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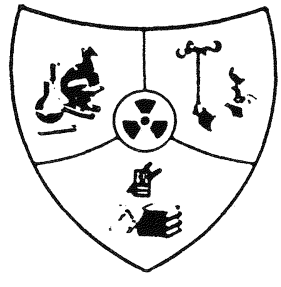
RADIOLOGICAL SCIENCES DEPARTMENT

ANNUAL REPORT

RESEARCH AND DEVELOPMENT
FISCAL YEAR 1954

September 15, 1954



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RADIOLOGICAL SCIENCES DEPARTMENT - ANNUAL REPORT
RESEARCH AND DEVELOPMENT - FISCAL YEAR 1954

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RADIOLOGICAL SCIENCES DEPARTMENT
RESEARCH AND DEVELOPMENT PROGRESS
REPORT FOR FY 1954

The following material is a progress report of work performed in Radiological Sciences Research and Development during F.Y. 1954. The report, primarily non-technical in nature, presents a summary of accomplishments achieved over the twelve-month period for each of the three programs: Biology, Biophysics and Radiological Engineering. A tabulation of manpower and costs associated with these activities appears in Table I and II appended.

RADIOLOGICAL ENGINEERING PROGRAM

The Radiological Engineering Research and Development program was initiated at the beginning of fiscal year 1954. The object of the program was to study the scientific research and development findings in the radiological sciences, and to select for radiological engineering development those phases of these findings and independently conceived ideas which may have practical application in the Operation. Emphasis was placed on the study of subjects which were expected to yield improved plant and environs radiation protection, especially in areas in which reductions of cost for construction or operation appeared feasible. Engineering studies were limited to those essential for the analysis of radiation phenomena or for creative design proposals on radiation problems.

SUMMARY OF ACCOMPLISHMENTS

DISPOSAL OF LIQUID WASTES FROM SEPARATIONS PROCESSES

Studies were undertaken to take full advantage of the unique Hanford geographical and geological conditions and of the findings of the Biophysics geology - hydrology program with the object of allowing significant reduction in the construction and operating costs associated with safe radioactive waste disposal, by maximum usage of ground storage techniques.

Evaluation of results of the geology-hydrology program indicated the need for formulation of revised waste disposal criteria for separations process wastes. On the basis of confirming evidence that ground water movement from the 200 Areas plateau to the Columbia River would occur only over a long time period (possibly the order of 1,000 years, almost certainly not less than 50 years), it was established that waste disposal limitations for the Separations plateau could be liberalized. Thus, a new policy was promulgated that ground disposal of radioactive wastes was feasible up to the point of ground water contamination to the level of that permissible in drinking water, by biologically important radioisotopes with half-lives of greater than three years.

While "cribbing" of waste streams of low activity density had been in progress for several years, substantial economies were effected based on extension of this method, elimination of ion exchange processes, curtailment of certain waste

evaporation processes, and ground disposal of certain wastes previously stored, thus clearing tankage for future high activity density wastes.

It is estimated that the revised waste disposal policy reduced current projects under construction by one-half million dollars and cleared underground storage tankage having a replacement value of over four million dollars. In one case expected operating expenses of about one-quarter million dollars were eliminated. Continued operating expense reductions are anticipated in certain cases. Reduced need for construction of additional waste storage tanks may greatly exceed current expectations dependent upon operating findings in the self-concentration of the highly radioactive wastes with disposal of condensate to ground storage.

A special unclassified summary report was prepared at the request of the Atomic Energy Commission entitled "Ground Disposal of Radioactive Wastes at the Hanford Site," (HW-32041).

DISPOSAL OF PROCESS WASTES TO COLUMBIA RIVER

Current and future wastes disposal facilities, practices, and policies in the 100 and 300 Areas were studied with respect to adequacy of radiation safety in the environs, and to methods of reducing operating costs. Results of specific studies follow.

Columbia River Contamination as a Production Limitation

Reactor effluent analysis results from the Biophysics Section sampling program were analyzed using statistical methods to determine the sources of the radioisotopes present in the effluent, factors affecting their concentration, and probable concentrations at higher power levels. Such information was critically needed to determine whether the Columbia River would be limiting from the radiation hazard viewpoint at "blue sky" operating levels, and to allow design recommendations to be made with regard to reactor cooling water quality, and methods of effluent water disposal. Results of significance include:

1. Fission products present appeared to have an irradiation time of the order of one day, thus indicating that the source probably was the natural uranium content of the Columbia River which was detained on the slug and tube film, rather than ruptured slugs or other non-routine conditions.

2. About two-thirds of the Na^{24} present arose from fast neutron capture reactions by aluminum and magnesium. Thus, any water quality changes which alter the sodium concentration would not affect the Na^{24} concentration entering the river as significantly as would have been previously predicted. This was of importance in evaluating the effects of the use of caustic soda instead of lime for pH adjustment.

3. The Mn^{56} concentration increased exponentially with reactor tube outlet water temperature and also appeared to be inversely proportional to tube water velocity. Thus, the tendency for increased Mn^{56} concentrations as power level is increased will be partially counterbalanced by any coincident tube water velocity increase.

4. The Cu^{64} concentration increased exponentially with effluent water temperature. The 12.8 hour half-life of this isotope makes this of interest in predicting concentrations at downstream water usage points.

5. The production of Si^{31} was inversely proportional to outlet temperature, flow, and sulphate ion concentration.

6. Unfortunately the concentration of P^{32}, the isotope of greatest biological concern in the effluent, has shown no correlation as yet with any other factor. However, this indicated that P^{32} would probably not increase exponentially as power levels increase.

7. The rare earth concentrations showed an apparent exponential increase with power level.

8. The Sr^{91} and Sr^{92} concentration appeared to increase linearly with power level.

This study indicated the complexity of the relationships in reactor effluent activity, and showed the importance of irradiation time increase caused by film holdup. Overall evaluations indicated that river water at Pasco might reach twenty to forty percent of the estimated MPC of the radioisotope mixture (assuming a required safety factor of ten for off-site application) based on presently planned future production levels and expected effluent temperatures. The P^{32} concentration in fish might constitute a control problem in the future. Recommendations were made for the river water sampling and analysis program to permit improvement of the evaluations made.

Inland Disposal of Reactor Effluent

To allow the proposed power level increases at the B and C reactors, new effluent piping is required to handle the increased flow, from 105-B to the center of the river. Radiological Engineering recommended consideration of inland disposal of effluent water from the C reactor, to allow usage of the C effluent system for the B reactor. It has been proposed that the C effluent be transported through a simply excavated canal to the several square miles of natural sump north and south of Gable Mountain, six miles to the east. It was theorized that percolation in the canal would provide an effective ground water dam on possible northern movement of 200 Areas' radioactive wastes released to ground.

In addition, the C reactor effluent contamination would be removed from the Columbia River. It is of interest to note that elevations will permit similar routing of effluent from the KW, KE, D, and Dr reactors should this prove desirable economically, or necessary due to river contamination limits.

Field tests of surface and subsurface vertical percolation rates were performed in the general area proposed for the canal and lake. Results of 14 to 23 gallons per square foot per day were lower than was anticipated. Mathematical analysis based on an assumed lateral permeability indicated that insufficient head would be available over the ground water for continuous disposal of C Reactor effluent; it was calculated that the 50 million square feet of lake area available within the 440 foot contour would fill in about six months. To provide a firmer basis for analysis, funds were provided to enable the USGS to install two additional test wells and to perform drawdown tests in the proposed lake area. The tests revealed an extremely high permeability for horizontal water movement. A transmissibility coefficient of 1,430,000 gallons/day/foot was reported for the immediate vicinity of the test wells, with a reported coefficient of storage of 0.03 for the same region. This calculated coefficient of storage is probably too low as a result of the conditions of the test. There was reason to believe that the area chosen for the test was located in an old river channel that now forms a distinct underground canal through which ground water drains at a significantly faster rate than the average for the region. This canal apparently discharges into the river just downstream from Hanford, which, assuming the calculated transmissibility coefficient to be representative of the entire canal, would result in a travel time of about seventeen years from the test site to the river.

A tracer test performed at the well draw-down test site while the pumps were operating did not give conclusive travel time data. The rate at which dilution occurred in a spiked well indicated considerable variation of velocity of movement throughout the thickness of the water table. The velocity of the surface layer of water appeared to be about three times the velocity at a depth in the water table of 20 feet, while below 25 foot depth of water, no movement was measureable.

Re-evaluation of the calculations indicated that if the area tested was representative of the entire proposed lake area, the lake could contain C reactor effluent for about ten years without overflow, and that travel time of the effluent to the river through the elevated ground water table would be several weeks. It is postulated that such operation would cause swamps to appear in the region between the lakes and the river from Hanford to White Bluffs. The geological-hydrological investigations in this region must be extended considerably before it will be possible to make a firm recommendation for plant application.

Development of Empirical Diffusion Equation for Reactor Effluent in the River

Funds were supplied to Applied Mathematics to develop an expression for the rate of diffusion of reactor effluent in the river. References and background information for this derivation were provided as well as tabulated field data to be used as a basis for the derivation. An equation was prepared containing empirical expressions that were being evaluated by Applied Mathematics personnel at year end.

Reactor Retention Basin Operation

Parallel operation of reactor effluent retention basins was proposed to reduce costs associated with proposed plant expansion and repetitive basin maintenance. Evaluation of the hazard of ruptured slug debris in the river indicated that release of this material in the quantity produced during the past several years would increase the drinking water hazard only slightly. Improved slug rupture detection instrumentation to be installed should make this proposal feasible.

Use of Reactor Effluent as Boiler Feed

At present steam usage rates in the reactor areas, and with present reactor effluent temperatures, about 31,000 tons of coal could be saved per year by using reactor effluent as boiler feed. Work to date indicated that steam made from effluent water would have an activity density lower by a factor of 4,000 over that of the feed water, and steam condensate would therefore be less active than current F Area raw water, and well below drinking water limits. However radiation problems requiring control would be introduced to the Power House. It is estimated that this process would pay off the necessary investment in less than a year. A possible alternate of placing heat exchangers in the effluent system, which is less attractive economically, but which would eliminate the radiation problems, was proposed. Subsequent to the initiation of this study, Project CG-558 for production increases at all current reactor areas was authorized. The scope of this project eliminated the use of steam for primary pumping of process water. Thus the powerhouse generating capacity is relegated to emergency backups plus the heating load, thus removing the economic desirability of the proposal.

Disposal of 300 Area Radioactive Liquid Waste to Ground or River

Past practice based on arbitrary disposal limits made it necessary to haul some 40,000 gallons a month of intermediate level laboratory waste to the 200 Area plateau for ground disposal at a cost of about $0.03 per gallon, with the possibility that an occasional 50,000 gallon batch of normally innocuous water might have to be hauled also if found at all contaminated. The new policy permits ground disposal if the activity

density of each radioisotope in the waste does not exceed its particular permissible concentration in drinking water. The study of this stream indicated that some of this waste need not be hauled to the 200 Area plateau but could be discharged to the present leaching trenches on the riverbank by 300 Area.

Wastes from the Metal Preparation facilities drain to leaching ponds requiring maintenance near the river bank and chronic ground water uranium contamination results. As operations contributing to large uranium waste losses have been recently discontinued, it may be desirable to discontinue leaching of previously deposited uranium with current wastes. Equipment to allow auditing of this stream was sponsored. Further study may indicate alternate desirable disposal methods.

IMPROVEMENT OF RADIATION PROTECTION DESIGN CRITERIA

Studies were undertaken to develop radiation protection design criteria so that costs associated with radiation control would not exceed those deemed essential. Estimates were made of the magnitude of radiation hazards resulting from postulated process disasters to point out possible criteria for control and evasionary action in the event of such an incident.

Disaster Consequences Prediction

The probable disaster consequences of release to the atmosphere of reactor material, ranging from the contents of one tube to the contents of a K reactor at an optimistic power level were evaluated for various meteorological conditions possible at this locality. For purposes of comparison, the deposition indicated by the "Green Run", a planned release of a large quantity of radioiodine several years ago, was scaled up to the magnitude of the disaster assumptions. A rough estimate of personal and property damage outside the reservation from such an incident was made.

For cases of release of significant portions of the fission products in a reactor, the results indicated that while lethal effects may be limited to the order of magnitude of distance indicated by the Reactor Safeguard formula, significant damage and radiation effects requiring control for extended periods might occur at much greater distances.

In the case of release of contents of a single tube, it was calculated that because of steam pressures generated, release of fission products probably would not be confined to the effluent water and pile atmosphere systems. Thus some venting to the stack would occur with resultant contamination of the environs dependent on meteorological conditions.

An estimate of the effects of a nuclear incident in the proposed lattice test reactor was made. Although calculated on the basis of maximum release, consideration of aspects such as delay in release time and

effect of buildings on turbulence and thus dilution, would indicate little likelihood of damage to personnel outside of the 300 Area. The skin dose caused by fission products deposited on skin of clothing could well be the limiting factor.

Hazards of Radioactive Particles from Process Stacks

Information on possible hazards due to small radioactive particles was accumulated. The rate of energy loss at distances from a source emitting with a Fermi Distribution was estimated by numerical integration. The possibility of using a total body monitor was suggested and some work done with Biophysics to assist in the use of a laboratory model. The possible influence of plutonium fission on the ratio of Ru^{103}/Ru^{106} was noted and preliminary calculations made. Correlations between particle size and activity were studied.

Fluorescent pigment was used to determine particle exposure probabilities for several typical operations involving motor vehicles. The method consisted essentially of associating a known number of ZnS particles with normal dirt in the location to be studied and determining the number of particles transferred to a given volume of air which would have been breathed under a given set of operating conditions. The data were used in evaluating exposure risk due to radioactive particles present in vehicles and assisted in establishing control limits for vehicle contamination. Techniques developed may be suitable for application in more extended studies involving particulate transfer.

Costs of Redox Plant Shielding

An analysis of the costs of primary shields for various attenuations at the Redox Plant showed that savings of the order of only 1/2 % in the overall cost of the 202-S Building would result if a ten-fold increase in transmitted radiation had been allowed. A 1 % saving by allowing a hundred-fold increase in radiation levels, would significantly interfere with operations because of chronic exposure.

MECHANICAL DEVELOPMENT

Development work was performed to improve radiation detection and protection.

Stack Gas Sampler System

Literature was reviewed to establish requirements for an adequate stack gas sampling system. The sampling error resulting from having a sampling velocity of other than the stack velocity was found to be a function of particle size, being less important for very small particles. The effect of particle inertia on sampling under various conditions was considered. Data obtained were used to scope design

of sampler probes, piping, and other details on two stack installations. The need for better defined criteria for designing particle collection systems was evident from the literature study. Scope design was initiated on an adequate replacement sampling system for the Redox stack.

Exposure Reduction in Instrument Calibration Operations

Increases in work load have caused noticeable increases in chronic radiation exposure to personnel engaged in the calibration of radiation measuring instruments by use of gamma and neutron radiation sources. A preliminary study suggested several minimum changes, and scope design was initiated.

BIOLOGY PROGRAM

Biological research continued under the three previously described* general study titles: Deduction of Permissible Human Exposure by Biological Experimentation, Effects of Process Effluents on Aquatic Organisms, and Effects of Process Effluents on Plant and Animal Life.

Comparison of accomplishments for this report period with stated objectives of a year ago discloses some change in emphasis within the several studies. This should not be taken as evidence of poor planning but rather that the program of biological research maintained sufficient flexibility to undertake new and more urgent problems as they arose. Of particular significance in this respect was the amount of effort devoted to the ruthemium hazard problem and to several other unexpected problems undertaken at the request of the AEC because of specialized personnel and facilities at this location. These latter assignments were conveniently integrated into existing problem investigations on plant absorption and translocation, I^{131} toxicity, and effect of beta irradiation on skin.

Of the aforementioned three major studies that constitute the Biology Program only one, "Effects of Process Effluents on Aquatic Organisms", was assigned entirely to one organizational unit. The other two were assigned to the remaining five units. Thus study titles define broadly the assigned responsibilities of the section, with problems in these general areas assigned to those units most adequately equipped to solve them.

SUMMARY OF ACCOMPLISHMENTS

DEDUCTION OF PERMISSIBLE HUMAN EXPOSURE BY BIOLOGICAL EXPERIMENTATION

Tritium Absorption and Metabolism

Results obtained during FY 1954 suggested that prolonged exposure to tritium oxide may cause binding of tritium to tissue components such that resultant

*See HW-30306, Radiological Sciences Department Annual Report, Research and Development - Fiscal Year 1953.

tissue radiation may be greater than that predicted from a knowledge of the concentration of tritium oxide in body water. In rats chronically exposed to tritium oxide bound tritium increased the radiation 10 per cent above that delivered by tritium oxide. Some tissues, notably fat, were being irradiated at a dose rate about 20 per cent greater than body water. Several implications important to fundamental knowledge resulted from this work. For example, it was observed that many tissues in the body are metabolically quite inert, which is in contrast to the popular concept of the highly dynamic state of tissue metabolism. Also noted was the fact that about 20 per cent of the organic hydrogen in the rat is metabolically derived from water.

During the course of the investigation there was some evidence that increasing tritium oxide concentrations cause increases in the per cent of tritium which becomes bound to organic molecules. This rather surprising result, if verified, would mean that as more tritium entered the body the percentage contribution to body irradiation by bound tritium would increase. Consequently time limits for personnel exposed to concentrations of tritium above the permissible limit may become a power function of the concentration of tritium in the atmosphere - apparently a singular concept in permissible limit estimations.

Of the various means by which an animal may become contaminated with tritium, the least well understood route is via inhalation of tritium gas. Studies of tritium oxide and tissue-bound tritium distribution and retention in rats, following exposure to tritium gas, indicated that the amount of bound tritium bears the same relation to body water tritium as is observed in animals injected directly with tritium oxide. This justifies the conclusion that bioassay results may be given the same interpretation regardless of whether the exposure was to tritium gas or tritium oxide.

Growing algae cells were shown to be a convenient tool for scoping magnitudes of isotopic differentiation between tritium and deuterium. Photosynthesizing cells lost deuterium at a rate approximately 10 per cent faster than they lost tritium. It was previously shown that amounts of both tritium and deuterium that can bind to organic constituents in the cells is 50 per cent of the amount that hydrogen can bind, and that deuterium binds somewhat less than tritium. Although tritium apparently is bound with more difficulty than either of the other two isotopes, once bound, it is more tenaciously held. Respiring cells not exposed to light showed no difference in the rate of loss of the two isotopes.

Fission Products Absorption and Metabolism

Early in FY 1954 concentrations of radioactive ruthenium found in wild waterfowl collected in HAPO environs prompted a study of the absorption and distribution of the element in the fowl. Findings were at considerable variance with those published by other laboratories, and, as a result, the metabolism of ruthenium in the rat was investigated. Gastro-intestinal absorption observed was about 100 times greater than the value previously reported and utilized in calculation of permissible limits. Following this discovery it was deemed advisable that

a check be made on the absorption of strontium and cesium in the rat. Experimental data for these two isotopes, however, confirmed earlier results obtained by others.

Plutonium Absorption and Metabolism

Experiments to determine the absorption of plutonium (IV) at pH 2 from the gastro-intestinal tract of rats covering the concentration range from 0.01 to 50,000 times the presently established MPC were completed. Average absorption with 95 per cent confidence limit was 0.0028 ± 0.0008 per cent. Skeletal deposition averaged 0.0025 ± 0.0003 per cent. There was no significant effect of concentration over the range investigated. These results were obtained from chronic feeding experiments involving 100 or more individual feedings to each animal. Single doses of plutonium were fed to three pigs, and the fraction absorbed and deposited in the carcass and skeleton determined. Absorption in the pigs did not differ significantly from the results obtained on rats. These findings provide support for an increase in the MPC for plutonium in drinking water, which had been based on the assumption of an absorption fraction forty times larger than that observed in these experiments. A study of the excretion rate of orally administered plutonium in rats showed that approximately 90 per cent of the amount present in the gut is excreted during each 24-hour period.

Studies of the percutaneous adsorption of plutonium from acid solutions revealed an absorption over a five-day period of approximately two per cent of the plutonium applied as a solution in 10 N nitric acid. Absorption from weaker acid solutions was considerably less; however, some of this difference is probably due to the fact that a portion of the plutonium applied in dilute acid solution was lost from the contaminated area before absorption could occur. Despite the mechanical loss of plutonium, it was surprising that the substance apparently was absorbed from weak acid solutions through the whole skin about 20 times faster than it was absorbed through the gastro-intestinal tract. This is probably due to the relatively high pH of the gut which keeps most of the plutonium out of solution, making it unavailable for absorption. Like gut absorption, the per cent of applied plutonium absorbed through the skin was shown to be independent of plutonium concentration, and further, independent of the area of skin contaminated.

Techniques were developed for studying the early course of plutonium transportation in the blood, using paper electrophoresis and micro ultrafiltration and dialysis procedures. Only very preliminary results were available from this study, but it was hoped that greater knowledge of the mechanism of plutonium transport in blood would suggest improved therapeutic procedures.

Plutonium Therapy

Nearly all experimental studies designed to test the efficacy of the two known drugs (zirconium citrate and CaEDTA), that remove some plutonium from the body, utilized plutonium concentrations in animals many thousand-fold higher than the minimal dose which may cause serious consequences in humans. Investigation

disclosed that their ability to remove plutonium was not affected by body burdens of plutonium in the range of from 10^{-9} to 10^{-} gram.

Additional comparisons were made between the effectiveness of CaEDTA and zirconium citrate, alone or in combination, for their effectiveness in removal of plutonium administered to rats. Zirconium citrate was more effective in preventing the deposition of plutonium in the bone, but had no significant effect on soft tissue retention. CaEDTA was somewhat less effective in preventing bone deposition, but more effective in promoting the excretion of plutonium deposited in the soft tissue. Combination of the two agents constituted the most effective treatment tried, combining the best features of both and resulting in about a four-fold reduction in plutonium retention when given 30 minutes after the plutonium was administered. When given 30 days after plutonium administration none of the treatments tried was effective. As a result of experiments and observations, it was concluded that the instability of zirconium citrate and the toxicity of zirconium were such as to contra-indicate its continued use as a practical drug. Consequently recommendations were made and adopted that zirconium citrate no longer be available for emergency administration in HAPO's first aid stations. Because preparations of CaEDTA have not been observed to deteriorate and since no toxic reactions have been experimentally observed, CaEDTA is being made available instead.

Respiratory Metabolism and Toxicity of Radioactive Particles

The critical hazard of radioactive particle inhalation was assumed to be one of lung tumor induction. To test this assumption the lungs of a special strain of tumor sensitive mice were sprayed via tracheal injections with particles of plutonium oxide and hydroxide suspended in water. Abscesses but no increased tumor incidence was observed 100 days after the administrations. A cancer producing chemical applied in the same manner increased the incidence of lung tumors. These results, however, were obtained by injecting the particles and not by permitting their deposition by normal respiration. The technique used caused localization of dose which may have caused the observed abscesses instead of other pathology. Apparent biological half-lives of these particles in the lungs of mice were found to vary from 30 to 600 days, seemingly dependent upon dose and form of the oxide administered.

Skin Irradiation

The high surface dose rates from radioactive particles located in HAPO environs suggested that the possibility of their causing localized skin injury should be determined. Particles were applied to pig skin, which is similar to human skin, and the approximate quantity of radiation to produce erythema and sloughing was determined.

Relative Biological Effectiveness Of Ionizing Radiations

In estimations of MPC's and radiation effects a knowledge of the rem rad ratio of the ionizing particles yielded by the isotope is required. The new technique previously developed for measuring this ratio was refined and improved by the

purchase of a special measuring instrument and by modifications in procedure. A ratio of 2.1 was obtained for tritium.

Genetic Effects of Internally Deposited Radioelements

Maximum permissible limits for radioelements in the body are usually based on those concentrations required to yield 0.3 rem per week to the tissue ("critical organ") containing the greatest concentration of the element. Since in current evaluations of permissible limits the longer range effects of gene mutation in germinal and somatic tissue are not considered, it is necessary to extend our knowledge of the possible genetic effects resulting from internal deposition of radioelements. Much work of this type is already being done elsewhere. Here the effort is primarily being directed toward an evaluation of the effects of transmutation. The work essentially measures the additive effect caused by an unstable (radioactive) atom being part of an essential molecule. When the atom transmutes by radioactive decay, it may render the molecule biologically ineffective.

Preliminary results indicated that sulfur-35 is potentially very effective in inducing mutation by transmutation, whereas phosphorus-32 is relatively ineffective. Differences in the conditions previously used in studies of these two elements suggest that comparative studies be made, and these are in progress.

Mechanism of Radiation Effects

An investigation of the rates of destruction of vitamins was undertaken as one means of evaluating cell damage by ionizing radiations. Results indicate that in pure solutions of vitamins at physiological concentrations there is a very rapid destruction of folic acid when irradiated with tritium beta particles. As much as 98 per cent of the folic acid was destroyed by doses which produce barely perceptible damage in skin tissue.

The effect of irradiation on fundamental metabolic processes in algae cells was studied by comparing the uptake of C^{14} and P^{32} by irradiated and unirradiated algae cultures. Incorporation of C^{14} supplied as the carbonate or as labeled acetate was increased as a result of irradiation, in the fatty acid fractions of algae and to a lesser extent in the nucleic acid fraction. Reduction of C^{14} incorporation into chlorophyll was observed. Studies with P^{32} indicated an increase in phosphoprotein and nucleic acids as a result of irradiation.

EFFECTS OF PROCESS EFFLUENTS ON AQUATIC ORGANISMS

Reactor Effluent Biological Monitoring

This is one of the two problems carried out by the section which was charged to protection of plant and personnel rather than research and development funds. However description of this problem is included here since this work is closely allied to the problems supported by research and development funds.

[redacted]

This work is designed to determine the amount of reactor effluent which can safely be discharged into the Columbia River without creating a health hazard to persons eating the fish and without affecting the salmon or local game fish or their food organisms. It also provides one type of continuous biological evaluation of reactor effluent hazard, and provides assurance to responsible organizations that the salmon resource is not affected.

Chinook salmon eggs and young were exposed to several concentrations of reactor effluent. A slight increase in mortality among the embryos occurred at one per cent concentration of the effluent. Substantial mortality occurred at five per cent. Only limited spawning of this species occurs in sections of the river where effluent concentrations may exceed one per cent. Fingerling size chinook and sockeye salmon, which migrate through the HAPO area from nursery areas up river, were found to tolerate effluent concentrations as high as 10 per cent for several weeks. Such high concentrations exist only in the immediate vicinity of the effluent outfalls.

Activity densities of river organisms were approximately the same as last year with maximum values near shore occurring in the vicinity of Hanford during late summer. Temporary discharge of effluent via overflow flumes at the river's edge resulted in abnormally high activity densities in organisms near shore immediately downstream. Bottom organisms in the McNary Dam reservoir were found to be only 5 to 10 per cent as radioactive as shore forms near Hanford. No change in the population of river organisms as a result of plant operations was observed. More salmon were observed to spawn near Priest Rapids (above the reactors) then in previous years. Whether this indicates a significant avoidance of conditions near the reactors is unknown.

Mechanism of Reactor Effluent Hazard to Aquatic Organisms

Reactor effluent might affect aquatic life because of its chemical toxicity, high temperature, radioactivity, or an interaction of these three factors. Knowledge of the importance of these factors permits better evaluation of the potential effect on river life and may suggest methods of reducing the hazard. Through studies on the mechanism of concentration of radioactivity in aquatic life more realistic limits on the kinds and quantities of radioactive materials released to the river should be possible and the feasibility of eliminating retention basins appraised.

Concentrations of reactor influent as low as 3 per cent were found to retard the growth of young salmon, presumably due to the dichromate content. Eggs from local salmon were not significantly affected when subjected to water temperatures estimated to occur in the Columbia River when all anticipated reactors (October 1953 estimate) are in simultaneous operation. However, little or no factor of safety apparently exists. The critical temperature period for the salmon occurs only during the spawning

season (October and November) and would apply only to eggs deposited in gravel beds immediately downriver from the reactors. Fingerling size salmon were found to tolerate Columbia River temperatures appreciably above anticipated levels.

Experiments in aquaria demonstrated the rapidity with which microorganisms remove radiophosphorus from the water. Small fish feeding on the contaminated microorganisms retained about 70 per cent of the ingested radiophosphorus. The results accounted for the high concentration of radiophosphorus found in most river life.

EFFECT OF PROCESS EFFLUENT ON PLANT AND ANIMAL LIFE

Separations Effluent Biological Monitoring

This is the second of the two problems charged to protection of plant and personnel rather than research and development funds. Similar to reactor effluent biological monitoring, this investigation occasionally signals the need for problems supported by research and development funds.

This operation primarily serves as a direct check upon the amount of radioactivity that deposits in animals common to the environs and secondarily seeks to correlate results observed with stack discharge rate, meteorological conditions, and vegetation contamination, which may be of practical value in detecting extent of reactor operations in remote locations. For the past seven months, activity densities due to fission products found in tissues of animals exceeded the permissible concentration for man.

As previously indicated, the finding of ruthenium in wildfowl in the process of routine biological monitoring resulted in an investigation of the element's absorption and distribution in chicken. Considerably more ruthenium (three per cent of the administered dose) was absorbed through the gastro-intestinal tract than had been previously reported elsewhere. Deposition occurred principally in the kidney, liver, and skeleton.

Effect of Reactor Effluent on Growing Plants

Since large quantities of Columbia River water below HAPO are diverted for crop irrigation, the growth, yield, and genetic effects on cereal crops of reactor effluent was studied in small outdoor plots. Although 100 per cent effluent clearly damaged growth through the effects of the chromate ion, the potential hazard through annual build up of this or other ions can be evaluated only be a study extending over several years. Likewise, the possibility of genetic effects resulting from a slight accumulation of radioactive elements in the soil can be evaluated only after several generations of plants have been grown.

Absorption and Translocation of Radioelements in Plants

In order to evaluate hazards resulting from the uptake into plants of radioelements from contaminated soils, determinations were made of the uptake of Sr, Y, Cs, I, Pu, Zr, Pm, Ce, and Ru in plants representative of local crops and weeds. Sr, Cs, and I^{131} were found to concentrate appreciably in the plants studied, while the other isotopes tested were less readily absorbed and translocated.

Studies of toxicity of chromium indicated that dichromate is relatively toxic to plants and cannot be overlooked in evaluating hazards from pile effluents.

Toxicity of I^{131} in Animals

This long-term experiment was designed to establish a realistic basis for exposure limits of I^{131} in sheep and in other farm animals. During the past year all of the original experimental ewes now over six years old were sacrificed. The majority of the ewes fed 5 uc of I^{131} daily since April, 1950, showed only minor thyroid damage, and some of the ewes appeared normal in every respect. New groups were established at 0.5 uc/day in order to determine within narrow limits the threshold quantity of chronically administered I^{131} that will produce no detectable damage.

In evaluating the hazard of consuming milk from animals contaminated with I^{131}, it was determined that up to one-fourth of the daily dose of iodine fed the ewe may be excreted in the milk in one day. The I^{131} was associated principally with the protein fraction of milk. The skim milk fraction had 95 to 97 per cent of the I^{131} concentration and the butterfat extracted showed no appreciable I^{131} content.

In order to determine the thyroid uptake pattern and test the theoretical values that are applied in calculations of the hazard to animals following a single contamination event, a series of experiments were performed. Hay was sprayed with a radioactive iodine solution and offered to sheep. The animals showed a peak thyroid concentration on the 12th day with a six to seven day effective half-life and a 40 to 50 per cent uptake. These data on the toxicity of I^{131} in sheep were of considerable value to the AEC in establishing factual bases for assessing whether radioactive fall-out from weapon tests damaged range sheep as claimed by Nevada ranchers.

To extend the findings in sheep to other animals, pilot studies were initiated on pigs at levels of 0.15, 0.5, 5 and 15 uc of I^{131}/day.

Beta Irradiation of Sheep Skin

Since many range sheep in Utah were noted to carry large sores on their back following the atomic weapon tests last spring, the question arose as to whether these sores were caused by fall-out. Although it was

considered improbable that these sores were caused by radiation, a literature search indicated that the dose required to cause a radiation burn in sheep skin was not known. As a consequence the AEC requested three laboratories (Los Alamos, Oak Ridge, and Hanford) to find the dose-effect relationship for beta particles. In experiments conducted here it was found that no functional damage occurred with an acute dose of 2000 rads. Some damage was detectable at 4000 rads and definite damage with partial temporary wool loss and concurrent hyperpigmentation took place at 8000 rads. Doses greater than 15,000 rads caused permanent loss of wool.

BIOPHYSICS PROGRAM

Biophysics research and development continued in the three general areas of "Environmental Studies and Adequacy of Waste Disposal Systems," "Instrumentation for Radiation Detection and Measurement" and "Monitoring Methods." No significant change occurred in the scope of these major program divisions except that increased attention was given to the problems of ground disposal of liquid waste and to those of radioactive particulates emitted from process stacks.

Organizationally, the Geology-Hydrology and Soil Science functions were combined into an Earth Sciences Unit to facilitate integration of those investigations having to do with ground disposal of radioactive wastes. This change also permitted closer cooperation with the new Radiological Engineering Section in "advance engineering" of research findings in this area for application by the Engineering Department to new process facilities, with substantial economies to the plant operation.

In improved research facilities the completion of the positive ion Van DeGraaff laboratory and installation of the accelerator represented a significant step toward the ultimate solution of many neutron dosimetry problems encountered in the operations.

SUMMARY OF ACCOMPLISHMENTS

MONITORING METHODS

Analytical Techniques

As a part of the general problem of the improvement of analytical procedures for the Bio-Assay Laboratory, efforts were directed toward the electroplating of plutonium on still smaller areas so that increased sensitivity of the analysis and decreased time requirements might result. Conditions for obtaining high yields on an area as small as 2 sq. mm. were obtained. Improvements in other parts of the Bio-Assay procedure, such as elimination of the tedious evaporation and ashing, will be required to realize the improved yields of the technique.

A rapid procedure for removing plutonium from acidified urine by ion exchange was found. The use of this procedure, when perfected, in conjunction with that mentioned in the preceding paragraph may result in significant improvements in this important determination.

It was demonstrated that the use of high volume air sampling equipment together with silver nitrate impregnated fiber glass filters permits the determination of lower concentrations of I^{131} in shorter collection intervals; cumbersome caustic scrubber systems are presently in use for the field collection of I^{131} from plant gases. While the oxides of nitrogen would interfere with this new method of iodine monitoring in the case of gases in or near the stacks, considerably more significant sampling of the atmosphere both on and off-site should be obtainable with the new equipment. Additionally it is possible that the necessity for certain time consuming laboratory procedures may be minimized.

Since the greatly modified system of reactor coolant disposal being installed in the K Areas would demand rigid scheduling of the manual operations of basin sampling and since the adequacy of sampling of present basins is questionable, attention was directed toward a continuous monitor of the total beta component in those waters. In the equipment developed, the samples are collected in dimples on a moving aluminum strip, evaporated to dryness, counted by a proportional flow counter tube, and the results recorded. The equipment is completely automatic.

A diffusion cloud chamber was constructed for use in determining the tritium in underground water as a part of the study of movement of underground water streams. The large chamber capacity makes this counting method more desirable than internal Geiger counting since little or no electrolytic enrichment of the tritium in the water is required. As a result, savings in equipment, time and money should be realized in this operation.

As a matter of plant interest, the permeability of HT through vinylite, neoprene, and lucite was measured by counting techniques to provide design data for hood and container construction. Tritium sources for surface monitor calibration were prepared by adsorbing HT gas on zirconium metal heated to 600°C.

New or improved procedures were developed for the determination of Fe^{55-59}, As^{76}, and Cr^{51} in reactor effluent water, Sb^{125} in process solutions, and Sr^{90} in milk. These procedures were developed for use in radiochemical laboratories and research units for hazard evaluation and other special applications.

In the ranges of low activity with which radiological monitoring is most concerned, it is of importance to distinguish between the background contributions of naturally occurring radioactive materials and the radioactivity of contaminants resulting from plant operations. Radium and

thorium are particularly significant in this respect. Radon and thoron are gaseous daughter products of these elements.

The counting of radon was utilized in a method developed to determine radium in soil, vegetation, and water samples. The minimum detection limit of the improved method is 5×10^{-14} grams Ra per gram of soil which is presently considered to be adequate. Similarly, thorium is determined by thoron counting. The thoron counter was improved and a method developed which resulted in average recoveries of 95.3 ± 6.3% from spiked soil samples and a satisfactory detection limit of 1×10^{-6} grams Th per gram of soil.

The accounting of liquid wastes disposed to the ground, or elsewhere, has been difficult at HAPO due to the lack of suitable samplers for waste lines carrying a variable flow. Testing of laboratory multi-weir proportional samplers was completed and the design of field scale samplers for waste systems, notably at the Purex tank farms, was completed.

There are many correction factors which must be applied to the raw data obtained from the radioactivity "count" of an analytical sample to get the true activity density of the material. The many nuclides of interest each have specific physical characteristics so that special correction factors must be developed for the individual isotope. During the year self-scatter and self-absorption measurements were completed on several more nuclides of interest to establish proper counter corrections for them. The correction factors obtained will be applicable to all counter work and will be particularly helpful in the analysis of 107 Basin waters.

A gas filled proportional counter chamber with beryllium window was fabricated in order to develop analytical procedures involving soft x-rays from the K-capture isotopes Fe^{55} and Cr^{51}. These and other isotopes with a similar property are of considerable importance in 107 Basin water and their determination has been exceedingly difficult.

Solution rate studies of radio-ruthenium particulate material in 0.1 M HCl were made to give an indication of the fate of particles which might enter the gastro-intestinal tract. Solution rate studies of UO_3 particles in distilled water and synthetic pleural fluid were completed to test procedures and to obtain information for use by the Biology Section in studies on the fate of plutonium particles in the lung.

Gamma Ray Dosimetry

Determination of the energy sensitivity of the Hanford film badge to gamma rays was completed for application to routine personnel monitoring problems. A method was developed for determining the gamma ray exposure of Hanford film badges in the event of exposures that would produce film blackening too dark to be read on a densitometer. The procedure involves exposure of the developed film to slow neutrons and measurement of the

induced radioactivity of the silver in the emulsion.

A scintillation counter system was arranged to permit measurement of gamma ray emitting materials within the body for application to problems involving inhalation or ingestion of radioactive material. A total body monitor, such as this, with adequate sensitivity would be a very useful tool in the personnel monitoring program.

Beta Ray Dosimetry

Techniques for using the electron Van de Graaff accelerator for electron exposure and calibration work were further developed. These include methods for beam extraction with minimum x-ray production, for control of a very wide range of beam currents, for monitoring the emergent beam current, and for determining the dose rate produced by the electrons. Extrapolation chambers were designed and built for measuring electron dose rates and determining effective electron energies by absorption methods.

The mathematical methods of neutron age theory were developed and extensive calculations carried out for application to beta ray dose problems. A wide variety of problems was successfully investigated and the results applied to experimental work and to investigation of exposure incidents.

It was shown that very thin anthracene scintillators used with photomultiplier tubes made instruments which were equally sensitive to beta and gamma ray dose rates and had proper response to sources displaced from the instrument axis. It is expected that this system will be employed in survey instrumentation.

It was found that tritium in ordinary air could be counted in a geiger counter at 10 cm Hg pressure with an efficiency of 25%. Application of the finding may be possible in the greatly needed improved tritium instrumentation.

Neutron Dosimetry

The positive ion Van de Graaff laboratory was completed and the accelerator installed. Several changes in the system were made to secure more efficient operation. Measurements were completed which will permit correlation of neutron experiments made with the accelerator with those using radioactive sources.

Studies of methods of fast neutron energy measurement were made to select the one best suited for use with the positive ion accelerator. Methods employing measurement of neutron flight times were selected. Instruments for making such measurements were procured or were being developed.

Measurements were made of the energy sensitivity and fading of nuclear track emulsions for neutrons from a plant process material. These serve as a basis for the neutron personnel monitoring program in that area. An approximate method of measuring fast neutron surface dose rates with ordinary survey instruments was developed for application to this same material to determine permissible working times for operators handling it.

ENVIRONMENTAL STUDIES AND ADEQUACY OF WASTE DISPOSAL SYSTEMS

Atmospheric Contamination Studies

A study of particles emitted from the Redox process stack was pursued intensively; particle size and activity, fission product content and, in a preliminary way, solubility in body fluids were investigated. An automatic filter sampler was specially developed for this problem; it permitted essentially constant monitoring of gas streams and proved to be of value elsewhere in plant studies correlating particle emission with plant processes. Ruthenium oxide particles were demonstrated to be present in mist droplets from a plant scrubber. Silica gel was found to have high collection efficiences for ruthenium compounds.

Studies were made of individual radioactive particles found on ground surfaces in the Hanford area. A microscope attachment was developed which facilitated isolation and manipulation of radioactive particles. Assistance was given to the Biology Section in developing apparatus and techniques for animal studies involving particle inhalation. Subjects considered were chamber design, aerosol generation, and air sampling techniques for the determination of particle size and concentration.

The protection afforded by filter respirators against ruthenium contaminated atmospheres was investigated. Ruthenium tetraoxide readily penetrated fiber filter media but was removed effectively by silica gel. The latter observation may be of considerable plant interest.

Air samples were collected daily at Hanford and Portland and periodically in the Pacific test area during the spring nuclear tests in the Pacific. Specimens were counted and examined by electron microscope to determine the frequency of spherical particles such as those previously demonstrated in the air at Nevada nuclear tests. The application of such a technique would aid in the frequently difficult differentiation between plant and off-plant fall-out materials.

The use of airfoils on laboratory hoods was investigated in a preliminary way to evaluate the degree of improved control and possible reduction of airflow; decreases in personnel hazard from radioactive substances in a hood and reduced ventilation costs could result. The data showed that the major improvement in control is from a foil on the hood window and that relatively less benefit is obtained from side and bottom foils.

Experimental Meteorology

Theoretical trajectories of hypothetical eruption clouds, such as would be expected in a reactor disaster, were analyzed for use in a predictor for the trajectory of a single eruption cloud utilizing only the immediate HAPO Meteorology Station observations taken near the time of the incident. The results indicated that such a single station analysis would not produce reliable long range trajectories, but rather, that the immediate and subsequent synoptic patterns over at least the entire Northwest must be considered before a reliable trajectory at 5000 ft. altitude could be forecast.

Research and development in the continuing problem of atmospheric diffusion was directed toward the stable atmospheric condition; field test data yielded an operational method for estimating both the short and long period concentrations of contaminants to be expected at large distances from the emitting source. Techniques were developed for dispersing fluorescent pigments for use in experiments to describe the behavior of atmospheric contaminants out to greater distances than is possible using the oil fog procedure. The oil fog technique for studying diffusion during unstable conditions was greatly improved.

A 42 foot portable mast supporting meteorlogical and dust-sampling instruments for investigating the relationship between the pickup of particulate matter from the earth's surface and meteorological conditions was completed and field tested. Considerable progress was made in anemometry problems associated with the mast equipment. Field experiments were initiated on the study of particle redistribution using naturally occurring sand and dust to yield the background information preliminary to the use of artifically-generated tracer materials. Results from these investigations will be used to study the spread of contamination after deposition on the desert floor.

A network of eleven meteorological field stations was operated throughout the plant environs, including the Wahluke Slope, to obtain basic information from which hazard to surrounding communities can be appraised. The wind predictor technique developed from these data for predicting the low altitude trajectory of contamination during a plant or civil emergency from a minimum or meteorological data was shown to have an overall 68 per cent correctness of predictions. The reliability of the forecasts increased considerably as the wind speeds increased. The wind information obtained from the network was also used in certain plant design and location problems. Plans were completed for radiotelemetering immediate meteorological and radiological data from surrounding areas to a central location; such a system would obviate the need for predicting the existent conditions at one station from data observed at another and would be invaluable in emergency as well as meeting the need for more complete observational data not now reliably obtained from remote stations. A wind climatology for the HAPO area was esstentially completed

The problem of measuring the turbulent characteristics of the lower atmosphere was studied from several different approaches. A wind-component meter was designed for use in both particle pickup and diffusion problems as well as for basic micrometeorological investigations.

The relationship between dilution and flow rate in the stack was clarified, permitting extension of the original Hanford values of least dilution to a stack emitting at any flow rate.

Fundamental aspects of an improved atmospheric pollution and stack discharge control program were studied in view of the present state of knowledge concerning stack parameters, meteorology, and maximum permissible concentration requirements. Results of this study were used to guide certain experimental and theoretical investigations toward immediate application to plant atmospheric pollution problems.

An analysis was completed of meteorological data obtained from the Meteorology Tower during 1951, 1952, and 1953 providing a climatology of the annual frequency of various wind speed, wind direction, and atmospheric stability combinations. Results of this analysis were used to estimate annual average air concentrations and the probability of radioactive particle inhalation at various locations as related to sand filter problems in the separations plants.

A proposal was prepared for a wind tunnel to provide a facility for calibrating wind instruments used by Experimental and Synoptic Meteorology and for estimating the first order effects of building design and stack location on atmospheric diffusion.

Ground Waste Investigations

The determination of patterns of distribution of natural sodium, calcium and nitrate ions in the ground water beneath the project indicated major sources of the ground water and probable directions of movement, verifying the data obtained from other sources. Use of the iteration process and improvement equation and the application of calculated and determined soil permeabilities resulted in estimates of travel time, from contamination Areas 1 and 2 to the Columbia River, which confirmed the magnitude of previous estimates. Well drawdown (pump) tests in cooperation with the U.S. Geological Survey and tracer tests in selected locations provided specific rates of travel of the ground water at those places.

Non-radioactive calcium ions were found to be valuable as tracers or indicators of contamination of the ground water by radioisotopes in the three areas of contamination. Nitrate ions, introduced into the ground water at one site, have moved 2200 feet in nine years, or an average of only 20 feet per month; in another site, no appreciable movement has occurred in seven years.

At the Works Laboratory Area the rate of movement of contaminants in the ground water at the site of contamination was determined to be about 900 feet in three years. The combined effect of the McNary Dam pool and the spring rise of the Columbia River on the ground water table was followed in this and nearby sites.

The adsorption of Cs and Sr on Hanford soils was found to be adversely affected by increasing the concentration of $NaNO_3$ in the solution, up to 40%. The adsorption of cesium was higher for high-clay soils and the replacement of calcium ions was roughly equivalent to the cesium removed from solution by a calcium-saturated soil in equilibrium with a cesium solution. These observations experimentally proved ionic exchange to be the most significant of the various possible mechanisms acting to remove ions from ground disposed aqueous solutions and furthermore, emphasized the great importance of controlling carefully the admission of concentrated salt solutions to underground areas where radioactive ions have already been fixed.

Adsorption of Pu on soils from 0.24 M oxalic acid solutions exceeded 99% at pH 1 to 2, but was less than 15% at pH 3.5 to 5. This behavior suggests that Pu forms a complex ion not readily adsorbed by the soil when the pH value is changed. Significant removal of Pu, previously adsorbed on soil, was also obtained by the use of ammonium acetate with the amount removed increasing as the acetate concentration increased. In addition, adsorption of Pu from calcium acetate solutions decreased with increasing calcium acetate concentration while adsorption from calcium nitrate solutions did not change greatly as the calcium nitrate concentration increased in comparable experiments. Further support was thus given to the concept of complex ion formation by Pu and further cautions regarding multiple disposal of different wastes to the same site.

INSTRUMENTATION FOR RADIATION DETECTION AND MEASUREMENT

Survey Instrumentation

A new scintillation type alpha survey probe for use with conventional poppies was developed and field tested; gains in sensitivity and decreased maintenance cost are expected to result from its use as a replacement for certain present monitoring equipment.

A study of the adverse effects of ionization within the electrostatic shield surrounding the sensitive elements of a C.P. circuit showed that such effects could be virtually eliminated by coating certain inner shield surfaces with graphite.

In preparation for developing a combined alpha and beta gamma hand and shoe counter, an experimental hand probe was developed and tested. Alpha scintillations from a zinc sulfide screen were sensed by six type 931-A

photomultipliers and beta-gamma radiation was counted by G.M. counters. Savings in first cost of the one instrument versus the two replaced and of space and counting time, and most importantly provision for the counting of alpha contamination on shoes would be realized by the use of this equipment.

A scintillation type survey instrument for monitoring ground contamination from a moving vehicle was developed. It was used for measuring ground deposition of ruthenium and iodine. Considerable savings in surveying manpower may be realized by its use.

A low cost, repairable, electronically operated, inductive high voltage supply for portable survey instruments was developed. It was used extensively to replace defective mechanical vibrators in portable G.M. counter survey instruments. A transistor high voltage supply was developed and tested, but not used in any conventional instrument because of the high initial cost.

Laboratory Instrumentation

Development of a low cost multiple channel gamma ray spectrometer was nearly completed. The instrument permits the detection and semi-quantitative determination of gamma-ray emitters in a complex mixture thus saving time and skilled manpower in both emergency and routine studies of contaminants. As part of this problem, a low cost scale of 100, using type E1T decade counting tubes was tested and found to be satisfactory for general counting work.

Development of a very low background counter for measuring small amounts of tritium in water was undertaken; application will be to the study of rate of movement of underground water of value to the waste disposal problem. Background reduction by rejecting coincidences with a liquid scintillation counter is the distinguishing feature of the instrument.

Biological Instrumentation

Hog thyroid monitoring equipment for Biology with a high ratio of sensitivity to background was completed and put into routine service.

Special Purpose Instrumentation

A stack monitor was designed in which scintillation counters will be used to determine Ru^{103}, Ru^{106} and I^{131} separately. These are the radioisotopes of outstanding current interest in stack gases. This is accomplished by multiple channel analysis of energies of beta and gamma radiations from the $Ru^{103-106}$ and I^{131} collected on a moving filter tape and in caustic scrubber solution. Some components of the monitor have been fabricated.

Studies of the age characteristics of geiger counters continued with emphasis on the details of breakdown of counters and on application of the previously discovered age indexes to routine use of the counters.

A scintillation type instrument for monitoring gamma radiation intensity in test wells was completed. It was subsequently modified into an experimental fixed channel energy analyzer for identifying Cs^{137}. The detection of radioisotopes underground will be facilitated by its use.

Design of a radio-telemetering system for recording pertinent wind and radiation data from 20 outlying Wind Stations at a central recording station was nearly completed and the design and assembly of electronic data analysis equipment for the wind component meter was commenced.

Planning, testing of available equipment, and preliminary design of a reliable sample changer for handling unattended large numbers of radioactive samples in the counting room was started. Application of such equipment would obviate the need for counting room personnel on late shifts.

TABLE I

SUMMARY OF OPERATING COSTS
RESEARCH AND DEVELOPMENT

	Budget FY 1954	Actual Expenditures FY 1954
Biophysics		
Direct Labor	284 187	267 634
Direct Materials	34 234	37 246
Service and Indirect Charges	238 718	241 837
Sub-Total (Biophysics)	$ 557 139	$ 546 717
Biology		
Direct Labor	377 006	295 182
Direct Material	53 905	57 597
Service and Indirect Charges	290 414	337 480
Sub-Total (Biology)	$ 721 325	$ 690 259
Engineering		
Direct Labor	16 689	21 206
Direct Material	434	4 543
Service and Indirect Charges	20 413	10 702
Sub-Total (Engineering)	$ 37 536	$ 36 451
Total Research and Development		
Direct Labor	677 882	584 022
Direct Material	88 573	99 386
Service and Indirect Charges	549 545	590 019
Total (R & D)	$ 1 316 000	$ 1 273 427

MANPOWER (DIRECT MAN-YEARS)*
RESEARCH AND DEVELOPMENT

	Budget FY 1954	Actual FY 1954
Biophysics		
Non-Exempt	11.0	11.85
Exempt	38.7	35.22
Sub-Total	49.7	47.07
Biology		
Non-Exempt	33.3	29.19
Exempt	33.9	32.21
Sub-Total	67.2	61.40
Engineering		
Non-Exempt	.3	.28
Exempt	2.5	2.39
Sub-Total	2.8	2.67
Total R & D Manpower		
Non-Exempt	44.6	41.32
Exempt	75.1	69.82
TOTAL DIRECT MAN-YEARS	119.7	111.14

*Includes vacation, holiday, absence and premium time but excludes pro-rata portion of section and department general supervision.