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QUARTERLY PROGRESS REPORT RESEARCH AND DEVELOPMENT ACTIVITIES IN THE FIELD OF RADIOLOGICAL SCIENCES JULY - SEPTEMBER, 1956

BY

MEMBERS OF THE STAFF
OF THE
HANFORD LABORATORIES OPERATION

HANFORD ATOMIC PRODUCTS OPERATION

RICHLAND, WASHINGTON

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RESEARCH AND DEVELOPMENT ACTIVITIES
IN THE FIELD OF RADIOLOGICAL SCIENCES
JULY - SEPTEMBER, 1956

By

Members of the Staff
of the
Hanford Laboratories Operation

Edited by

J. W. Healy

Consulting Radiological Scientist
Radiation Protection
Hanford Laboratories Operation

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....................................)
By Authority of [illegible]
DBCRE [illegible] 58
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October 30, 1956

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

Work performed under Contract No. W-31-109-Eng-52 between the Atomic Energy Commission and General Electric Company

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QUARTERLY PROGRESS REPORT RESEARCH AND DEVELOPMENT ACTIVITIES IN THE FIELD OF RADIOLOGICAL SCIENCES JULY - SEPTEMBER, 1956

I. INTRODUCTION

During this quarter, the Hanford Atomic Products Operation reorganized with the elimination of the Radiological Sciences Department as a separate organizational entity. The new structure which was effective on September 1, 1956, is outlined below to indicate the new relationships. This twenty-eighth report in the series now presents research and development activities in the field of the Radiological Sciences. The old format is retained on this report since the activities were carried out for the bulk of the quarter under the old organization.

Some items charged to control work and to programs other than those of the Division of Biology and Medicine are included for general interest. Such items are identified in the program headings.

II. PERSONNEL

The integration of the former Radiological Sciences Department into the new Hanford Laboratories Operation resulted in some shift of reporting channels. The Biology Operation retains all of the functions and manpower of the former Biology Section. The Biophysics program is now divided between the Chemical Research and Development Operation and the Physics and Instrument Research and Development Operation.

The number of people involved in Radiological Sciences work in each of the new operations is given on the following page:

	Biology Section			Bio-physics Section	CRDO[a]	PIRDO[b]	
	6/30/56	9/30/56	Net Increase	6/30/56	9/30/56	9/30/56	Net Increase[c]
Supervisors	7	7	0	6	2	3	- 1
Scientific and Technical	27	25	- 2	32	18	14	0
Non-Technical	21	19	- 2		4	4	0
Clerical	8	8	0	3	1	1	- 1
Total	63	59	- 4	49	25	22	- 2

(a) Chemical Research and Development Operation

(b) Physics and Instrument Research and Development Operation

(c) Over Biophysics Values for 6/30/56

III. LABORATORY FACILITIES

The office addition on the Experimental Animal Farm was essentially completed. This addition provides more change room facilities, a ladies lounge and additional office space required for the Experimental Animal Farm personnel.

The remodeling of the small animal quarters is 90% complete. This work provides additional isolation rooms and improved temperature control.

IV. RESEARCH AND DEVELOPMENT PROGRESS - BIOLOGY

(H. A. Kornberg, Manager)

A. Aquatic Biology (R. F. Foster)

Biological Chains (R. C. Pendleton)

Inactive

Radiobiological-Ecological Survey of the Columbia River (Partially charged to research) (J. J. Davis and D. G. Watson)

The activity density of small fish living in the Columbia River below the outfalls of the reactors increased about tenfold over the values for the last quarter to 2×10^{-2} μc/g. Such an increase is normal for this quarter when river temperatures reach a maximum. Caddis fly larvae also reached about this same level. The increase in caddis fly larvae was due to the temperature increase while the increase in plankton resulted from diminishing flow of the river. The values for plankton and bottom organisms are approximately the same as in 1955, but the contamination level in small fish is slightly higher.

The contamination in whitefish flesh increased about threefold to reach a level about equal to that of one year ago. Results for the quarter are summarized in Table 1.

TABLE 1

ACTIVITY DENSITIES OF WHITEFISH FLESH

Collection Site	Average μc/g	Maximum μc/g
Priest Rapids	6×10^{-6}	4×10^{-5}
Immediately below reactors (No public fishing)	1×10^{-4}	6×10^{-4}
Ringold	9×10^{-5}	4×10^{-4}

About one thousand specimens of aquatic life were collected from the lower section of the Columbia River, from the ocean beaches immediately north of the river's mouth, and from the southern Oregon coast. When processed, these samples should give a reasonably good picture of the background activity in marine organisms of this region and show any significant contamination originating from the Columbia River. For comparison, a few specimens were also obtained off Cape Cod on the Atlantic Coast.

[redacted]

Effect of Reactor Effluent on Aquatic Organisms (Not charged to research)
(P. A. Olson, R. C. Pendleton, and R. F. Foster)

Routine monitoring of reactor effluent was carried out during the quarter with juvenile whitefish. This is the first time that this species has been used for such studies. After one month of exposure to 6 and 8% effluent, mortality was significantly above normal for this species. After three months there was some indication that mortality was affected in 2% effluent. Confirmation of the result would indicate that whitefish are more sensitive than juvenile salmon or trout. Adverse effects have been attributed to the presence of chromium ion and increased temperatures rather than radiation. Results are summarized in Table 2.

TABLE 2

EFFECTS OF REACTOR EFFLUENT ON WHITEFISH AFTER THREE MONTH EXPOSURE

Condition	Per Cent Mortality	Average Weight (g)
River Water*	6	3.1
2% Area Effluent	14	2.8
4% Area Effluent	28	2.6
6% Area Effluent	48	2.2
8% Area Effluent	71	2.3

* Contains about 1.2% effluent from upriver reactors.

Algae which is typical of that covering the rocks on the bottom of the Columbia River (Zygnema, Ulothrix, and Stigeoclonium) was killed by 25% strength reactor effluent.

[redacted]

Young trout have not been affected by exposure to 0.07 ppm of "Separan" - a chemical for use in process water purification plants. This strength exceeds any concentration which might ultimately exist in the Columbia River by several orders of magnitude.

B. Experimental Animal Farm (L. K. Bustad)

Toxicology of I^{131} (L. K. Bustad, V. G. Horstman, L. J. Seigneur, L. A. George, Jr.*, S. Marks, M. E. Kerr, P. L. Hackett, N. L. Dockum, E. J. Coleman, and G. S. Vogt)

The first of a series of studies was initiated to determine if a difference in thyroid metabolism is detectable between animals maintained on a high and those on a low plane of nutrition for a number of generations. These studies are being performed at the request of the Department of Animal Husbandry, State College of Washington, who furnish the pigs. These pigs will also be used in determining the threshold damaging dose of I^{131} in prolonged administration.

Peak values of I^{131} in the thyroid after oral administration were evidenced within 40 hours after I^{131} administration. Pigs on a high plane of nutrition showed a tendency to concentrate more I^{131} than did the pigs on a low-plane. The difference may be due to a real difference in thyroid metabolism, larger thyroids or less available stable iodine in the high-plane pigs. (The diet of the low-plane pigs is supplemented with KI in an amount estimated to be the same as that in the feed of the high-plane pigs). Maximum thyroidal absorption coefficients ranged from 0.20 to 0.34. Effective thyroidal I^{131} half-life was six days in all pigs.

In a continuation of the study to determine the I^{131} concentration in fetal thyroids during various stages of gestation, pregnant first-year offspring of the original experimental ewes were sacrificed as they approached six years of age. The I^{131} concentration in the fetal thyroid was about equal to or exceeded that of the dam in advanced pregnancy in the group

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* Now at University of Minnesota, St. Paul, Minnesota.

[redacted]

fed o.15 μc/day. However, in the group fed 5 μc/day since weaning (at four months of age) the I^{131} concentration in the fetal thyroids was three to four times that of the damaged thyroid of the dam.

Whole-Body X-Irradiation of Sheep (L. A. George, Jr., P. L. Hackett, and L. K. Bustad)

A short-term study was performed in order to determine if 15 r or 30 r of whole-body X-radiation would cause perceptible leukocytic depression in sheep. Although no clinical manifestations were observed in any animal following 15 r or 30 r, a significant drop in lymphocytes was observed in the group exposed to 30 r whole-body irradiation. In previous multiple radiation studies involving whole-body radiation, beta irradiation of skin, and oral ingestion of I^{131}, 50 r of total-body radiation caused a severe leukopenia, while the results were negative following 10 r.

Transfer of Radiostrontium to Sheep Milk (V. G. Horstman, A. A. Selders[a], F. P. Hungate[b], P. L. Hackett, W. L. Nickolson[c], L. K. Bustad)

In the studies it was found that the amounts of Sr^{90} secreted in the milk of sheep were the same when the strontium was orally administered as the nitrate or in plant material which had been grown in strontium contaminated soil.

When Sr^{90} was fed daily to sheep for two weeks, apparent equilibrium was reached by the fifth day. At that time about 1-1/2% of the strontium ingested appears in the milk.

C. Metabolism (R. C. Thompson)

Plutonium Absorption and Metabolism (J. E. Ballou, B. Kawin)

Studies of the increased absorption following intragastric administration of plutonium in very young rats were extended to include determinations of the tissue distribution of the plutonium. This distribution is essentially similar to that in the adult rat with 80% of the absorbed plutonium being deposited in bone 30 days after feeding.

(a) Now at Eastern Research Division, Ratonnier, Inc., Whippany, N.J.
(b) Plant Nutrition and Microbiology
(c) Statistics Operation

Using newly developed procedures employing isolated pig skin squares, the skin decontaminating efficiency of the proprietary agent CP-600 was compared with the standard permanganate bisulfite procedure. The CP-600 was less effective by a factor of 3.

Fission Product Absorption and Metabolism (J. E. Ballou, B. Kawin)

The 500-day ruthenium chronic feeding experiment was completed except for histological studies. During the feeding period from 200 to 500 days ruthenium concentrations did not increase significantly in tissues of hazard significance. Kidney, bone, and gonads are the tissues of greatest hazard significance and any of these might qualify as critical organs depending upon the methods employed in extrapolating rat results to man, and upon the significance given to the increased deposition of ruthenium in the bone of young growing animals. The previously suggested MPC in drinking water of 4×10^{-3} μc/ml still seems the most reasonable value in the light of total data presently available.

The gastrointestinal absorption of ruthenium was studied in rats 2, 7, 14, and 26 days old. For the first two weeks of life, absorption is from 5 to 10 times higher than in the adult rat and a greater proportion of the ruthenium absorbed is deposited in bone. In 26-day-old animals absorption has decreased to three times that observed in adult animals. Deposition of ruthenium in the brain of these very young animals was increased more than 100-fold over that in adults. This is no doubt due to incomplete development of the blood-brain barrier in these very young animals. Despite this marked increase in brain deposition it still shows the lowest ruthenium concentration of any tissue in the animal and is, therefore, of no hazard concern.

A study of the therapeutic effectiveness of EDTA, growth hormone, and cortisone in promoting the excretion of ruthenium from rats was initiated. This study was designed not only for the study of ruthenium therapy but as a pilot study for possible similar experiments with plutonium.

A study of the build-up of Cs^{137} in rats during chronic feeding has now proceeded through 100 days with animals sacrificed at 30, 60, and 100 days. Partial results indicate somewhat lower cesium levels than predicted from previous acute studies.

Absorption and Metabolism of Reactor Effluent Radioisotopes (R. F. Palmer)

All rats in this study have now been sacrificed. The last animals had received concentrated reactor effluent for a period of approximately one year. The only radioisotopes detected in soft tissues were P^{32} and the naturally occurring K^{40}. In bone, P^{32} is the predominant radioisotope present. There appears to be good evidence for detectable quantities of strontium-89 and possibly barium-140. The amounts of all radioisotopes present are considerably lower than would have been predicted from the radioisotope levels in the reactor effluent fed and the presently accepted biological parameters. Quantitative interpretation of the data must await further analyses and the interpretation of decay curves on low level samples.

Gastrointestinal Radiation Injury (M. F. Sullivan, R F Palmer)

As yet incompleted analysis of the histologic results of irradiation of the exteriorized intestine of rats indicates that epithelial damage occurred as early as one day after doses ranging from 900 to 1900 r. Damage ranged from decreased mitosis after 900 r to extensive necrosis after 1900 r. At the higher radiation levels maximum damage was seen 6 days after exposure, with regeneration of the intestinal epithelium evident by the 9th day, but still incomplete by the 12th day. The greatest damage was apparent in the illium. Additional animals were exposed to obtain histologic and hematologic data at later time intervals following exposure.

Experiments were initiated to study incorporation of intravenously injected Fe^{59} in the red blood cells following intestinal irradiation. Results will serve as an indication of the relative damage to the hematopoietic system following various types of irradiation. Preliminary results indicate very little red cell destruction following irradiation of the exteriorized

intestine or irradiation of the intestine by ingested Y^{91}. This is in contrast to the marked red cell destruction following total body irradiation.

Preliminary indications from electrophoretic studies of plasma protein patterns are that marked changes occur following total body irradiation and considerably smaller changes following intestinal irradiation.

Tissue analyses on two rats which had received 75 and 100 mg of plutonium by stomach tube indicated that from 10 to 20 times as much plutonium was absorbed from the GI tract as would have been predicted from previous studies at lower feeding levels. This increased absorption is presumably due to radiation damage and may be responsible for the erratic toxicity results which have been obtained.

The LD_{50}^{30} for oral Y^{91} as determined from approximately 30 animals was 17 mc/kg, in close agreement with previously reported results. Approximately 0.03% of the Y^{91} was absorbed from the GI tract, also in substantial agreement with previously reported results.

D. Pharmacology and Experimental Therapeutics (R. W. Wager - V. H. Smith)

Radioactive Particles: Metabolism and Toxicology (V. H. Smith, L. A. Temple, J. L. Terry, D. H. Willard)

Alcolholic suspensions of ferric oxide and ruthenium oxide colloids were prepared and mixed with very finely-ground sodium chloride (1 - 2 μ) and sealed into a small gelatin capsule. By firing the capsule from an air pistol into a special exposure chamber, high concentrations of $Ru^{106}O_2$ and $Fe_2{}^{59}O_3$ aerosols were achieved for inhalation studies.

While approximately 4 μc of $Ru^{106}O_2$ in the lung of BAF_1 mice at 180 days appears to be tumorigenic, the effect is not noted in doses one-tenth that size. Plutonium in doses ranging from 0.003 μc to 0.1 μc produces a tumor incidence similar to an inert material ($BaSO_4$ or non-radioactive RuO_2) at 180 days. However, both Ru^{106} and Pu^{239} produce non-specific pneumonitis in proportion to the dose (with Pu^{239} being several

times more effective than the Ru^{106}-Rh^{106}). When Ru^{106} was administered intratracheally with a chemical carcinogen, no increase in lung tumor incidence above that produced by the chemical carcinogen alone was noted.

An interesting side-light of the intratracheal injection studies is the anti-tumorgenicity of Tween-80. Tween-80 was used as a suspending agent for the particulate material in the first study and depressed the normal incidence of tumor 50% in the BAF_1 mouse. A comparison between $BaSO_4$ in water and $BaSO_4$ in Tween-80 shows a similar depression in tumor incidence. However, it apparently has no effect on the pneumonitis. Another surface-tension depressant and suspending agent of non-ionic type (Pluronics) has no effect on either tumor incidence or other pathology.

Ruthenium oxide particles (in the size range 90% of 1 - 2.5μ) were prepared by a new method involving the preparation of a ruthenium acetate-sodium chloride mixture followed by atomization through a quartz tube at 800 C. This method yielded a dilute but fairly constant aerosol concentration and will be used in the chronic administration of $Ru^{106}O_2$ particles to animals. It is more convenient to use than aspiration of preformed ruthenium particles, less subject to fluctuation in particle content and particle size and eliminates having large amounts of Ru^{106} on hand in an unstable suspension.

E. Plant Nutrition and Microbiology (F. P. Hungate)
Plant Nutrition (A. A. Selders*, F. P. Hungate)

Neubauer tests with Cs^{137} indicate that the addition of carrier to the soil increases the concentration factor of Cs^{137} from 0.4 with no carrier to 6.2 with 1000 μg Cs carrier/g of soil. The amount of increase is almost as great as previously observed with iodine although previous tests using nutrient solution had indicated that the effect of carrier was much greater with iodine than with cesium. With both elements, yield is depressed with from 100 to 1000 μg of carrier/g of soil and the concentration factor is depressed following the appearance of this toxicity.

*Present address: Rayonnier, Inc., Whippany, New Jersey

Current theories on the uptake of ions by plants propose that the ions are absorbed through specific sites on the root. Failure to inhibit nuclide absorption by the addition of carrier, as found in our experiments, appears to be at variance with this theory of specific sites. Thus the uptake of Sr^{90} by intact plants was compared with the uptake by plants whose roots had been removed and with plants whose roots had been killed by immersion in boiling water. Over a four-day period the uptake of Sr^{90} into the stems and leaves of the three types of plants was similar. This suggests that the roots may play a passive role in Sr^{90} uptake by plants.

Some data previously obtained suggested that differential adsorption of nuclide and carrier to the soil might account for some of the "inverse carrier effects" observed with plants. If this inverse effect did result from soil adsorption, the uptake of the nuclide into the plant should be different from the uptake of the carrier atoms. Barley grown by the Neubauer technique on I^{131} and iodide levels up to 500 μg/g of soil, upon harvesting, gave comparable concentration factors for both the I^{131} and for the I^{127} carrier. From this it appears that differential soil adsorption and release of I^{131} by addition of carrier cannot account for the marked increases in I^{131} uptake.

RBE by Microbiological Methods (M. P. Fujihara, F. P. Hungate, R. T. O'Brien)

Several organic colloids as well as yeast cells and metal surfaces have been tested for their ability to take up Po^{210} and prevent its subsequent movement to yeast cells. Under the conditions used none of these materials hold more than 80 to 90% of the Po^{210} initially bound to their surfaces.

Genetic Effects of Metabolized Isotopes (F. P. Hungate, W. J. Bair)

The types of biochemical mutants found following X-irradiation appears to differ from the types found in cultures grown on S^{35}. It is at present not clear which of several possible hypotheses might account for this difference.

[redacted]

Yeast grown on media containing minimal concentrations of sulfur (as sulfate) is more radioresistant than is yeast grown on media containing higher concentrations of sulfur. The increased resistance is evident in survival curves following x-radiation and in growth curves using continuous radiation from tritium. A higher mutation rate is also obtained from cultures grown on high sulfur, but the difference is most noticeable in the controls receiving no radiation. With radiation the difference in mutation rate between high and low sulfur levels is relatively the same as in the control cultures but the magnitude of the difference appears to decrease with increasing radiation.

The growth of yeast cells grown in the presence of EDTA and tritium is more suppressed than cells grown in the absence of EDTA but the same concentration of tritium. Similar enhancement of growth inhibition by EDTA was observed with plutonium in spite of the fact that the cells removed less of the plutonium from solution when EDTA was present. The EDTA appeared to be ineffective in changing radiosensitivity when the radiation dose was delivered by X-rays during a relatively brief period.

F. Minor Problems (D. E. Warner)

Biological Monitoring (Not charged to research) (W. C. Hanson)

During the quarter, concentrations of I^{131} in rodent thyroid glands were the highest in fifteen months at the collecting site east of the Separations Areas. The maximum was 4×10^{-2} μc/g, occurring in July, with a downward trend at all sites since that month.

Columbia River waterfowl samples of edible tissues and bone were generally slightly lower in concentrations of P^{32} than in the same period of 1955. Shorebirds contained consistently greater amounts than other waterfowl. The average bone concentration was 3×10^{-2} μc/g in September.

Electron Microscopy (R. Borasky)

Twenty compounds were tested for their electron staining reactions with collagen. Four gave positive results: phosphotungstic acid, osmium

[redacted]

tetroxide, uranyl acetate, and plutonium nitrate. As the organic matrix of bone is 90% collagen, osmium and plutonium are useful in vitro collagen

[redacted]

unsuitable stains; examples are strontium and lead.

V. RESEARCH AND DEVELOPMENT PROGRESS - BIOPHYSICS

A. Biophysics Research Program

Chemical and Monitoring Methods (J. M. Nielsen)

Analytical Methods (R. W. Perkins W. B. Silker, L. J. Kirby)

The system for the quantitative measurement of Na^{24}, P^{32}, Sc^{46}, Cr^{51}, Mn^{56}, Cu^{64}, Zn^{65}, As^{76}, and Np^{239} in reactor effluent water which requires no chemical separation was applied to the daily analysis of eight reactor effluent streams for a one month period. The only sample preparation involved was evaporation of 100 ml aliquots of the streams into one-inch counting dishes. On the day the sample was collected Na^{24} and Mn^{56} were measured by gamma energy analysis and Cu^{64} by gamma-gamma coincidence counting of its positron annihilation photons. As^{76} was measured the second day by a selective beta-ray absorption technique, and Cr^{51} and Np^{239} were measured the third day by gamma energy analysis. Sc^{46} and Zn^{65} were measured by gamma energy analysis and P^{32} by a beta-ray absorption technique after 12 days. The nine analyses on each of the eight

A tentative procedure was developed for the determination of the rare earth group in reactor effluent water. The procedure consists of the extraction of Np^{239} with 0.45 M TTA in benzene from a 1N HCl solution of the sample, followed by a lanthanum fluoride carrier precipitation of the rare earths from an oxidizing ($NaBrO_3$) solution. The rare earths are then extracted from a solution buffered at pH 4-5 with acetic acid-sodium acetate buffer into 0.45 M TTA in benzene. After re-extraction into 0.1 N HNO_3 the solution is plated for beta or gamma ray counting. The procedure appears to give a clean separation of the rare earths with a radiochemical yield greater than 95%.

La^{140} and Sm^{153} were identified as the major gamma-ray emitting isotopes in the rare earth group of day old reactor effluent water. The identification was made by comparing the four characteristic photopeaks of La^{140} and the two photopeaks of Sm^{153} with the gamma ray scintillation spectrum of the separated rare earth group. The identification was further substantiated by the beta and gamma ray decay measurements. The ratio of La^{140} to Sm^{153} corrected to four hours after the sample left the reactor was 0.37 to 1.

Complete fractionation of yttrium and the four rare earths, neodymium, promethium, samarium, and europium was accomplished by ion exchange on a 2.5 mm by 40 cm column of Dowex 50 x 8, 100-200 mesh, in the ammonium form. After sorption of the rare earth tracers, containing 5 mg lanthanum carrier, elution was made with 0.47 M lactic acid at a pH of 2.2. Separation of Y, Eu and Sm is complete after 20 hours, and Nd is separated in 40 hours.

Group separations of radioisotopes by a modified qualitative analysis scheme were made on reactor effluent water to determine the presence of trace radioactive constituents and to test the feasibility of gamma counting in conjunction with these group separations for rapid analysis of reactor effluent water. Trace (less than one per cent) short half-lived isotopes emitting gamma rays of 0.3, 017-0.8, and 2.0 Mev have not been identified

[redacted]

as yet. A beta emitter in the rare earth fraction with half life longer than 50 days is also unidentified and represents about 0.1% of the total beta emitters.

Monitoring Methods (W. B. Silker)

An improved water sampling system was installed at the Pasco Water Plant inlet. This system provides a continuous sample which is not dependent upon the water plant operation. Weekly samples of cations are obtained on an ion exchange resin with a 40 liter sample of the river water provided for studies on the radioisotope content.

Counting Methods (J. D. McCormack, J. M. Nielsen, R. J. Walker)

A low background beta counting system was developed consisting of four end window proportional chambers in an anticoincidence shield of cosmic ray tubes and a 6" iron shield. The background rate for each unshielded proportional tube is 35 counts per minute. Shielding with 6 inches of iron in all directions reduced the rate to 16 counts per minute. Addition of an anticoincidence ring of cosmic ray tubes reduced the background to 0.9 - 1.0 counts per minute. Further lowering of the background may be realized by using counting tubes with plastic walls.

Final drawings, schematic drawings, and specifications were completed for the end window proportional counting apparatus for beta emitters. These drawings were submitted to the Radiological Chemical Analysis Operation for their proposed counting room modification.

Special Studies (R. E. Ewing)

The addition of soluble chemicals to the cooling water of one of the reactor tubes was continued in a study to determine the sources of the radioisotopes observed in reactor effluent water. In one test 3.68 ppm sodium and 1.29×10^{-2} ppm copper were added and Na^{24} and Cu^{64} determined. The average hold-up times of sodium and copper were calculated to be 4.6 seconds and 8.6 minutes respectively, assuming a constant rate

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of addition and constant known thermal neutron flux. In separate tests additions of sulfur and phosphorus indicated that sulfur cannot be the major source of P^{32}. These tests would indicate that only 6×10^{-11} g/ml of phosphorus need to be present in the cooling water to account for the P^{32} observed in the normal effluent. No routine analytical method is available for determining phosphorus in this low concentration.

Chemical Dosimetry (D. R. Kalkwarf, W. E. Keder)

Investigations continued in a search for a chemical dosimeter suitable for radiation dosages in the range of 0.600 rads. Aqueous solutions of organic dyes were irradiated with Co^{60} gamma rays or 2 Mev electrons and the absorption spectra of the solution examined for changes which could be utilized. Of those examined, erioglaucine, as a 10^{-3}% solution in water, was found to be most sensitive, capable of detecting 50 rads when its absorbance is measured at 637 mu in 1 cm cells.

The decomposition of the dye erioglaucine by gamma radiation from Co^{60} was also used as a means for evaluating the protective effect of various reagents. Such reagents presumably protect erioglaucine and other radiation-sensitive materials from decompostion by competing with the free radicals formed by the irradiation of water. The concentrations of erioglaucine solutions decrease exponentially with dose in the absence of a protective agent, the magnitude of the exponent being less in the latter case. Using the values of this exponent as a measure, the protective effects of the following reagents on an equi-molar basis were found to decrease in the order: t-butanol > thiourea > ethanol > isopropanol > dextrose > acetone > acetate > chloride. This technique should aid in a search for reagents which offer intense protection action in aqueous solutions of industrial or biological interest.

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Earth Sciences Studies (J. F. Honstead, D. W. Rhodes)
Geological Studies (R. E. Brown, D. J. Brown)

The reality of a marked correlation between the attitude of the Ringold formation and that of the basalt bedrock was supported by the preparation and study of detailed plots of certain key cross-sections. The relationship is being used to expand the knowledge available from the few wells that have been drilled to basalt; a much clearer picture of the surface contours of the basalt is emerging. The recognition of Ringold deformation and the subsequent revaluation of geological data is permitting rationalization of a number of ground water anomalies previously unexplained.

A survey was made of geophysical firms from the standpoint of services offered, equipment and techniques employed, and personnel available preparatory to the choice of a consultant for a geophysical investigation of the Hanford region. Geophysical techniques that show most promise are seismic reflection and seismic refraction measurements. Since such investigations would require a certain amount of drilling to provide shot holes, it should be possible to utilize the extensive experience and equipment of the consulting firm to make in addition a study of drilling techniques.

Soil Physics (P. P. Rowe, J. R. Raymond, W. H. Bierschenk)

A new method was developed for deducing aquifer characteristics from natural fluctuations of the water table resulting from the annual rise and fall of the Columbia River. Equations previously derived from this application were based upon an assumed sine wave fluctuation of the level of the surface water body, a condition not generally applicable to Columbia River flow variations. The present technique assumes a situation in which the level of the surface water body increases linearly with time and the average change in height of the water table between the edge of the water body and the observation point at the distance x is expressed by an equation derived from this assumption. The equation was tested by means of a sand box model for both artesian and water table conditions. In both cases the equation was found to agree with the test data with reasonable accuracy.

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Soil Chemistry (J. R. McHenry, K. C. Knoll)

Experiments were continued to investigate the effect of various commercial water additives upon the infiltration rate of water into a column of the Hanford soil. Agents tested include wetting agents, anti-foaming agents, and filter aids. Of those studied the one showing the most promise in providing increased infiltration rates was Separan 2610 in concentrations of 1 ppm. Solutions of Separan displayed equilibrium infiltration rates 1.5 to 2 times that of tap water in a series of six soil columns. The presence of Separan does not reduce the effectiveness of the soil for removing and retaining Sr, Cs, or Pu.

Laboratory research was conducted to investigate the ion exchange of yttrium for calcium on Hanford calcareous soil. In particular the effect of pH on the exchange reaction was studied. Equilibrium experiments utilizing 10^{-4}, 10^{-5}, and 10^{-6} M YCl_3 solutions were conducted over a wide range of pH values. The equilibrium exchange was found to decrease markedly at low pH. The exchange was nearly complete between pH 6 and 8, decreased slightly between pH 9 and 11, and again approached 100% above pH 11. This pattern was apparent at all concentrations tested with the decrease in the pH 9 to 11 range less marked for higher concentrations.

A series of measurements was made to evaluated several physical and chemical characteristics of soil samples obtained from well drilling operations to assist with the identification and characterization of specific formations. In addition to size fraction determinations, the 15-atmosphere percentage moisture retention and the total cation exchange capacity of these samples are being measured. One of the objectives of these tests is to provide simplified procedures for evaluating the pertinent soil variables to permit the rapid examination of many samples. This is being done by evaluating correlations between some of the characteristics to permit their estimation from a minimum number of tests. The total cation exchange capacities of 22 drilled samples were correlated with the 15-atmosphere moisture percentages and with the two-micron clay percentages measured

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on these samples. In both cases the calculated regression coefficient showed linear correlation to greater than 99% confidence.

Ground Waste Investigations (D. W. Rhodes)

Previous investigations showed that the presence of Al in wastes inhibits the removal of Sr by soils, particularly when the Al concentration is above 3.7×10^{-4} M. On the other hand, concentrations of Al up to 1.6×10^{-3} M have little effect on the removal of Cs by soils. The removal of both Sr and Cs is reduced by high total salt concentrations in the waste. It has been found that the removal of both Sr and Cs by soils may be improved in the case of certain wastes by diluting with water. The effect must be examined for each batch of waste individually to assure optimum removal. Dilution may be helpful in those cases where the Al and total salt concentrations are slightly above the critical level and are prohibiting ground disposal.

Further research was conducted on the behavior of Co^{60} in Hanford wastes. Nickel ferrocyanide scavenging of certain wastes leaves the Co^{60} in a chemical form that is not removed by passage through the soil. It is believed that the cobalt is probably in the form of a neutral or anion complex. The complex is very stable and cannot be readily broken by ordinary sulfide precipitation treatment. Equilibrium tests with an anion resin suggest that the cobalt exists in part as an anion complex, such as $Co(CN)_6^{-3}$.

Automatic Isotope-Analyzing Monitor (L. C. Schwendiman, H. G. Rieck) (Not charged to Biology and Medicine)

Development progressed on an automatic monitor for analyzing a reactor effluent stream for Na^{24}, Mn^{56}, Cu^{64}, Np^{239}, As^{76}, P^{32}, and Si^{31}. The monitor will sample the stream and evaporate a known volume to dryness, then using gamma scintillation and proportional beta counting techniques, will record the quantities of the isotopes of interest. The instrument will be useful in providing more detailed information on the isotopic composition of important waste streams so that immediate control

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becomes practical and will permit an evaluation of the usefulness of this type of monitoring.

Meteorology Studies (G. R. Hilst)

Diffusion and Transport Studies (G. R. Hilst, J. J. Fuquay, P. W. Nickola, M. F. Scoggins, C. L. Simpson)

Major research effort was concentrated on field measurements of the transport and diffusion of material emitted continuously into a stable atmosphere from a point source at 200 feet above ground level. The horizontal plume width and position was measured from each of a sequence of aerial photographs taken from an elevation of 6000 feet. The horizontal diffusion and meandering of the effluent material was deduced from these measurements according to a technique described previously. The vertical growth of the plume was measured using an array of impaction samplers held aloft in a vertical line at 1000 and 2000 feet downwind from the source by tethered balloons. Fluorescent particles were used as a tracer material for these vertical distribution measurements and, from the relative number of these particles on each sampler, it was possible to deduce quite accurately the variance of the concentration distribution in the vertical direction. These experiments provided the first known quantitative measurements of the bi-directional variation of concentration in stable atmospheres.

Two significant results emerged from the partial analyses of these experiments: (1) Quantitative simultaneous measurements of the horizontal and vertical cross-wind variance of the concentration distribution showed the predominance of horizontal growth and meandering in the diffusion process in stable atmospheres. For example, in one experiment the horizontal variance at 1000 feet from the source was 5070 m^2 while the vertical variance was only 31 m^2. (2) The rate of growth of the plume is, on the average, much more rapid in the horizontal direction than in the vertical and, in particular, the dependence of the vertical distribution of concentration upon the distance from the source does not conform to Sutton's model. In one experiment the vertical variance of concentration

was found to be proportional to $x^{-0.40}$ rather than lying between $x^{-1.0}$ and $x^{-2.0}$ as required by Sutton's model. Since the dependence of the horizontal variance of concentration upon the distance from the source has always been found to lie within the limits prescribed by Sutton, these observations appear to require a revaluation of the meteorological significance of this exponent of x which appears in the diffusion equations.

Particle Pick-Up Study (P. W. Nickola, M. F. Scoggins)

Periodic photographs of the test plot at the Benson Ranch site were continued but no full-scale field experiments were undertaken because of the scarcity of erosive wind conditions and preoccupation with other experiments.

Trajectory Study (P. W. Nickola)

Trajectory data and meteorological parameters available from previous computational work were referred to the Computing Operation for machine analyses of proposed empirical forecasting rules. No significant results were obtained during this period.

B. Dosimetry Program

Gamma Ray Dosimetry (W. C. Roesch, I. T. Myers, J. W. Baum)

An instrument, based on the information developed from the body monitor studies, was built to measure plutonium in wounds of the hand. A lead shield was built around a small sodium iodide scintillation counter and the wound was positioned almost in contact with the counter. Sensitivity estimated for shallow wounds is on the order of 2×10^{-4} μc. In application to two cases, quantities on the order of 0.01-0.02 μc and 0.0015 to 0.002 μc were measured. In the higher case the site of deposition was localized to two small punctures by the use of thin lead collinators.

To establish a criterion of body monitor performance it was decided to define the minimum detectable amount (MDA) of a radioisotope as the amount which can be expected to be detected 90% of the time when three succesive measurements equal to or greater than a critical measurement are

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said to establish the presence of the radioisotope; the critical measurement is chosen so that 0.1% of uncontaminated subjects can be expected to be judged contaminated erroneously. The MDA will depend on counter sensitivity, background, and counting time. For plutonium detection, the sensitivity and counting time are fixed so that improvements in the MDA must come from reduction in background. It was found that the backgrounds of a set of crystals that differed only in thickness consisted of two parts: (1) a part independent of thickness which presumably comes from beta rays and gamma ray secondaries originating near the crystal, and (2) a part proportional to thickness coming from similar particles originating in the crystal. A major contributor to the former was found to be a beryllium window which had been placed on the counter because of its high transmission of plutonium X-rays. The gamma ray contribution was materially reduced by improved shielding. Since electrons secondary to the X-rays seldom leave the sodium iodide, but background electrons could be expected to, an attempt was made to reduce background by placing a layer of anthracene above the sodium iodide and rejecting counts in which light came from both scintillators. The source of the light was to be determined by differentiating the counter pulse and identifying the rise time as characteristic of NaI or anthracene. Unfortunately, at the low pulse heights resulting from the X-rays there was so much statistical variation in pulse shape that the ranges of rise times over-lapped. Enough separation was possible, however, to establish that similar methods based on this principle of background reduction should be useful.

As part of the determination of the energy lost by tritium beta particles per ion pair formed in air, relative measurements were made of the isotopic vapor fractionation ratio of tritiated water for the range 0° to 45°C. In this range, the ratio was constant to within 2%. An experiment to measure the absolute value at one temperature was begun.

A constant temperature bath was fabricated in preparation for calorimetric work at the electron Van de Graaf. Further improvements

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were made in the techniques of gamma ray calorimetry. Better reproducibility resulted from more care in eliminating transient effects at the start of a measuremen . Interchange of two recorders which were found to have different noise levels increased the sensitivity of the system.

Beta Ray Dosimetry (W. C. Roesch, E. E. Donaldson)

An investigation was made of the use of film badges for certain non-surface beta ray measurements. By comparison with an extrapolation chamber it was established that the badge overestimates some non-surface doses by about 75%.

Neutron Dosimetry (W. C. Roesch, J. De Pangher, H. V. Larson)

The magnetic resonance detector used to measure the field of the positive ion accelerator analyzing magnet was calibrated by measurement of the Li(p, n) and T(p, n) threshold energies and appears capable of measuring beam energies to an accuracy of 0.03%. After the calibration was performed it was necessary to open the accelerator for maintenance work. It was assumed that this would upset the calibration completely, but it actually changed it only 0.1% which is negligible except for certain very precise experiments. The device has been valuable in increasing the reproducibility of results from the accelerator. Certain results for the moderated dosimeter, which had been assumed to be a case of poor statistics, were shown to be due to a fine structure in the response of the instrument as a function of neutron energy.

A combination neutron fluxmeter-dosimeter-energy meter was fabricated and tested. It consisted of a detector surrounded by a paraffin moderator thick enough to make the response proportional to neutron flux. Around this is a tank which can be filled with water to increase the moderator thickness till the response becomes proportional to neutron dose rate. The behaviour of these two moderators was found to be as expected. In general; however, the use of water proved undesirable because at energies near certain resonances in the cross section of oxygen small deviations

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in response occurred. An annular paraffin cylinder was fabricated to replace the water tank. The ratio of the readings with the two moderators was found to provide a simple method of determining the neutron energy.

A scattering chamber was fabricated for use in an experiment to measure W for protons. In this chamber a portion of the Van de Graaf accelerator beam will be deflected at right angles to the main beam by scattering in a thin gold foil to form a low intensity, monoenergetic beam for the experiment. A method was found for mounting thin nickel foils so that the scattered beam could pass from the accelerator into the measuring apparatus and yet the accelerator vacuum not be lost by leakage of air at the window.

C. Instrumentation Program

Survey Instrumentation (D. A. Campbell, R. A. Harvey, G. D. Linsey, W. G. Spear)

An experimental model of an alpha air monitor for detecting "bursts" of airborne plutonium was developed and submitted to the field for testing purposes. Sample air at the rate of two cubic feet per minute is drawn through a one and one-half inch diameter filter. Contaminated particles collected on the filter are detected by a 6292 photomultiplier tube. The output pulses are amplified by a two-stage amplifier, injected into a pulse shaper and then integrated by a counting-rate meter. The instrument is adjusted to alarm at twice the maximum radon or natural background observed in this area. At this sensitivity, a standard man located in the monitored region would have inhaled 0.16 times the maximum permissible amount for insoluble plutonium in the lungs. This sensitivity may be improved by the use of an impact sampler; the improvement being proportional to the separation ratio of the airborne contaminants to the naturally occurring alpha emitters.

Development was completed on the experimental Alpha-Beta-Gamma Hand and Shoe Counter and the instrument was put into use for field tests. It was designed to combine the functions of both the four-fold and five-fold

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counters in a single unit. Scintillation hand and shoe probes are used for alpha detection and GM probes are used for beta and gamma detection. The presence of contamination is indicated by a red light that also indicates which surface is contaminated and which type of contamination is present.

A five-stage transistor amplifier was designed for use in count-rate meter type of portable survey instruments. The gain is 1000 with an input sensitivity of five millivolt pulses and an output of five volt pulses to drive the two-transistor count-rate meter circuit. The amplifier requires only 30 milliwatts of power from six series 1.25 volt mercury cells. We now have available standard transistor circuits including a high voltage supply, an amplifier, a count-rate meter, and a loudspeaker driver amplifier. These standard circuits will be used in the design of easily maintained instruments.

The crystal and light shield thicknesses on an experimental scintillation dose-rate meter were reduced to 50 mg/cm^2 and 3.6 mg/cm^2 respectively resulting in an instrument with an energy independence from 60 kev to about 2 mev. This instrument is expected to be more reliable than the present beta-gamma dose-rate instruments.

Special Instrumentation (G. E. Driver, R. A. Harvey, M. O. Rankin)

Fabrication was started on an experimental scintillation scanning device which will be utilized to determine the feasibility of mapping radioactive deposits in animals. The instrument will utilize a collimator on a carriage which automatically scans a predetermined area. The results will be presented on an X-Y graph in the form of dots, with the dot density being proportional to the isotope concentration.

The final design was completed on the radiation monitoring channel of the Radiotelemetering system data station. Using an HM chamber for beta-gamma detection, the unit integrates directly the chamber ionization current with a capacitor. At station call-in, the capacitor voltage is measured by means of an electrometer that feeds an amplifier-modulator

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unit. The high sensitivity of the circuit provides a low-level full-scale reading of 0.2 mr/hr with a maximum error of ±4%. The telemetering system design provides the automatic recording of weather and radiation data from twenty data gathering stations in the Hanford vicinity.

As an auxiliary to the time-of-flight measurement facility, an instrument was developed to limit the chopped ion beam to a relatively small number of ion groups per second. Normally, the beam chopper produces eight million of these "bunches" per second, a number too great to be easily detected and analyzed electronically. The beam gate generator, synchronized with the beam chopper, produces deflection pulses which allow only one out of approximately 4000 groups to proceed to the detector; thus the detector counting rate is held to a value within the ability of the pulse circuits.

VI. SUMMARY OF STATUS OF THE RESEARCH PROGRAMS

The application of the thin sodium iodide scintillation counter to the measurement of plutonium in wounds has solved a problem which has been of concern since the start of the Manhattan Project. Although field equipment is not yet available, it is possible to assess the quantity of plutonium remaining in a wound after surface decontamination. This provides a ready index to the need for surgical treatment so that decision may be based on the measured quantity present. Although some uncertainty arises from the unknown depth in the wound and, thus, the unknown self-absorption, the sensitivity is adequate to measure quantities in the range of 10^{-4} μc.

The simultaneous measurements of the growth of a smoke plume in both the vertical and horizontal directions has provided additional information on behaviour of such plumes in stable atmospheres. It has long been recognized that Sutton's equations do not provide a complete explanation of the patterns noted under these conditions but the difficulties of observation on an aloft plume have prevented the accumulation of quantitative data on the spread. Such studies are of considerable importance to this site because

of the large fraction of the time that the stable condition occurs.

The studies on the increased uptake of radioisotopes during the early stages of life are of considerable importance in assessing the influence of waste disposal operations on the environs. Present maximum permissible concentrations are evaluated on the basis of the standard man and standard uptakes usually measured in the adult annual. Although the use of 10% of the maximum permissible concentrations for exposure of the general population is partially based on the possibility of increased uptake in children, quantitative data to assess the exact effects are lacking. The work on plutonium and ruthenium uptake in immature animals will provide a more firm basis for extrapolating to the effects on general populations.