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SEMIANNUAL PROGRESS REPORT
FOR PERIOD ENDING JULY 31, 1954

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For Period Ending July 31 1954

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CONTENTS

THEORETICAL PHYSICS 1
- Passage of Charged Particles Through Plasma 1
- Effect of Medium Density on Stopping of Moving Ions 1

PHYSICS OF NUCLEAR RADIATION 2
- Applied Dosimetry 2
- Electron Drift Velocities 2

RADIATION MEASUREMENTS 4

RADIATION DOSE 4
- Internal Dose 4
  - Spectrographic analysis of human tissue 4
  - Maximum permissible concentration experiments on mice 5
  - Radiochemical analysis 5
- External Dose 6
  - Resonance frequency variation of piezoelectric crystals 6
  - Measurement of ionizing radiation by high frequency variation 6
  - Film dosimetry for fast neutrons 6
  - Energy losses of electrons in foils 6
  - Ion recombination errors in pocket chambers 7
  - Film dosimetry 7

AIRBORNE RADIOPARTICULATE CONTAMINATION 8
- Study of Radioparticulate Contamination at X 10 8
- Air Pollution Caused by Ground Disposal 8
- Sand Entrainment Separators 8

RADIOACTIVE WASTE DISPOSAL 11
- Liquid Waste Decontamination Processes 11
  - Flotation 11
  - Process waste treatment experimental plant studies 13
  - Chemical laboratory studies with reactor waste solutions 13
- Surveys and Evaluations – Field and Laboratory 14
  - Waste pit studies 14
  - Field explorations 16

EDUCATION TRAINING AND CONSULTATION 16
- AEC Fellowship Program 16
- Other Training Programs 16

PUBLICATIONS 17

PAPERS 18

LECTURES 19

HEALTH PHYSICS DIVISION
SEMIANNUAL PROGRESS REPORT

THEORETICAL PHYSICS

J Neufeld
W S Snyder R H Ritchie

PASSAGE OF CHARGED PARTICLES THROUGH PLASMA

When plasma problems are dealt with the customary approach involving interactions of individual electrons can be replaced by a phenomenological approach in which the plasma is treated as a homogeneous dispersive medium In conventional dispersive media the dielectric constant is an operator which operates on the time variable In plasma however the dielectric constant is characterized by essentially different properties since it operates not only on the time variable but also on the space variable The representation of plasma as a dispersive medium is subject to certain validity criteria which are satisfied for such typical cases as the ionosphere and electrical discharge through gases but are not satisfied for electrons in the conduction band of a metal The passage of charged particles through plasma is investigated by means of straightforward application of Maxwell s equations for a dispersive medium The Debye screening which is applicable to the potential of an incident particle having velocity $V \ll \langle v^2 \rangle^{1/2}$ (where $\langle v^2 \rangle^{1/2}$ is the root mean square velocity of plasma electrons) loses its significance when $V \gg \langle v^2 \rangle^{1/2}$ and in the latter case the potential decreases with the distance in accordance with an inverse cube law The stopping power has been calculated for incident charged particles having $V \ll \langle v^2 \rangle^{1/2}$ and $V \gg \langle v^2 \rangle^{1/2}$ in a plasma comprising electrons distributed in accordance with Maxwell Boltzmann and Fermi Dirac statistics

EFFECT OF MEDIUM DENSITY ON STOPPING OF MOVING IONS

Early experiments performed by Michl[1] and Philipp[2] and confirmed more recently by Appleyard[3] have established that water in the liquid state has a stopping power for alpha particles higher by 10 to 20% than that of water vapor Consequently the Bragg rule which claims additivity of atomic stopping power for all media is questioned Several experiments have shown an anomaly in the stopping power which for incident heavy particles appears to be greater in condensed media than in gases It is suggested that this anomaly is characteristic of incident ions i e of particles that are not completely stripped of orbital electrons and seems to be due to the reaction of the perturbed medium upon the moving ion having charge Ze resulting in a field $F = (1/Ze)(dW/dz)$ acting against the motion of the ion (dW/dz is the energy loss per centimeter) Although F is relatively weak in gases it is substantial in condensed media and may cause the spontaneous emission of electrons carried by the ion (autoionization) thus increasing the effective charge of the ion The higher effective charge accounts for the higher stopping power in condensed media When an incident helium atom passing through a liquid undergoes a collision and thus emerges in a singly ionized and excited state it has been determined that it cannot exist in such a state since it becomes instantly doubly ionized However the same type of collision occurring in a gas leaves the atom singly ionized The effective charge of the incident particle depends upon the values ϕ_0 ϕ_1 and ϕ_2 which represent the probability of the particle being neutral singly ionized and doubly ionized respectively where ϕ_0 ϕ_1 ϕ_2 $= \sigma_{10}$ σ_{21} σ_{01} σ_{21} σ_{01} σ_{12} (σ_{if} represents the cross section for electron loss or capture i and f represent the charge before and after the event respectively) It has been shown that ϕ_{if} is higher for a condensed medium than for a gas if $i < f$ and lower if $i > f$ σ_{if} has been calculated for helium passing through argon gas at 400 kev which gives roughly ϕ_0 ϕ_1 $\phi_2 = 0\ 05$ $0\ 75$ $0\ 20$ the average square charge is thus $\overline{\epsilon^2} = 1\ 55e^2$ When autoionization is taken into account σ_{if} for helium in liquid argon gives roughly ϕ_0 ϕ_1 $\phi_2 = 0\ 04$ $0\ 70$ $0\ 26$ and thus $\overline{\epsilon^2} = 1\ 74e^2$

[1] W Michl *Sitzber Akad Wiss Wien Math naturw Kl* 123 1965 (1914)

[2] K Philipp *Z Physik* 17 23 (1923)

[3] R K Appleyard *Proc Cambridge Phil Soc* 47 443 (1950)

PHYSICS OF NUCLEAR RADIATION

G S Hurst W G Stone
T E Bortner W A Mills
M Slater

APPLIED DOSIMETRY

After additional investigations with the standard fast neutron tissue dosimeter [1] the gas amplification of the dosimeter was decreased from 150 to 25 which improved the resolution of the internal alpha source used for calibrating the dosimeter

Figure 1 is a graph of the curves of integral count rate vs pulse height for the alpha source for the two amplification values 150 for curve *A* and 25 for curve *B* By differentiating curve *B* the resulting width at half maximum pulse height gives a resolution of 7% The previous resolution was 20% The operating conditions for curves *A* and *B* of Fig 1 are listed in Table 1

By using the standard fast neutron dosimeter with the improvement in resolution a polonium beryllium (Po Be) neutron source was calibrated in terms of rep per neutron per square centimeter The measured value was $4\ 65 \times 10^{-9}$ rep/neutron/cm^2 and agreed with the value of $4\ 71 \times 10^{-9}$ rep/neutron/cm^2 calculated by using the Po Be neutron spectrum as reported by Elliot *et al* [2] weighted against first collision dose calculations

[1] G S Hurst *Brit J Radiol* **27** No 318 353 357 (1954)

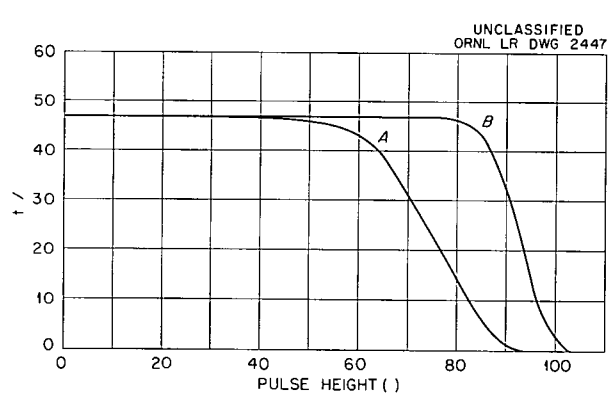

Fig 1 Count Rate vs Pulse Height for Alpha Source for Two Amplification Values

The value previously measured[1] for a Po Be source was $4\ 45 \times 10^{-9}$ rep/neutron/cm^2

A proportional counter suitable for use as a neutron dosimeter around cyclotrons has been developed This counter is similar to the ethylene polyethylene counter reported by Hurst [1] However the intensity of the neutron emission and the magnetic field present in a cyclotron necessitated certain changes in design By decreasing the sensitive volume of the counter the dosimeter has a sensitivity of 2×10^{-5} rep/count at the lowest integral pulse height i e at the pulse height of maximum count rate In addition the magnetic field required that the stainless steel collecting wire be replaced by a platinum wire The very successful design was achieved through the cooperation of R K Abele and E Plasterer of the Instrumentation and Controls Division

ELECTRON DRIFT VELOCITIES

The drift velocities of electrons in a few gases and in mixtures of gases have been obtained by using the method described previously Drift velocities (cm/μsec) of electrons in argon and nitrogen as a function of E/P (v/cm/mm Hg) are shown in Fig 2 and the velocities in mixtures of argon and methane are shown in Figs 3 through 5

[2] J O Elliot W I McGarry and W R Faust *Phys Rev* **93** 1348 1349 (1954)

TABLE 1 OPERATING CONDITIONS FOR AMPLIFICATION VALUES SHOWN GRAPHICALLY IN FIG 1

Curve	Preamplifier Gain	Linear Amplifier Gain	Operating Voltage (v)
A	>1	32 × 1	3400
B	30	8 × 1	2900

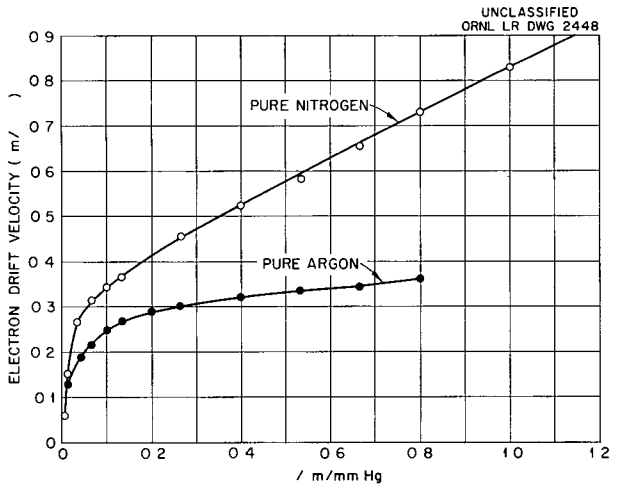

Fig 2 Electron Drift Velocity in Pure Nitrogen and Pure Argon

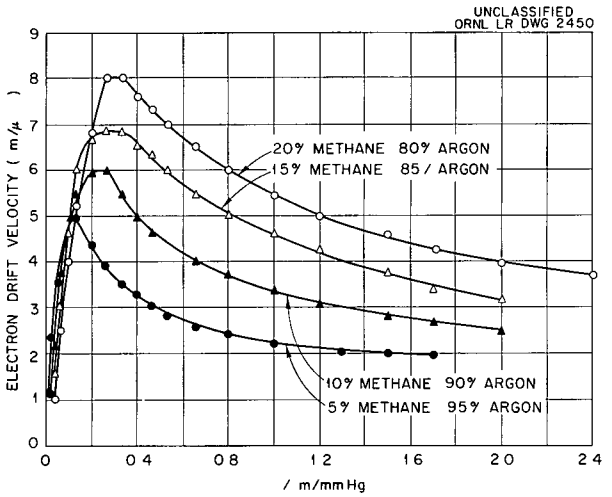

Fig 4 Electron Drift Velocity in Mixtures of Argon and Methane

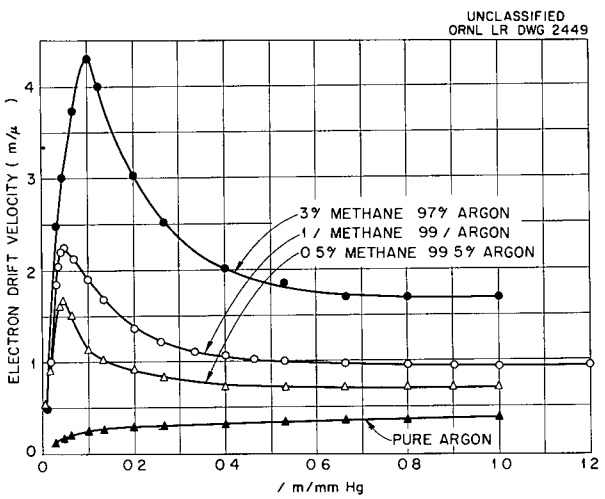

Fig 3 Electron Drift Velocity in Pure Argon and Mixtures of Argon and Methane

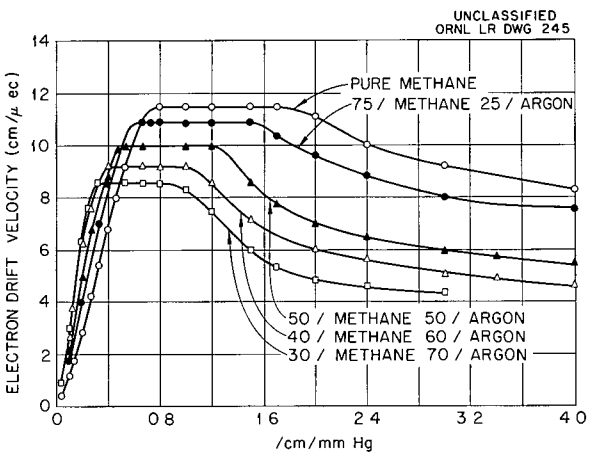

Fig 5 Electron Drift Velocity in Pure Methane and Mixtures of Argon and Methane

RADIATION MEASUREMENTS

F J Davis P W Reinhardt
J A Harter

The small aircraft scintillation equipment was supported in the crew compartment of the Tower Shielding Facility (TSF) Measurements were made at heights from 25 to 200 ft above the ground in order to determine the scattering and absorption in air of the gamma rays from Au^{198} and radium These data now being analyzed supplement meas urements taken previously at higher levels by using aircraft

In the joint program with the U S Geological Survey aerial surveys for uranium prospecting were conducted in the vicinity of Cedar City Utah The efficiency of the survey was hampered by contamination presumably the fall out from the bomb tests in the Pacific Survey flights in the vicinity of the TSF are planned for the near future

Difficulty arises in the use of the scintillation counter equipment for measuring the spectral dis tribution of gamma rays of Co^{60} scattered from concrete since the NaI crystal and photomultiplier combination are exposed to variable outdoor tem peratures Thus a temperature compensating con trol has been incorporated in the apparatus A separate rate meter is introduced and its dis criminator is set at a voltage corresponding to a point on the steepest portion of the pulse height distribution curve for the 1 33 Mev cobalt gamma Through the use of a servomechanism the output of this rate meter controls the high voltage (i e gain) in the photomultiplier tube so that the count rate remains constant during temperature changes

RADIATION DOSE

H H Hubbell
R D Birkhoff
A W Blackstock
J L Blankenship
J S Cheka
M J Cook
L B Farabee
E D Gupton
G R Harrison
H K Richards
I H Tipton

INTERNAL DOSE

Spectrographic Analysis of Human Tissue[1]

During the six months from January 20 to July 20 1954 the spectrographic laboratory for analysis of trace elements in human tissue has analyzed 326 samples of dry ashed tissue from persons who were victims of an instantaneous accidental death During this time considerable refinement of the spectrographic method has been achieved As re ported previously the cathode layer of the d c arc is used as the analytic source however the size of the sample burned has been increased to 4 mg The method has been made more quantitative by the use of internal standards

Since the concentrations of a large number of elements are desired simultaneously and since these elements have widely varying volatilization characteristics two internal standards are em ployed one for those elements which volatilize and burn out in the first 15 sec and one for those ele ments which volatilize at a slower rate The sepa ration of the two groups of elements is accomplished by the use of a modified Hartman diaphragm with two overlapping steps Fifteen seconds after the arc is struck the slide is shifted so that a 15 and a 130 sec exposure of the same sample are juxta posed on the plates Curves of concentrations vs intensities for 20 elements have been obtained by using indium as an internal standard for the short burn and palladium for the long burn

A method for sample preparation which does not employ dry ashing has been worked out A device

[1]Unive s ty of Tennessee resea ch and development contract

which reduces the tissue to a homogeneous mass has been built in the Health Physics Shop and a vacuum system for quick-drying the ground tissue is being fabricated A number of difficulties have been encountered and this work is going more slowly than had been anticipated To check the methods of sample preparation and spectrographic analysis recovery and reproducibility studies have been made

This laboratory is cooperating in an interlaboratory comparison of analyses for strontium and the strontium to calcium ratio in plants milk animal tissues and soils A special program of the determination of strontium in normal fresh human bone is in progress

Maximum Permissible-Concentration Experiments on Mice

The previously reported study[2] on continuous and single internal exposures of mice to Co^{60} has been completed The conclusions of this experiment are

1 Single exposure data can be used to obtain approximate maximum permissible values for continuous exposure

2 The gastrointestinal tract should be taken as the first choice and liver as the second choice for the critical body organ receiving the greatest radiation dose from ingested Co^{60}

3 The percentage of ingested Co^{60} retained in the liver is 0 7 ± 0 2

4 Five days after a single oral dose of Co^{60} the elimination rate follows an exponential curve which gives an effective half life of 9 5 ± 2 days in the liver and in the total body minus the gastrointestinal tract

5 Within the limits of error of this experiment this same effective half life of 9 5 days is applicable to the kidney spleen and gastrointestinal tract minus contents At the end of 6 hr 50% of the contents of the gastrointestinal tract has been eliminated

6 The best estimate of the maximum permissible concentration of Co^{60} in water for continuous exposure is $1\ 4 \times 10^{-2}$ $\mu c/ml$ if the liver is the critical organ and 3×10^{-4} $\mu c/ml$ if the gastrointestinal tract is the critical organ These values are in agreement (within the limits of error of this experiment) with those given in the report *Maximum Permissible Internal Dose* to be published in 1954 by the International Commission on Radiation Protection Those values are 2×10^{-2} $\mu c/ml$ for the liver and 4×10^{-4} $\mu c/ml$ for the gastrointestinal tract

An experiment similar to the Co^{60} study is in progress in which Ru^{106} Rh^{106} is administered orally to DBA strain mice In one group of mice each mouse receives a single dose of 8 μc of the radioisotope and in a second group each mouse receives a single dose of 40 μc For the mice in a third group the drinking water contains the radioisotope in a concentration of 0 1 $\mu c/ml$ and for the mice in a fourth group the drinking water contains 1 0 $\mu c/ml$

Radiochemical Analysis

An analytical procedure for the determination of radioactive strontium in urine specimens of approximately 1500 ml volume has been developed The advantages of the method are that (1) it is specific for strontium and (2) the separation of strontium can be done on one resin column More than 98% of the Sr^{89} tracer can be recovered from a large urine specimen The essential difference between this procedure and the one previously described[3] is that calcium and magnesium are removed from the Dowex 50 resin column with a solution of 1% Versene–1% sodium citrate at pH 5 0 instead of with ammonium citrate

The essential steps in the new procedure are (1) alkaline earth phosphate precipitation to reduce the bulk of inorganic constituents (2) destruction of organic material with HNO_3 (3) chelation of alkaline earths with Versene (20% additional Versene is added to provide adequate chelation when the pH is reduced to 5 5 at this pH value the effective chelation for calcium is reduced by some 20%) (4) passing the solution at pH 5 5 over a column of Dowex 50 (sodium cycle) (some 4% of the calcium 30% of the magnesium and all of the radioactive strontium stays on the resin) (5) removal of extraneous calcium and magnesium with a solution of 1% Versene–1% sodium citrate at pH 5 0 (6) removal of sodium with 0 5 *N* HCl and (7) elution of radioactive strontium with 6 *N* HNO_3 Complete separation from magnesium and calcium can be achieved Flow rates as fast as 5 ml/min per square centimeter of cross sectional area can be used

[2] H H Hubbell *et al* H P Semiann Prog Rep July 31 1953 ORNL 1596 p 4

[3] H H Hubbell *et al* H P Semiann Prog Rep Jan 31 1954 ORNL 1684 p 13

The advantage of using a mixture of Versene and sodium citrate at pH 5 0 is that the calcium and magnesium are removed simultaneously by the Versene and sodium citrate respectively Neither eluting agent alone is as effective in the removal of both calcium and magnesium

EXTERNAL DOSE

Resonance Frequency Variation of Piezoelectric Crystals

The same method of frequency measurement as that described previously[4] has been used to determine the frequency change of quartz crystals after exposure to gamma radiation and to fast neutrons

Quartz crystals cut at an angle of plus 35 deg 15 min (AT cut) with a resonance frequency from 5 to 9 Mc were gamma irradiated from a Co^{60} source The crystals were enclosed in commercially available metal holders which had been either evacuated or filled with a nonoxidizing gas These crystals have been silver plated and cemented to their electrodes with silver cement The dose varied from 5×10^7 to 2×10^8 rep

Some disintegration of the cement under irradiation is possible however the silver surface should not be changed by irradiation Frequency changes of 50 to 500 cps were observed at the dose level of 2×10^8 rep The frequency change was attributed to a change of the elastic constants In a few cases no frequency change was found Strong color changes were observed after irradiation Measurement by X ray diffraction showed no change in lattice constants After heat treatment up to 200°C the frequency returned approximately to its original value and the color disappeared Further investigations designed to exclude any possible loading of the crystals by vapors which might be produced by the gamma radiation are in progress

Since no conclusive results were obtained after irradiation with fast neutrons the investigation will be continued

Measurement of Ionizing Radiation by High Frequency Variation

In continuing the work on the measurement of ionizing radiation by high frequency variation[4] improved barium titanate capacitances have been made part of the frequency determining network The charge losses due to the finite resistance of the barium titanate capacitances produce a drift in the frequency of the circuit which will be reduced by the use of two oscillators one of which is connected to the ionization chamber

Film Dosimetry for Fast Neutrons

It has been found that the latent image fading of nuclear emulsion exposed to gamma radiation is rapid but reproducible This makes possible the use of such emulsion for high range gamma monitoring (10 to 200 r) provided the time elapsed between exposure and development is known so that a correction for fading can be made A full report of this study has been accepted for publication in *Nucleonics*

The possibility of suppressing gamma fog in nuclear emulsions in order to extend its range of usefulness for neutron measurements in a high gamma field has been investigated Some experiments which used surface oxidants on the exposed film before development in an attempt to differentiate between the images formed by different radiations on the assumption that heavy particles formed internal latent images gave negative results A subsequent literature search indicated that such a method is not feasible

The accelerator became available for use and the NTA film response to several groups of monoenergetic neutrons was measured These values were compared with the response calculated on the basis of hydrogen atom content of the emulsion and surrounding media neutron scatter cross section of hydrogen with respect to energy and the ranges of protons of various energies in the surrounding media[5] It was found that the number of tracks counted was less than the number calculated and that the discrepancy increased with decreasing neutron energies The deficiency of tracks counted is probably due to the greater proportion of very short tracks at low energies such short tracks are easily missed during microscopic study A 40 μ emulsion rather than the present 30 μ was suggested as a remedy and the suggestion is being considered by the Eastman Kodak Company

Energy Losses of Electrons in Foils

Beta Spectrometer A new Geiger counter and filling system have been installed on the beta

[4] H H Hubbell *et al* *H P Semiann Prog Rep Jan 31 1954* ORNL 1684 p 14

[5] J S Cheka *Nucleonics* 12 No 6 40 43 (1954)

spectrometer this should make possible the use of the instrument at energies down to approximately 100 kev A mixture of two thirds argon and one third ethylene has been found to be the most suitable of several counter gases tried Sources of Cr^{51} Ru^{106} Rh^{106} and Hg^{203} were prepared and their conversion line spectra determined Of these only the Hg^{203} will be suitable for the low energy stopping power measurements contemplated However the high carrier content of the mercury isotope available at ORNL makes it unsuitable and it appears that only a sample of separated Hg^{202} irradiated in the MTR will have a sufficient activity per milligram to permit the measurements to be made

The program for the beta spectrometer has been delayed by the increased use of the electron accelerator The personnel requirements of the latter machine and defocusing of the beam of the accelerator by the fringe magnetic field of the spectrometer make the simultaneous operation of the two machines impossible

Accelerator The problem now under investigation with the accelerator appears to be of more current interest than the stopping power data from the spectrometer so that the major effort of the group has been directed toward obtaining the maximum amount of data from the accelerator in the minimum time To this end the cathode gun supply has been replaced with a newly designed unit which permits more careful control of gun potentials and enables the accelerator to be operated at energies up to 125 kev

A paper on the operation of the accelerator was presented at the meeting of the Southeastern Section of the American Physical Society and a second more detailed report has been submitted to the *Review of Scientific Instruments* for publication Cross sections for the excitation of the electron plasma in aluminum as a function of the bombarding energy have been determined Additional measurements of those elements for which the data do not appear to agree with the theory of Pines and Bohm are in progress

A vacuum evaporator which enables faster preparation of thin foils and saves the expense of having such foils prepared elsewhere has been constructed and is in daily use

Preliminary measurements of the distribution of dose as a function of depth for 100 kev electrons striking a slab of aluminum have been carried out Such measurements have previously been made for energies above 300 kev by a group at MIT but there appears to be no data in the literature for lower energies It is planned that this program will be continued in the energy range from 10 to 250 kev with a more elaborate ion chamber the design of which is partially completed

Ion Recombination Errors in Pocket Chambers

Pocket chambers of the widely used 200 mr type were exposed to small doses of X rays at dose rates which ranged from 100 to 8000 r/hr and at charging voltages which ranged from 35 to 450 v in order to determine the errors introduced in the chamber readings by ion recombination when the dose rate was high or the collecting field was low It was found that for dose rates below 8000 r/hr and for initial charging potentials above 200 v the total effects due to recombination were not greater than the errors normally encountered (5 to 10%) in the use of these chambers When the chamber is no longer saturated the error increases approximately 5% for each tenfold increase in dose rate and as the chamber voltage is decreased from 200 to 60 v within the range of dose rates used the error increases approximately 15%

The results indicate that the pocket ion chamber as normally charged to 150 v for any readable exposure of 0 1 sec or more duration will be in error by less than 20% as a result of recombination effects For exposures at a rate of 15 r/hr or lower the error would be less than 5%

Film Dosimetry

A nomograph technique has been developed which will permit reasonably rapid determination of the probable radiation exposures from film badge density readings with a probable error of about 30% This represents some improvement over the possible error of from 200 to 2000% inherent in the usual method of interpreting all exposures in terms of a radium dose Beta exposures can be separately estimated The nomograph can be altered to cover combinations of filters other than those used in the present ORNL badge and the same technique can then be applied to determine the doses and so forth

An open air ionization chamber of the Bureau of Standards design has been modified and is now in operation to serve as a laboratory primary standard of dose for X and gamma rays below 200 kev

AIRBORNE RADIOPARTICULATE CONTAMINATION

E G Struxness
R L Bradshaw B G Saunders
W D Cottrell J W Thomas

STUDY OF RADIOPARTICULATE CONTAMINATION AT X 10

A one year study of the radioparticulate air contamination at X 10 with the U S Weather Bureau Office Oak Ridge cooperating has been concluded and a report on the study has been written Recommendations have been made for reducing the radioparticulate air contamination in the Laboratory area

AIR POLLUTION CAUSED BY GROUND DISPOSAL

A program for studying the air pollution associated with the ground disposal of radioactive wastes by means of pits has been initiated Most of the period of time covered by this report has been spent in program planning and research on aerosol entrainment separators

SAND ENTRAINMENT SEPARATORS

Boiling liquids evolve aerosol particles as a result of the breakup of bubbles as they reach the surface The object of this work was to study sand beds as filters for evolved radioactive aerosols The effectiveness of the bed may be expressed by an over all decontamination factor which is the ratio of the activity per unit volume in the boiling liquid to the activity per unit volume of the discharged condensed distillate

It was desired to investigate entrainment separators having over all decontamination factors up to about 10^{12} To measure decontamination factors of this magnitude directly the use of multicurie levels of radioactivity in the boiling liquid is necessary This work will be done outside the immediate ORNL area However it is feasible to determine decontamination factors approaching 10^{12} in the laboratory by an indirect method This method involves (1) determination of decontamination factors due to distillation effect alone using no entrainment layer and (2) determination of decontamination factors due to the sand layer filtration effect only by generation of a concentrated aerosol and the measurement of influent and effluent concentrations

Sodium 24 was used to tag a concentrated sodium aluminate solution and the activity in the distillate was determined at boilup rates of 2 to 8 lb of water per square foot per hour using no entrainment layers

Decontamination factors of about 10^5 to 10^7 were obtained depending on the amount of foaming present

The sand layer decontamination factor was measured by using ordinary river sand The median diameter of the sand granules was 0 007 in A dioctyl phthalate aerosol (particle radius ~0 1 to 0 4 μ) was supplied by a La Mer generator [1] and particle sizes were measured with the diffusion battery[2] and the servo owl [3] The sand column was 5 in thick and 4 in in diameter supported on a 1 in layer of pea gravel

Figure 6 is a plot of the percentage of aerosol penetration as a function of superficial velocity For the larger particle sizes there is a maximum in the curves At the low velocities diffusion and/or settling are effective in permitting only low penetrations at the very high velocities inertial impaction of the aerosol on the sand granules becomes predominant causing the penetration curve to turn downward

Figure 7 a graph of the results plotted to show penetration as a function of particle size at different air velocities shows the existence of an aerosol size for maximum penetration through the sand bed At small particle sizes rapid diffusion of the particles causes low penetration values at larger sizes interception gravity settling and inertial impaction are effective The combination of these effects results in the existence of an aerosol size for maximum penetration through the sand bed

---

[1] E E Grassell *Construction of a La Mer Type Thermal Aerosol Generator for Radioactive Compounds* ORNL CF 54 3 46 April 13 1954

[2] J W Thomas *The Diffusion Battery Method for Aerosol Particle Size Dete mination* ORNL 1648 Dec 14 1953

[3] R L Br dshaw *A Servomechanism for Measuring Aerosol Size and a Servomechanism for Controlling Particle Size in the Dioctyl Phthalate Aerosol Generator* ORNL 1660 Jan 18 1954

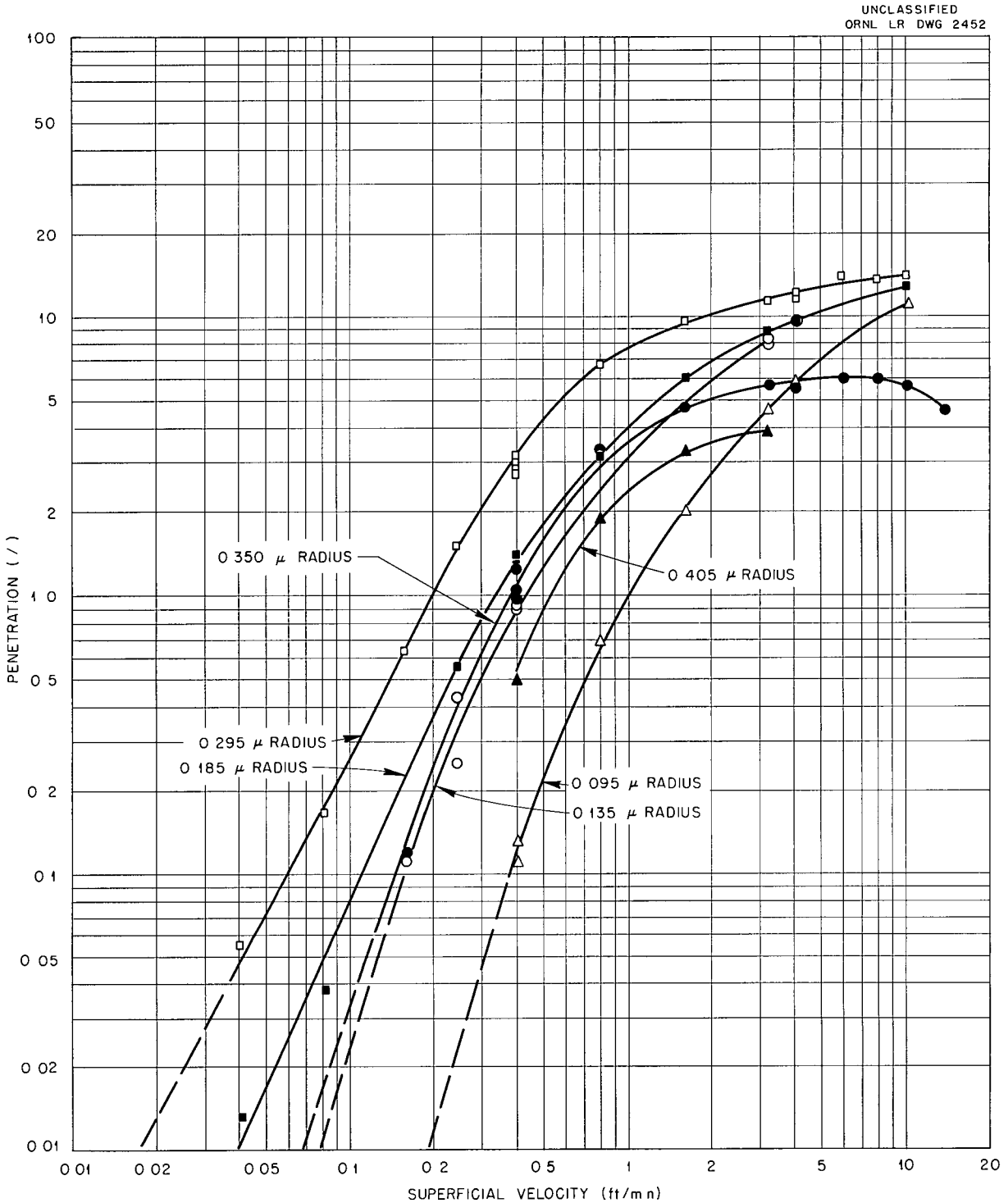

Fig 6 Aerosol Penetration Through a Sand Bed Penetration vs superficial velocity

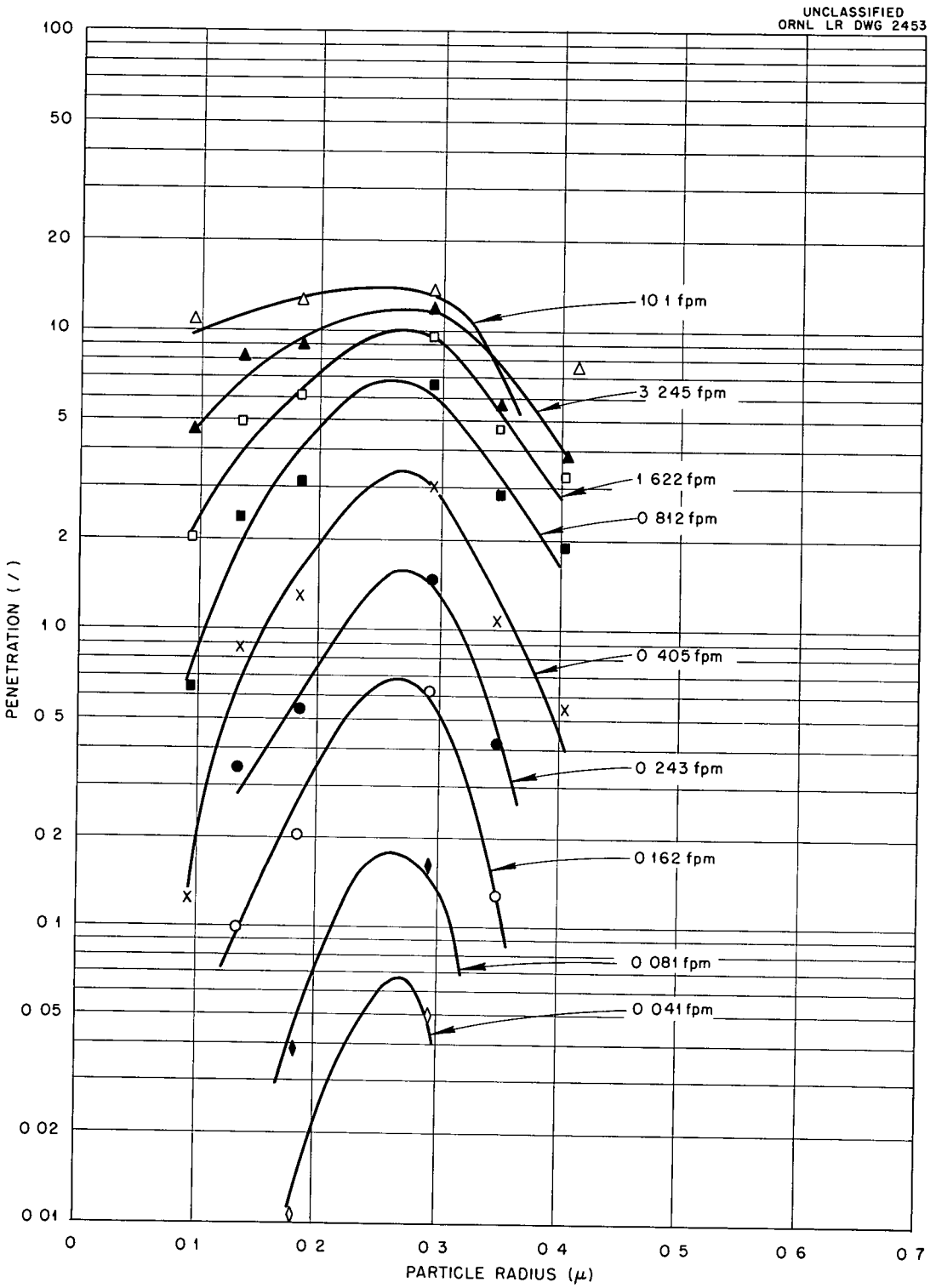

Fig 7 Aerosol Penetration Through a Sand Bed Penetration vs particle size

The establishment of the size for maximum penetration is very important since if sand beds are tested against this size aerosol it is assured that the beds will have a better performance in filtering aerosols of any other size larger or smaller The possibility that the penetration curves may turn upward again at some other value of particle size seems remote however further work is necessary to confirm the present results and to extend the range of the investigation

Figures 6 and 7 show that at a superficial linear flow rate of 0 4/ft/min through the bed (equivalent to about 0 1 lb of water vapor per square foot per hour) the decontamination factor was better than 10^3 for the most penetrating particle size This gives an over all decontamination factor of at least 10^8 for the combined distillation effect and filtration effect for a 5 in sand bed at this flow rate At the present time it seems quite likely that less than 3 ft of sand will be required to obtain decontamination factors of 10^{12} at a superficial velocity corresponding to 0 1 lb of water vapor per square foot per hour

The above conclusions are valid only for dry sand If large amounts of water exist in the sand bed in the liquid phase it is anticipated that a much thicker layer will be required to achieve a decontamination factor of 10^{12}

RADIOACTIVE WASTE DISPOSAL

R J Morton
O R Placak
K E Cowser
J M Garner
W J Lacy
W T Miller
R M Richardson
H J Wyrick
C P Straub
B Kahn
D A Pecsok
T W Brockett
H L Krieger
M S Seal
F L Cobler
E R Eastwood

On March 15 the Radioactive Liquid Waste Research and Development Section was reorganized and integrated into the over all Reactor Waste Disposal Project directed by E G Struxness Field investigations hydrologic and geologic explorations and instrumentation are under the immediate direction of R J Morton and the laboratory studies of chemical and engineering problems are directed by C P Straub The fixation and fusion of clays and other materials and of radioactive wastes into insoluble glasses or compounds with a view to fixing waste products will be investigated by the Ceramics Group Metallurgy Division ORNL The activities of the Section are concerned with three general problems (1) liquid and solid wastes associated with the nuclear power reactor program (2) the disposal of wastes from operations and research projects at ORNL and (3) other general associated problems

During this period the participation by cooperating agencies in liquid waste studies has been increased The effort of the assignees of the Public Health Service has been shifted almost entirely to the problems of power reactor wastes The U S Army Corps of Engineers (ERDL) group has been increased by the assignment of three additional workers (A L Donahew L M Lawless P B Pruett) for a three month period This was done to facilitate the operation of the Process Waste Treatment Experimental Plant [1] The U S Geological Survey has increased and has planned further expansion of its joint program with ORNL particularly in geologic and hydrologic studies pertinent to disposal of wastes in surface pits

Two research participants Marvin L Granstrom University of North Carolina (full time) and Richard B Hahn Wayne University (part time) have joined the Section for the summer

LIQUID WASTE DECONTAMINATION PROCESSES

Flotation

Flotation processes may be effective in the removal of suspended or colloidal radioactive materials from water The particular surface active agent chosen for study was a cyclic amine – cetylpyridinium chloride It is reported[2] to have worked very well for water clarification under many chemical conditions

[1] R J Morton *et al* *H P Semiann Prog Rep Jan 31 1954* ORNL 1684 p 19

[2] S H Hopper and M C McCowen *J Am Water Works Assoc* 44 719 726 (1952)

A sufficient amount of the radioactive material under investigation was added to tap water to give approximately 10^{-2} $\mu c/cc$ (2220 counts/min/ml) One liter of this solution was placed in each of five 1 liter graduates Kaolinite clay $(Al_4)(Si_4O_{10})(OH)_8$ was added to four of the graduates to give 25 50 100 and 200 ppm respectively The fifth cylinder containing no clay was used to evaluate the process without turbidity To each graduate was added 15 ppm of the surface active reagent These solutions of surface active reagent radioisotope and clay were aerated at a rate of 1 5 to 2 liters of air per minute for 5 min

As the air bubbles formed they collected clay particles on their surfaces and were swept over the top of the beaker in the foam After 5 min of aeration the surface active agent had been exhausted another 15 ppm of the surface active reagent was added and the solution was aerated again After this second aeration samples were taken prepared and counted The results listed in Table 2 indicate that this is a rather favorable

TABLE 2 REMOVAL OF RADIOISOTOPES BY FLOTATION

Radioisotope	Raw Water			Treated Water		Radioactivity Removed
	Radioactivity (counts/min/ml)	pH	Turbidity (ppm)	Radioactivity (counts/min/ml)	Turbidity (ppm)	(%)
Ba^{140} La^{140}	2620	7 3	0	1990	0	24
			25	1600	4	39
			50	1080	5	59
			100	1000	6	62
			200	590	6	78
Cs^{137} Ba^{137}	2590	7 2	0	1620	0	38
			25	1000	4	59
			50	582	4	77
			100	786	3	80
			200	387	3	85
Ru^{106} Rh^{106}	1230	7 3	0	841	0	43
			25	834	7	56
			50	836	8	61
			100	817	9	64
			200	765	10	74
Sr^{90} Y^{90}	2430	7 4	0	1410	0	42
			25	1290	6	47
			50	898	6	63
			100	842	6	65
			200	775	9	68
Zr^{95} Nb^{95}	3020	7 4	0	1520	0	50
			25	1360	6	55
			50	958	7	68
			100	707	9	77
			200	698	8	77
I^{131}	3220	7 4	0	2040	0	37
			25	2080	4	36
			50	2110	5	35
			100	2020	7	37
			200	2030	7	37

After second aeration

TABLE 3 REMOVAL EFFICIENCIES OBTAINED IN PROCESS WASTE TREATMENT EXPERIMENTAL PLANT

T eatment	Range of Removal (%)		
	Accelator	SR Accelator	Erdlator
(1) Ferric chloride limestone and clay	9–46		13–43
(2) Alum limestone and clay	32–50	0–28	34–56
(3) L me and soda ash			
Sto chiometric amounts	27–55	26–48	47–54
100% excess	29–42	22–52	60–74
200% excess	34–53	36–47	66–82
(4) Trisod um phosphate lime and sodium hydroxide (pH control)	29–87	23–79	33–87

process for water clarification However it is slightly inferior to other methods for removing radioactive materials The process does not affect the pH of the water and the amount of surface active material remaining in solution is not harmful to man Results also indicate a 99% reduction in the number of bacteria Further investigation is necessary to ascertain the optimum procedure for removing radioactive contaminants by this process

Process Waste Treatment Experimental Plant Studies

The ORNL ERDL PHS study group has completed several runs with the Process Waste Treatment Experimental Plant using the effluent from the settling basin Removal efficiencies obtained in these preliminary runs indicated in Table 3 are not entirely adequate Additional runs following modifications in the process may show higher removals

Chemical Laboratory Studies with Reactor Waste Solutions

Procedures for the removal of fission products from 1 6 *M* $Al(NO_3)_3$ solution 0 2 *M* in HNO_3 and containing weighable amounts of fission products are under investigation The radioisotopes used as tracers are Cs^{137} Sr^{90} Y^{90} Ru^{106} Rh^{106} Zr^{95} Nb^{95} and in some cases Ce^{144} Pr^{144}

Precipitation of the Fission Products The addition of the above solution to one half its volume of 18 *M* NaOH caused the precipitation of a majority of the fission products without precipitating the aluminum More than 90% of the cerium praseodymium zirconium and niobium tracers were removed as well as some of the strontium and cesium tracers The strontium removal could be increased by the addition of calcium strontium or barium carrier plus phosphates or carbonates The results obtained with this procedure are shown in Table 4

Since the addition of large volumes of NaOH is rather costly decontamination of the acid solution is being attempted Specific precipitating agents are used for each radioisotope so that most radioisotopes may be removed by a combination of reagents Best results have been obtained with the use of the reagents listed in Table 5

TABLE 4 REMOVAL OF RADIOISOTOPES FROM REACTOR-WASTE SOLUTION

(25 ml of 18 *M* NaOH 50 gpg of Na_2CO_3 and 50 mg of Ca^{++} added to 50 ml of boiling solution solution filtered)

Radioisotope	Total in Initial Solution (%)	Removal (%)
Ce Pr	37 2	99 97
Sr	18 7	97 7
Ru	9 8	99 0
Nb	18 6	95 6
Zr	8 6	96 3
Cs	7 1	52 2
Total over-all	100 0	95 0

TABLE 5 REMOVAL OF RADIOISOTOPES FROM REACTOR WASTE SOLUTION

Precipitating Agent	Removal (%)					
	Cs	Sr	Y	Ru Rh	Zr Nb	Total
150 mg $K_4Fe(CN)_6$ + 130 mg $FeCl_3$	94	0	0	31	46	24
H_2S then 100 mg Pb^{++}	10	7	5	78	48	17
5 ml H_2SO_4 + 200 mg Ba^{++}	14	83	7	12	17	
10 ml HF + 500 mg Ca^{++}	15	65	85	10	15	
20 g silica gel (column)	43	0	5	9	97	

Soil Sorption The waste solution made basic by its addition to one half its volume of 18 *M* NaOH was passed through columns containing 5 g of local soil Virtually complete removal of cesium strontium yttrium zirconium and niobium was obtained while some ruthenium rhodium was found in the effluent and no I^{131} was retained by the soil After the passage of 45 to 50 ml of waste solution a white precipitate formed in the soil clogged the soil and prevented further passage of the waste solution

The filtrate from the treatment indicated in Table 3 was passed through a 5 g soil column which resulted in the removal of more than 75% of the remaining radioactivity

In another series of tests 50 ml of the acid waste solution was shaken with two types of local clay soils in amounts up to 5 g The results are given in Table 6 and show that even for a specific isotope the percentage removal varies over a wide range of values

Cesium tracer and carrier were brought into contact with acid and basic solution both in the presence and absence of aluminum The results indicate that the presence of aluminum does not decrease the adsorption of cesium on soil

A procedure for recovering the major fission products fixed to clay soils has been developed and consists in shaking the soils with the solutions listed in Table 7 and then separating soil and solution by centrifugation Ten grams of local clay soil was leached with three successive 25 ml portions of the solutions by shaking for 20 min periods in 50 ml rubber stoppered lusteroid centrifuge tubes The results of a recent series of tests are given in Table 7

TABLE 6 REMOVAL OF RADIOISOTOPES FROM REACTOR WASTE SOLUTION

(50 ml of acid solution shaken 16 hr with 5 g of local soil)

Radioisotope	Removal (%)	
	Soil No 1	Soil No 2
Cs	0–8	0–4
Sr		1–12
Y		10–23
Ru	2–12	2–18
Zr	0–62	5–47
Nb	0–37	48–99

SURVEYS AND EVALUATIONS – FIELD AND LABORATORY

Waste Pit Studies

Waste Storage Pit No 2 Prior to June 15 1954 a total of 505 857 gal of liquid wastes containing 11 628 curies of radioactivity has been transferred to the pit Wells Nos 52 and 54 continue to show the same order of magnitude of radioactivity due to radiochemical contamination by Ru^{106} and its daughter product Rh^{106} While Well No 53 has previously been reported as uncontaminated it now appears that Ru^{106} Ru^{106} has reached this well as evidenced by grab sample analyses the latest showing 275 counts/min/ml Surface break through of Ru^{106} Rh^{106} and nitrates has been observed 400 to 500 ft southwest of the pit in a

TABLE 7 REMOVAL OF CARRIER FREE RADIOISOTOPES FROM CLAY SOIL BY LEACHING

Leaching Agent	Removal (%)					
	Cs^{137}	Sr^{90}	Y^{90}	Ru^{106}	Zr^{95}	Nb^{95}
0 5 *N* HCl	2 8	98 6	97 6	90 8	3 5	0 9
55 g/liter $H_2C_2O_4$	1 4	1 1	2 2	4 0	93 5	93 0
Concentrated HCl	74 9	0 3	0 1	3 0	2 3	4 4
Rema nder	20 9	0	0 1	2 2	0 7	1 7

Isotopes n the form received from Operations Div sion ORNL odsorbed from d l te solution onto clay soil fol lowing app oximately 5 min of shaking

marshy area and creek The possibility of a hazard created by this condition is being eval uated

Experimental Unlined Pit An earthen pit 30 ft in diameter and 5 ft deep in the shape of a right cone was installed in the Conasauga shale Nine teen auger holes ranging from 12 to 19 ft deep and one core hole 61 ft deep were spaced around the pit Where possible the inner ring of wells is 35 ft and the outer ring of wells 65 ft from the center of the pit Because of the limestone en countered during the drilling of the auger holes it was necessary to offset several of these test wells in order to obtain maximum depth Samples from each well were analyzed for uranium and nitrates by the Analytical Chemistry Division Background readings in the well water were taken with a portable beta probe Seven hundred and forty one gallons of a solution containing uranium nitric acid and aluminum nitrate were obtained from the Chemical Technology Division and have been discharged to the pit By routine field nitrate determinations and by periodic uranium analyses of the well water it is hoped that the length breadth and rate of movement of any resulting pollution stream can be defined and that a decontamination factor for uranium in the soil can be obtained It is also hoped that the vertical dimensions of any resulting pollution stream within the depth limits of the observation wells can be defined with a beta probe It is expected that if uranium is removed by the soil the fission products Ce^{141} Pr^{143} Ce^{144} Pr^{144} Nd^{147} Pm^{147} Y^{90} Y^{91} and La^{140} will be removed to the same extent

Experimental Lined Pit This pit having di mensions similar to the unlined experimental pit has a bituminous liner which was sprayed on in an average thickness of approximately $\frac{3}{8}$ in over this liner 6 in of tamped earth was applied The pit was filled with sand and partially filled with water A roof was provided over the pit to prevent the access of rainfall Evaporation cans have been sunk in the sand and the evaporation from these cans will be compared with the evaporation from the pit in an attempt to determine the water tightness of the applied bituminous liner under the hydrostatic head available

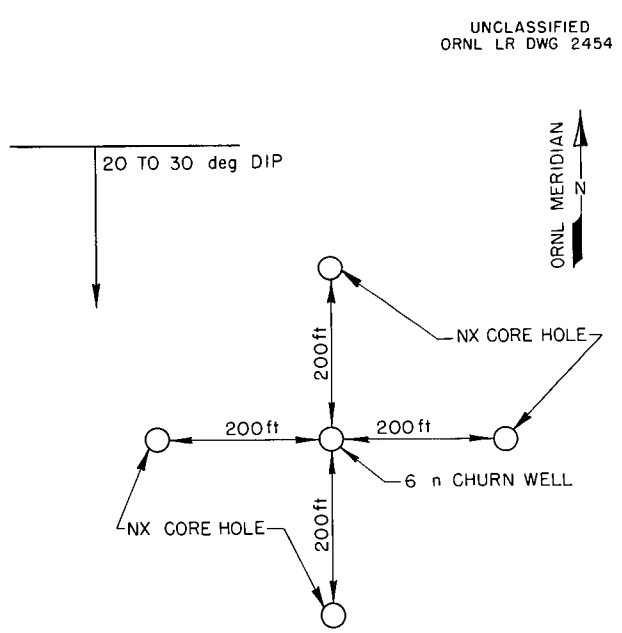

Fig 8 Layout of NX Core Hole and 6 in Churn Well

Field Explorations

Core drilling in a generol area selected for possible pit disposal was completed by a U S Army Corps of Engineers drilling rig utilized in connection with a special project Drilling logs and a geological report including specific conclusions and recommendations for additional study were received On the basis of this information an area of approximately 4 acres situated in the lower regions of the exposed Conasauga shale was selected for a concentrated geologic and hydrologic exploration For these studies it has been proposed to locate four NX core holes each 200 ft deep and a churn well 300 ft deep and 6 in in diameter as shown in Fig 8 At present the ORNL drillers have completed two of the 200 ft NX core holes

EDUCATION, TRAINING, AND CONSULTATION

E E Anderson
M F Fair M R Ford

AEC FELLOWSHIP PROGRAM

The 1953–1954 group of 21 AEC Fellows in Radiological Physics completed the year of academic work at Vanderbilt University on June 6 and reported to the Laboratory for training in Applied Health Physics on June 8 From February 1 until the close of the school year members of the Health Physics Division of ORNL gave a 6 credit graduate course in radiation physics at Vanderbilt University

OTHER TRAINING PROGRAMS

Six officers from AFSWP spent six weeks at the Laboratory in the Health Physics Division during the period from February 16 to April 30 The period was devoted to lectures discussions and observation of Health Physics practices

The course in atomic and nuclear physics for 14 members of the Applied Health Physics Section which began in January will be completed in two weeks

Miss Lois Wehrnmann General Electric Company Cincinnati Ohio spent two weeks with the Personnel Monitoring Section learning the techniques of neutron film dosimetry

PUBLICATIONS

T F Bortner and G S Hurst Ionization of Pure Gases and Mixtures of Gases by 5 Mev Alpha Particles *Phys Rev* **93** No 6 (1954)

T W Brockett Jr and O R Placak Removal of Radioisotopes from Waste Solutions by Soils – Soil Studies with Conasauga Shale *Proc 8th Ind Waste Conf Purdue Univ May 4–6 1953* Extension Series No 83 393–409 (1954)

J S Cheka Recent Developments in Film Monitoring of Fast Neutrons *Nucleonics* **12** No 6 40 (1954)

E E Grassel *Construction of La Mer Type Thermal Aerosol Generator for Radioactive Compounds* ORNL CF 54 3 46 (April 13 1954)

E T Hungerford (University of Tennessee) and R D Birkhoff Electron Straggling in Thin Foils *Phys Rev* **95** 6 (1954)

G S Hurst J A Harter P N Hensley W A Mills and R H Ritchie ORNL 1671 (March 30 1954) (classified)

G S Hurst An Absolute Dosimeter for Fast Neutrons *Brit J Radiol* **27** No 318 353–357 (1954)

L A Krumholz[1] and J H Rust[2] Osteogenic Sarcoma in a Muskrat from an Area of High Environmental Radiostrontium *Am Med Assoc Arch Pathol* **57** 270–278 (1954)

W J Lacy and B Kahn Survey Meters and Electroscopes for Monitoring Radioactivity in Water *J Am Water Works Assoc* **46**(1) 55–65 (1954)

W J Lacy Decontamination of Radioactively Contaminated Water by Slurrying with Clay *Ind Eng Chem* **46**(5) 1061–1065 (1954)

J L Meuschke[3] R M Moxham[3] and T E Bortner Airborne Radioactivity Survey of Parts of the Atlantic Ocean Beach North and South Carolinas U S Department of the Interior Geological Survey Trace Elements Memorandum Report 673 (1953)

J L Meuschke[3] R M Moxham[3] and T E Bortner Airborne Radioactivity Survey of the Gulf of Mexico Beach Between Sanibel Island and Caladesi Island Florida U S Department of the Interior Geological Survey Trace Elements Memorandum Report 678 (1953)

W A Mills and G S Hurst Fast Neutron Dosimetry in a Small Tissue Equivalent Phantom *Nucleonics* **12** No 4 17–19 (1954)

K Z Morgan Maximum Permissible Concentration of Radioisotopes in Food Water and Air and Maximum Permissible Equilibrium Amounts in the Body *Acta Radiol* **41** No 1 (1954)

K Z Morgan and M R Ford Developments in Internal Dose Determinations *Nucleonics* **12** No 6 (1954)

R J Morton Report of the Chairman of the Executive Board of the American Public Health Association to the Governing Council 1952–1953 Eighty First Annual Meeting of the American Public Health Association November 9–11 1953 *J Am Public Health Assoc* **44** No 4 (1954)

P W Reinhardt and F J Davis Improved Method for Standardizing High Voltage for Scintillation Detectors *Rev Sci Instr* **25** No 8 (August 1954)

C P Straub Statistical Evaluation of Packing House Waste Data *Proc 8th Ind Waste Conf Purdue Univ May 4–6 1953* Extension Series No 83 222–239 (1954)

C P Straub and H L Krieger Removal of Radioisotopes from Waste Solutions Soil Suspension Studies *Proc 8th Ind Waste Conf Purdue Univ May 4–6 1953* Extension Series No 83 415–438 (1954)

C P Straub Chairman Committee on the Sanitary Engineering Aspects of Nuclear Energy Sanitary Engineering Division American Society of Civil Engineers I The Role of the Civil Engineer *Civil Eng* **24**(5) 93–94 (1954) II Tracer Applications *Civil Eng* **24**(6) 93–94 (1954) III Structure of the Atom *Civil Eng* **24**(7) 80 (1954)

J W Thomas Effectiveness of Air Filters for Containment of Radioactivity Following an Incident *U K –U S –Canada Reactor Safety Conference* RSC 1 187–193 (1954)

A G Wheler Jr S A Reynolds and W A Brooksbank Jr Thallium as a Reference Standard for Beta Radioactivity *J Am Water Works Assoc* **46** No 1 (1954)

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[1] Tennesse Valley Authority

[2] Veterinary Corps U S Army

[3] U S Geological Survey

PAPERS

A W Blackstock R D Birkhoff and M Slater *Discrete Electron Energy Losses in Thin Foils* Southeastern Section American Physical Society April 3 1954 Knoxville Tenn

T E Bortner and G S Hurst *Ionization of Pure Gases and Mixtures of Gases by 5 Mev Alpha Particles* American Physical Society Meeting April 29–May 1 1954 Washington D C

T E Bortner and G S Hurst *The W Value in Electron Volts for 5 Mev Alpha Particles in Gases and Gas Mixtures* Southeastern Section American Physical Society April 3 1954 Knoxville Tenn

J W Cure and G S Hurst *Neutron Scattering* Southeastern Section American Physical Society April 3 1954 Knoxville Tenn

D M Davis *Calibration Problems – Physical Aspects* Region III Radiological Defense Conference (FCDA) Georgia Institute of Technology July 8–9 1954

D M Davis *Portable Equipment and Health Physics* ORINS Advanced Instrumentation Course June 28–July 2 1954

M F Fair *Personnel and Area Monitoring*, Region III Radiological Defense Conference (FCDA) Georgia Institute of Technology July 8–9 1954

W J Lacy and F L Cobler *Surface Adsorption A Mechanism of Removal for Radioactive Material from Aqueous Solution by Clay Slurry* Second AEC Sanitary Engineering Conference April 15–16 1954 Baltimore Md

W J Lacy *Food and Water Monitoring Techniques and Decontamination* Region III Radiological Defense Conference (FCDA) Georgia Institute of Technology July 8–9 1954

C E Melton G S Hurst and T E Bortner *Measurements of Ionization Produced by 5 Mev Alpha Particles in Argon Mixtures* Southeastern Section American Physical Society April 3 1954 Knoxville Tenn

R J Morton *Future Sanitary Engineering Problems and Development Work – Waste Disposal Problems* Second AEC Sanitary Engineering Conference April 15–16 1954 Baltimore Md

J Neufeld *Bohr s Theory of Energy Losses of Moving Charged Particles* American Physical Society Meeting January 28–30 1954 New York N Y

P W Reinhardt *Airborne Radioactivity Measurements* IRE Conference February 4 1954 Tulsa Okla

W S Snyder *Disordering of Solids by Neutron Radiation* American Physical Society Meeting January 28–30 1954 New York N Y

W G Stone and L W Cochran *Energy Per Ion Pair for Recoil Atoms in Methane* Southeastern Section American Physical Society April 3 1954 Knoxville Tenn

C P Straub *Progress Review of Accomplishments at ORNL Since September 1952* Second AEC Sanitary Engineering Conference April 15–16 1954 Baltimore Md

LECTURES

E E Anderson *Principles and Practices of Health Physics* ORINS Radioisotope Techniques Course (February March June and July 1954)

M F Fair *Health Physics* MIT Practice School ORNL July 29 1954

M F Fair Five Orientation Courses in Health Physics for the Summer Research Participants (June–July 1954)

G S Hurst *Neutron Measurements* Advanced Instrument Course at ORINS July 2 1954

W A Mills *Recent Neutron Dosimetry Experiments* Fifth Conference on Radiation Cataracts Washington D C March 1954

K Z Morgan *MPE to Ionizing Radiations* University of Alabama February 26 1954

K Z Morgan *MPE to Ionizing Radiations* Mississippi State College February 25 1954

K Z Morgan *Control of Radiation by the Health Physicist* U S Naval Medical School Bethesda Maryland March 9 1954

K Z Morgan *Peacetime Developments in Atomic Energy* North Carolina Bankers Association Conover North Carolina March 11 1954

K Z Morgan *Relative Biological Effectiveness* Radiation Cataract Conference Washington D C March 26 1954

K Z Morgan *Instruments for Measuring Radiations* University of Michigan Ann Arbor Michigan May 26 1954

R J Morton *A Balanced Local Sanitation Program* Meeting of Sanitation Section Tennessee Public Health Association Nashville Tennessee May 14 1954

R H Ritchie *Passage of Charged Particles Through Plasma* Physics Seminar University of Tennessee March 30 1954

W S Snyder *On the Approximate Solution of an Integral Equation Relating to Radiation Damage* University of Tennessee Mathematics Colloquium April 21 1954

W S Snyder *On the Disordering of Solids by Heavy Corpuscular Radiation* University of Tennessee Physics Seminar April 13 1954

E G Struxness *Quantities of Fission Product Wastes Associated with Power Reactors* Conference on Ground Disposal of High Level Radioactive Wastes AEC Division of Engineering Washington D C May 24–25 1954

J W Thomas *Air Pollution Problems Associated with Nuclear Reactors* Industrial Hygiene Conference University of Texas Austin Texas June 5 1954