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## OAK RIDGE NATIONAL LABORATORY

## STATUS AND PROGRESS REPORT

JULY 1954

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# OAK RIDGE NATIONAL LABORATORY

# STATUS AND PROGRESS REPORT

July, 1954

F. T. Howard

and

W. H Sullivan

Date Issued: AUG 6 1954

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July, 1954

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OAK RIDGE NATIONAL LABORATORY

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July, 1954

The subject material of this report represents approximately half of the Laboratory's program, which is covered with some exceptions on a bimonthly schedule.

## PROGRAM 2000 - SOURCE AND FISSIONABLE MATERIALS

Waste Metal Recovery - During the period March 10 - July 15, the Metal Recovery Plant isolated 38 kg of plutonium from Hanford metallurgical waste. The recovery, on the basis of losses, was 99.7%. The 36 kg of plutonium product shipped to Rocky Flats was reported to be satisfactory, presenting no processing difficulty. (AEC Activity 2344)

Amex Process - During the period March 10 - July 15, approximately 7 g of americium was recovered from Hanford metallurgical waste by the Amex process. The presence of lanthanum in the feed caused periodic breakthrough of americium in the resin column, resulting in an excessively dilute americium product, 0.035 g/liter, containing about 30 g/liter of lanthanum. (AEC Activity 2344)

Feed Materials - In further studies on sodium amalgam reduction of a propylenediamine (PDA) solution of thorium tetrachloride, as a step in the production of thorium metal, 40 to 50% of the thorium in the organic phase was reduced and transferred to the amalgam phase in one contact at 100°C. A series of contacts of fresh 3.5 M amalgam with the same organic thorium chloride solution at 100 and 120°C indicated that the amount of thorium reduced was a direct function of both the Th/PDA ratio and the temperature. The reduction yield per contact at 120°C was at least 20% greater than that at 100°C. Distillation of thorium quasi-amalgam at 800°C and 0.1 mm Hg pressure produced a pyrophoric residue containing 5% residual mercury.

Indications from small-scale runs are that a more than 10-fold increase in the rate of chlorination, with chlorine, of thorium oxide to produce anhydrous thorium chloride can be achieved by partial carburization of the thoria with coke at temperatures above 1800°C.

Preparation of thorium metal by electrodeposition from a fused salt bath into a liquid metal cathode has not given encouraging results. (AEC Activity 2601)

Excer Program - For use in the continuous moving-bed production of uranium tetrafluoride from uranyl nitrate, pellets of $UO_3.xH_2O$, containing up to 33%



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uranyl nitrate hexahydrate, were prepared on a laboratory scale by a molding technique. The pellets were readily dehydrated and denitrated in air at 400 to 450°C with no change in stability. When the $UO_3$ was reduced, by hydrogen at 500°C, to $UO_2$ for eventual hydrofluorination to $UF_4$, a marked decrease in pellet strength was noted. In only a few cases did the resulting $UO_2$ pellet strength approach that required for moving-bed conversion to $UF_4$.

In preliminary studies on a single-stage conversion of $UO_3.\underline{x}H_2O$ pellets to $UF_4$ by means of HF and $NH_3$ in a 4-in.-diam. by 4-ft-high moving bed reactor, a product containing 80 to 90% $UF_4$ was produced at a feed rate of 10 to 12 lb of pellets per hour. (AEC Activity 2604)

RaLa Production - Decontamination of the operating area, which was heavily contaminated during RaLa Run No. 56, was completed in July. RaLa Run No. 57 proceeded uneventfully, and approximately 22,000 curies of product was shipped July 24.

Since the RaLa facilities now being installed at Arco will be ready for operation by June 1955, it is planned to make only the most necessary repairs to the ORNL RaLa plant to permit operation up to that time. (AEC Activity 3702)

## PROGRAM 4000 - REACTOR DEVELOPMENT

### HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Experiment - The only remaining HRE components--the underground storage tanks--were excavated and removed to the equipment storage pool. With the removal of the dump tanks and several cubic yards of contaminated earth surrounding them, the building is ready for occupancy by the HRT shielding pit contractor.

In the examination of HRE parts, the 4-in. schedule--160 pressurizer has been opened by cutting off the top cap. The 30-in. long thermocouple well removed with the cap showed no signs of severe corrosion upon visual examination. The thermocouple well was subjected to ~5000 hours operation in uranyl sulfate solution and water at 285°C. (AEC Activity 4103.1)

Homogeneous Reactor Test - A contract for digging the reactor pit and installation of a steel liner was awarded to V. L. Nicholson and Chicago Bridge and Iron for $238,388. This brings the total amount of money committed on contracts to ~$485,000, approximately 60% of the eventual total for outside contracts. Excavation work will begin August 1. A building extension to house the Chemical Technology core-blanket processing equipment will be awarded on a separate contract.

Drawings of the 10 megawatt capacity heat removal system have been submitted for final approval by the K-25 engineering group.

Component design is now progressing on schedule. Construction of components to be fabricated by ORNL must await delivery of outstanding piping and fitting orders. (AEC Activity 4109.11)

HRP Reactor Analysis - An investigation of the problem of demonstrating thermal breeding in the Homogeneous Reactor Test (HRT) with a $ThO_2$-$D_2O$ slurry blanket shows that there is a rather large uncertainty in the estimated breeding ratio due to the uncertainty in the value of $\alpha$ for the $U^{233}$ resonances. At a reactor temperature of 280°C for a 1000 gm Th/l slurry blanket, about 20% of the fission captures occur in the $U^{233}$ resonances. The breeding ratio will be 1.02 if $\eta$ is independent of neutron energy and equal to its thermal value, which was taken to be 2.32. On the other hand, if $\eta$ for resonance fission is as low as 1.6, which is not at all improbable, the breeding ratio will be reduced to 0.85.

This uncertainty can be reduced by making the HRT fissioning spectrum thermal by lowering the reactor temperature to 200°C or less, in which case the breeding ratio will be 1.14 (based on $\eta = 2.32$). The reactor can also be made more thermal by reducing the thorium concentration in the blanket. In this case, however, the breeding ratio becomes less than unity due to an increase in the leakage of thermal neutrons.

If a thermal breeding demonstration is to be made at the higher reactor operating temperatures, the reactor size must be increased slightly. An increase of the core diameter from 32 in. to 40 in. and of the pressure vessel diameter from 60 in. to 72 in., for example, should result in a thermal reactor for which the breeding ratio is 1.16. (AEC Activity 4109.2)

HRP Math and Computation - A two group--two region Oracle code was completed and is now available for reactor calculations. This code was used in computations for a number of reactor designs.

Kinetic and dynamic equations for circulating fuel reactors, adequate for reactor safety analysis, were also coded for the Oracle. A short formula for calculation of core pressure rises was compared with Oracle calculations and found adequate for all cases except those in which the peak pressure occurs slightly later than the power maximum. (AEC Activity 4109.2)

HRP Chemistry - Radiation Studies - Studies of the effects of irradiation on the corrosion of type-347 stainless steel by uranyl sulfate solution were continued. Out-of-pile experiments showed a rapid initial rate followed by a much slower rate. The results of in-pile experiments are similar except that after a period of time at the slow rate there is a return to the rapid rate of corrosion initially observed. If irradiation is delayed until after the initial corrosion period, the period of slow corrosion is prolonged.

The effects of chromate ion and of iodide ion (or iodine) were partially investigated. The chromate ion decreased the amount of corrosion and the iodine had no effect on the out-of-pile corrosion. This latter fact may have been because of the possibility that the iodine was oxidized to iodate ion.

The hydrogen yield and the nitrogen yield from pile irradiation of 5.8-m thorium nitrate solution containing one atom of $U^{235}$ to 500 atoms of thorium were found to be 0.25 molecule of $H_2$ per 100 ev and 0.05 molecule of $N_2$ per 100 ev. In this case 81% of the energy was estimated to be fission energy. These numbers are to be compared with previously determined values of $G_{H_2} = 0.05$ and $G_{N_2} = 2$ to $5 \times 10^{-3}$ for 5.8-m thorium nitrate containing no uranium and where essentially none of the energy is fission energy. Any further increase in the U/Th ratio should not greatly increase the gas yields since most of the energy is already due to fission. (AEC Activity 4109.31)

HRP Large-Scale Dynamic Corrosion Tests - An all-titanium loop was used to circulate 1.34-m uranyl sulfate at 300°C. At this concentration and temperature the uranyl sulfate solution existed as two immiscible liquid phases, and the above experiment was made to determine the corrosiveness of such a heterogeneous liquid. After 327 hours of test, there was no measureable corrosion damage to either the titanium loop or the titanium and zirconium corrosion specimens exposed in the loop. Both titanium and zirconium specimens developed thin surface oxide films which were of the order of thousands of angstrom units thick, but the weight changes were immeasureable.

The corrosion rate of austenitic stainless steel in 0.06-m uranyl sulfate containing 0.006-m sulfuric acid at 250°C was determined. At flow rates less than 30 fps a stable protective film formed on the steel and a corrosion rate of one mil per year (mpy) was observed. Above 45 fps, stable films did not form and the corrosion rate was 120 mpy. In the intermediate velocity range only partial films formed and corrosion rates ranging from 1 to 120 mpy could be observed.

Recent experiments in which 200 ppm of chromium, as potassium dichromate, was added to 0.17-m uranyl sulfate at 250°C showed that the presence of dichromate ions is very effective in aiding the formation of a protective film. For example, in 0.17-m uranyl sulfate circulated at 250°C a critical velocity range of 15 to 25 fps was observed; when 200 ppm of chromium, as potassium dichromate, was added to the same system, the critical velocity range was 50 to 60 fps. (AEC Activity 4109.4)

HRP Laboratory Corrosion Studies - ORNL heliarc-welded Zircaloy-2 weldments on Zircaloy-2 base plate showed general moderate white deposits on weld skin regions, no attack on machined or other regions, and generally appeared acceptable after 3-week tests in simulated HRT solutions containing: (a) 0.08-m uranyl sulfate, 0.0065-m cupric sulfate, and 0.008-m sulfuric acid, tested under 150 psi oxygen at 300°C, and (b) 1.56-m uranyl sulfate with 0.00035-m cupric sulfate under 150 psi oxygen at 250°C. Machined

Zircaloy-2 weldments on Zircaloy-2 base metal received from the Newport News Shipbuilding and Drydock Company, contractors for HRT core tank fabrication, exhibited slight dark oxide spots but no other significant attack, when exposed under the latter (b) conditions. However, a pure zirconium weld on Zircaloy-2 base, and also an argon-faced Zircaloy-2 weld on a 2.9% titanium, Zircaloy-2 base metal, received from this Company, showed substantial general pitting attacks on the weld regions under the same conditions.

Studies are being made in an effort to find a suitable material for containing high-concentration thorium-nitrate breeder blanket solutions. Stainless steel, type-347, in a 3-week test at 250°C in a solution which at 25°C contained 1.31-m thorium nitrate and 2.25-m nitric acid, gave an average corrosion rate of 4.5 mpy. Titanium 75-A underwent practically no attack under these conditions. (AEC Activity 4109.4)

HRP In-Pile Loop Experiment - Construction and installation of equipment at Hole HB-4 in the LITR for in-pile loop operation is now complete. A systematic check of all instruments, piping, and auxiliary equipment is underway.

Mock-up tests on a second in-pile loop were completed; approximately 550 hours of operating time were accumulated during the test period with no operating difficulties. A number of tests were made to determine the effectiveness and stability of copper as an internal catalyst for the recombination of hydrogen and oxygen. Fourteen such tests were made with 0.17-m uranyl sulfate containing 0.0085-m sulfuric acid. It was found necessary to use 0.031-m copper in order to maintain a suitably low equilibrium pressure of 2 $H_2$ + $O_2$. This required concentration of copper is about a factor of two higher than expected. The stability of the copper was satisfactory over all test periods. This loop is now being disassembled in the loop dismantling facility as a test of the remote equipment and disassembly procedure.

Additional tests were made on the ORNL 5-gpm canned-rotor pump used in the in-pile loops. It appears that the all-metal bearing combination of Stellite 98M2-Stellite 98M2 is not satisfactory in the pump as presently designed. For the present, Stellite 98M2 journal bushings against graphite No. 14 bearings will be used. A redesign of the pump bearings has been completed, and two pumps are being fabricated for further test in the search for other bearing materials more compatible with the in-pile system. (AEC Activity 4109.4)

HRP Metallurgy - Experimental rolling and heat treatment of large size plates of Zircaloy-2 and evaluation of the results have established procedures which are now authorized for use in the production of the plate to be used in the first experimental core tank for the HRT. Plate thus produced has demonstrated adequate mechanical properties and weldability for this purpose.

Examination of several failures of small diameter austenitic stainless steel tubes in severely corrosive uranyl sulfate at elevated temperatures revealed corrosion due to velocity effects, intergranular attack, and weld seam attack.

The examinations further emphasized the importance of close control of specifications, including composition, heat treatment, and fabrication procedures, in the use of stainless steels in these environments. (AEC Activity 4109.4)

HRP Instrumentation - A panel arrangement proposed for the HRT was mocked-up by using plywood, instrument photographs, cardboard symbols, and colored tape. In this mock-up, the central section contains strip chart instruments recording fuel and blanket temperatures, the temperature drop across the fuel and blanket heat exchangers, count rates, Monitron outputs, neutron flux, and the temperature at twelve important points in the system. To the left and right of the strip chart instruments are, respectively, graphic layouts of the core and blanket systems. At the extreme left is a graphic jumper diagram with sockets so that unnecessary or undesirable interlock contacts may be by-passed. Turbo-generator instruments and controls are at the extreme right of the mock-up.

The following HRT drawings were completed: engineering flowsheets for blanket system and core system, block diagram for nuclear instrumentation, block diagram for health physics instrumentation, and a total of fifty instrument control loop sheets.

Instrument procurement for the reactor is underway; the first three purchase requests have been circulated for comments. A cursory investigation of surplus instruments from the now inactive Orex process has been started to determine suitability for the HRT.

Flooding of the HRT cells for maintenance purposes has raised the possibility that galvanic action might occur that would corrode thermocouple wires during repair periods. Two factors aggravate this situation: the strongly anodic behavior of iron, normally used in thermocouples in the temperature range of $0^{\circ}$-$400^{\circ}C$; and the small mass of the thermocouple wire as compared to that of the 347 stainless steel reactor system to which it would be attached. Despite their lower emf output, chromel-alumel thermocouples were selected for the HRT after vacuum-tube voltmeter tests of various thermocouple materials and stainless steel suspended in tap water. These tests indicated that a minumum amount of galvanic action is produced when chromel, alumel, and 347 stainless steel are coupled together in any combination. (AEC Activity 4109.6)

## AIRCRAFT NUCLEAR PROPULSION PROJECT

Aircraft Reactor Experiment (ARE) - All installation work necessary for testing the ARE circuits with water was completed. Shift operation of the systems on water is scheduled to begin August 2. The main fuel pump was removed for installation of the impeller for use with the fuel mixture so that it would not have to be disassembled between the water test and operation with fuel. (AEC Activity 4401.1)

ANP General Design - The Lucite model of the pump and expansion-tank region of the Circulating Fuel Reactor Experiment (CFRE), a 60-Mw reactor, was tested further with water. With a centrifuge cup on the back of the impeller, performance was good, even at high speeds, if the liquid in the expansion tank was maintained at a high level. However, when the liquid level was allowed to drop below the 85% full point, aeration of the main fluid stream occurred. By using a single-column cylindrical expansion tank between the two fuel pumps at the top of the reactor, it was found that such aeration could be prevented. (AEC Activity 4401.1)

ANP Experimental Engineering - A horizontal-shaft sump pump for circulating fluoride mixtures that is small enough for insertion in LITR and MTR horizontal beam holes was found to operate satisfactorily when tested with water and with tetrabromoethane. Priming difficulties were encountered, however, in tests with molten fluorides. A vertical-shaft, centrifugal sump pump was modified to make possible an increase in delivered flow rate from 2 to 12 gpm without gassing and internal splashing of the pumped fluid. This pump, which was designed for use with in-pile loops, is to be used for high-turbulence corrosion studies. A shaft speed of 6000 rpm will be required, in contrast to the previous maximum shaft speed of 4000 rpm. In an operability test with sodium, a pump of this type has operated continuously at 1400°F for 500 hr at a shaft speed of 6000 rpm.

The large-scale loop for isothermally (1375°F) circulating a fluoride mixture to test the corrosion and structural stability of ARE components has operated without significant difficulties for 1100 hr. The loop was shut down at the end of 1040 hr so that one of the hairpin fuel tubes could be removed for metallurgical examination. The results of the examination are not yet available. Radiation damage studies were made of organic materials used in ARE pumps. The life-expectancy for the rubber O-ring seals was found to be adequate, but gamma-ray shielding must be provided for the V-belt pump drives.

Tests of sodium-beryllium-Inconel systems are under way. No attack was visible on a beryllium sample removed from a system in which the temperature of the beryllium was 1200° to 1300°F, the temperature gradient in the sodium was 300°F, and the Reynolds number was $>15,000$. Results of metallurgical and chemical examinations are not yet available. (AEC Activity 4401.1)

ANP Math and Computations - A recalculation of the two-region, Teflon and uranium-foil, beryllium-reflected critical assembly was made to take into account some modifications in the assembly and an error in the carbon cross section. The recalculation gave a critical mass of 23 lb of $U^{235}$, as compared with the previous value of 16.1 lb of $U^{235}$. The recalculated mass agreed, to within 10%, with the value determined experimentally with the critical assembly.

A report on the study of the effects of reactor proportions on various other reactor parameters was prepared and is to be issued as ORNL report CF 54-7-5. The UNIVAC calculations mentioned previously were used as a basis for this study. (AEC Activity 4401.4)

ANP Reactor Chemistry - Difficulties accompanying production of fuel mixtures containing only alkali-metal fluorides and $UF_3$ were overcome, and batches of NaF-KF-LiF mixtures containing up to 5 wt % of $UF_3$ are being processed regularly. The alterations required to permit safe operation with $BeF_2$ were completed.

Removal of iron and nickel compounds from $NaF-ZrF_4$ preparations by electrolysis at high temperature was shown to be feasible. Electrolysis of 3-kg charges at a current of 10 amp at 6 to 7 volts between a graphite anode and the nickel-container cathode serves to prepare material of comparable purity in one-tenth the time presently required for the hydrogen-reduction cycle.

Values for the equilibrium constant for the reaction

$$Fe + 2UF_4 \rightleftharpoons FeF_2 + 2UF_3$$

in molten $NaZrF_5$ were determined at 800°C, using various concentrations of $FeF_2$, $UF_3$, and $UF_4$ in the initial charge. The values of the equilibrium constant, calculated from concentrations of the various species, as determined by analysis, ranged from $1.1 \times 10^{-5}$ to $3.7 \times 10^{-5}$, while the $UF_4/UF_3$ ratio in the initial charge varied from 0.1 to 4. These values differ appreciably from the values near $1.5 \times 10^{-6}$ which were previously reported for experiments in which $UF_4$ and $Fe^{o}$ were used in the initial charge; the new values are believed to be more accurate.

An ion-exchange column was constructed and used to improve the purity of the RbF prepared for use in phase-equilibrium studies. One pass through a 3-in. column containing a 6-ft bed of Amberlite IR-105 served to reduce the CsF concentration from near 10% to about 0.1%. Effective separation of RbF from KF (a less important contaminant) was not realized. (AEC Activity 4401.5)

ANP Corrosion Research - A test "loop" made of Inconel was operated for 500 hr at a "hot-leg" temperature of 1500°F with a mixture of alkali-metal fluorides (NaF-KF-LiF) and an unknown amount of $UF_3$ and $UF_4$. The usual subsurface-void type of attack was not found, but there was some surface roughness and pitting. There was no deposit in the hot leg, but a deposit was present in the "cold leg". This was the first loop to be operated with a mixture of alkali-metal fluorides.

No attack or deposits were found on either the Inconel or the beryllium insert in two loops that circulated sodium at 900° and at 1100°F. In a loop in which the sodium was circulated at 1300°F, there was intergranular penetration to a depth of 2 mils on the side of the beryllium insert that was exposed to stagnant sodium, but there was no attack on the beryllium surface exposed to flowing sodium or on the Inconel. Metallographic examination did not reveal deposits in any of these loops.

Two Inconel loops were operated for 500 hr at hot-leg temperatures of 1500°F with high purity $NaF-ZrF_4-UF_4$ (53.5-40.6-6.5 mole %); both loops developed heavy, subsurface-void attack to a depth of 10 mils. This attack is slightly more than the 8 mils normally found with the 50-46-4 mole % mixture. An intermittent metallic deposit was found in the cold leg of each loop.

Additional tests of beryllium specimens in contact with Inconel and molten sodium were made in the NACA dynamic-toroid corrosion-testing apparatus. These tests were of 300-hr duration and the sodium flow rate was 10 fps. After tests at 1100° and 1200°F, minor beryllium deposits were found on the Inconel. After the test at 1400°F, large deposits were found, but there was no penetration greater than 10 mils. The beryllium deposition varied considerably throughout the apparatus. (AEC Activity 4401.5)

ANP Metallurgy - Fabrication - Metallographic examination of high-conductivity radiator fins that were protected on the edges by aluminum bronzing indicated that no noticeable oxidation was present after 500 hr at 1500°F in air. It is therefore expected that this method of edge protection will be suitable for use with actual sodium-to-air radiators.

Satisfactory air and gas nozzles for the gas-fired sodium heater assembly were fabricated by brazing small-diameter wires together in suitable arrays. A radiator for the gas-fired heater loop with sufficient rigidity to withstand the bending necessary to fit into cylindrical sections was assembled. (AEC Activity 4401.5)

ANP Metallurgy - Mechanical Properties - In the program to develop high conductivity sodium-to-air heat exchangers, a series of creep and stress-rupture tests of type-310 stainless steel-clad copper (0.002-in. cladding on 0.004-in. OFHC copper) was completed at 1500°F in air. The results of these tests show that, for long-time exposures (1000 hr, approximately), stresses greater than 500 psi and less than 1000 psi do not give indication of brittleness in the core or oxidation due to clad failure. In all tests which failed by rupture, oxidation of the copper at the point of fracture was complete, and the copper which did not appear to be oxidized was brittle. It was also noted that when the strain in 2 1/2 in. was 10%, the copper was still ductile, while elongations of 20% produced brittleness.

A study of the alloys in the Ni-Mo system is being made to determine their workability and oxidation resistance. Tubes of 24% Mo-76% Ni were extruded, and sound sections of sufficient lengths to warrant redrawing were obtained. (AEC Activity 4401.5)

ANP Reactor Physics - Samples of $Li^7$, Na, and K were shipped to the MTR for cross section measurements. Sample calculations for determining the energy distribution of neutrons slowing down in an absorbing moderator were run successfully on the Oracle. (AEC Activity 4401.7)

ANP Shielding Research - A procedure was developed and tested for making a calorimetric power determination of the Tower Shielding Facility reactor. The procedure involves measurement of the bulk water temperature in the 12-ft-dia reactor tank. Sufficient stirring is used to keep the temperatures the same at the twelve thermocouples installed at various positions in the tank. Results consistent to within 1% were obtained for two determinations at different temperature ranges, and the indications are that the heat loss of the system is also on the order of 1% for temperature rises of 15°C above ambient.

In further investigations at the Bulk Shielding Facility of the visible light to be expected around a nuclear-powered airplane, the air-glow intensity appeared to be at a maximum at operational altitudes (~40,000 ft). It was also shown that the decay of the air-glow intensity after reactor shutdown followed that of the gamma-ray intensity within 2 or 3%. The attenuation in water of the radiation which causes the air glow is more nearly like the attenuation of gamma radiation than of neutrons.

Measurements at the Lid Tank Facility on GE-ANP helical air ducts have indicated that the fast-neutron dose at the end of an array of three ducts side-by-side was a factor of ~1.4 greater than the dose at the end of a single duct. However, the measurements were made in a low-flux region, and the statistics of the experiment were considered poor. The thermal-neutron measurements were ~70% higher at the end of the three-duct array. These indications of the interaction of adjacent ducts are of considerable importance to the air-cooled reactor projects. No adequate theory is available for prediction of this effect at present. An array of 35 ducts has been received and is being assembled for further measurements. (AEC Activity 4401.7)

ANP Fuel Recovery - In studies on the fluorination process for recovering uranium from ARE fuel, it was found that the contamination carried over with the uranium hexafluoride was mainly ruthenium and niobium. Presparging of molten ARE fuel with hydrogen fluoride prior to fluorination removed 95% of the niobium but none of the ruthenium. The corrosion rate of Inconel, Monel, and nickel containers, when hydrogen fluoride was passing through this type of mixture, was 0.01 mil/hr or less. (AEC Activity 4401.81)

GENERAL REACTOR RESEARCH

General Reactor Math - A multigroup, multiregion reactor calculation which allows self-shielding and hydrogen scattering was programmed for and "debugged" on the Univac. Except for part of the editing, this problem can be considered in a production state. Over 60 distinct calculations have been completed, some for package reactors and some for critical experiments. Each of these requires, on the average, about 20 minutes, which is roughly only half of the time required by the "Medusa" code used previously. (AEC Activity 4510)

Radioactive Waste Studies - In preliminary studies on the disposal of solvent extraction wastes containing aluminum nitrate, the practicability of storing the fission products in molten aluminum nitrate was investigated. $Al(NO_3)_3.9H_2O$ was found to be dehydrated at temperatures above 78°C, its melting point. The product redissolved readily when water was added, indicating that no degradation to the hydroxide had occurred. (AEC Activity 4582)

Instrument Development for Reactors - A device for plotting isodose curves directly was developed for the Tower Shielding Facility. The instrument is completely remote controlled and has a high degree of flexibility, e.g. other types of curves, such as slant scans, can be made. The Automatic Isodose Plotter has greatly enhanced the speed, accuracy and efficiency of the Tower Shielding Facility for data taking and data handling. Isodose curves are plotted continuously with detector head speeds of approximately 6 in./min and with an accuracy of 1% of the count rate. The accuracy improves to a fraction of a percent at high count rates where statistics are better. A typical closed curve is completed in a few minutes whereas point-by-point methods require considerably more time.

This instrument generates isodose curves by driving a radiation detector head in a tank at constant speed but in a controlled direction along a path of some pre-selected value of constant radiation intensity. A simultaneous rectangular (X,Y) plot is made on a Variplotter "slaved" to the position of the detector head. Any two of the three rectangular tank dimensions are selected for an isodose plot.

The device is essentially a null-balance system in that if the actual count rate (I) is different from the pre-set value ($I_o$), the direction of the detector movement is changed until the difference ($I - I_o$) is reduced to zero. The detector head is positioned near the desired isodose contour and the plotter will locate the isodose line automatically with plot speed and turning rate adjustable during the course of plotting.

## PROGRAM 5000 - PHYSICAL RESEARCH

Reactor Operations - The operation of the graphite reactor (3700 kw) was according to schedule except for a bearing failure on a 900-hp fan motor, which had to be replaced, and minor electrical repair work as a result of lightning damage to motor control circuits. The operation of the LITR (3000 kw) was normal, except for high "down time" caused by insertion of loop-test equipment and other research work.

A new intermittently-operating servo-controller was installed on the No. 3 shim rod of the LITR to test this type of controller as compared with the continuous servo now used. The operation has been satisfactory, except that the servo-mechanism does not give quite as steady a power control as the continuously-operating type.

The Oak Ridge Research Reactor (ORR) - The history of the ORR Project began in the early part of 1950 when it was determined that a permanent reactor facility was required at ORNL in order to carry out successfully the various research programs then being planned. The reactor selected was a simplified version of the MTR, to operate at a power level of 5 megawatts, requiring a minimum of design and development, and to cost an estimated 2.8 million dollars. Preliminary design of the ORR has been supported by the AEC for the past three years, during which period the facility has undergone a number of design changes as required by the shift in emphasis in the experimental programs. The necessity for making changes in the design in order to better fit the requirements of the Laboratory has resulted in a realization that one of the primary requirements for a new reactor facility at ORNL is that it be readily adaptable to a wide range of types of experiments.

The proposed facility is to be housed in a mill type building about 100 feet square. In addition to the reactor and experimental area near the reactor the building houses the water pumping system for reactor cooling, the control room, offices and instrument space for reactor operations and six work rooms which may be used as laboratories or offices. The reactor proper is located in the center section of three aluminum tank sections about 5 feet in diameter, the total tank height being 15 feet. This reactor enclosure is placed in (near one end) a pool of demineralized water 10 feet wide, 60 feet long and 28 feet deep, the concrete walls of the pool and the water serving as shielding. The shield is penetrated by six 6-in. diameter beam holes for research type experiments and two large facilities, each about five and one-half feet in diameter for engineering type experiments. Access for experiments within the fuel and reflector region is from above, through the water shield. Removable gates divide the pool into three sections, one section containing the reactor and two sections for storage areas.

The preliminary proposal (ORNL-54-3-49) has been submitted to the AEC and approval of the selection of the McPherson Company of Greenville, South Carolina as a Carbide sub-contractor for Architect-Engineer work has been received; preliminary drawings and specifications have been transmitted; thus allowing the A-E to begin design work on the building and structure.

It is proposed that a lump sum construction contract be let for the building, reactor structure and cooling system. Design of the reactor, reactor tanks, control system and cooling system is being done by ORNL and present planning is for ORNL construction and installation of the reactor unit and reactor control system.

The following schedule has been set up to allow reasonable time for the specified phases of this project without sacrificing economy by rushing or delaying the progress of the work.

SCHEDULE

| Description | Completion Date |
|---|---|
| Preliminary Drawings and Specifications to A-E | 9/15/54 |
| A-E Finishes Design | 12/15/54 |
| Let Construction Contract | 2/1/55 |
| Reactor Drawings | 3/1/55 |
| Construction Finished | 6/1/56 |
| Critical | 8/1/56 |

ISOTOPE PRODUCTION

Radioisotope Production - Radioisotope production has continued at a higher level than is usual during the summer. A notably large amount of purified $Sr^{90}$ (200 curies) was made recently; starting material was Purex waste from the Metal Recovery Plant. (AEC Activity 5111)

Radioisotope Research - It was necessary to continue test runs on the new $I^{131}$ plant for a longer period than previously expected in order to adjust equipment. Getting the many remote radiation ionization chambers to operate properly has caused most of the difficulty. The test runs have indicated that, in general, the unit is satisfactory.

Fission-product $Cs^{137}$, from which the recently-reported 1540-curie teletherapy source was made, was analyzed for isotopic composition, with the following results: $Cs^{133}$, 43.37%; $Cs^{134}$, 0.05%; $Cs^{135}$, 20.11%; $Cs^{137}$, 36.53%. Only traces of Rb and K were found. By using the known specific activity of the material and the isotopic composition, the half-life of $Cs^{137}$ was calculated to be about 30 years. It was noted that a smaller percentage of $Cs^{135}$ was present in the mixture than would be calculated from published fission yields.

It was determined that solutions suitable for feed to the cesium alum process could be obtained by alkaline peroxide digestion of Hanford ferrocyanide process sludge; the sludge is a product of a process to scavenge cesium from Hanford wastes. (AEC Activity 5131)

PHYSICS

Recoil Spectrometry - The recoils resulting from neutrino emission from the electron-capture-decaying radioisotope $A^{37}$ were observed under magnetic analysis. A source volume in the apparatus contains the radioactive gas under a total pressure (with impurities) of less than $10^{-5}$ mm Hg. Recoils emerging from this volume can be accelerated by a few volts, if desired, and then are subjected to 96.5-degree magnetic deflection before being further accelerated by 5000 volts to enable them to be counted with an electron

multiplier. Differential pumping reduces the background arising from local decays near the detector. Since the apparatus acts as a mass spectrometer, the mass assignment 37 is certain. Charge states 2, 3 and 4 were observed; they are known to result from Auger emission. Ions of charge 2 and 4 are about half as abundant as those of charge 3. Singly charged ions were sought but not found; apparently this peak is quite weak. The ions are predicted to have a recoil energy of 9.6 ev, on the basis of the known energy available for the radioactive transition (816 kev) and zero rest mass for the neutrino, but the observed peaks indicate an energy of 11 ev. Experimental reasons for this discrepancy are being investigated. (AEC Activity 5200)

Neutron Diffraction - The atomic magnetic moment distribution within a series of disordered binary alloys of the Co-Cr, Fe-Cr, and Ni-Fe systems was investigated by neutron diffraction. An analysis of the ferromagnetic disorder scattering obtained on the diffraction pattern combined with results from magnetic measurements has given information regarding the individual atomic magnetic moments of the elements in the alloys. Such information is essential to the complete understanding of ferromagnetism and cannot be obtained from the usual magnetic experiments which are invariably representative of the macroscopic average over the whole component system. In all three alloy systems, it was found that the magnetic moments associated with the two elements in the alloys were different and that both magnetic moments varied regularly with changes in atomic composition. Moreover, the magnetic form factor associated with the scattering was not noticeably different for the various alloys and agreed quite satisfactorily with the theoretical calculations for the 3d-shell by Steinberger and Wick. (AEC Activity 5200)

High Voltage Program - Measurements were made of the absolute thick and thin target yields of the nuclear $\gamma$-rays produced when $Ta^{181}$ was bombarded by protons of energy 1.5 to 5.0 Mev. The absolute accuracy was 10 to 20% while the relative accuracy was about 5%. It appears that the present theory of electric excitation is not in complete agreement with experiment. For example, the thin target yield of the 303-kev $\gamma$-ray in tantalum (Ta) was increased by a factor of 18 as the proton energy was changed from 2.0 to 4.8 Mev, whereas the theory predicted a factor of 14.

More serious discrepancies with the present theory were found in the angular distributions of the $\gamma$-rays. The anisotropy of the 303-kev $\gamma$-ray in tantalum for 4.0-Mev protons on a thick tantalum target was found to be 18% lower than the theoretical values. The 330- and 354-kev $\gamma$-rays in $Pt^{194}$ and $Pt^{196}$ were particularly suitable for comparison with the theory since these have large anisotropies characteristic of 0-2-0 transitions. Angular distribution measurements of these $\gamma$-rays for thick targets at several proton energies were made. The anisotropy changed from 46% at 2.0 Mev to 26% at 5.0 Mev, whereas the theory predicted about 42% and 35%, respectively.

The neutron thresholds from the proton bombardment of $N^{15}$, $Mg^{26}$, $Cu^{63}$, and $Cu^{65}$ were measured to be 3.784, 5.074, 4.224, and 2.172 Mev $\pm$ 0.2% respectively.

The thin $N^{15}$ targets were prepared by using $HNO_3$ enriched to 64.5 at. % $N^{15}$, obtained from Eastman Kodak Co. The $Cu^{63}$ targets were prepared from CuO enriched to 99.1% $Cu^{63}$, obtained from the Stable Isotopes Division. The $Mg^{26}$ and $Cu^{65}$ targets were thin metallic foils of the natural isotopic mixture. (AEC Activity 5200)

Theoretical Physics - Previously reported calculations on electron scattering by nuclei at high energies are nearly complete. The Oracle code was completed and tested by calculating angular distributions for a simple nuclear model. The results are completely in agreement with those expected and further calculations on more interesting models will be completed very rapidly.

An Oracle code is being prepared for the interpretation of scattering experiments. The code will search for that choice of scattering matrix elements which yields the best fit to a given angular distribution.

Calculations are underway on orbits in fixed frequency cyclotrons of the Thomas type. It is planned to conduct a search by an Oracle code for the magnetic field shapes which appear to be most favorable from the point of view of particle energy achieved, intensity, and cost. (AEC Activity 5200)

Interaction of Radiation and Matter - The measurements of the cross section for electron loss by fast (20 to 250 kev) neutral hydrogen atoms passing through various gases were improved and extended. Present values for the cross section at the broad maximum and the energy at which it occurs are as follows: in hydrogen, $8.15 \times 10^{-17}$ $cm^2$ at 34 kev; in nitrogen, $24.3 \times 10^{-17}$ $cm^2$ at 55 kev; in oxygen, $21.2 \times 10^{-17}$ $cm^2$ at 55 kev; in neon, $20.0 \times 19^{-17}$ $cm^2$ at 65 kev; and in argon, $45.0 \times 10^{-17}$ $cm^2$ at 70 kev. The cross section for helium is decreasing throughout the energy range studied, from a value of $13.3 \times 10^{-17}$ $cm^2$ at 20 kev.

These measurements are currently being extended to lower energies. Also, the cross section for electron capture by protons passing through the various gases is being measured. (AEC Activity 5200)

CHEMISTRY

Chemical Separation of Isotopes - Experimental results on a gas-liquid system for the concentration of boron isotopes were obtained. The system utilizes the exchange reaction:

$$B^{10}F_3(gas) + B^{11}F_3.anisole \rightleftharpoons B^{11}F_3(gas) + B^{10}F_3.anisole$$

In this proposed system boron trifluoride gas is passed countercurrent to the liquid boron trifluoride-anisole complex in an exchange column. Reflux is accomplished at the bottom of the column by heating the complex to decompose it and drive off the $BF_3$ which returns up the column. The anisole is recycled to the other end of the system where it is used to absorb the $BF_3$ to accomplish the top reflux.

The separation factor or equilibrium constant for this exchange reaction was evaluated in a five-stage run. Equimolar amounts of complex and boron trifluoride were equilibrated, separated, and half the boron trifluoride converted to complex. The remaining boron trifluoride was then equilibrated with the new complex. In this way, five stages were processed and samples of boron trifluoride from each stage analyzed isotopically. Analysis of the data yields a single-stage separation factor of $1.032 \pm 0.011$ at the 95% confidence level. The $B^{11}$ concentrates in the gas phase. This is an effective separation factor and may be smaller than the true equilibrium constant if uncomplexed boron trifluoride dissolves in the liquid complex to any extent. Preliminary experiments show that boron trifluoride-anisole complex can be reasonably quantitatively decomposed by heating to drive off the boron trifluoride gas. (AEC Activity 5361)

Instrumentation for Chemical Research - In order to count spontaneous fissions in $Pu^{240}$, a fission counter with exceptional alpha background tolerance was designed and built. The high tolerance against alpha particles was obtained by using double delay line differentiation to minimize the effects of pile-up. This permits operation at lower bias settings to give a higher fission count yield for a given alpha count background, or for the same yield a higher alpha background can be tolerated. The instrument has not been in use long enough to definitely evaluate the improvement. (AEC Activity 5361)

Hot Laboratory Research - The special multicurie-lots of 9.2-hr xenon-135, used for velocity selector cross section studies, were assayed by isotopic dilution and mass analysis, and by absolute beta counting of the cesium-135 daughter. Previously these samples had been assumed to differ by a factor of two, one having been estimated at 500 and the other at approximately 1000 curies. The second sample actually contained only about 10% more xenon or about 550 curies. Repeated isotopic analyses at different mass ratios have reduced the limit of error in this determination from 6% to 2%. (AEC Activity 5361)

Chemistry of Corrosion - It was demonstrated that the corrosion of cast iron in distilled water at 100°C and in contact with air can be inhibited by 50 ppm of technetium as the pertechnetate. Not only was a higher concentration required than is necessary for the inhibition of SAE 1010 steel, but a much larger amount of reduced technetium remained on the active cast iron surface. This pick-up of activity was reduced by a factor of approximately 10 when the iron was first heated with $10^{-3}$ f potassium chromate. The experiment has continued for seven weeks without significant corrosion, and the beta activity has not increased. (AEC Activity 5361)

Ion Exchange Technology - Demonstration runs with synthetic solutions in a 2-in.-diam. continuous ion exchange contactor, using IRA-400 resin, showed that both sulfuric acid and sodium carbonate ore leach solutions can be successfully processed by this method. The uranium was concentrated by factors of 6.5 and 11.0 with yields of 99.6 and 99.7%, respectively, for the acid and carbonate systems.

In limited studies on the separation of rubidium, which has possible uses in reactor technology, from potassium and cesium, the separation factors for rubidium from potassium were determined to be 1.10 in both the 1-M ammonium fluoride--Dowex 50 and the 0.5-M acetate--Cr-61 cation exchange membrane (electromigration) systems. The factors for separation of rubidium from potassium and from cesium in the 0.5-M ammonium carbonate--Amberlite IR-105 resin system were 1.35 and 3.0, respectively.

The feasibility of producing, in an electrodialysis cell, acid-deficient aluminum nitrate solution for use as scrub solution in solvent extraction processes was demonstrated in a 100-hr continuous run. A cost survey showed that material could be prepared in this way at a saving of $0.55 to $0.95 per pound of aluminum processed, compared with purchasing the commercial product. (AEC Activity 5361)

## OTHER PHYSICAL RESEARCH PROJECTS

The Oracle - The magnetic tape auxiliary memory unit was received at ORNL on July 5. Preparatory steps for the installation were already well under way and the unit was placed in position in the Oracle room. Construction of the control circuitry is being done by ORNL and is now nearly complete.

During June and July, a total of 393 hours of computation was performed with an overall efficiency of 92%. This figure represents the percentage of scheduled time actually used for computations and does not include the scheduled time for preventive maintenance. The Oracle went on second shift operation starting June 28. A third shift is tentatively planned for October first. (AEC Activity 5511)

Instrument Development - A one-hundred-channel pulse height analyzer of the Hutchinson and Scarrott type is being developed. Differing from the conventional voltage discriminator type of pulse analyzer, this analyzer converts pulse-height into time and stores the pulse-height information, in time, in a mercury delay line memory unit. The analyzer can be broken down into four basic sections: the input section, which amplifies and stretches the voltage pulses from the detector; the time discriminator, which converts the stretched pulses into proportional-time by comparing the stretched pulses to a sweep-rising linearly in time; the memory unit, which stores the pulse-height information; and the display, which presents the pulse-height information on the face of a cathode ray tube.

Since sound transmissions are much slower than electrical transmissions, a large time delay can be obtained with a mercury delay line. Pulse-height information, in the form of pulse sequences, are fed into the delay line, delayed and then fed back into the delay line. When new information is to be added, the pulse sequences are changed accordingly. By using this technique of storage, a great deal of information can be stored with relatively few vacuum tubes. At the present time the time discriminator, memory unit, and display are completed.

## BIOLOGY

Cytogenetics - Oxygen, by itself, will break chromosomes and cause chromosomal aberrations in pollen grains of the plant *Tradescantia*; the effect is indistinguishable from that caused by radiation. Earlier work suggested that the oxygen did not cause chromosome breakage directly, but acted indirectly by stimulating cellular reactions, respiratory enzymes perhaps, which in turn caused the breakage. This idea was confirmed by experiments in which known enzyme inhibitors--cyanide, carbon monoxide, and cold temperatures--were tested for their effect on the oxygen reaction; all strongly inhibited the breakage of chromosomes by oxygen. These same factors have no effect, or a different effect, on radiation-induced breakage. The results demonstrate that, in an oxygen atmosphere, the chromosomal breakage is induced by a physiological reaction of the cells themselves.

In order to obtain the isolated cells of grasshopper embryos needed for certain types of mitotic studies, embryos must be subjected to trypsin in the absence of calcium. In view of the fact that calcium is known to be important for normal cell activity, an experiment was designed to determine the effects of calcium deficiency on mitotic behavior of cells. It was found that the duration of the mid-mitotic phases is 25% longer in the absence than in the presence of calcium and that this retardation is due entirely to a slow development of the spindle at prometaphase and metaphase.

Some years ago it was reported that *Paramecium aurelia* was less sensitive to the induction of genetic changes by ionizing radiation when treated in a period of about one hour before visible division of the cytoplasm of the cell than when treated at other times. It has now been shown that this insensitive period includes the whole prophase stage in the division of the micronucleus. Whether it also includes the later metaphase and anaphase stages is not yet certain.

The form of the dose response is different from that of the sensitive period, which includes all or nearly all the interphase, the stage between divisions of the micronuclei. Thus the magnitude of the difference in sensitivity cannot be adequately represented by a single number. However, some appreciation of the very great difference can be given by stating that a dose of about 20,000 r is required during prophase to produce the same effect as 1,500 r during interphase. It is of interest that A. R. Whiting has shown that the prophase of the first meiotic division in the wasp, *Habrobracon*, is likewise very insensitive to the induction of genetic changes. The prophase of the mitotic division in *Paramecium* differs in many respects from the prophase of the first meiotic division so that it may be hoped that a comparison between the two will make possible a narrowing down of the possible causes of the insensitivity. It can already be stated that it is unlikely that the special features of meiosis (chromosome pairing, etc.) are involved. (AEC Activity 6400)

Microbiology - A previous report described attempts to fractionate the enzymes concerned with (a) succinate activation, (b) succinate decarboxylation to a $C_1$ fragment and propionyl-CoA, and (c) conversion of the $C_1$ fragment to $CO_2$. Ammonium sulfate fractionation gave increases in specific activity of about 3-fold with only a 10% recovery. Subsequent solvent fractionation proved to be unsuccessful; gel adsorption and elution methods showed some promise in removing extraneous protein, but great difficulty was encountered in eluting the active fractions.

Consequently, the recently developed technique of starch electrophoresis was investigated. The apparatus consists of a 1000-volt dc regulated power supply; and Tiselius-type platinum electrodes connected to the ends of a potato starch column which has been equilibrated with a buffer. Crude cell extracts are dialyzed against buffer and placed near the cathode end of the column. The column is maintained at 5°C, while a 600-volt potential is applied through the column for about four hours. At the end of this time, starch sections along the length of the column are cut out, protein eluted and prepared for testing of enzyme activity.

As yet it has not been possible to move the active fractions in quite as narrow bonds as one can do with partially purified preparations or mixtures of pure proteins. It has been possible, however, to achieve a better purification than with ammonium sulfate fractionation, while recovering essentially all of the starting activity. The nearly complete recovery of the starting activity is one of the main advantages of the starch electrophoretic method, which gives good possibility of obtaining far higher enzyme purifications than any of the other methods so far tried. (AEC Activity 6400)

Radiation Protection - Marked progress was made in the last two months in studies on the mechanism of protection of *Escherichia coli* from the lethal effects of ionizing radiation by cysteamine (β-mercaptoethylamine). Data were accumulated which indicate that cysteamine gives remarkable radiation resistance to *E. coli* (DRF = 12 as comared to BAL:DRF = 5, or β-mercaptoethanol: DRF = 8). Furthermore, it was shown that the greater part of the protection afforded by this compound is probably due to an interaction of cysteamine with the bacterial cell which leaves a much greater proportion of the cells able to recover from the effects of a given dose of radiation when supplied with certain nutrients or grown at a favorable temperature (18°C as opposed to 37°C). The nutrients required for recovery are found in yeast extract, beef broth, and other natural extracts. A chemically defined growth medium which promotes recovery of unprotected, irradiated cells will also support recovery of cysteamine-protected, irradiated cells. This medium contains, in addition to inorganic salts and glucose, an amino acid, glutamic acid; a purine, guanine; and a pyrimidine, uracil.

Studies are under way to determine the effect of the protective compounds, cysteamine and β-mercaptoethanol on the induction by radiation of reversions to the nonrequiring state of several mutant strains of *E. coli*, which require

specific growth supplements (adenine, tyrosine, proline, threonine, methionine). It was shown that β-mercaptoethanol is highly effective in reducing the reversion rate of several strains. Cysteamine, however, is ineffective in reducing the reversion rate when the cells are not supplied with the recovery factors mentioned above following irradiation.

Data from a previous report (ORNL-1733) established that partial recovery of Escherichia coli B/r from ionizing radiations (X and γ rays) can be brought about by the addition of glutamic or aspartic acid or glutamine to a synthetic medium. Since an amino acid requirement is present, it would seem fruitful to investigate the effect ionizing radiations have on transaminating enzymes. A decided difference in concentration of the enzyme transaminase was noted (evidenced by the formation of glutamic acid) between the nonirradiated particulate component fraction of E. coli B/r (ORNL-1497) and the irradiated one, the irradiated fraction forming much less glutamic acid as compared to the nonirradiated fraction.

A study of the residual growth of Escherichia coli auxotrophs on an unsupplemented minimal medium at several incubation temperatures is in progress. These studies are being conducted to determine if the reported temperature effect (ORNL-1614) on the induction of mutations by X rays can be accounted for by a temperature-dependent residual growth response. The present data on one of the auxotrophs, E. coli strain T83-8 (tyrosine$^-$) reveals a marked degree of residual growth by the survivors of a plated irradiated suspension. However, the residual growth at 37°C is equal to that obtained at 24°C although at the latter temperature maximum population is reached over a longer period of incubation. Thus, in this strain, increased residual growth at 24°C is not responsible for the increased number of induced mutations observed when incubated at 24°C as compared to incubation at 37°C for 48 hours following exposure. (AEC Activity 6400)

Biochemistry - In the continuing study of the relation of structure to activity in radiation-protective compounds, a new series of isothiouronium salts, related to β-mercaptoethylamine, were prepared. In addition, most of the previously reported compounds were tested for protective effects in C57BL mice subjected to 900 r total body X radiation. A new compound in the thiouronium series, S,B-aminoethylisothiouronium bromide HBr, proved to be at least as effective as β-mercaptoethylamine and appeared to be less toxic, raising the $LD_{50}$ from 750 r to 1150 r. Other derivatives (250 mg/kg) which did not decrease the radiation-induced mortality but enhanced the survival time include N-acetyl and N,S-diacetyl-β-mercaptoethylamine, bis(β-aminoethyl) disulfide and S,S-ethylenediisothiouronium dibromide. Little or no protection was furnished by β-carboxyethylisothiouronium bromide, S,S-methylenediisothiouronium dibromide, S,S-ethyldiisothiouronium dibromide, and 2-mercaptothiazoline. These preliminary results seem to indicate the essential nature of the free amino group for protective activity in β-mercaptoethylamine and its derivatives. It may well be that the structure of β-mercaptoethylamine is unique among protective agents having sulfhydryl groups. (AEC Activity 6400)

Plant Biochemistry - Green plants and chloroplasts have previously been shown to emit light for a short time after illumination. Potassium ferricyanide, which is a strong oxidizing agent, was found to suppress this light emission in chloroplasts. The intact barley plant emits more delayed light in a $CO_2$-free atmosphere than at high concentrations of $CO_2$. Exposure of the plant to carbon monoxide prolongs the period of light emission. Since carbon monoxide is known to inhibit $CO_2$ fixation and exposure to carbon monoxide stimulates light emission, it is believed that the carbon ioxide fixing process is in competition with the production of delayed light. (AEC Activity 6400)

Biophysics - *Tradescantia* inflorescences and dry pollen were exposed to fast neutrons in the facility at the 86-Inch Cyclotron. Dose curves for 4-day chromosome aberrations in the microspore division, as well as chromatid aberrations in the pollen-tube division, were obtained. The pollen experiments also included comparison control treatments (200 r) by 250-kv x rays and by cobalt $\gamma$ rays. These studies, based on recent neutron dose measurements in the cyclotron facility, indicate a relative biological effectiveness for fast neutrons relative to cobalt $\gamma$ rays of approximately 10 for 4-day chromosome aberrations and 8 for pollen-tube chromatid aberrations. (AEC Activity 6400)

Pathology and Physiology - In a study of the toxic and radiation effects of radioactive sulfate, rats were given a single subcutaneous injection of $Na_2S^{35}O_4$ in doses ranging from 1 to 32 mC/rat. The following blood cell counts were made at 5, 7, 10, 14, 20, and 27 days after administration of the sulfate: erythrocyte, platelet, total white blood cell and a differential white blood cell count in which the percentages of lymphocytes, monocytes, and polycytes were observed. No significant difference in any of these counts was apparent at any of the sampling times. Two of the three rats in each group were sacrificed and autopsied 27 days following injection of the sulfate. Histological sections of the following organs were studied: lymph nodes, thymus, liver, spleen, kidney, adrenal, testis, intentine, skin, and bone marrow. No effects were observed in either the gross or histological material.

Experiments in progress suggest a relation between the throid-pituitary axis and the susceptibility of AK-strain mice to transplants of lymphoid tissue from leukemic mice of the same strain. A series of radiothyroidectomized mice receiving thyrotrophic hormone and thyroxine injections proved to be more susceptible to transplanted tumor tissue (83% deaths after 2 weeks) than untreated controls (20% mortality), thyroidectomized-thyroxine injected (50% mortality), and uninjected thyroidectomized mice (20% mortality). It remains to establish the nature of the relation between the hormones involved and the susceptibility to leukemia.

Separation of basic cell nuclear proteins by ion-exchange methods was attempted and the suitability of Linde "molecular sieves" for the purpose was tested with favorable preliminary results. Improvements in technique were

made for the detection of lithium in autoradiograms produced by slow neutron exposure of material enriched in $Li^6$. Observations were made on the histology of the rudimentary eye in Gyrinophilus palucus, a rare cave salamander recently discovered in this locality. Synthesis of acetylcholine at a low level by acetone powders of human red cells was finally confirmed. This elusive effect was established by the use of acetyl coenzyme-A as the acetate donor. (AEC Activity 6400)

Enzyme Chemistry - Studies on substances which influence the bioluminescence of extracts of Achromobacter fischeri revealed that cytochrome-c is a moderately effective inhibitor of light production. The light-producing system is known to require reduced diphosphopyridine nucleotide and an enzyme to transfer hydrogen from this compound to riboflavin phosphate, in addition to bacterial luciferase. The results with cytochrome-c are interpreted as suggesting that the bacterial extracts contained Slater's factor which competes for energy by oxidizing the reduced flavin through cytochrome-c and cytochrome oxidase without concommitant light production. In support of this hypothesis it was found that 2-methyl-1,4-naphthoquinone is rapidly reduced by reduced diphosphopyridine nucleotide in the presence of bacterial extract and the flavin phosphate. The presence of the quinone reduced the light output of the complete system but did not abolish it. The 2,3-dimercaptopropanol restored light production which had been depressed either by addition of the napthoquinone or by cytochrome-c. These results point the way to a relatively complete description of the luminescent system and open the way to the use of it for the elucidation of other metabolic pathways.

The decay curve for the delayed light from green plants was originally studied from 0.25 seconds to 10.0 seconds. By the use of a rotating sector phosphoroscope this study was extended to periods down to 0.002 seconds. By using very large volumes of suspensions of Chlorella the decay was followed for as long as 100 minutes. Over this wide range, the delayed light falls off approximately as 1/t. (AEC Activity 6400)

## RADIOISOTOPE SALES AND COSTS

| Type of Transaction | June | FY to Date |
|---|---|---|
| Domestic Sales | $ 100,072 | $ 933,920*** |
| Foreign Sales | 4,367 | 53,133 |
| Project-Cash Sales | 21,790 | 198,016 |
| Project-Transfer Credits | 1,845 | 6,128 |
| Technical Cooperation Program Credits | -0- | 7,957 |
| Plant Credits | 40,820 | 148,194 |
| Civilian Defense Credits | -0- | 655 |
| Cancer Program Credits | 19,429 | 238,170 |
| *Miscellaneous Income | 7 | 344 |
| Total Income | $ 188,330 | $ 1,586,517 |
| **Income - No production costs incurred Subtract from Total Income | $ 11,209 | $ 59,458 |
| Net Radioisotope Income | $ 177,121 | $ 1,527,059 |
| Radioisotope Costs | $ 233,917 | $ 1,329,983**** |
| Radioisotope Shipments | 1,184 | 12,573 |

* Miscellaneous Income - $D_2O$, Freight, Missing parts, TCP.
** Income from $H^3$, $He^3$, $B^{10}$, and miscellaneous items in excess of handling cost.
*** Includes additional $ 275 which was omitted in May report.
**** Includes additional $ 45 which was omitted in May report.

## GROSS OPERATING COSTS

| | Cost for June | FY 1954 Cost to Date |
|---|---|---|
| Programmatic Operating Cost - Net | $ 2,791,491 | $ 29,111,627 |
| Plant and Equipment Cost | 494,223 | 3,559,267 |
| Construction Program "H" | 71,411 | 652,392 |
| Work for Other Parties - Transfers | 43,078 | 518,477 |
| Inventory Changes | 44,558* | 365,426* |
| Reimbursable Work for Other Parties | 185,292 | 1,787,149 |
| Deferred Charges | 4,035* | 3,223 |
| Total Laboratory Cost - Net | $ 3,536,902 | $ 35,266,709 |
| Estimated Cost for Next Month - Net | $ 3,250,000 | $ 3,250,000 |

*Credit

[redacted]

PERSONNEL SUMMARY

| | Number of Employees July, 1954 | New Hires July | Terminations July |
|---|---|---|---|
| Administration | 63 | 0 | 1 |
| Operations* | 122 | 2 | 0 |
| Engineering, Shops and Mechanical | 828 | 10 | 11 |
| Laboratory and Research | 1924 | 31 | 10 |
| Protection | 148 | 1 | 0 |
| Service | 385 | 8 | 6 |
| | 3470 | 48 | 28 |

*Includes Electrical Distribution and Steam Plant as well as the Operations Division.

A total of 715 Laboratory personnel are located in the Y-12 Area.

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Previous reports in this series:

| | |
|---|---|
| July 1953 | ORNL-1600 |
| August 1953 | ORNL-1612 |
| September 1953 | ORNL-1622 |
| October 1953 | ORNL-1643 |
| November 1953 | ORNL-1651 |
| December 1953 | ORNL-1665 |
| January 1954 | ORNL-1676 |
| February 1954 | ORNL-1695 |
| March 1954 | ORNL-1703 |
| April 1954 | ORNL-1719 |
| May 1954 | ORNL-1733 |
| June 1954 | ORNL-1748 |

[redacted]