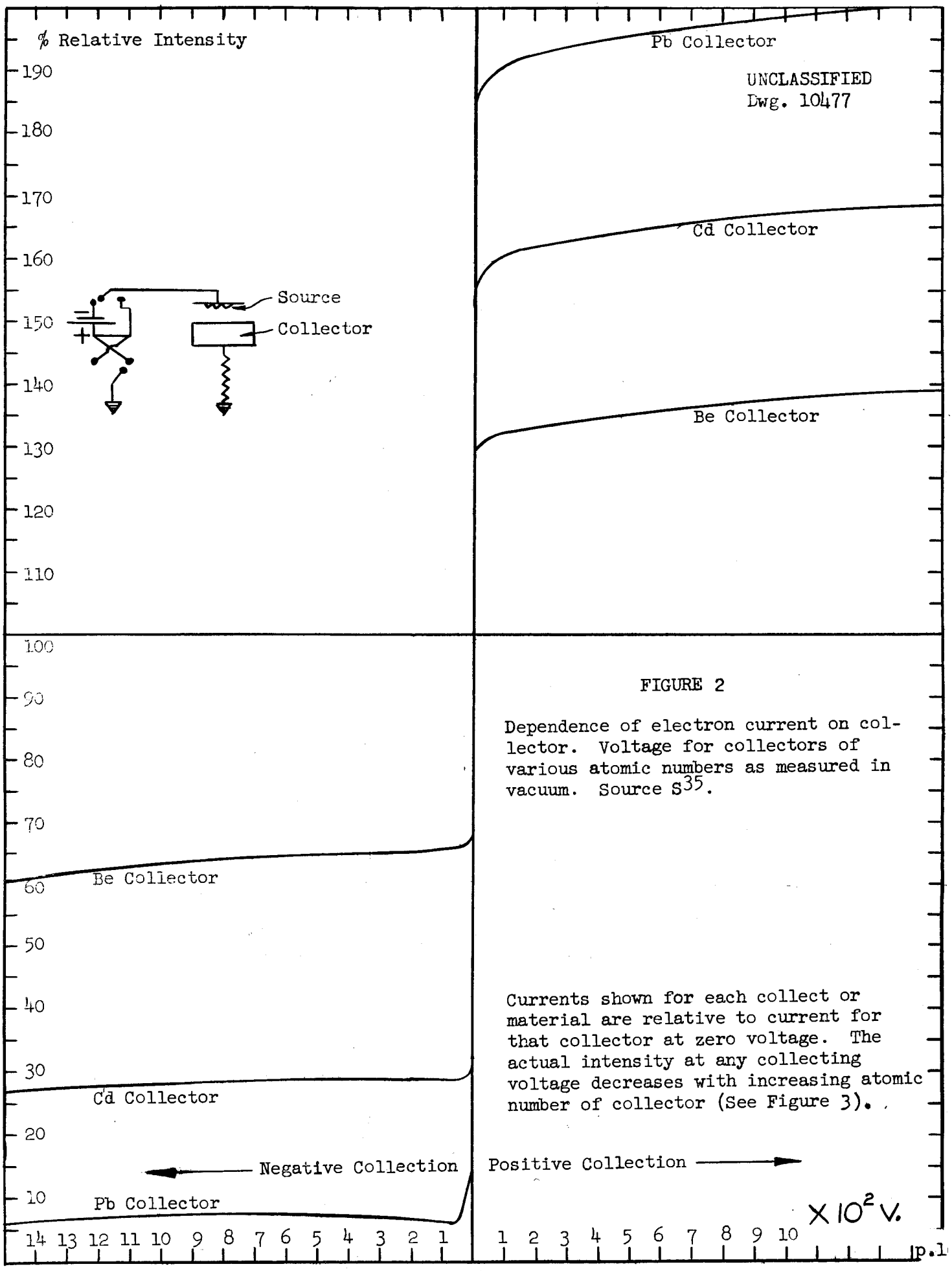

FIGURE 2

Dependence of electron current on collector. Voltage for collectors of various atomic numbers as measured in vacuum. Source S^{35}.

Currents shown for each collect or material are relative to current for that collector at zero voltage. The actual intensity at any collecting voltage decreases with increasing atomic number of collector (See Figure 3).

$f(E_Z)$ = the distribution of energy of the beta particles backscattered from a collector of atomic number Z. (This distribution is, of course, dependent upon the distribution of energy of primary particles which, for purposes of this discussion, is assumed constant.)

$F(E_p)$ = the distribution of energy of the primary betas.

E_B = battery voltage.

The currents will be given, neglecting second-order terms, as a rough approximation by

$$I_+ = I_\beta \left\{ 1 - \alpha_Z \left[1 - \int_{10}^{E_B} f(E_Z)\, dE \right] + S_p \right\} \tag{1a}$$

$$I_- = I_\beta \left[1 - \alpha_Z - \int_{10}^{E_B} F(E_p)\, dE - \alpha_Z S_Z \right] \tag{1b}$$

The following treatment makes the assumption that the fast particles are producing secondaries principally in the direction of their movement. For an exact quantitative result this is not quite correct.

The secondaries, except for a small number with energies more than 10 volts (see Figs. 1 and 2), opposed by the applied voltage E_B cannot reach the opposite electrode, i.e., in Eq. (1*a*) the secondaries originating from the collector, in Eq. (1*b*) those originating from the source carrier are eliminated. The secondaries in the direction of the applied field will reach or leave the collector and will be counted. In Eqs. (1*a*) and (1*b*) the electron current flowing into the collector is counted as positive and the electron current leaving the collector as negative. These equations show that for increasing values of α_Z the total currents decrease. Since α_Z always increases with A, the current measured decreases with increasing atomic number of the collector. Furthermore, owing to the positive sign of S_p and to the minus sign of $\alpha_Z S_Z$, I_+ is always larger than I_-. Both conclusions are fully confirmed by the experiment (Fig. 3).

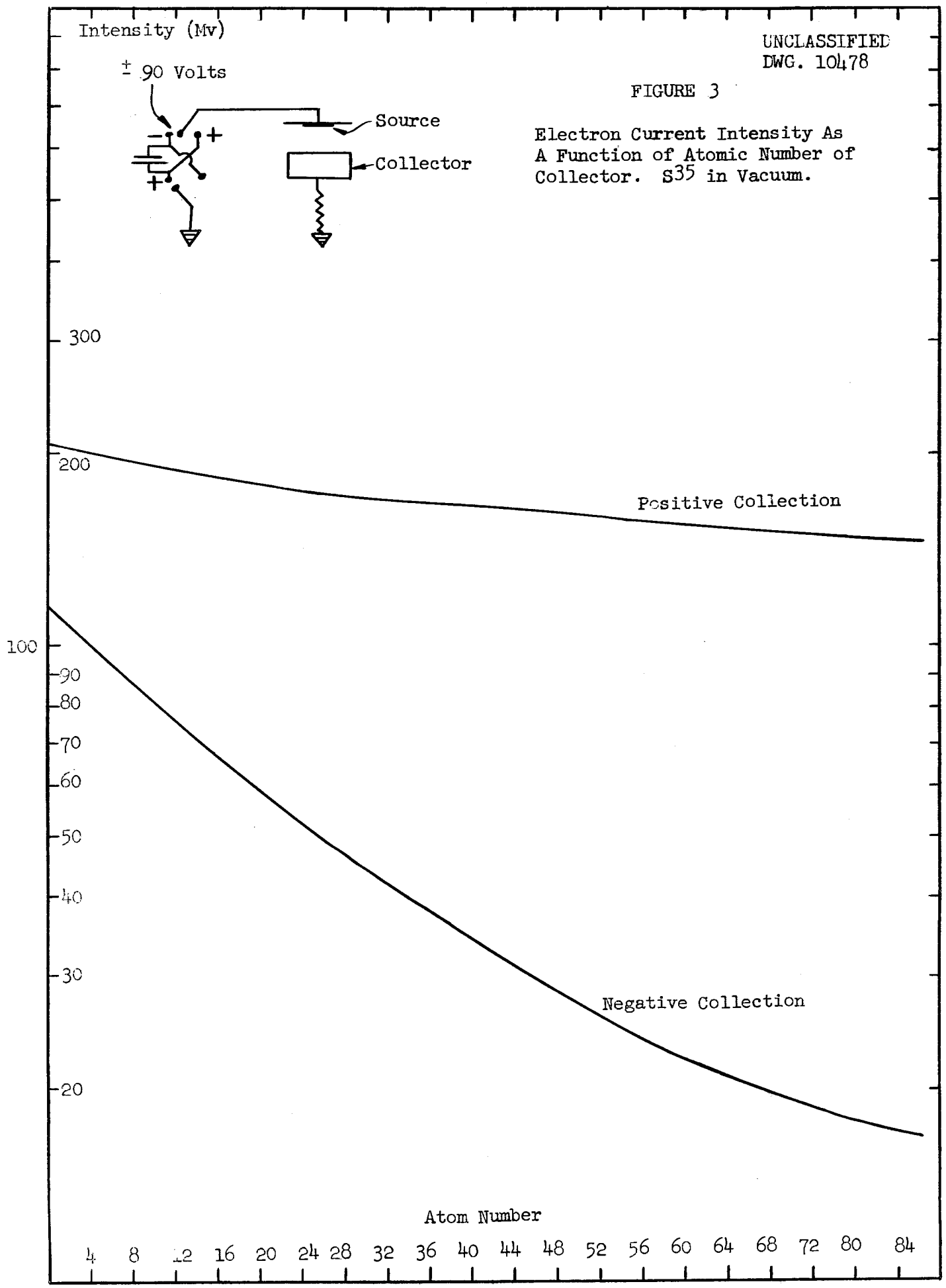

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FIGURE 3

Electron Current Intensity As A Function of Atomic Number of Collector. S^{35} in Vacuum.

Equations (1a) and (1b) can be simplified for collector voltages less than 200 volts by neglecting the contributions of the integrals

$$I_+ = I_\beta(1 - \alpha_Z + S_p) \tag{2a}$$

$$I_- = I_\beta(1 - \alpha_Z - \alpha_Z S_Z) \tag{2b}$$

Plotting I_+ and I_-, for a constant collector potential of 90 volts, on semilog paper (Fig. 3) the curves can be extrapolated to $Z = 0$. For $Z = 0$, α_Z should be equal to zero (no backscattering) and $I_- = I_\beta$; S_p can now be obtained from Eq. (2a). Using the value of I_β as a constant and S_p as approximately constant, the α_Z can be calculated from Fig. 3.

They were found to be

COLLECTOR	α_Z
4 Be	6
13 Al	19
29 Cu	30.5
48 Cd	41.0
73 Ta	49.5
89 Pb	53.0

For applied potentials less than 15 or 20 volts, the secondary electrons will partially overcome the opposing field. Beginning with zero voltage and increasing the field for positive collection, the current of electrons flowing out the collector will be $-\alpha_Z S_Z$ less those that cannot overcome the opposing voltage; i.e., $\alpha_Z S_Z \int_0^{E_B} f(E_{S,Z})$. The integral will be equal to 1 for $E_B = \infty$, which is actually approximated by E_B = 15 volts.

Applying the same consideration for negative collection, the result is given by:

$$I_+ = I_\beta \left\{ 1 - \alpha_Z - \alpha_Z S_Z \left[1 - \int_0^{E_B} f(E_{S,Z})\, dE \right] + S_p \right\} \tag{3a}$$

and

$$I_{-} = I_{\beta} \left\{ 1 - \alpha_{Z} - \alpha_{Z} S_{Z} + S_{p} \left[1 - \int_{0}^{E_{B}} f(E_{S,p})\, dE \right] \right\} \tag{3b}$$

where $f(E_{S,Z})$ and $f(E_{S,p})$ are the distribution functions of the secondaries originating from the collector and from the source carrier.

5. RADIOCHEMICAL ANALYSIS

Analytical Procedure for Analysis for Plutonium in River Water. There exists a need for a procedure for analysis of river and stream water for plutonium. It is of special interest at Oak Ridge National Laboratory since water from the White Oak Dam is discharged into the Clinch River. The procedure which is presently used is unsatisfactory because of the difficulty of separating the plutonium from iron and other inorganic constituents of the sample. Also, indeterminate self-absorption of alpha radiation results from extraneous inorganic materials being plated with plutonium.

The development of a procedure has been complicated by such problems as (1) working with a minimum volume of 1 liter, (2) complete destruction of silicates, and (3) separation of plutonium from iron. At present a method for separation of plutonium from iron has not been satisfactorily worked out. Most promising is a procedure in which plutonium is coprecipitated with calcium oxalate at a *p*H of 2.5. However, separation from iron is not complete, and the control of the *p*H is difficult under the conditions of precipitation.

It is desired to have a procedure which is reproducible and quantitative to approximately 90 per cent.

6. PHYSICS OF RADIATION DOSIMETRY

Neutron Dosimetry. The development of fast-neutron proportional counters of specialized design discussed in the Health Physics Division's last four quarterly reports, ORNL-596, 695, 786, and 877, has been written up in detail as a report just issued, ORNL-930, entitled *A Count-Rate Method of Measuring Fast Neutron Tissue Dose.*

Currently work is continuing on designs for a counter that will have a uniformly cylindrical electric field with negligible end corrections, to be used with the pulse integration type of neutron dosimeter previously described. The purpose of this field arrangement is to produce a uniform gas amplification throughout the active volume of the counter so that calibrations in terms of reps may be made with an alpha particle source built into the counter, instead of requiring a known neutron source each time recalibration is needed.

The Instrument Development Section of this Division has designed a circuit and preliminary packaging, and we have adapted one of the types of counters described in ORNL-930 to make a complete fast-neutron survey meter. This instrument represents a distinct improvement in weight, convenience, and reliability over the preliminary models of the instrument which have proved reasonably satisfactory in field work by our Radiation Survey Section. Commercial production of this instrument will be discussed in the near future.

Shielding Calculations. As a part of our cooperation with the Shielding Program of the Physics Division, calculations have been made and a report will shortly be made to the Shielding Group estimating the corrections to be made to the fast-neutron dosimeter readings inside a thick shield containing water. The purpose is to correct from the experimental observations within a large tank, where scattering material is on all sides of the dosimeter, to the practical situation where all the shielding material is between the dosimeter and the source. There will also be given a method of extending the theory of Bethe, Hurwitz, and Tonks (AECD-2790) to include neutron capture when the theory is used to calculate dosimeter readings in shields composed of heavy materials. This method reduces considerably the amount of work which is required to obtain numerical results.

Personnel Monitoring for Beta Rays. The widely used pocket ionization chamber has relatively thick walls and hence is opaque to beta rays of energy

less than 700 to 900 Kev. The ionization in its chamber produced by higher energy betas is reduced by about this amount, so the chamber is very insensitive to ordinary beta rays. Work is in progress on a chamber of similar gamma sensitivity but with a wall thickness of only 6.7 mg/cm^2, equivalent to the average thickness of the insensitive layer of the human epidermis and penetrable by beta rays of about 70 Kev energy. This thin paper wall is protected by a fine-mesh screen of metal or perhaps plastic for mechanical strength. Preliminary models show about the expected gamma sensitivity, and a response to known beta sources which is very promising. Leakage seems to compare very favorably with the commercial gamma chambers.

X-rays. A 250-kv-constant-potential X-ray machine has been purchased from Westinghouse and is in process of installation. This will be operated both for research projects of this section and as a service to the entire division.

Stopping of Heavy Ions. Preliminary studies are being made of the feasibility of experimental investigation on the damage caused by heavy ions to tissue-like materials in the region beyond the end of their ionization range. Protons may have energies of hundreds of Kev, and fission fragments may have energies of even several Mev, yet be going too slowly to ionize, at least according to presently accepted theories of Bohr and others. This residual energy has heretofore either been neglected in Health Physics calculations, or it has been assumed that the total damage is proportional to the ionization. The object of the project will be to investigate the validity of these assumptions.

7. EDUCATION AND TRAINING

AEC Fellowship Program. The present group of 20 AEC Fellows in Radiological Physics have completed the first quarter of their graduate work at Vanderbilt University with satisfactory records and have begun the second quarter of work there. Beginning February 12 members of the Laboratory staff will go to Nashville two days a week to teach the Health Physics course. The course will continue throughout the remainder of the school year.

Physics Course for Division Personnel. A course in atomic and nuclear physics at the college level which was instituted for a group of health physics surveyors who expressed a desire for such a course has continued throughout this period. It is given in the evening 3 hr per week.

Miscellaneous Activities. Members of the staff are assisting in other teaching activities in the Laboratory, particularly in the Apprentice Training School and in the Reactor School. The Education and Training Section has assumed the responsibility for that portion of the weekly orientation program pertaining to health physics.