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HANFORD ATOMIC PRODUCTS OPERATION
RADIOLOGICAL SCIENCES DEPARTMENT

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RADIOLOGICAL SCIENCES DEPARTMENT - ANNUAL REPORT
RESEARCH AND DEVELOPMENT - FISCAL YEAR 1953

- Part I - Biology Program
Part II - Biophysics Program

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PART I - BIOLOGY PROGRAM

INTRODUCTION

The biology program is comprised of three major studies: (1) Deduction of permissible human exposure by biological experimentation; (2) Effects of process effluents on aquatic organisms; (3) Effects of process effluents on plant and animal life.

The first encompasses work which includes investigations to determine the permissible maxima of radioisotopes of significance at Hanford by using suitable biological materials. The work is necessary in order to establish on a firmer basis the rules governing the art of personnel protection. Its scope includes the determination of the metabolic properties of a variety of radioisotopes, the special toxicities that they may exert and the ratio of the biological effectiveness of the various ionizing radiations where such ratios are unknown or poorly defined.

The second has for its main objective the detection and evaluation of effects of waste effluents that may find their way into water courses containing aquatic organisms. This information is needed to determine whether production can cause a change in the normal biota of the water which may be of economic importance to the fish industry or of hazard significance to humans and animals ingesting the water. Its scope presently includes the determination of the effects of reactor effluent water and related wastes on aquatic life, as to whether the biological balance in the Columbia River is being disturbed, and if activities may be transferred from one organism to the next until a commercially valuable species is contaminated.

The third is a study designed to determine the metabolic and toxic behavior of radioactive substances, present in process effluents, with respect to plant and animal life. This work is needed and intended to establish long-term criteria for the safe disposal of radioactive waste materials. Its scope includes the determination of the chronic toxicity of I^{131} in sheep and the uptake, translocation and toxic effects of nuclides in commercially important vegetation.

SUMMARY OF ACCOMPLISHMENTS

DEDUCTION OF PERMISSIBLE HUMAN EXPOSURE AND BIOLOGICAL EXPERIMENTATION

1. Tritium Absorption and Metabolism

The rate of tritium oxide vapor absorption through human skin in a single total body exposure of a human was found to be approximately equal to the rate of pulmonary absorption from the same atmosphere. Absorption of the gas through the skin was found to be independent of water vapor pressure. Both of these observations are of considerable significance in hazard control - the first indicating that little real security results from wearing fresh air masks, and the second that isotope dilution of tritium oxide vapor with water vapor does not decrease uptake by humans exposed.

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These observations contrast with those obtained in the study of skin and pulmonary absorption of elementary tritium. In rats, absorption of tritium gas through the skin amounts to but one to two percent of the quantity absorbed through the lungs from a given atmosphere. During lung exposures tritium content of the blood increased rapidly but also decreased rapidly when exposure was stopped.

Various types of physiological compounds in rats and in a sheep were shown to retain incorporated tritium (built up from chronic tritium administration) with biological half-lives of the order of months or years. This may be taken as evidence that there are conditions in humans once exposed, when knowledge of the concentration of tritium in body water may cause an unjustified sense of safety. It points to the necessity for frequent urine assays among tritium workers. Of fundamental significance were the observations that many physiological compounds in the body have very slow turnover rates, dependent upon the tissues in which they occur.

That our knowledge of the behavior of the inactive isotope of hydrogen cannot always be directly applied to tritium was shown by comparing the uptake of protium, deuterium, and tritium in a rapidly growing algae. Deuterium and tritium were incorporated at approximately one-half the rate at which protium is incorporated. A much smaller, but still significant isotope effect was noted in certain tissues of the rat.

2. Plutonium Absorption and Metabolism

In an experiment involving 200 rats, plutonium solutions were fed chronically over a period of nearly a year at concentrations from 0.04 to 1.2 times the maximum permissible concentration. Gastro-intestinal absorption and eventual deposition in the skeleton of rats which received 1.2 times the MPC was 0.00234 ± 0.00028 percent at the 95 percent confidence limit. This absorption fraction is a factor of about four times lower than values previously obtained from experiments in which solutions of much higher plutonium concentration were fed and may serve to revise the MPC for Pu in drinking water upward.

Studies were made of the rates of absorption of plutonium solutions of different acidity through the skin of rats. Absorption was generally less than .001 percent per hour except at acid concentrations which essentially destroy the skin. The relative effectiveness of a large number of decontaminating agents administered according to various procedures was also determined. Many recommended procedures were found to be no more effective than water alone.

3. Plutonium Therapy

Despite the attempts to develop a method for either preventing absorption or deposition of plutonium once ingested or mobilizing plutonium once deposited in bones, there is yet no practical prophylaxis or therapy for plutonism. Two kinds of treatments (first investigated elsewhere) enjoy the reputation of causing the removal of a greater fraction of a body's burden of plutonium than if no treatment is administered. However, neither the method of choice nor the most favorable conditions for the application of either method is defined.

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Last year this laboratory was engaged in trying to define the most effective means for administering zirconium citrate. Quantities of the drug to be recommended for treatment were found such that if it is administered (to an experimental animal) within 30 minutes after plutonium enters the blood, the body retains only 50 percent of that it would have were no treatment given.

The other method employs calcium ethylene diaminetetraacetic acid (Ca EDTA). By itself it does not appear outstandingly better than zirconium, but recent preliminary work indicated that the administration of both zirconium citrate and Ca EDTA is superior to either one of these agents alone.

4. Radioactive Particles Metabolism and Toxicity

Since 1947, when radioactive particles were found to emanate from separations stacks at Hanford, little has been done to definitely establish whether active particles deposited in lungs can cause cancer. In preliminary work using a strain of mouse that spontaneously develops lung tumors, development of special techniques for exposing them began.

5. Relative Biological Effectiveness of Ionizing Radiations

In estimations of MPC's and radiation effects a knowledge of the rem/rep ratio of the ionizing particles yielded by the isotope is required. The classical procedure required to find this ratio is a tedious one, requiring large numbers of animals. A new technique was developed by this laboratory that largely overcomes this disadvantage, yet it yields results comparable with animal procedures. In some cases it yields results technically unobtainable by other means. Essentially, the test simultaneously measures inhibition of bacterial growth and physical dose due to the presence of a radioelement.

Preliminary data on the rem/rep ratio of tritium was obtained. Refinement of this figure depends upon the availability of a nearly completed instrument that will automatically record turbidities caused by the bacteria growing in the presence of various quantities of the pertinent radioelements.

6. Radium in Individuals Having No Known Radium Exposure

The practical lower limit of maximum permissible quantities of internally deposited radioelements must not be less than that which deposits in humans living normal lives during which very small quantities of radium become fixed in the skeleton from traces of the element in water and foods. In Germany and Rochester, New York, determinations of radium in ashed cadavers having no known radium exposures were made.

To find if there is a geographic difference in the quantities of radium in individuals from the Northwest as compared with those sampled in Rochester, we have analyzed more than 50 ashed humans* for radium. Quantities found were similar to those observed in the Rochester work.

*Samples were supplied by Dr. F. B. Queen, Pathologist, University of Oregon Medical School, Portland, Oregon, as outlined in his contract with the AEC, HOO.

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7. Mechanism of Radiation Effects

The destruction of the B vitamins by ionizing radiations has been studied elsewhere but at concentrations much higher than those encountered in living cells. Through the application of sensitive assays for vitamins, it was shown that greater destruction occurs in pure solutions of vitamins at concentrations approaching those in cells. For the future it is planned to extend this work to determining rates of vitamin destruction in living cells in the hope of finding a cell material which is more selectively destroyed by radiation than other materials.

EFFECTS OF PROCESS EFFLUENTS ON AQUATIC ORGANISMS

1. Mechanism of Reactor Effluent Hazard to Aquatic Organisms

One cause of toxicity of reactor effluent to fish has been shown to be the chromate ion when concentrations of effluent are in excess of five percent. Radioactivity does not seem to play a major role, but the elevated temperature of the effluent does. Particularly is this true during the egg and fry stages which occur during the fall season when the river flow is lowest and its temperature highest.

It was noted that fish in the river become more radioactive than fish in troughs containing the same average concentration of radioactivity. From controlled laboratory experiments it was observed that the added radioactivity in river fish was accumulated from their food which, in turn, accumulated activity from other life which serves as food for them. In general, as we proceed down the biological scale we find greater concentrating ability among the organisms.

EFFECT OF PROCESS EFFLUENTS ON PLANT AND ANIMAL LIFE

1. Effect of Reactor Effluent on Growing Plants

Since large quantities of Columbia River water below HAP0 are diverted for crop irrigation, the growth, yield and genetics effect on cereal crops of reactor effluent is being determined in small plots. Direct effects on plant growth is observable at effluent concentrations of 50 percent and greater. The toxicity was shown to be due to chromate ion. Genetic effects may take several generations to manifest themselves. It is for this reason that the experiment is presently indeterminant and should be continued until genetic changes become manifest and measurable.

2. Absorption and Translocation of Radioelements in Plants

To have adequate information for evaluating effects of a reactor catastrophe, of underground seepage of radioactive waste solutions, and of other situations where soil (hence, growing plants) become contaminated, determinations were made of the absorption and translocation of Sr, Y, and Cs in plants representative of major local crops and weeds. Sr and Cs were found to absorb and translocate readily, but Y did not penetrate the roots appreciably.

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At the request of the Commission, plants were grown in "Jangle" soil, sent us from a test site. Under experimental conditions and locally they were found to absorb 2.8 percent of the activity in the soil. How this value compared with other laboratories investigating Jangle soil is not known.

3. Mechanism of Radiation Effects

By growing previously irradiated algae in media containing C^{14} it is possible to learn some of the effects of the radiation on the algae by following incorporation of C^{14} in various compound fractions from the algae. In preliminary studies using this procedure it has been shown that fatty acid synthesis is markedly increased following irradiation. More extensive application of this technique is planned.

4. Toxicity of I^{131} in Animals

This extensive and definitive experiment is designed to establish a realistic basis for firm exposure limits for I^{131} in sheep and other stock animals. During the past year, by statistical analyses of experimental data, it was found that 5 μ c I^{131} fed to sheep each day caused a decrease in the avidity with which thyroid tissue absorbs radioiodine. Histological examinations showed that the change in function was pathological. These effects were slow in developing and became apparent only after prolonged feeding. Before this occurred new groups were started at 45 and 135 μ c/day since toxic manifestations from feeding 240 μ c/day were defined last year. Once the syndrome of radioiodine damage in these two groups was noted, that part of the experiment ceased.

Range animals usually have available to them iodized salt and thereby may be less sensitive to radioiodine than experimental animals. In the main lot of our sheep the quantity of inert iodine is limited to the minimum essential to prevent hyperthyroidism among controls. This is done to promote experimental precision and to gather data under more pessimistic conditions. For these reasons a supplementary experiment determined that when inert iodine is fed to sheep, 90 percent less radioiodine deposited in the thyroid, with the consequent conclusion that the average range animal is further protected from radioiodine by 5 to 10-fold. Dessicated thyroid fed to other sheep had little sparing effect of radioiodine on the thyroid, nor did it supplant thyroid tissue destroyed by radiation.

So that minimal damage from more acute doses of radioiodine could be recognized, a study of early histologic damage was initiated. With a daily administered dose of 480 μ c, initial damage was observed at 19 days, during which an estimated dose of 15,000 rep was delivered.

- In order to define the effects of radioiodine in parts of the body other than the thyroid, two pairs of sheep were fed toxic quantities of radioiodine (240 μ c/day). Previously one of the pairs was surgically thyroidectomized, the other remained normal. By comparison of blood constituent changes in the experimental animals with those from suitable controls, it was found that no

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significant effects could be attributed to I^{131} independent of thyroid destruction.

The gestation time at which the fetal thyroid becomes functional as manifested by its ability to absorb iodine was determined to be 50 days. This information is of value in relating effects on animals in utero of exposing the mother ewe to radioiodine.

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PART II - BIOPHYSICS PROGRAM

INTRODUCTION

Research in biophysical sciences is conducted under three activities entitled: (1) Environmental studies and adequacy of waste disposal systems; (2) Instrumentation for radiation detection and measurement; (3) Monitoring methods.

Activities conducted under the first are designed to determine the relations between the various waste disposal systems and the ultimate site of deposition of the wastes. Information obtained from investigations of problems in this category is used to evaluate the possibility of increased disposal of radioactive materials to the ground, for local control of immediate or future hazards arising from the Hanford Operations and to provide basic information upon which advisory bodies such as the Columbia River Advisory Group, Reactor Safeguard Committee and the Wapluke Slope Risk Committee can appraise the adequacy of our protective program as it relates to areas of public interest. Additionally, data are obtained for use in possible emergency conditions which may be occasioned by major failure of an operating plant. The work includes measurement of the exposure of employees to specific airborne contaminants, the determination of the relationships between meteorological variables and concentrations of airborne pollutants in the atmosphere (both on a local and Columbia Basin-wide scale), field tests on the actual spread of liquid wastes in the ground and dilution in the river, and laboratory investigation of the mechanisms involved in the soil retention of wastes.

Instrumentation for radiation detection and measurement is necessary to provide proper instrumentation for all phases of radiation measurement and radiological hazard determination and evaluation. This requires development of new instruments, application and adaptation of instruments already available and improvement of existing instruments. Instrument needs of survey organizations and problems related to maintenance requirements are also investigated.

Monitoring methods includes activities related to the development of radiation measuring techniques involving the application of physical and chemical disciplines to the specific problems encountered in radiation protection. The scope of this study includes dosimetry of alpha, beta, gamma and neutron radiations, differentiation of the types and energies of the radiations from various nuclides and the development of radiochemical assay techniques for materials having very low activity density. The results from this work are applied to such things as the calibration of field survey instruments, the interpretation of biological experiments, the precise laboratory measurement of radioisotopes in human materials, the establishment of permissible work times in the various operations in process areas and the analyses of complex exposure problems.

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SUMMARY OF ACCOMPLISHMENTS

MONITORING METHODS

1. Analytical Techniques

Plutonium was electroplated on very small (2 sq. mm) areas in yields of 50 to 70 percent. This is not considered satisfactory for application to the bioassay analysis, which would be greatly improved if small area plating in good yield could be realized, but promising approaches have been indicated by this preliminary work.

A satisfactory continuous monitor for radioactive noble gases was tested and calibrated. Through the use of this facility it is possible to follow the evolution of Kr^{85} as an index of plant process activities. Additionally, the equipment will be of value in the study of diffusion in the lower atmosphere.

By specially treating asbestos filter papers or fiber glass filters with silver nitrate a large increase in I^{131} collection efficiency is noted. These media will replace the caustic scrubber collector presently used in equipment for surveying the distribution of that significant element.

A procedure was developed by which vegetation samples can be analyzed for radioactive ruthenium. Since ruthenium isotopes have become important constituents of the separations area gaseous effluents, the method is required to trace the deposition of these materials.

A fluorometric method for the determination of the concentration of oil fog was developed, tested, and placed in routine use. This method makes possible the study of the dispersion of gases in the lower atmosphere through the use of an oil fog as indicator material.

Studies were performed to characterize the radioactive noble gas constituents in reactor effluent water, using the fractional distillation of Xe, Kr, and Ar together with a proportional counter technique. Information obtained can be used as design criteria for a noble gas continuous monitor as well as an index to the source of these radioactive gases.

Analytical methods for plutonium and uranium employing ether and other organic solvents were investigated for the improvement of control laboratory procedures. Improvement in yield and reproducibility were obtained and less toxic solvents were designated for use in the Bioassay Laboratory.

Improved methods were developed for the determination of Cu^{64} , Mn^{56} and P^{32} in reactor effluent. More accurate determination of these activities has been required to provide reliable estimates of the hazard resulting from river disposal of reactor effluents. The method for P^{32} can be applied in a constant monitor for this element to permit continuous recording of this important "hazard constituent" of effluent water.

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Laboratory scale proportional samplers were designed and were under test at year end. Design data obtained will be applied to samplers in new area waste lines to provide more accurate knowledge of the volumes and concentrations of the several types of radioactive waste solutions.

The counting characteristics of several of the more important isotopes were studied to determine corrections for air and mica window absorption, back-scatter, self absorption, and sample diameter. Results permit a more accurate calculation of the absolute disintegration rate of samples necessary for more accurate interpretation of laboratory radiochemical analyses.

The problem of determining the concentration of tritium oxide in aqueous samples by counting techniques was studied from several different approaches. Though not complete, the data obtained have given support to the presently used procedure for measuring tritium oxide concentration in water and have provided counting techniques and hydrogen generation schemes to allow an accurate calibration of tritium oxide samples in direct support of tritium hazard monitoring.

2. Gamma Ray Dosimetry

Development of the K source, a device producing monoenergetic X-rays, was essentially completed. This source will supplement the Van de Graaff for energy dependence studies for development, calibration, and instrument appraisal.

The surface dose rate of X and gamma rays from plutonium metal and the absorption in typical shielding materials was measured. These data were used to set safe working times in the process.

A gamma ray monitoring system for the Van de Graaff was constructed and calibrated to permit rapid measurement of dose rates in new experimental or calibration arrangements.

A preliminary model was made of a proportional thimble chamber, a dose rate measuring device for low dose rates. It was used in a study of dose rates outside tanks of active material of process importance.

3. Beta Ray Dosimetry

With the aim of replacing the surface beta calibration with a calibration more nearly representing the conditions under which beta instruments are used, an external extrapolation chamber for standardization of beta fluxes was built. It was used to calibrate a Sr^{90} source and will be used to calibrate the electron beam of the Van de Graaff.

An independent study of the calibration of tritium water samples was made. It was shown that departmental standards are accurate to 4%.

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4. Neutron Dosimetry

The effects on fast neutron calibrations of neutrons scattered from the air, walls, and floor were determined and found to be of considerable magnitude. Materials for the determination of fast neutron source strengths of total absorption in a tank of liquid were obtained and tested for impurities by reactor irradiation.

Slow neutron detectors distort the very flux they are meant to measure; for accurate measurements the amount of distortion must be known. The flux depression caused by a standard BF_3 tube was measured in the pile in which it is calibrated.

Molded disks of lucite and zinc sulfide phosphors were prepared and studied for application in fast neutron scintillation counters for survey work. Other molded scintillators are being investigated for this and other applications.

ENVIRONMENTAL STUDIES AND ADEQUACY OF WASTE DISPOSAL SYSTEMS

1. Atmospheric Contamination Studies

Radioautograph and microscope techniques were used in a study of the composition and activity density of stack gas particulates. Peak concentrations from certain stacks appeared to coincide with certain plant operations.

A respirator testing apparatus was designed and fabricated to demonstrate the over-all protection afforded by respirators. The pumping system, simulating human respiration, permitted accurate appraisal under typical airflows. Face-piece leakage was shown to be a more significant factor than filter inefficiency.

Filter media used for air sampling, air cleaning, and in respirators were tested for efficiency, pressure drop, and loading characteristics by using various test aerosols. Molecular membrane filters used for air sampling were evaluated to determine efficiencies when employed in conjunction with cascade impactors against fission products in stack gases.

Several studies were made in cooperation with process development groups desiring knowledge of possible health hazards from operations involving toxic substances. Investigations made on experimental runs using materials such as beryllium, lead, fluorides, etc., indicated in certain instances that hazards would have occurred in regular production.

Evaluations were made of exposure to gases from separations stacks and concentrations were correlated with plant operations.

An air sampling instrument for rapid field evaluations during stack discharge studies, and a similar instrument for determination of chlorinated hydrocarbons in plant and laboratory air were developed.

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2. Experimental Meteorology

Theoretical trajectories of hypothetical emergency eruption clouds, such as would be expected in a reactor disaster, were prepared to determine the probability that various regions in the Northwest would be contaminated. These probabilities were summarized in a series of five reports covering fifteen months of data.

Field experiments were performed to study the diffusion of stack effluent in the atmosphere within one-half mile of the source. Oil-fog was generated on the Meteorology Tower to simulate a stack and its effluent. The oil-fog plume was both photographed and sampled during various meteorological conditions to estimate the downwind concentrations of effluents such as nitrogen oxide fumes or I^{131} . In order to study the dispersion of air pollutants over greater distances, prototype fluorescent pigment dispersing and sampling equipment was designed and fabricated.

A 42 foot portable mast supporting meteorological and dust-sampling instruments for investigating the relationship between the pickup of particulate matter from the earth's surface and meteorological conditions was about two-thirds completed. Results from the investigations will be used to study the spread of contamination after deposition on the earth's surface.

A network of twelve remote wind stations was operated to study the air flow patterns throughout the valley in order to predict the trajectory of airborne contamination released either in the routine manufacturing processes or as the result of an emergency eruption. A wind predictor was assembled for use in the emergency control program.

A review of the literature on attempts to measure turbulent velocity fluctuations in the atmosphere was followed by the design of a wind component meter for use in basic atmospheric diffusion studies.

3. Ground Waste Investigations

The rates and directions of movement of the ground water in selected areas were monitored. The effect on the ground water of the discharge of large volumes of cooling water at a new production facility were qualitatively determined to aid in the evaluation of hazards that might result from the contamination of the ground water by radioactive materials.

Test cribbing of radioactive liquids containing large amounts of non-radioactive salts had contaminated the ground water early in Hanford history. Comparisons between these areas of contamination and others of low non-active salt, but significant radioactive content, were made. Non-radioactive sodium ion was determined to be useable as a tracer of radioactive contamination although it does not lead all the radioactive elements as the nitrate ion appears to do.

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The determination of the basic geology at the work laboratory area disclosed geologic barriers to the spread of present and possible future contamination in the ground water from local disposal sites. From this, areas in which wells for sanitary water supplies can be drilled without fear of contamination were disclosed. An artesian aquifer was also found from which pure water can be obtained in large amounts during emergency conditions.

Geologic information obtained from the various problem investigations was integrated into a comprehensive geologic picture to explain the origin of geologic features of importance to plant operation and to guide future exploration, construction, and waste disposal operations.

The order of adsorption of fission products on Hanford soils was delineated and the data found to check well with the field observations. The deleterious effects of high salt concentrations in waste solutions disposed to the ground were similarly shown by laboratory experiment and correlated with field evidence. General soil science data have been applied in conjunction with those from geology and hydrology as guides to the ground disposal of radioactive wastes.

INSTRUMENTATION FOR RADIATION DETECTION AND MEASUREMENT

1. Survey Instrumentation

Two new scintillation type alpha survey instruments, using specially developed phosphors, were developed and working models were field tested.

A new C. P. type instrument was built by utilizing a known circuit and engineering the product for ruggedness, efficiency of layout, and ease of decontamination. Existing C.P. type instruments were studied from the engineering viewpoint and a design for remodeling to a standard plan was evolved. Considerable maintenance savings are expected.

The feasibility of using an anthracene crystal detector in a current measuring circuit as a gamma dose rate meter was investigated. Such a system would be about 25 times more sensitive than ion chamber systems.

By year end, laboratory tests had indicated that the anthracene detector used with a newly developed transistor high voltage supply might build a notably smaller and lighter survey instrument which should be considerably more reliable and cheaper to maintain than conventional gamma survey instruments.

2. Laboratory Instrumentation

A single channel gamma ray spectrometer and a gray wedge spectrometer were built and used for determining the gamma energies of various unknown samples.

Development of a low-cost multi-channel gamma ray spectrometer had started at year end.

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3. Biological Instrumentation

In support of the biology program study on I^{131} toxicity, specialized equipment for monitoring the I^{131} activity in hog thyroids was designed and laboratory tested. A simple circuit was developed to discriminate against radiations other than those emitted by I^{131} .

4. Special Purpose Instrumentation

Studies of the age characteristics of geiger counters resulted in the discovery of two simple ways to measure the amount of use a tube has had. These will be valuable tests for users of the tubes since it will permit removal from service before failure due to tube deterioration.

A simple and accurate recording anemometer was developed for meteorological experiments. A test-well monitor for use in the earth science studies was developed and construction was nearly completed. A curve-plotting air monitor to graph both collection and decay of airborne radioactive solids was completed. Semi-automatic equipment for monitoring dummy slugs rapidly and uniformly was completed. An electrostatic precipitator was designed and built to meet the requirements of particulate studies. A metal evaporator was designed and built to meet electron microscopy specifications. A system for measurement of the temperature at various depths below the bed of the river was devised using a specially designed probe. The equipment will be used in Biology in evaluating potential damage to aquatic life because of operations at Hanford.

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COSTS AND MANPOWER

The budgeted and actual cost and manpower for fiscal 1953 are shown below. The budget figures are those submitted in the mid-year review. Later in the year it became evident that an over-run in Biology was imminent and an additional \$26,000 was applied for and obtained from the Division of Biology and Medicine of the Atomic Energy Commission.

SUMMARY OF OPERATING COSTS

	<u>Budget FY 1953</u>	<u>Actual Expenditures FY 1953</u>
<u>Biophysics</u>		
Direct Labor	\$ 285,010	\$ 240,003
Direct Materials	34,953	29,107
Service and Indirect Charges	<u>181,385</u>	<u>227,499</u>
Sub-total (Biophysics)	\$ 501,348	\$ 496,609
<u>Biology</u>		
Direct Labor	\$ 394,007	\$ 329,910
Direct Materials	57,435	59,436
Service and Indirect Charges	<u>305,512</u>	<u>353,771</u>
Sub-total (Biology)	\$ 756,954	\$ 743,117
<u>Total Research and Development</u>	<u>\$1,258,302</u>	<u>\$1,239,726</u>

MANPOWER (DIRECT MAN-YEARS)*

	<u>Budget FY 1953</u>	<u>Actual FY 1953</u>
<u>Biophysics</u>		
Non-Exempt	15.0	11.41
Exempt	<u>37.5</u>	<u>36.41</u>
Sub-total (Biophysics)	52.5	47.82
<u>Biology</u>		
Non-Exempt	37.5	33.72
Exempt	<u>35.0</u>	<u>36.08</u>
Sub-total (Biology)	72.5	69.80
<u>Total Direct Man-Years</u>	<u>125.0</u>	<u>117.62</u>

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

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