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RADIOLOGICAL SCIENCES DEPARTMENT

ANNUAL REPORT
RESEARCH AND DEVELOPMENT
FISCAL YEAR 1955

September 23, 1955

GENERAL ELECTRIC
HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

HW-39558

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RADIOLOGICAL SCIENCES DEPARTMENT - ANNUAL REPORT RESEARCH AND DEVELOPMENT - FISCAL YEAR 1955

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RADIOLOGICAL SCIENCES DEPARTMENT RESEARCH AND DEVELOPMENT PROGRESS REPORT FOR FY 1955

The following material comprises a summary of work performed in Radiological Sciences Research and Development during FY 1955. The report, primarily non-technical in nature, presents accomplishments achieved over the twelve-month period in each of the three sections conducting research and development work: Biology, Biophysics, and Radiological Engineering. A tabulation of manpower and costs associated with these activities appears in Tables I and II appended.

RADIOLOGICAL ENGINEERING

SUMMARY OF ACCOMPLISHMENTS

DISPOSAL OF LIQUID WASTES FROM SEPARATIONS PROCESSES

From studies begun last year (HW-33128), based on the new policy of radioactive liquid waste disposal and research in the Biophysics geology-hydrology program, disposal of several waste streams not heretofore disposable because of high radioisotopic content was initiated. Disposal criteria were established for Metal Recovery Plant waste scavenged with nickel ferrocyanide and calcium phosphate, and four million gallons of supernate containing 85,000 curies of beta-emitting radioisotopes including 8,900 curies of strontium-90 were sent to ground in 200 East Area, thus alleviating storage tank space shortage.

In-plant scavenging of bismuth phosphate plant first cycle wastes was recommended to eliminate need for continuing evaporation processes.

Separate storage of coating removal waste was found essential to successful scavenging; initial tests of scavenged supernate indicated general suitability for ground disposal.

The concept of ground storage of the more hazardous radioisotopes in the soil column above the groundwater table has been applied to disposal of these wastes, and to others in which the entire liquid is retained above the water table (specific retention). By this latter principle 6.6 million gallons of first cycle waste containing 48,000 curies of beta-emitting radioisotopes were transferred from tanks to trenches at a cost of $45,600, eliminating a tank shortage, releasing $1,500,000 worth of tank space, and saving $800,000 over evaporation of the waste.

Studies were initiated for alternate disposal methods of radioactive sludges not constituting a thermal problem now in storage tanks to clear space for current wastes. The use of separations plant cooling water retention basins no longer required for their initial function was recommended for initial testing in this program.

It was recommended that the excess self-concentration capacity of stored Purex wastes be used for the volume reduction of other stored wastes found not suitable for ground disposal, rather than use water addition for control. Condensate resulting from the self-evaporation and volume reduction of stored Redox wastes was found generally suitable for continued ground disposal as predicted, because of the high decontamination factor evident in the self-evaporation, low concentration of long-lived fission products, and low total salt content compatible with efficient adsorption in the soil column.

Findings of low water percolation rates into the ground while investigating the feasibility of disposal around Gable Mountain, suggested that apparent percolation rates noted on small cribs may have been overestimated. Recommendations were made that Purex cribs be tested for percolation; subsequent findings indicated the need for larger disposal areas to avoid production limitations.

Field tests north of Gable Mountain indicated ground water movement of significant rate, and suggested that a similar "underground river"

might exist south of Gable Mountain and adjacent to the separations area plateau. Subsequent investigations by Earth Sciences confirmed rapid ground water movement in this area thus indicating that the secondary defense of the previously predicted ground water movement time of 750 years from the separations areas to the Columbia River probably was overly optimistic. Pending clarification of the ground water movement prediction, ground disposal of long-lived fission products in the northern portion of the 200 East Area was restricted. It was recommended that future cribbing of waste streams containing significant quantities of strontium and cesium be performed south and west of the 200 East Area. For similar reasons, it was found essential to alter plans for large volume cooling water disposal from the region generally east of the area to the region north of 200 East Area where rapid ground water movement was evident. Failure to make this significant change in practice could cause leaching of contaminated soil columns by raising ground water and movement of ground water to the highly permeable areas around Gable Mountain.

DISPOSAL OF PROCESS WASTES TO COLUMBIA RIVER

Effluent Dispersion Patterns

Data collected from the Columbia River were reported as document HW-32506, which was a final compilation of essentially all data collected during 1951-1953 in a survey intended to determine the effluent dispersion patterns in the river. An attempt was made to obtain a mathematical expression for the dispersion, a tentative form of the equation being reported in an appendix of the document. The effluent patterns reported were utilized during the year in conjunction with evaluation of the effect of effluent discharged from existing reactors on the influent to the downstream reactors as a function of effluent flow and river stage variation (natural and as a result of upstream dam manipulation), the location of replacement effluent disposal lines, and the effect of an effluent line failure on downstream intakes.

While work last year indicated that only a small fraction of the total reactor effluent, could be disposed via ground percolation in a closed sump near Gable Mountain, the potentially significant future effects on water treatment plant contamination and increased influent water temperatures resulting from multiple use of river water, added importance to the consideration of an effluent disposal system south of the reactors with an installed return point to the Columbia River near Hanford. Such a system could mitigate river pollution problems by permitting thermal cooling of the effluent, allowing decay of radioisotopes of significance to GI tract irradiation from downstream drinking water usage, and presenting the possibility of using natural or artificial materials or barriers to reduce the radioisotopic content by ion exchange.

Ruptured Fuel Element Waste Disposal

The possible use of higher coolant temperatures both in a recirculating reactor cooling system and a one-pass, pressurized reactor cooling system raised the possibility of increased fuel element rupture frequency and severity. Preliminary studies of the problem indicated that due to the probable complete disintegration of rupturing fuel elements at the high coolant temperature, direct disposal to the river would not be possible, disposal to a crib near the river would be questionable due to the long time required to reduce the hazard by radioactive decay, and that waste stream decontamination facilities would probably be required.

Downstream Domestic Usage of River Water

A study of the effects of disposal of reactor cooling water on the domestic use of the Columbia River was completed in order to provide a basis for future interpretation of data, recommend work needed and allow extrapolation to future conditions. It was noted that the P^{32} has increased at a rate faster than that expected from a proportionality with power level. A correlation with bulk outlet temperature indicated an increase of exp(0.06T). Average concentrations and standard deviations

of the outlet water were obtained for six month intervals from 1951 through 1954 and the rates of output calculated from these values. A comparison between fission products as calculated from an assumption of 24 hours irradiation and the $Sr^{91,92}$ concentration and actual spot analyses of Sr^{89}, Sr^{90}, I^{131}, and Ba^{140} indicated general agreement except for Sr^{90}. The spot analyses of Sr^{90} indicated more than the calculation from $Sr^{91,92}$. An increase in quantities of fission products was postulated from the increased number of ruptures now occurring. In addition, those areas which contain uranium-aluminum alloy elements appear to have a higher rate of output than those areas with natural uranium.

The monthly average hazard situation at Pasco-Kennewick was computed from the rates of output. These data indicated that a maximum of 15% of the appropriate limit as based on GI tract irradiation occurred during low river flows. This value may be an overestimate by a factor of 3 due to a discrepancy in the measured and calculated analysis at this point. The bone dose from continual drinking of the water reached a maximum at about 4% of the limit (off-plant) during periods of low river flow.

Extrapolation to conditions expected when the K reactors achieve anticipated levels and following completion of expansion projects CG-558 and CG-600, indicates that downstream river water at domestic intakes could approach permissible drinking water concentrations. Further extrapolation to conditions of rear-face pressurization indicated that effluent contamination of the river would limit such production advances; in particular, P^{32} in game fish and drinking water would be expected to be a serious problem. Cooperative studies with Pile Technology indicate the probability that the activation and corrosion of aluminum jacket and tube impurities may be a significant contributor to radioisotopes in the effluent, and point out the need for activation analyses of pile water system materials to indicate methods of reducing effluent contamination.

Reactor Purge Waste Disposal

As disposal criteria for effluent containing reactor purge material have been uncertain, a study was established to evaluate the safety of using normal retention basin operating procedures during purge flow. However, a typical river water quality in the spring of 1955 significantly reduced purge requirements; further evaluation next spring is indicated.

Disposal of Reactor Experimental Control Solution

Evaluation of disposal of irradiated boron solutions tested for more variable control of neutron flux in atomic reactors was completed with publication of document HW-33524, "Disposal of Irradiated Waste 'Ink' Solution".

Metal Preparation Area Waste Disposal

Procedures and equipment were established to allow an audit of volume and radioactive content of the metal preparation area waste currently percolating in ponds near the river shore. Initial results indicated that uranium content of waste to the ponds was small compared to the natural content of the Columbia River; direct river disposal may be feasible.

Columbia River Studies

The Columbia River is an important natural asset to the Hanford operation and in its use no health hazard, due to discharge of waste effluents, must result to downstream users.

Physical, hydraulic, and radiological data have been collected as a basis for determining the effect of the new KW and KE reactors on the river and McNary Reservoir.

Monthly observations directly above McNary Dam from November 1954 through April 1955 indicate only small differences in radioactivity. In May and June 1955 the radioactivity was slightly lower

in the surface water than for the sub-surface areas.

In general the temperature of the Columbia River at Umatilla, Oregon, and McNary Dam is greater during the months of March through September and less during October through January than that in the upper reaches of the river in the Hanford reservation. During June, July, and August the temperature difference above and below the Hanford operation is, in general, less than the temperature increase due to the Snake River and other minor tributaries.

For the period November 1954-February 1955, there was no significant difference in the water temperature between the surface and the bottom of McNary Reservoir near the dam. During April-June 1955, slightly higher temperatures were noted at the surface of the reservoir.

The application of these studies may govern the extent to which the present reactors may be modified or operated to increase production. The knowledge learned about McNary Reservoir may have a direct application to the Priest Rapids Dam and reservoir, if built, above the Hanford reservation.

The average nitrate nitrogen concentration, 0.06 ppm to 0.22 ppm, of water above McNary Dam indicates that future increases due to chemical wastes may be permitted without detriment or hazard to domestic water users.

A substantial increase in hardness, sodium and sulfate concentrations occurred in the Columbia River entering the Hanford reservation during the first half of 1955. Further investigation is required to determine the cause and continuation of this situation.

DEVELOPMENT OF RADIATION PROTECTION DESIGN CRITERIA

Radiological Disaster Studies

The possible radiological consequences of a single reactor tube failure were re-evaluated, following a revision of the aluminum

melting time estimate by the Engineering Department. The reactor atmosphere system probably would not contain the fission product release; therefore contamination may be released to the atmosphere through the exhaust system.

An analysis of the environmental effects of a nuclear accident in the physical constants test reactor was made. In the event that the fission products from a burst of about 3×10^{17} fissions were released to the atmosphere, pessimistic assumptions indicated that hazardous conditions were possible; momentary severe conditions would exist close to the reactor site with considerable lingering ground contamination requiring control.

Radioactive Particle Hazard Studies

A study of vehicle contamination arising from stack fallout was conducted. Temporary contamination control limits were recommended, and experimental work was performed which indicated that the inhalation hazard probability in operating and servicing plant vehicles was low compared to the direct risk in the operating areas.

Experiments were performed to determine the probability of transfer of a small particle from the ground to the skin and clothing of personnel performing outside work. The results indicated that when the ground concentration was one particle per square foot, a transfer would occur in .25 exposure hours. These data were useful in estimating the probability of hazard on large construction project within the reservation. Calculations were made to evaluate the external radiation hazard from small particles, and correlations between size and activity of ground deposited particles were evaluated. Studies of the Pu^{239} fission yield showed the significance of its Ru^{106} contribution to the Ru^{103} -Ru^{106} ratio in process material, and brought calculations into a much better agreement with measurements obtained on material emitted from stacks.

Other contributions to the general department program included: recommendation of revision in field survey techniques to permit statistical analysis of particle fallout; a procedure for calculating the dosage rate in tissue from a skin-deposited particle; derivation of the relationship between particle activity content, survey meter reading, and particle size; and derivation of an analytical expression for the particle concentration in the air as a function of size, area contaminated, wind speed, and atmospheric turbulence.

Hazards of Possible Process Materials

The evaluation of the hazards of thorium processing was initiated in connection with laboratory studies at HAPO and to enable provision of consultation service to the Bureau of Mines.

A review of the literature indicated no toxicity problem of major importance. The metabolism data available are poor with major sites of deposition strongly dependent upon the mode of administration. An MPC in air of 3×10^{-13} μc/cc of Th^{232} for soluble compounds was derived by comparison with the accepted MPC of plutonium. Since this value is two orders of magnitude below the presently accepted MPC for thorium, considerable discussion is now being carried out throughout the country in an attempt to reconcile the various data to a true value of the MPC.

Calculations of the relationships between the members of the thorium decay chain were made and applied to the problem of interpreting air sampling results. This work resulted in the recommendation that ThX and ThB be obtained from decay measurements and solution of equations given for these components; $MsTh_1$ be obtained from long term measurements of both alpha and beta emitters; and thorium by chemical analysis, if possible, and by energy analysis if chemical analysis is not feasible.

Recommendations were made that thorium bioassay be done by chemical techniques to avoid the ambiguity resulting from changes in the daughter products. The need for a radium analysis for $MsTh_1$ was also indicated. Such procedures are now being developed.

The hazards of handling U^{233} were indicated to be closer to those of Pu^{239} than to those of natural uranium, because of the high specific activity of U^{233} compared to U^{238} and the consequent probability of intake of a given quantity.

MECHANICAL DEVELOPMENT

A flow-splitter proportional sampler for liquid waste streams previously designed was tested following fabrication and prior to installation in the Purex Plant. The test flow was within ten per cent of design flow, and variation in flow did not exceed six per cent.

A design was developed to improve the handling of radium sources during calibrations of survey instruments. The design incorporated features to permit moving the survey instrument to the calibration point with an electrical drive and automatic positioning device. The design was developed to further protect the calibrators from radiation and to expedite the calibration procedure. The design has not been incorporated into the calibration operation since extensive changes in calibration methods and sources are being considered.

An exposure enclosure was designed and detailed to permit safe conduct of experiments in which mice are to be permitted to breathe air containing radioactive particulates. The design embraced provisions for controlling air flow to the particle generator, exposure chamber enclosure, and the exposure chamber proper.

The adequacy of the Redox stack sampling system was evaluated. The principal deficiency found was the probability of inadequate sampling of the larger particle sizes because of non-isokinetic sampling, low

transfer velocities, and devious sample line routings. Alternate facilities were scoped for obtaining representative samples of particulate matter at two points in the stack system.

A test facility was designed with which it will be possible to measure variables associated with sampling particulate materials flowing through ducts. This work was undertaken to provide firm design criteria for particle samplers and to permit a realistic evaluation of presently installed samplers. Experimental work will be initiated shortly when assembly of the facility is completed.

BIOLOGY PROGRAM

SUMMARY OF ACCOMPLISHMENTS

DEDUCTION OF PERMISSIBLE HUMAN EXPOSURE BY BIOLOGICAL EXPERIMENTATION

Tritium Absorption and Metabolism

Last year evidence was reported that increasing tritium oxide concentrations cause a disproportionate increase in the per cent of tritium that becomes bound to organic molecules. If this were true, it would mean that as more tritium entered the body the percentage contribution to body irradiation by bound tritium would increase. These findings were not confirmed in experiments performed this year.

The chemical agent cysteine is known to afford some protection against radiation damage under acute exposure conditions. Thus an attempt was made to determine whether this substance would provide similar protection under chronic exposure conditions from tritium present in tissues of the rat. Unfortunately, attempted pilot experiments disclosed that the amount of cysteine required in the animal body was so large that the rats would neither eat food nor drink water containing the required concentration of the agent and the experiment had to be abandoned.

Further studies on the retention of tritium following chronic exposure to the oxide showed that a large fraction of the animal body constituents are not in a state of dynamic equilibrium that turn over with half-lives on the order of 100 days or longer. It was determined also that exposure to tritium gas results in deposition and retention of tritium in the animal which differ in certain details from that observed following administration of the oxide. The differences were not so great, however, as to be of significance in the evaluation of bioassay results following exposure of personnel to either the gas or the oxide.

Fission Product Absorption and Metabolism

Of the fission products, most attention has been directed toward the behavior of radioactive ruthenium in biological materials. Our first observations date back to the summer of 1953 when this element was found in wild waterfowl on the reservation. Subsequent findings that gastro-intestinal absorption of ruthenium in chickens was considerably higher than that indicated in earlier experiments done elsewhere, plus the detection of radioactive particles largely composed of ruthenium and widely distributed over the project, indicated the need for an accelerated progress of biological research on this hazard topic. From experiments in which parameters measured included gastro-intestinal absorption, kidney and bone deposition, and biological half-lives, it was indicated that the present MPC for ruthenium in liquid media should be revised downward by a factor of 100. When administered in particulate form, the gastro-intestinal absorption was about 100-fold less than when applied in solution. Holdup of particulates in the intestinal tract varied widely, but for the most part they were excreted within 48 hours from time of administration.

One of the problems associated with the degree of control that may be necessary in the event of food contamination is whether a difference exists in gastro-intestinal uptake of an element in combination with organic matter as compared to absorption from a true solution of the

clement. Animal experimentation conducted during the year disclosed no difference in absorption of radioactive cesium and strontium when fed as a solution or combined in plant materials. Likewise radiophosphorous fed to rats produced no essential difference in gastro-intestinal absorption and bone deposition when administered in combination with fish flesh or as a true solution.

Plutonium Absorption and Metabolism

The previously reported work on absorption of plutonium from the gastro-intestinal tract of rats was partially confirmed in large animals.

Studies on the absorption of plutonium through the skin were extended to include transfer of contamination through punctures and lacerations. For these situations highly acidic solutions were absorbed to a lesser degree, probably due to a cauterizing effect in the wound. Findings such as this are useful in determining the nature and extent of treatment to be applied to injuries received by employees in contaminated work zones.

Respiratory Metabolism and Toxicity of Radioactive Particles

The tumor producing potential of radioactive particles inhaled into the lung is still unknown. Should the particles be tumorigenic, their permissible concentration in air would probably be based on the probability for this occurrence rather than on the present 0.3 rem/week exposure limit to the organ. Although animal experimentation to assess this biological hazard achieved momentum during the year, the major portion of the effort was devoted to the design and testing of the necessary and complex experimental equipment and techniques. At year end the apparatus for controlled exposure of mice to aerosols of radioactive particles had been completed. Preliminary tests with non-radioactive particles indicated the exposure chamber to be satisfactory and operable. Thus it is anticipated that the large scale controlled exposure project will get underway during fiscal year 1956.

Concurrent with the development of this equipment, some exposure tests were run by intratracheal injection of mice. Ruthenium particles administered by this method produced lung tissue damage (fibrosis); whereas plutonium particles during a 100-day exposure gave presumptive evidence of tumor induction. In both cases the number of particles introduced into the lung was relatively large. Whether it is practically possible to inhale the quantities required to produce the observed damage is yet to be determined.

Skin Irradiation

Several skin exposure studies were conducted to determine the potential for localized damage from particles that could conceivably lodge on the body surface or clothing of employees. Radioactive ruthenium particles collected from ground surfaces in the plant areas and calibrated by Biophysics Section personnel were applied to the skin of pigs. These tests showed that the more highly active particles were capable of producing vicious burns if allowed to remain in contact with the skin for more than four hours. There was little likelihood that the necessary combination of circumstances would actually occur in the plant areas to permit exposures of this magnitude to personnel. The evidence, however, was a factor in support of control measures applied--such as the previously mentioned doorway monitor at personnel exit points from the more heavily affected operating areas.

EFFECTS OF PROCESS EFFLUENTS ON AQUATIC ORGANISMS

Temperature and chromate ion concentrations of reactor effluent were observed to be more damaging to salmon eggs than its radioactive isotope content; existing chromate ion concentrations in the river closely approached permissible levels for the maintenance of the fish population. Local Columbia River salmon eggs were found to be slightly more resistant to increased temperature than other strains previously used, a point of some considerable interest in view of possible future increases in

effluent temperatures.

Some important consequences of the remarkable ability for life forms to pick up radioactive phosphorus became increasingly apparent during the year. If the radiophosphorus content of the Columbia River were permitted to rise to the level presently written as safe in national standards, many of the fish and other aquatic forms in the river would die from radiation damage. Even though the radiophosphorus concentration in the Columbia River is far below the presently established permissible limit, there is a sufficient concentration in some fish at certain seasons to furnish a near permissible radiation dose to anyone eating them in quantity.

EFFECT OF PROCESS EFFLUENT ON PLANT AND ANIMAL LIFE

Effect of Reactor Effluent on Plants

The small outdoor plots designed to determine whether there is any hazard that could result from reactor effluent in downstream farm land irrigation water were utilized for the third successive year. No significant buildup of isotopes in the soil nor any increase in the number of mutants has yet been observed.

Absorption and Translocation of Radioelements in Plants

Radioactive materials from operating plants and nuclear test operations escape to the environs and contaminate available biological forms in varying degree. The objective is to keep the levels down to where no harmful effect occurs in the first or subsequent elements of a biological community system--such as the ground-vegetation-man biological chain. It is essential to know how much of a radioactive substance can be taken up from contaminated soil by growing plants and then transferred to animals and humans consuming them for food. Studies on these problems continued during the year. Although up-take and transfer results were not surprising, the numbers representing transfer coefficients for several radioelements were derived and will find application

in contamination hazard control practice.

The criteria in general use throughout the country for disposal of radioactive wastes is based in part on the isotopic dilution theory. In isotopic dilution, the radioactive isotope is diluted prior to disposal with the non-radioactive isotope of the same element. On the assumption that the rate of uptake by a biological entity is essentially constant and independent of the total amount of the element available, this would mean that less of the radioactive material would be absorbed. Experimental evidence obtained during the past year at this laboratory indicates that so far as plants are concerned this presumption is invalid. The findings suggest a general theory in which isotopic dilution is effective under only special conditions and these rarely occur in nature. This generalization on the ineffectiveness of isotopic dilution, if confirmed by further biological experimentation in progress, will require changes in the nationally accepted standard for safe disposal of radioactive wastes.

Toxicity of I^{131} in Animals

Results obtained during the year from the long term experiment on toxicity of I^{131} in sheep definitely established that ingestion of 5 μc of I^{131} per day would result in damage to the thyroid gland. Application of this finding to permissible limits for range contamination will require that the current "official" limit for I^{131} in air be lowered by four orders of magnitude to assure radiation safety of grazing animals.

BIOPHYSICS PROGRAM

SUMMARY OF ACCOMPLISHMENTS

BIOPHYSICS RESEARCH

The Biophysics Research Program is one to advance the basic knowledge in analytical and physical chemistry, the earth sciences, meteorology, and industrial hygiene insofar as the work may lead to improved radiological protection at HAPO. The following material describes under

the various study titles, the principal achievements during the year.

Analytical Methods

Some of the basic data needed for determining the hazards from radioisotopes are the identification and activity measurements of the isotopes. Many of the present methods for accomplishing these measurements are difficult, time consuming, and in some cases without sufficient sensitivity for special problems. New procedures were developed for determining Na^{24}, P^{32}, As^{76} and Zr^{95} - Zr^{97} in reactor cooling water, these have high yields and obtain the isotopes radiochemically pure. Use of these procedures will eliminate any decay counting for evaluating the radiochemical purity, thus reducing the need for swing shift counting measurements in the routine laboratory. A procedure was developed for determining Ru^{103} and Ru^{106} in particulates and a paper chromatographic technique showed promise as a method for determining the Zr^{95} and Nb^{95} in such materials. Quantitative ion exchange separations of strontium from barium and barium from lanthanum were developed which should provide the bases for sensitive procedures for these important bone-seeking isotopes.

Monitoring Methods

The radioisotopes in gaseous and liquid waste streams of the plant are generally determined by radiochemical analysis using samples obtained manually from the streams. Methods of monitoring were studied which would reduce the amount of labor required by providing instruments which automatically perform the sampling, then analyze and record the data on the radioisotopes present. One such monitor was developed and is now operating satisfactorily in the field; it automatically measures and records the total beta activity (but not the individual isotopes) in reactor cooling water as it is released to the river. Monitors of this type will be placed on all reactor cooling water lines emptying into the river and will provide a continuous record of the disposed radioactivity. This

complete record could not be obtained economically by the old sampling methods but the final objective, that of obtaining a determination of each individual important isotope remains to be achieved and must be the subject of later intensive work.

Counting Methods

After a radioisotope has been chemically separated in the laboratory it must be counted to determine the amount present. Beta emitting isotopes are counted by mica window G. M. counting tubes. These tubes have a limited life and are expensive to replace. Each tube must be instrumented individually and the counting results must be corrected by certain factors specific to the individual tube since each tube has different characteristics. A proportional counting tube was therefore developed as a replacement. This tube lasts indefinitely and, since replicate tubes have nearly identical characteristics, the same power supplies can be used with several tubes. In addition to these savings, the proportional counter has a higher efficiency and should provide more accurate results since fewer correction factors will be needed. Development work was begun on a prototype multiple tube counting system for the Counting Room to utilize these proportional counting tubes.

In some cases identification and quantitative measurement of radioisotopes in a mixture can be made by counting techniques without a chemical separation. These methods are of special interest since they are readily adaptable to monitoring. Both scintillation and proportional counting spectrometry were studied. A gamma ray spectrometer method of determining the activities of Ru^{103} and Ru^{106} in mixtures of these isotopes was successfully developed. The method is non-destructive of the sample and measurements may be made on solid sources needed intact for other investigations. Preliminary results indicated that Na^{24} and Mn^{56} can be determined in reactor cooling water by gamma scintillation counting and a monitor to accomplish this was under development at year

end. Proportional spectrometry appeared to be valuable in identifying and counting K-capture isotopes such as Fe^{55} and Zn^{65} which are very difficult to measure by the standard techniques.

Bioassay Methods

Special bioassay procedures are needed to analyze biological samples from all employees potentially exposed to radioactive contaminants. Analytical procedures for long-lived alpha emitting isotopes of plutonium and thorium were studied. A urine procedure to determine one part of thorium per billion was developed and applied to special samples from both on and offsite. Work proceeded to make this procedure suitable for routine use in the Bioassay Laboratory. Ion exchange and Millipore filtration techniques were studied and showed promise as rapid means of separating plutonium from urine. These techniques may simplify the present bioassay procedure for plutonium with a resultant saving in time and money.

Special Studies

Special studies were undertaken and methods and apparatus developed for other programs. As a part of the hazard evaluation study of the ingestion of particulate material, studies were made of the dissolution rates of UO_3 powders in water and radio-ruthenium containing particulate material in synthetic alveolar and gastric fluids. The data pertain to the important biological question of how particles dissolve in various significant body fluids. A diffusion cloud chamber was constructed for use in a new method counting tritium in ground water; the technique should contribute to the study of the effect of the rates of movement of underground water on waste disposal operations. A vacuum coating apparatus was assembled and procedures developed for making positive ion accelerator targets for dosimetry studies and special source mounting materials were prepared for radioisotope counting.

Geological Studies

Geological field mapping on the periphery of the Hanford project further delineated the sequence of formations and the structure of the basalt bedrock, such that projection of the structures beneath the project, correlated with test well data, provided a firmer basis for delineation of the basalt surface. The basalt, generally relatively impermeable, rises above the water table in local sites and here the ground water flow is controlled by the basalt. Closer observation of waste disposal activities is required in such locations than elsewhere.

Mapping in the White Bluffs proved the deformation of the Ringold formation and that the deformation has continued nearly to the present. The earthquake potential at Hanford is accordingly somewhat greater than originally believed. Moreover, this more exact definition of the attitude of the Ringold formation aids in the correlation of the formation between the wells around waste disposal sites. This information is generally of low permeability but provides a major factor in the decontamination and control of radioactive liquid wastes; it is therefore of considerable importance to recognize it when it is encountered underground and to understand as clearly as possible its relationship with the other beds of sands, gravels, and clays.

Development of a dilution-velocity technique for the measurement of ground water velocities by the measurement of the dilution rate of an electrolyte in a well provided a means for determining the specific behavior of ground waters. Field application of the technique disclosed highly variable flow rates in materials underlying the Hanford project, clearly pointing out which areas were poorly adapted for liquid waste disposal. Planned waste cribs were relocated to take maximum advantage of areas of lower flow rates.

The development of a flow direction indicator, applicable to use in a standard well, provided a means to further utilize to the maximum

those wells already in existence, and to more adequately determine which sites were of greater potential hazard if used for waste disposal.

Soil Chemistry

Plutonium was found to occur as large, negatively-charged complex ions in the presence of acetate and oxalate solutions. In this form it is inadequately adsorbed by soil so that disposal to ground is not advisable. Since the formation of these complexes can occur underground also, the disposal of such "complex formers" to sites of previous plutonium deposition also presents a hazard in the possible translocation of the plutonium.

Strontium ion studies determined the effect of various monovalent, bivalent, and trivalent ions on the adsorption of Sr from solution. All three types inhibited adsorption but in general, the trivalent ions most markedly reduced adsorption followed by the bivalent and the monovalent ions. Similarly, adsorbed Sr was removed from soil in the same order. The understanding of such phenomena guides liquid waste disposal operations so that incompatible mixtures are not formed either in tanks previous to disposal or underground if disposed separately.

Soil Physics

Equations were derived to aid in the solution of ground water flow problems and to supplement other techniques requiring either years of time or many observation points. The equations, using data obtained from ground water contour maps and employing the use of iteration or relaxation processes and improvement equations, resulted, in a test case, in the determination of flow rates approximating those determined by other means; the applicability of the method was thus demonstrated. While the equations are complicated, their use is expected to aid greatly to the knowledge of the movement of ground water under the HAPO area.

Fick's 1st and 2nd diffusion equations were applied to the study of the diffusive movement of Sr adsorbed on soil. The equations, applied to a 3-year column experiment, provided data roughly correlating

with the experimental results and indicated a means by which the movement of the Sr toward the ground water table can be estimated. The use of the one-shot, specific retention principle, of value in emergency cases can now be more safely guided and the previous large safety factors reduced.

Laboratory model experiments were performed to test saturated and unsaturated flow conditions and to determine the effect upon waste disposal operations. These included tests with the dilution-velocity equipment and technique and the flow-direction equipment. The use of both techniques, under the controlled conditions, indicated their usefulness. The refraction of water flowing across an interface between two materials of different permeability was also demonstrated and an equation derived to permit an estimate of the change in permeability along a flow path that changes directions.

Process Waste Disposal

Major efforts of the Earth Sciences Laboratory personnel were concentrated on the evaluation of process wastes for possible ground disposal. Most notable of these were the first cycle wastes from the older process and the metal recovery wastes. Both wastes, scavenged of Cs and Sr to more satisfactory levels with nickel ferrocyanide, produced solutions generally suitable for ground disposal. However, highly variable end products required and evaluation of each such tankful produced. A total of 12 tanks of waste, aggregating nearly 9,000,000 gallons were thus evaluated. The behavior of some of the wastes resulted in the significant conclusion that phosphate ion aided decontamination in the soil; this may prove to be a most valuable observation pertaining as it does to a very hazardous isotope.

Diffusion and Transport Study

In the normal operation of nuclear reactors and chemical separations plants it appears inevitable that a certain amount of noxious material will be released to the atmosphere. These emissions, which

may be continuous or periodic, depending upon the nature of their generation, are generally carried to tall stacks to minimize ground-level concentrations of the offensive material. Use of tall stacks by no means assures adequate dispersal of the effluent at all times, however, since the diffusive properties of the atmosphere vary drastically from time to time and place to place.

A program of research designed to assist in the specification of the diffusive properties of the atmosphere, and thereby to specify maximum permissible emission rates, has been continued during the past year. Measurements of ground-level concentrations of tracer materials emitted from elevated sources on the Meteorology Tower were made and an extensive review of all such observations available for this site led to a more reliable empirical system for predicting short-period maximum ground-level concentrations from stack effluents. This system, which is applicable in the Separations Areas only, utilizes the wind speed and vertical temperature stratification as primary meteorological parameters and takes into account the flow-rate in the stack, an important and highly variable quantity among the various 200-foot stacks employed here.

An extensive series of aerial photographs of smoke plumes emitted from the Meteorology Tower was made during periods when stack effluents travel long distances before they intersect the ground. These experiments mark the natural completion of the first stage of a research program initiated some time ago and will provide an appraisal of this phase of atmospheric diffusion and transport of stack effluents.

In the event of a large release of noxious gases or particulate materials at Hanford, immediate knowledge of the direction and speed of motion of the airborne part of this material would be essential for the evacuation or protection of populated areas downwind. Studies of local flow patterns in and around the Hanford reservation have been continued using wind data collected from a network of wind stations. These studies are

designed to provide prompt definition of the initial motion of airborne material released at any point within the reservation and thus provide information for the immediate evacuation or protection of nearby areas.

Particle Pick-up Study

Another problem is the unintentional release of active particulate matter through process plant operations. Such particles are dispersed and settle to the ground in a widely varying manner dependent upon their size, shape, and density as well as upon the meteorological situation at the time of their release. But even after a particle has been deposited on the ground surface, it presents a potential hazard to distant areas since its radioactivity decays only gradually and the particle is subject to pick-up and translocation by natural wind forces.

In order to ascertain the probability of particle pick-up, the rate of particle migration, and the distances particles travel before they are finally fixed permanently on the ground, a program of particle pick-up experiments was conducted. The number and size of natural dust particles in the air were measured under a limited variety of meteorological and surface conditions. The data have been useful in ascertaining dust loading of the atmosphere and the maximum particle size likely to become airborne. The relative retention efficiency, for small particles, of grass- and rock-covered surfaces, a furrowed surface, and a grass-covered surface protected by a snow fence, have been measured using small fluorescent particles as a tracer. The data, when extended by observations scheduled for the immediate future, will provide a more satisfactory basis for the appraisal of potential hazards due to particles on the ground surface in the Hanford area and the most effective means of treating the ground surface to minimize particle removal by wind forces.

Trajectory Study - 200-Mile Scale

At larger distances, say up to 200 miles from HAPO, forecasts of future positions of airborne material must be based on the large-

scale flow patterns at various elevations over the pacific Northwest. Studies of the correlation of large-scale flow patterns and computed trajectories of hypothetical emissions have been extended during the past year and, when complete, will provide more reliable rules for the forecasting of contaminant trajectories.

Atmospheric Contamination Problems

In a cooperative study with Biology, stack gas particles selected from a large collection were studied individually to determine their physical characteristics for a better understanding of the potential inhalation and radiation risks. The particle size ranged from 100 μ to 5000 μ, the weights varied from 4 μg to 15.5 mg, and the individual dosage rates were from 0.15 - 25.5 rads/hr. Similarly, to aid in the resolution of the question of translocation of ground-deposited particles, the terminal settling velocities were obtained by the use of a settling tube technique with some of the collected particles. Microscope techniques for handling individual radioactive particles were devised to effect a considerable gain in speed of separation and better analysis.

Samples of fall-out material collected in the Northwest and in the Pacific during the 1954 tests were used to study the usefulness of spherical particle frequency as a monitoring parameter. While individual spheres and radioactive particles were occasionally observed at each sampling location, no statistical correlation was evident with specific nuclear tests.

Aerosol Sampling Methods

Methods for improving the collection of electron microscope samples directly on the specimen holders were investigated to minimize errors introduced by the handling of specimens prior to microscopy. Some advances were made in the development of a new type of electric precipitator.

Respirator Testing

Various types of respirators were tested to appraise their protective features for plant application. Penetration was noticeably increased by poor facepiece fit and by the wearing of glasses and beards. Ruthenium tetroxide was found to pass readily through filter-type respirators. A plastic air-supplied hood was shown to offer inadequate protection as a replacement for air-supplied masks.

Toxic Materials

Attention was turned sharply toward the problem of nitrogen oxide emission from various plant stacks because of the national lowering of the Maximum Allowable Concentration from 25 to 5 ppm for continued exposure. Cooperation from Biology was requested for animal research on the short-period high concentration case. A method was developed to permit the collection of the major constituents (NO_2 and NO) separately when sampled together thus permitting more precise appraisal of concentrations in the air and analytical methods for these materials were improved. In other related work, an air sampling instrument was devised which included means for generating more precisely controlled calibration atmospheres containing these oxides so that the analytical, sampling, and proposed monitoring methods could be studied on standardized samples. The potential exists for relatively high ground concentrations in the separations areas and preliminary sampling at ground level has occasionally shown the existence of short term concentrations above MAC. The proposed recovery of the oxides for economic reasons and to permit the use of caustic scrubbers for back-up I^{131} removal would minimize the several related stack emission problems.

Recently developed inert-gas-shielded arc welding and cutting operations were studied in the plant to evaluate the inhalation hazards for the operators. Excessive concentrations of metal fume, ozone and, in one instance, nitrogen oxides were found. Recommendations for control

were made.

DOSIMETRY

The Dosimetry Program provides for the development of radiation measurement techniques basic to the problems encountered in radiation protection. The scope includes research on the methods of measurement of beta, gamma, and neutron radiations, differentiation of the types and energies of the emanations from the various radioactive isotopes, the development of assay techniques for materials of low activity density, and the derivation of suitable calibration standards and techniques. The results from this work are for application by others to such things as field survey procedures and survey instrument calibration, the interpretation of biological experiments, the precise laboratory measurement of radioisotopes in humans and human materials, the establishment of permissible working times in the operations areas, and the analysis of complex exposure problems. The program breaks down conveniently into studies concerned with the individual radiations of most immediate interest and the accomplishments of the Fiscal Year will be described under those heads.

Gamma Ray Dosimetry

The necessary information was obtained on which to base the design of a facility for detecting, locating, identifying, and measuring by external means radioactive materials which have found their way into the human body. The need for such equipment for the control of internal radiation hazards was made clear by certain measurements of this kind on personnel exposed at Redox plant and by an increasing number of positive results from the bioassay program. Studies were made of the shielding requirements of very sensitive gamma ray detectors and of other methods of reducing the background counting rate; this was necessary because the natural radioactivity of the components of the equipment itself and that of the natural background would interfere seriously with the measurement

of the very low activities which produce the internal hazards it was desired to study. To investigate the feasibility of detecting plutonium by external measurements, the possibility of measuring plutonium in mice was demonstrated by the use of phantoms.

A study of the Bragg-Gray principle at x-ray energies similar to those from plutonium showed the validity of the principle at those energies and provided a basis for recalibration of earlier measurements of the plutonium surface dose rate. Such a study was necessary because free air chambers are the standard for x-ray measurements and the validity of the use of small ion chambers in the plutonium measurements had not been shown. When the work is completed, recalibration of the plutonium instrumentation can proceed and plant radiation control procedures will be clearly improved.

Beta Ray Dosimetry

Three beta ray measurement problems of particular significance were completed. The surface dose rate from thorium metal was measured and correlated with calculations so that the dose rate for different decay times could be estimated; the results were used in plant hazard control. In a problem proceeding from the general contamination of the HAPO areas, the dose rate very close to a small particle of Ru-Rh^{106} material was measured using a special extrapolation chamber; the results were required in the interpretation of certain related biological experiments and in determining the extent of the existing hazard. In the third problem, a tritium standard from the Argonne National Laboratory was shown to be in agreement with the Hanford standard thus assuring that tritium measurements made elsewhere in the country agreed with those made here.

A large, shallow ion chamber for use on a CP instrument was designed and shown to make possible beta ray measurements without the use of the correction factors ordinarily required. The fact that ordinary survey instruments could not be used directly for beta ray measurements

led earlier to the development of thin scintillator detectors which needed no correction and the present chamber was developed in a parallel study to provide a detector to which presently available instruments could be easily converted.

• Neutron Dosimetry

The positive ion Van de Graaff accelerator was put into operation to produce neutrons for use in radiological physics experiments and in instrument calibration. Many alterations were required in the system to permit more efficient use of the facilities. Several different target systems were developed to permit generation of neutrons in a wide range of energies. A study was made of the response of moderated slow neutron detectors to neutrons of various energies. A certain thickness of paraffin was found to moderate neutrons of different energies so that the detector response was proportional to dose rate; this provides an excellent basis for the development of a fixed monitor for neutrons.

The strengths of the natural neutron sources available at Hanford were intercompared by a water tank moderation method which was independent of the energy of the neutrons emitted. This established the validity of the neutron instrument calibration system which was based on a secondary neutron standard.

A beginning was made on the measurement of the average energy expended by electrons and protons in producing an ion pair in various gases. This quantity is fundamental to radiation measurements employing ionization and will be used as the basis for standard neutron measurements with the positive ion accelerator.

INSTRUMENTATION

Only the more common general purpose radiation detection and measurement instruments are available on the market or may be used for the HAPO special needs without modification. It is therefore generally

necessary to develop the unusual instrumentation required for the other research programs or for routine use in the department. The following description outlines the principal advances made in the various categories of instrument development during the Fiscal Year 1955.

Survey Instrumentation

The emission and spread of radioactive particulate matter from the process stacks presented the most demanding problems during the year. The possible contamination of orchards in the environs called for the development of a Fruit Monitor for the survey of a large crop sample; extensive road contamination surveys that became necessary required the development of a mobile Survey Monitor. Since the usual hand and shoe checks do not provide a method of detecting particles on clothing, a Doorway Monitor was designed and assembled for monitoring personnel passing through the gatehouse door. A Stack Effluent Monitor to sample the process stack gases, analyze them for the most important radioisotopes, and provide a continuous record neared completion.

The use of modern components such as transistors and scintillators has resulted in instruments more widely applicable and more easily maintained than the old. The measurement of alpha contamination in the air has previously been made by passing a known amount of air through a filter and then measuring the alpha activity on the filter with the Long Tom instrument; a prototype of an improved scintillation instrument was developed as a more rugged and reliable replacement for routine use. Portable survey instruments using transistors were developed and are expected to be almost completely maintenance free requiring only replacement of batteries and detector tubes.

The hand and shoe check in laboratory and process buildings still utilizes both the Five-Fold beta-gamma counter and the Four-Fold alpha counter essentially as originally designed. Maintenance costs are

severe. With the objective of simplifying the equipment, development work was started on a combined Alpha-Beta-Gamma Hand and Shoe Checker designed for standardization and ease of maintenance. The initial cost is expected to be lower than that of the present instruments.

Biological Instrumentation

In a biological investigation it was desired to measure the retention of internally administered radio-ruthenium in small animals. A prototype scintillation counter was designed and fabricated which allows both partial and whole body measurements to be made in the living animal.

Laboratory Instrumentation

Development work was essentially completed on an Automatic Sample Changer for the Counting Room which will expedite the routine work by automatically measuring and recording the radioactivity of many samples in sequence and allow elimination of a shift operation. The present time-consuming chemical procedure for the determination of alpha emitters should be eliminated by the Alpha Energy Analyzer which neared development completion.

Special Purpose Instrumentation

Certain meteorological information is presently routinely collected from data stations located on and in the vicinity of HAPO; maintenance problems have been severe and the record has suffered from missing data. Development work continued on the Radio Telemetering System which will automatically measure the meteorological and radiological parameters desired, telemeter the information to a central point and record it for each of the twenty different data gathering stations. The system when installed will serve additionally as a valuable adjunct to the monitoring procedures under emergency conditions.

A meteorological research problem involves the use of the recently constructed Portable Mast; among the instrumentation required is an extremely low-torque anemometer for measurement of very low wind speeds. The interception of a light beam for revolution counting obviated the need for mechanical loading of the shaft but required the development of electronic circuitry not commercially available. All major problems were solved.

In the use of the Positive Ion Accelerator for neutron dosimetry studies, neutrons are emitted from the bombarded target over an energy spectrum rather than at one energy. For the selection of more nearly monoenergetic neutrons for dosimetry determinations, time-of-flight measurements were desired and a system was developed in laboratory model for pulsing the positive ion beam and for measuring the time interval from target to detector. For the same study, an instrument was developed to determine the neutron dose by measuring the charge displaced at the target by the positive ion bombardment.

TABLE I

SUMMARY OF OPERATING COSTS

RESEARCH AND DEVELOPMENT

	Budget FY 1955	Actual Expenditures FY 1955
Biophysics		
Direct Labor	268,000	232,471
Direct Materials	20,000	41,672
Service and Indirect Charges	240,000	248,590
Sub-Total (Biophysics)	$ 528,000	$ 522,733
Biology		
Direct Labor	317,000	270,018
Direct Material	48,000	75,420
Service and Indirect Charges	343,000	373,304
Sub-Total (Biology)	$ 708,000	$ 718,742
Radiological Engineering		
Direct Labor	48,000	37,222
Direct Material	5,000	1,800
Service and Indirect Charges	37,000	25,907
Sub-Total (Radiological Engineering)	$ 90,000	$ 64,929
Total Research and Development		
Direct Labor	633,000	539,711
Direct Material	73,000	118,892
Service and Indirect Charges	620,000	647,801
Total (R and D)	$ 1,326,000	$ 1,306,404

TABLE II

RESEARCH AND DEVELOPMENT MANPOWER*

	Budget FY 1955	Actual FY 1955
Biophysics		
Non-Exempt	12.5	11.6
Exempt	34.0	30.8
Sub-total	46.5	42.4
Biology		
Non-Exempt	25.5	27.4
Exempt	36.0	29.9
Sub-total	61.5	57.3
Radiological Engineering		
Non-Exempt	1.0	.7
Exempt	5.5	4.7
Sub-total	6.5	5.4
Total R and D Manpower		
Non-Exempt	39.0	39.7
Exempt	75.5	65.4
TOTAL MAN-YEARS	114.5	105.1

*Excludes pro-rata portion of section and department general supervision.