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OAK RIDGE NATIONAL LABORATORY  
STATUS AND PROGRESS REPORT  
JANUARY 1955

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OAK RIDGE NATIONAL LABORATORY  
STATUS AND PROGRESS REPORT

January, 1955

F. T. Howard

and

W. H. Sullivan

Date Issued: FEB 4 1955

OAK RIDGE NATIONAL LABORATORY  
Operated by  
CARBIDE AND CARBON CHEMICALS COMPANY  
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OAK RIDGE NATIONAL LABORATORY

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January, 1955

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

January, 1955

This status and progress report presents material on approximately one-half the Laboratory's program, which is covered, with some exceptions, on a bimonthly schedule.

PROGRAM 2000 - SOURCE AND FISSIONABLE MATERIALS

Waste Metal Recovery - The Metal Recovery Plant was modified for use in recovering 75 tons of uranium and 10 kg of plutonium from reactor elements of the Brookhaven and the ORNL graphite reactors.

A preliminary proposal for expansion of the Metal Recovery Plant was presented to the AEC. In this facility 100 tons per year of highly radioactive Chalk River irradiated fuel will be processed by the Scrup method, beginning in FY-1958. A new, heavily shielded processing cell and auxiliary areas are included in the proposal.

The americium commitment to UCRL at Livermore was completed with a shipment on December 3, 1954, of 4.54 g recovered from the Hanford metallurgical waste; 50 mg was shipped to Savannah River. Approximately 370 mg of purified americium is now on hand; no lanthanum is detectable by either neutron activation analysis or spectroscopic analysis, and there is less than 0.5 mg of plutonium per gram of americium. The major impurity is yttrium (about 10%), and there are small amounts of nearly all the medium-weight and heavy rare earths (total of less than 1%). The americium was separated from lanthanum by citrate elution (ORNL-1824), concentrated by hydroxide precipitation, and further purified by dissolving the hydroxide in excess HCl and passing it through an anion-exchange resin column. Another 1.3 g of americium was separated from lanthanum by the citrate elution, but has not been further purified and concentrated. (AEC Activity 2344)

Excer Program - A preliminary construction request was prepared for a pilot plant to produce  $UO_3$  from uranyl nitrate solution by the Moving Bed process. The estimated cost of such a plant with a capacity of 1 ton of uranium per day is \$78,000.

In further development work on the Moving Bed process, pellets containing 19 mole % uranyl nitrate ( $\sim 30$  wt %) were prepared from molten uranyl nitrate and uranium trioxide at a rate of 1200 lb/hr. Denitration of these pellets at a rate of 25 lb/hr was satisfactorily demonstrated in a moving bed 4 in. in diameter and 4 ft deep. A hot wall was used as the source of heat and the outlet bed temperature was  $355^\circ C$ . The final product contained about 0.5 wt

## PROGRAM 2000 - SOURCE AND FISSIONABLE MATERIALS (Continued)

% nitrate. The thermal conductivity of the bed during denitration was  $0.1 \pm 0.03$  Btu/(ft x hr x °F).

UF<sub>6</sub> was produced by oxidation of UF<sub>4</sub> pellets in air at 800°C in a vertical moving bed reactor by a reaction yielding UO<sub>2</sub>F<sub>2</sub> and UF<sub>6</sub>. This method avoids the use of expensive elemental fluorine in the production of UF<sub>6</sub>. The reaction was easily controlled. A 50% yield of UF<sub>6</sub> was obtained, based on the available oxygen. The UO<sub>2</sub>F<sub>2</sub> by-product remained in the pellet form and could be recycled to the reductor-hydrofluorinator. (AEC Activity 2602)

## PROGRAM 4000 - REACTOR DEVELOPMENT

### HOMOGENEOUS REACTOR PROJECT

HR Design - Construction drawings were issued for most of the items of equipment for the HRT low pressure core and blanket system. Fabrication of the zirconium core tank is nearing completion, and drawings were approved so that construction of the pressure vessel can be started at the Newport News Shipbuilding and Dry Dock Company. Work on the equipment and piping layouts for both the core and blanket systems is approximately 50% complete. Emphasis is now being placed on locating and detailing the penetrations through the shield wall. The analysis of piping stresses in the high pressure systems was completed except for checking the final layouts. Drawings for the steam system were reviewed for final revisions.

Design studies for a 450 Mw homogeneous reactor are being continued. Most economical operating conditions were established for the reactor, based on present cost information. (AEC Activity 4109.1)

Homogeneous Reactor Test - The final welds are being made on the reactor shield tank for the HRT. The completed tank will be filled with water and tested for leaks through the seam welds at the end of January. ORNL craft forces completed the concrete and structural work on the control room area, and installation of electrical equipment will begin in February. In the shops, two high pressure feed-pump heads were completed, and another is ready for welding; and five cold-trap assemblies were completed, except for the final closure welding. (AEC Activity 4109.1)

## PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

HR Math and Computation - An Oracle code has been completed which performs safety calculations for homogeneous reactors consisting of a core only. The kinetics of the core system are described by four simultaneous first order differential equations. The code uses the Range-Kutta method of solution and calculates maximum pressure and maximum power within the core for arbitrary values of nine parameters. (AEC Activity 4109.2)

HRP Chemistry--Radiation Studies - Radiation corrosion experiments with small rocking autoclaves in the LITR at 250, 275, and 280°C indicate a positive temperature coefficient of approximately 0.2 mils per year per degree centigrade for the corrosion of Zircaloy-2 by a solution 0.16 m in uranyl sulfate, 0.01-0.02 m in copper sulfate, and 0.04 m in sulfuric acid. The rates observed at 250 and 280°C were about 6.4 and 12.4 mpy, respectively.

It was observed that the copper used as a recombination catalyst is slowly precipitated from solution during in-pile experiments with Zircaloy-2. Loss of copper in these experiments varied between 20% and 60%. Calculation of the loss of copper from equilibrium pressure data was found to agree with the results of solution analysis at the end of the experiments.

One in-pile experiment is now in progress to determine the rate at which a titanium bomb is corroded by the uranyl sulfate solution listed above. The results obtained thus far indicate a corrosion rate of 2 mpy, or less. The fission power density in this experiment, as in the corresponding 250°C experiment on Zircaloy-2 is approximately 6 watts/ml at a LITR power of 3 Mw.

A method was developed for stripping corrosion films from irradiated Zircaloy-2 pins. It consists of dehydrating the film by washing with acetone and air drying, followed by a cathodic treatment in 5% sulfuric acid. (AEC Activity 4109.31)

HRP Dynamic Loop Tests - A series of tests recently completed showed that austenitic stainless steels, titanium, and zirconium have a high corrosion resistance to 0.06 m uranyl sulfate containing 0.006 m sulfuric acid at 320°C. Types 347, 304L, and 309SCb stainless steel showed corrosion rates of less than one mil per year, and the critical velocity (the velocity in excess of which a protective film does not form) was greater than 80 fps. Both titanium and zirconium had negligible corrosion rates.

The corrosion resistance of gold and platinum to uranyl sulfate solutions at all temperatures was shown to be very high; however, if the solution contained iodine or chlorine (added as potassium iodide or chloride) the attack on both metals was appreciable.

Three loops are being used for very long term tests. The circulating solution in all loops is 0.04 m uranyl sulfate, 0.006 m sulfuric acid, and 0.005 m cupric sulfate. One loop is at each of the following temperatures: 200, 250, and 300°C. Preliminary results indicate low corrosion rates in all three loops. (AEC Activity 4109.4)

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

HRP Laboratory Service Corrosion Tests - Thorium oxide slurries of concentration from 100 to 2300 g Th/kg water were circulated in type-347 stainless steel toroids at 26 fps relative velocity over the temperature range 200 to 300°C, and under an oxygen or inert gas atmosphere. The corrosion rates of type-347 stainless steel, titanium (75A), and Zircaloy-2 by slurries prepared from Ames, Lindsay batches No. 7 and No. 8, and an ORNL experimental pyrohydrolyzed-900°C-fired thorium oxide were generally less than 4 mpy. It was possible to distinguish some of these slurries on the basis of their corrosion rates of type-347 stainless steel under selected conditions.

Corrosion attack by simulated HRT maintenance pool water, with subsequent visibility loss and damage to materials, was mitigated by adding 50 ppm sodium chromate to the water. Sodium metasilicate (neutral) and sodium nitrite each render a less adequate degree of protection to carbon steel and other materials to be found in the pool. Flange bolts, easily rusted without inhibitor, were practically unattacked by alternate exposure (1 cycle per day) to chromate-inhibited water and moist air.

Fully hardened type 17-4PH and 17-7PH stainless steels exhibited blisters, cracks and pits when exposed to various simulated reactor environments, including boiling 0.02 M  $\text{UO}_2\text{SO}_4$  + 0.005 M  $\text{H}_2\text{SO}_4$  and boiling 1.3 M  $\text{UO}_2\text{SO}_4$ .

A satisfactory simple twin-strip stress-corrosion specimen was developed. (AEC Activity 4109.4)

HRP In-Pile Loop - Exposure of a second in-pile loop in the LITR was completed. This loop, designated FF, was equipped with Zircaloy-2 specimens and holders, and was designed to study the effect of irradiation on the corrosion of Zircaloy-2 by uranyl sulfate solution at 250°C. The solution composition used was 0.17 M  $\text{UO}_2\text{SO}_4$ , 0.04 M  $\text{H}_2\text{SO}_4$ , and 0.031 M  $\text{CuSO}_4$ . Exposure in the LITR was for a period of four weeks. The loop will now be dismantled and examined for corrosion. (AEC Activity 4109.4)

HRP Metallurgy - As previously reported, experimental welds involving several proposed design combinations were evaluated in order to select a procedure for the final girth-closure weld on the HRT pressure vessel. The subcontractor has now been authorized to proceed with weld-qualification tests on full thickness clad specimens taken from the actual plates which are to be used in the pressure vessel. The sequence of weld deposits is as follows: (1) type-347 weld metal in the root and groove up to a point about 1/16 in. below the carbon steel-stainless steel interface; (2) two layers of type-308L stainless steel weld metal over the type-347 weld metal to a point approximately 1/8 in. above the interface; (3) two layers of ingot iron weld metal over the 308L weld metal; and (4) type-7016 carbon steel electrodes for completion of the weld.

A fully austenitic modified type-347 welding wire containing added manganese was used successfully in a number of weld tests which followed the Heliarc

## PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

welding procedure of the HRP-2 specification. Experimental welds made on several tubular sections will be subjected to service testing in dynamic corrosion test loops.

Efforts to establish an acceptable testing procedure for evaluating the stress corrosion susceptibility of austenitic stainless steels in homogeneous reactor environments resulted in the construction of equipment designed for direct loading of small diameter wire specimens. This test procedure produces failure within a reasonable period of time in an environment known to produce stress-corrosion cracking. It will be used for a study of the stress-cracking propensity of homogeneous reactor environments.

Impact tests on Zircaloy-2 specimens from the first in-pile corrosion loop run were made and the results compared with results for specimens exposed to similar environments out-of-pile, as well as those for unexposed control specimens. No significant changes in transition temperature resulted from the in-pile exposure. (AEC Activity 4109.4)

HRP Radiation Damage - Irradiation of impact specimens of hot-rolled ASTM-A-212-B boiler plate, SAE-1040 steel in two heat treatment, and annealed type-301 stainless steel was completed in the HB-3 facility of the MTR and tests will be made when the specimens are received at ORNL.

An irradiation of a group of specimens was completed in an LB piece at the MTR, and the specimens are being returned to ORNL for testing. Included in this group are impact and tensile specimens of annealed types 301, 302, 302B, 304L, 305, 321, and 347 stainless steels. (AEC Activity 4109.4)

HR Instrumentation - Conduit layouts for electrical distribution in the HRT control area were completed. Re-evaluation of the procurement status shows an estimate of \$20,000 for equipment yet to be specified out of a revised total estimate of \$146,000.

The design was completed for the nuclear sleeve through which the chamber for measuring reactor power will be inserted into the HRT shield. This design incorporates lead for gamma shielding and water for moderation and shielding; the use of water permits access to the chamber for positioning and maintenance. (AEC Activity 4109.6)

## AIRCRAFT NUCLEAR PROPULSION PROJECT

ANP Experimental Engineering--Basic Developments - Two Inconel forced-circulation loops successfully circulated a zirconium-base fluoride mixture for over the scheduled 500 hr. Operation of one of the loops was terminated because of a pump bearing failure, and operation of the other was terminated because of a small leak. These loops operated for more than 600 hr at Reynolds numbers 10,000 and 15,000 and temperature differentials of 300°F and 200°F,

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

respectively. These loops are now being examined for evidences of corrosion and mass transfer. A small, 20-kw, resistance-heated, forced-circulation, Inconel loop was put in operation; it is circulating a zirconium-base fluoride mixture at a Reynolds number of 1000 and a temperature differential of 300°F. A similar gas-heated loop is operating successfully under the same conditions.

A loop for testing mass transfer in a sodium-beryllium-Inconel system was terminated following 1000 hr of scheduled continuous operation with highly turbulent flow, a peak temperature of 1300°F, and a temperature differential of 300°F. A similar loop is now operating in which the peak temperature is 1500°F. (AEC Activity 4401.1)

ANP Experimental Engineering--In-Pile Loop Components - A knurled-tube heat exchanger in which recirculated helium would be used to cool the fuel circulated in the loop was tested with air and found to meet design requirements. The helium system was found to be impractical, however, because no really suitable blower for recirculating the helium can be found. As a result, a double-walled, fuel-to-static sodium-to-air heat exchanger is again being proposed. The double wall is to prevent a salt leak into the air stream in the event of tube failure. One heat exchanger of this type was tested and found to meet requirements.

A high-temperature test of a horizontal-shaft turbine-type fuel pump was started. The peak temperature is 1400°F and over 500 hr of very successful operation has accumulated. (AEC Activity 4401.1)

ANP Math and Computation - The omission of a factor of 2 in the computation of the Teflon density was found to account for the disagreement between reflector-moderated reactor critical assembly calculations and experiments. A three-group calculation made with the correct Teflon density and rough group constants gave a critical mass that was in reasonable agreement with that obtained by experiment.

An ORACLE code for computing group constants for heavy media was written and partially tested. The code computes bare sphere fluxes that can then be used to weight cross sections.

A code which computes shell constants for the three-group, three-region code (ORNL report CF-55-1-76) was written but remains to be tested. (AEC Activity 4401.2)

ANP Reactor Chemistry - A stockpile of 5700 lb of purified fluoride mixtures has been accumulated and is available for experimental usage. Operation of the production facility was discontinued until further need arises.

Continued phase equilibrium research in the NaF-ZrF<sub>4</sub>-UF<sub>4</sub> ternary system disclosed the existence of the previously unreported compound 5NaF·3UF<sub>4</sub> and also led to an assignment of the temperature range of stability of various forms

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

of  $\text{Na}_2\text{ZrF}_6$ . The accumulated information on this ternary system appears to be adequate for mixtures of interest as reactor fuels. Study of this system will, accordingly, be discontinued in the near future.

Repeated experimentation shows that in nickel equipment only 50 to 70% of the  $\text{UF}_4$  dissolved in  $\text{NaF-LiF}$  or  $\text{NaF-KF-LiF}$  mixtures can be reduced to  $\text{UF}_3$  by metallic uranium. When pure  $\text{UF}_3$  is added to such mixtures it apparently disproportionates to  $\text{UF}_4$  and uranium metal; the ratio of  $\text{U}^{3+}$  to  $\text{U}^{3+} + \text{U}^{4+}$  obtained agrees rather well (0.5 to 0.7) with values obtained in the attempted reduction.

The rapid electrolytic purification of a  $\text{UF}_4$ -bearing melt and a partial conversion of  $\text{UF}_4$  to  $\text{UF}_3$  was demonstrated on a 3-kg scale. Graphite electrodes were employed, and a high cathode current density (3 amp/cm<sup>2</sup>) was used to obtain a cathode deposit of  $\text{UF}_3$ . The current was then reversed to ensure fast and thorough dissolution of the  $\text{UF}_3$  into the melt. Some of the minor disadvantages were the failure to obtain an adherent cathode deposit of iron and nickel and the appearance of a small amount of graphite scum in the reactor heel.

The hydrofluorination-hydrogenation treatment previously demonstrated for purification of  $\text{ZrF}_4$ -bearing mixtures was satisfactorily applied to  $\text{BeF}_2$ -bearing systems. It appears that stripping of HF by sparging with  $\text{H}_2$  is more rapid when the  $\text{BeF}_2$  mixtures are treated. (AEC Activity 4401.5)

ANP Corrosion Research - Metallographic examination was completed on seven thermal-convection loops in which alkali-metal-base fluoride mixtures containing  $\text{UF}_3$  were circulated. The total uranium content of the fluoride mixture was 10 wt %, and the  $\text{UF}_3$  content varied from 5.3 to 7.7 wt %. Hot-leg deposits up to 2 mils thick were found in both type-316 stainless steel and Inconel loops. The deposits have not yet been identified. In every case the  $\text{UF}_3$  concentration after operation was much lower than before; thus, there was additional evidence of disproportionation of the  $\text{UF}_3$ .

A Hastelloy-B loop was cleaned with hot dry hydrogen and then operated with sodium for 1000 hr at 1500°F. Since metallic crystals were again found in the cold leg, as in the previously operated uncleaned loop, the mass transfer of nickel in the Hastelloy-B-sodium system does not seem to be dependent upon impurities. A nickel loop was then hydrogen cleaned and operated with sodium for 592 hr. Metallic crystals were found in the cold leg.

Metallographic examination of two molybdenum loops that circulated  $\text{NaF-ZrF}_4\text{-UF}_4$  (50-46-4 mole %) for 843 and 1000 hr, respectively, indicated some surface roughening in the hot legs, with depressions to a depth of 1 mil; however, the hot-leg surfaces did not appear to be different from the surfaces of as-received samples. No mass-transferred, cold-leg deposits or metallic crystals were found.

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

The diffusion of sodium into beryllium at 1200 and 1500°F was investigated. After 1000 hr at 1200°F, approximately 5 mils of corrosive attack and a maximum diffusion penetration of approximately 20 mils was measured. An exposure of 1000 hr at 1500°F resulted in corrosive attack to a depth of 20 mils; thus, it was impossible to obtain valid measurements of the total diffusion penetration. (AEC Activity 4401.5)

ANP Metallurgy--Fabrication - The Al-UO<sub>2</sub> solid fuel elements clad with 52S Al which were fabricated for use in the delayed-neutron shielding experiment cracked when bent to the design radius. By substituting 24S Al for the 52S Al the cracking during formation was eliminated and enough acceptable fuel plates were fabricated to completely load the test apparatus.

An experimental investigation has confirmed the belief that the addition of Cr to Ni-Mo alloys would result in improved oxidation resistance. Preliminary tests indicates that vacuum melting will also improve the resistance of Ni-Mo-base alloys to oxidation at 1500°F. Varying the composition of a basic 80% Ni-20% Mo alloy to include up to 10% Cr resulted in extruded rod that could not be successfully hot rolled because of edge cracking. It was found that minor additions of Ce improved the hot forgeability of the Cr-Ni-Mo alloys, and, since Ce is a deoxidizer, it was postulated that the difficulties encountered with Cr-Mo-Ni alloys might be due to oxygen introduced into the alloy as an impurity in the electrolytic chromium used as melting stock. Sample melts prepared by using high purity chromium with only 0.011% oxygen, as compared with the 0.47% oxygen in electrolytic chromium, resulted in 7% Cr-20% Mo-Balance Ni and 10% Cr-20% Mo-Balance Ni alloys that could be rolled after extrusion without edge cracking. (AEC Activity 4401.5)

ANP Metallurgy--Welding and Brazing - Experiments are being conducted to devise techniques for preplacing the proper amount of dry-powder brazing alloy at each tube-to-fin joint of NaK-to-air radiators. The use of a stainless steel template having precision drilled holes slightly larger than the radiator tubing has resulted in the preplacement of an adequate amount of alloy in all cases, but often a slight excess of alloy is present which drains to the lower fins of the radiator during brazing. By placing two closely spaced Inconel sheets in close contact at intervals of 2 in. along the radiator tube in lieu of one of the high-conductivity fins, a sump is provided into which any excess brazing alloy flows by capillary action.

The semiautomatic rotating-arc welding procedure to be used in the construction of the fluoride-to-sodium intermediate heat exchangers was perfected by experimentation with full-scale header models.

Sound weld joints were produced in Hastelloy-B plate by manual arc welding with coated electrodes. In all but one case the welded joint was found to be ductile when evaluated in a bend test. (AEC Activity 4401.5)

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

ANP Metallurgy--Mechanical Properties - Stress-rupture tests are being run on Ni-Mo alloys ranging from 20 to 32% molybdenum to evaluate the relative strength and ductility of the various combinations. These materials are being tested at stresses of 8000 and 5000 psi in argon at 1500°F. Although this program is not complete, it has been found that two alloys, one containing 80% nickel-20% molybdenum and the other 78% nickel-20% molybdenum-2% columbium, are solid-solution alloys with stress-rupture strength about the same as Inconel. The alloy containing 76% nickel-24% molybdenum has poorer strength properties than Inconel. Metallographic examination of this alloy revealed alternate bands of two-phase and single-phase regions. At the test temperature, 1500°F, all three of these alloys had lower ductility than either Inconel or Hastelloy-B. The 68% Ni-32% Mo and the 75% Ni-20% Mo-5% Cb alloys are two-phase alloys and have superior strength and ductility in comparison with the other alloys in this group, but they are not as strong as Hastelloy-B. The table below lists the stress-rupture strengths of these alloys at 1500°F, as well as those of Inconel and Hastelloy-B, which are included for purposes of comparison. All of these alloys were tested after a high-temperature anneal. Hastelloy-B would show higher strength if age hardened before testing.

<u>Alloy</u>	<u>Stress to Produce Rupture in 1000 hr (psi)</u>
76% Ni-24% Mo	3,500
Inconel	4,000
78% Ni-20% Mo-2% Cb	4,500
80% Ni-20% Mo	4,500
68% Ni-32% Mo	6,500
75% Ni-20% Mo-5% Cb	7,000
Hastelloy-B	12,000

An alloy of magnesium with 20% lithium has been proposed as a possible shielding material. Tensile and stress-rupture tests are being run to determine its strength properties. The following table shows the results of the tensile tests.

<u>Temp. (°F)</u>	<u>Tensile Strength (psi)</u>	<u>Yield Point (psi)</u>	<u>Elongation (%)</u>
Ambient	12,500	11,200	35.0
200	3,000	2,970	45.0

Room-temperature, stress-rupture tests are in progress and the creep rate for the first 300 hr allows the prediction of 1% strain in 1000 hr at a stress of 1500 psi. (AEC Activity 5501.5)

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

ANP Shielding Analysis - A Monte Carlo calculation is being applied to the problem of air scattering. The solution will give the neutron flux due to air scattering from a monoenergetic neutron source for various points in space. In another calculation, multiple anisotropic scattering was analyzed with the aid of the Fourier transform for constant velocity neutrons in an unbounded medium. Exact equations for determining the exponential form of an asymptotic solution were derived.

A study of the effect of the geometry of the uranium fuel contained in a tube bombarded by thermal neutrons was completed. The tube was held in a larger air-filled tube placed against the LITR core. A self-protection factor of 0.55 was calculated which is accounted for by the absorption of neutrons with large axial velocity components in the outer layers of the uranium. (AEC Activity 4401.7)

ANP Shielding--Bulk Shielding Facility (BSF) - Prompt fission gamma-ray spectral measurements were made in the region from 0.5 to 2.5 Mev and the data are now being analyzed. Data will be obtained for higher energies when reactor time becomes available in the summer. (AEC Activity 4401.7)

ANP Shielding--Tower Shielding Facility (TSF) - In an experiment which contributed to the Los Alamos Weapons Testing Program, the neutron attenuation by air was measured out to distances of 600 ft from the TSF. The reactor was placed in a 28-in.-dia tank at an altitude of 200 ft and measurements were made on the ground with sulfur threshold detectors, gold foils, and a fission foil spectrometer. The results will be compared with Monte Carlo calculations to help in determining the neutron yield in the Nevada bomb tests.

In conjunction with the Los Alamos experiment, some Health Physics Division (HP) detectors were calibrated against TSF instruments. The neutron attenuation of a 7-in.-thick lead shell was measured with an HP sulfur threshold detector, an HP fission foil spectrometer, and the TSF fast-neutron dosimeter. The gamma attenuation was measured with HP film and the TSF 900-cm<sup>3</sup> ion chamber. One set of the Los Alamos neutron measurements was made with the HP instruments.

A second series of differential shielding experiments using the fast-neutron dosimeter was initiated. The reactor is positioned in the 12-ft-dia tank which is located 64 ft from the detector tank. The reactor-detector altitude is 195 ft, and the reactor face is 45 cm from the tank wall nearest the detector tank. In a traverse along the detector-tank y axis (coincident with the reactor-detector tank axis) the relaxation length ( $\lambda$ ) for the first 30 cm of water from the side nearest the reactor was 9.5 to 10 cm. In a traverse along the x axis (other horizontal axis),  $\lambda$  was 5.7 cm in the first 20 cm from either side of the detector tank. (AEC Activity 4401.7)

## PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

ANP Fuel Recovery - Preliminary design was started on a pilot plant to recover the ARE fuel by a fused salt--fluoride volatility process. The design is based on a flowsheet calling for excess fluorine to be passed through the molten fuel at 1200°F. The  $UF_6$  and volatile fission-product fluorides formed will pass from the fluorinator into a bed of 20- to 40-mesh sodium fluoride at 1200°F, where the volatile fission products will be absorbed. The  $UF_6$  will collect in a series of three cold traps at +40, -40, and -80°F, which will then be heated electrically under pressure so that liquid  $UF_6$  can be drawn off. An aqueous caustic scrubbing system will be required for disposing of excess fluorine. The preliminary cost estimate for the plant, including a 20% contingency factor, is \$285,000.

Kinetic data obtained in further laboratory studies on the process indicate that the fluorination step will take place in three stages: (1) an induction stage in which the fluorine is completely absorbed to form the relatively stable NaF- $UF_6$  complex, (2) a period of constant  $UF_6$  evolution in which the fluorine is 100% utilized and  $UF_6$  outflow is equal to fluorine inflow, and (3) a period in which fluorine breaks through and serves as a carrier gas to completely volatilize the uranium from the molten salt.

The overall corrosion rate of nickel for the entire fluorination step was about 0.1 mil/hr. The data indicated that most of the corrosion took place during the period that the NaF- $UF_6$  complex existed. (AEC Activity 4401.81)

### GENERAL REACTOR RESEARCH

General Reactor Math - Two rather general but elementary programs were coded for the investigation of two-dimensional reactors. These programs are preliminary steps to the preparation of more general multi-group, multi-region two- and three-dimensional reactor calculations. The method being used is the iteration or relaxation technique, which makes it mandatory to investigate the problem of mesh sizes and the speeding up of convergence processes.

One of the programs is a one-region or bare reactor type calculation; this program allows almost arbitrarily shaped regions. A large number of cases were run for squares and L-shaped objects, and some cases were run for T-shapes, cross-shapes, and square doughnuts. It has been found most satisfactory to carry out the iterations by using an appropriate Chebyshev polynomial of the difference operator.

The other problem consists of the simplest two-region, two-dimensional type of calculation. The particular problem chosen can be solved analytically, both in the differential and difference form of the reactor equations. Numerous cases were calculated on the Oracle by using the iteration technique, and the results compare satisfactorily with the analytical results. (AEC Activity 4510)

## PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

Instrument Development for Reactors - The MTR in-pile loop experiment is for the purpose of obtaining radiation-induced corrosion information for the Aircraft Reactor Test Program. The instrumentation requirements were analyzed and design work has been started on the necessary recording, controlling, and indicating equipment to perform the following functions: (1) radiation monitoring of both water and air coolant, of the pump off-gas and helium purge lines, and of air in the work areas; (2) measurement of loop pump speeds, with provision for automatically scrambling the reactor in case of pump failure; and (3) fast neutron counting to detect delayed neutrons generated within the loop piping.

Item 3 is of major importance as these delayed neutrons serve as an indication of the fluid flow inside the loop. Since the intensity of the neutron flux is a direct function of reactor power as well as fluid flow, circuitry is provided to cancel reactor flux variations by the use of differential detectors that are designed to display loop neutron signals only. Neptunium fission chambers specially designed for this application are under construction. Delivery of the equipment to the site is expected by May 15, 1955. (AEC Activity 45XX)

School of Reactor Technology - The first semester was completed, with final examinations being given the week of January 17-21. Applications for the 1955-56 session are now being accepted and processed. (AEC Activity 4841)

## PROGRAM 5000 - PHYSICAL RESEARCH

Reactor Operations - The operation of the graphite reactor and the LITR was uneventful during this period, except for an unusually large amount of down-time for the LITR, occasioned by the insertion of ANP and HRP test loops. Several of the fuel pieces were relocated in the LITR to improve the flux at hole HB-4; the flux was increased by approximately 60%. Beryllium pieces were placed in the lattice positions near the pneumatic tube where the fuel elements were removed; this caused a 12% reduction in thermal neutron flux at this point.

Samples of aluminum and carbon steel were exposed in the upper tank of the LITR in a position where they were out of any appreciable flux and identical samples were placed in the lattice of the reactor in a neutron flux of about  $2 \times 10^{13}$  n/cm<sup>2</sup>-sec. The samples were removed after six months. Both aluminum and steel showed approximately twice the corrosion rate in the lattice as in the upper tank; it is not known whether this is due to the slightly higher temperature in the lattice, caused by gamma heating, or whether it is due to a radiation effect.

## PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

The Oak Ridge Research Reactor (ORR) - Two major decisions were made in December which have required changes in the scheduling for this project.

(1) The AEC ruled that no contracts be made with prospective contractors until ORNL and the Advisory Committee on Reactor Safeguards have resolved the questions raised regarding the hazard involved in operation of this proposed facility in the X-10 Area.

(2) ORNL and the OROO of the AEC reached the decision that the added investment required for an initial reactor power level of 20 Mw can be justified on the basis of requirements for experimental use by the ANP and HRP.

The question regarding hazard will be discussed at the meeting of the Safeguard Committee scheduled for February 3 and 4 at ORNL and an early decision on this question is looked for.

Preliminary work to establish the changes required for increasing the initial reactor power to 20 Mw was completed and authorization was received from the AEC to proceed with detailed design. The McPherson Company is now starting the necessary redesign of the cooling system in the building and ORNL forces are beginning the design of the cooling system external to the building. The present schedule calls for design completion by The McPherson Company on March 1, 1955 and for design completion by ORNL on March 15, 1955.

### ISOTOPE PRODUCTION

Radioisotope Production - There has been an acceleration in the production of cesium-137 and the fabrication of pelleted cesium chloride sources for radiographic work. Approximately 900 curies of cesium-137 was purified and stored for use in preparing sources, and 26 sources of pelleted cesium-137 chloride were made and sealed in double stainless steel jackets for use in radiography. Source strengths ranged from 5 curies to 15 curies per piece, totaling 195 curies for the entire batch of 26 sources. A number of radium-type needles were also loaded with cesium-137. These are the first cesium-137 needles prepared for use in the irradiation of tumors by implantation.

Additional cobalt-60 was received from Hanford and the MTR for use in teletherapy sources. The specific activity of the discs from the MTR ranged from 37 to 55 curies per gram. These discs are 2 cm in diameter and 1 mm thick; they contained up to 150 curies each.

There has also been an increase in the use of iridium-192 for radiography. Equipment is now in use for recanning hot sources which have been returned so that they can be re-inserted into the reactor to bring the source strength back up to the desired level. (AEC Activity 5111)

## PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

Radioisotopes, Process Development - The main effort of the radioisotope development group is now on the design of the Multicurie Fission Products Pilot Plant. Preliminary drawings and design data were completed for use by the architect-engineer in the design of the building structure. One-quarter-plant scale tests were made to determine centrifugation rates for the various precipitates expected in the plant operations; it was found that a centrifuge can successfully handle all the liquid-solid separations.

Studies were continued on methods for remote control of the cesium alum crystallization process. It was found that a good indication of the start of crystallization can be obtained from a continuous recording of the temperature; a definite temperature break is found at the start of crystallization. A device was also designed and tested for finding the height of a bed of crystals in a remote crystallizer by lowering a dip-tube through the solution and noting the point at which a sudden increase in pressure occurs as the tube encounters the first layer of crystals.

Prototypes of the source containers that will be used for packaging fission products for industrial use were made. These are metal containers approximately 1/2-inch in diameter by 10-inches long, sealed by Heliarc welding. It is proposed to use two thin-walled sealed containers, one inside of the other, to reduce the possibility of leakage. Studies were made with inactive cesium chloride on the methods of putting the solid into the rods. It was found that pelletizing is probably not necessary for industrial sources, since the finely-ground powder can be packed very firmly in a container by vibration alone. The density of the pulverized cesium chloride powder obtained by this method is  $\sim 2.1$  grams/cc. The welding operations for closing the containers were found to be adaptable to remote control. (AEC Activity 5112)

### PHYSICS

Math and Computation--Physics - The Gaussian numerical integration codes for evaluating single, double, and triple integrals on the Oracle were all used on scattering calculations completed for Tower Shielding Facility. Production was completed on each of these problems, and the codes are now being modified for additional calculations of the same general nature. These numerical quadrature codes are now so effective that in two distinct cases it was possible to complete the evaluation of scattering integrals within two hours of the time the problem was turned over to a programmer. (AEC Activity 5211)

Recoil Spectrometry - The beta recoil spectrometer was modified by the installation of magnetic and electric deflection, in series. This permitted the introduction of a third stage of differential pumping, and thus reduced the background by a factor of 10. The charge spectrum of the chlorine-37 ions which recoil as the result of neutrino emission in the decay of argon-37

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

was measured. The results are as follows:

Charge	Percentage of Charged Recoils	
	Pressure $7 \times 10^{-6}$ mm. Hg	Pressure $12-16 \times 10^{-6}$ mm. Hg
1	$6.2 \pm 0.1$	$6.9 \pm 0.1$
2	$15.7 \pm 0.4$	$16.8 \pm 0.4$
3	$39.2 \pm 0.5$	$39.0 \pm 0.5$
4	$26.7 \pm 0.4$	$25.9 \pm 0.4$
5	$10.0 \pm 0.2$	$9.6 \pm 0.2$
6	$1.8 \pm 0.1$	$1.5 \pm 0.1$
7	$0.4 \pm 0.1$	$0.2 \pm 0.1$

Mean charge of charged recoils	$3.6 \pm 0.03$	$3.20 \pm 0.03$
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Corrections were applied to cover slight variations of the detector sensitivity with the charge (and therefore the energy) of the ions. Comparison of the results in columns 2 and 3 indicates that at these pressures the perturbing effect of the gas is rather small, and that consequently the figures in the  $7 \times 10^{-6}$  mm Hg column are probably closely representative of the unperturbed charge spectrum. There is a hint in the data that the effect of collisions is to "degrade" the charge spectrum; the spectrum obtained at the higher pressure shows relatively more ions of low charge, and fewer of high charge.

The recoil momentum arising from neutrino emission is apparent in all the peaks observed. It is most sensitively studied with the singly-charged recoils. There the energy as given by magnetic analysis is  $9.6 \pm 0.2$  ev, which is to be compared with 9.66 ev expected on the basis of the emission of a neutrino of zero rest mass departing with the known transition energy 816 kev. (AEC Activity 5200)

Neutron Diffraction - Neutron diffraction investigations were performed on anhydrous  $MnCl_2$  at temperatures down to  $1.38^\circ K$  in an attempt to determine the magnetic structure of this compound at low temperatures. Specific heat measurements on polycrystalline samples, which were made previously at this laboratory, showed definite maxima at  $1.81$  and  $1.96^\circ K$ , and these maxima are believed to be associated with the transition from a paramagnetic to an antiferromagnetic state. The neutron scattering data obtained from both powdered samples and single crystals confirm this belief and show an antiferromagnetic transition at about  $1.96^\circ K$ . The structure appears, however, to be rather complicated, with a very large unit cell; the exact details have not been determined. (AEC Activity 5200)

Theoretical Physics - An Oracle code was completed and tested for performing the interpretation of angular distribution data in terms of angular momentum assignments. The code is thus far restricted to cases where only a single compound state is involved; but within this limitation the code automatically searches for the scattering matrix which best fits the data.

## PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

A series of Oracle calculations was completed for exploring the feasibility of a high-energy fixed-frequency proton cyclotron which utilizes azimuthal magnetic field variations to compensate for relativistic defocusing (Thomas-type cyclotron). From this work it appears that a billion-volt fixed-frequency cyclotron is technically feasible.

A very simple method was found for avoiding the perturbation theory which is invalid for use in calculations with the pseudo-scalar meson theory. It is planned to apply the scheme to the computation of several of the more interesting properties of nucleons.

Work was started on a general phenomenological treatment of the two-body problem, essentially based on a machine solution of the relativistic two-body wave equation. It is hoped that this treatment will be very useful in the interpretation of high energy nucleon scattering experiments. (AEC Activity 5200)

### CHEMISTRY

Chemical Separation of Isotopes - The isotopic separation factor for nitrogen isotopes was determined between aqueous ammonium hydroxide and the ammonium form of Dowex 50W resin. The ammonium form of the resin was equilibrated with aqueous ammonium hydroxide at 24°C. After separation of the resin and the solution, the resin was washed free of adsorbed ammonium hydroxide and the ammonium ion eluted with acid. Samples of nitrogen were then prepared from the ammonium hydroxide solution and from the eluted ammonium ions from the resin. Mass analyses of a total of seventeen samples yielded a separation factor of  $1.0271 \pm 0.0005$  (95% C.I.). This factor compares favorably with a value of 1.029 calculated from the published values for the exchange between gaseous ammonia and ammonium ion (1.034) and for the exchange between gaseous ammonia and aqueous ammonium hydroxide (1.005).

Exchange experiments using enriched  $B^{10}$  tracer showed that exchange between  $BF_3(g)$  and  $BF_3$ -anisole (l) complex is very rapid.  $BF_3(g)$  enriched with  $B^{10}$  was contacted with  $BF_3$ -anisole (l) with vigorous shaking at room temperature. Samples of the gas showed exchange to be essentially complete between the two phases in less than 7 second. Since exchange is rapid, it can be concluded that the system previously proposed for enrichment of boron isotopes by using the  $BF_3(g)$  vs  $BF_3$ -anisole (l) exchange reaction can be carried out satisfactorily in countercurrent exchange columns. (AEC Activity 5300)

Hot Laboratory Research - In an effort to obtain gram quantities of long-lived neptunium 237 for urgent research needs, several possible sources were investigated, including the crude waste from a large metal recovery program at ORNL and a group of highly burned-out MTR shim-fuel rods. The latter source, a total of 8 shim rods and 4 fuel units, appears to be capable of furnishing up to 2 grams of Np. In this material the radiation level is ex-

## PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

tremely formidable because of the high burn-up and relatively short cooling period. It was, therefore, considered fortunate that the scale of the current metal recovery program, involving up to 50 tons of ORNL and BNL metal, provides a possible source of up to 20 g of neptunium.

Two possible treatments of the concentrated aluminum nitrate waste stream were considered. The first involved oxidation of Np(V) with dichromate, followed by Hexone extraction; the second involves a direct alkaline precipitation, followed by an anion exchange separation. Since equipment is already existing for the second method, it will receive first attention. (AEC Activity 5300)

Chemistry of Corrosion - In prolonged observation of specimens of SAE 1010 carbon steel inhibited by potassium pertechnetate, two samples have now been followed for two years. The metal shows no sign of corrosion whatever and the beta activities are remaining essentially constant. These tests were made with 50 ppm of technetium. Another test with only 5 ppm has continued for over 15 months with a similar result. A report summarizing the technetium work was issued (ORNL-1833).

In order to check the negative results obtained in testing potassium perrhenate for inhibitor properties, a few experiments were repeated with a sample of the salt known to be exceptionally pure. Again, no inhibition was found. This great difference between the otherwise very similar pertechnetate and perrhenate ions is important in the theory of inhibitor action. (AEC Activity 5300)

Hope Project - It is planned to use the expanded Metal Recovery Plant, in the interval between completion and Scrup equipment installation, for testing various Hope-type designs and ideas, such as the new slug charger (ORNL-1824), a slug cutter and dejacketer (ORNL-1824), and various types of piping and equipment disconnects. Decontamination, underwater maintenance, and removal of equipment following use in processing of low-activity materials will also be studied as part of the Hope program.

A facility designed to demonstrate the feasibility of an air lift for pumping metered radioactive liquid, thus eliminating potential maintenance problems connected with pumps having moving parts, was constructed and testing was begun.

Direct chlorination of uranium-aluminum alloy, as a possible means of reducing costs of chemical processing of expended fissionable fuels, was investigated on a laboratory scale. Direct chlorination of a 15% uranium--85% aluminum rod was readily accomplished at 340°C, but the relative volatilities of the uranium and aluminum chlorides were not sufficiently different to permit a one-stage separation of the two metals. (AEC Activity 5300)

## PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

Ion Exchange Technology - Uranium recovery from sulfuric acid ore leach liquor by ion exchange is being studied. In the 2-in.-diam. Higgins continuous contactor the uranium sulfate sorbed from clarified liquor was converted to chloride by concentrated sodium chloride and eluted with water, the uranium loss was less than 0.02%. From the  $UO_2Cl_2$  product, ammonium diuranate with a chloride content of 0.3% was precipitated. The ammonium diuranate was redissolved in sulfuric acid and reprecipitated to give a product with a chloride content of 0.002%; it was also calcined to give one with a chloride content of 0.0005%. (AEC Activity 5300)

Feed Materials Processing - Thorium amalgam is being produced in 400-lb batches, containing about 4 lb of thorium, by sodium amalgam reduction of  $ThCl_4$  dissolved in propylene diamine. In further laboratory-scale studies, an 80% yield was obtained by keeping the amalgam temperature 5 to 10°C above the boiling point of the amine. Preliminary studies indicate that yields up to 95%, based on thorium chloride charged, can be obtained by treating solid, powdered, anhydrous  $ThCl_4$  with sodium amalgam at 150 to 250°C.

Anhydrous thorium chloride was produced in 300-g batches by chlorination of a mixture of  $ThO_2$  and lampblack (10 wt %) with chlorine gas at 500 to 700°C. Product purity of 99% was obtained by sublimation at 800°C in an argon stream containing 10% chlorine. Thorium chloride was also prepared by chlorination of thorium oxalate with a 50-50 mixture of carbon tetrachloride and chlorine. Nearly quantitative yields of > 99% pure  $ThCl_4$  were obtained.

Metal satisfactory for fuel element fabrication was produced from thorium quasi amalgam. Typical analyses showed the impurities to be 12 to 65 ppm Hg, < 300 ppm C, < 200 ppm N, 40 to 200 ppm Na, 12 to 18 ppm H, and 2000 ppm O. (AEC Activity 5300)

### OTHER PHYSICAL RESEARCH PROJECTS

Oracle - During the months of December and January, the Oracle continued regular two-shift operation with a third shift available on a voluntary basis. A total of 567 hours of computing time was scheduled for problem solution of which 51 hours were lost due to machine break down. A total of 157 hours was scheduled for engineering modification and maintenance. (AEC Activity 5511)

## PROGRAM 6000 - BIOLOGY AND MEDICINE

### BIOLOGY

Cytogenetics - Paramecium aurelia normally has two diploid micronuclei; it is mutations in these nuclei which are detected by the standard method. During the sexual processes of autogamy and conjugation, which bring mutations to light, these nuclei undergo two reduction divisions (meiosis). One product of these divisions survives, and the others die. It is possible, a priori, that meiotic products having mutations or deficient chromosomes would be more likely to die than normal products. Strains of Paramecium can be obtained which have two haploid instead of two diploid micronuclei. The products of the reduction division from these haploid nuclei lack a number of chromosomes, i.e., they are even more deficient than products from heavily irradiated nuclei. A strain was obtained which had one diploid and two haploid micronuclei, and it was found that the meiotic products from the diploid survived almost to the exclusion of those from the haploid. Apparently, the gross chromosomal deficiency of the meiotic products from the haploid put them at a marked selective disadvantage as compared with the complete products from the diploid. This selective disadvantage was almost eliminated by a dose of 5,000 r of X-rays. Probably the relatively small chromosomal deficiencies in the meiotic products from an irradiated diploid nucleus are sufficient to reduce them to equality with the grossly deficient products from the haploid. Thus, selective processes may be important at low doses of X-rays but probably cease to be very important as the dose increases.

Experiments on the effects of various enzyme inhibitors and chemicals on the repair or rejoining of radiation-induced chromosome breaks in the seed of Vicia were continued. To date these may be summarized as follows: (1) Any inhibition of cellular respiration inhibits chromosome rejoining. This was found by treatment with low temperatures, KCN, carbon monoxide in the dark, or by complete oxygen removal (vacuum plus  $\text{Na}_2\text{S}_2\text{O}_4$ ). (2) The uncoupling of oxidative phosphorylation from respiration, by treatment with dinitrophenol, also inhibits rejoining. It is hypothesized that the high-energy bonds of adenosine triphosphate are necessary for the biosynthesis of those chemical bonds formed during rejoining. Treatment with ATP itself has the opposite effect of dinitrophenol (i.e., stimulates rejoining) and helps to corroborate the hypothesis. (3) Experiments with nitrogen mustard indicated that the dose levels of 5-10 micromole hours, which are commonly used on the growing roots of Vicia, are too strong to be applied to the seed. At these levels the nitrogen mustard does not affect cell elongation but does completely inhibit mitosis, and no cell divisions occur before the germinating seeds die. (AEC Activity 6400)

Microbiology - Previous work from this Laboratory has established the existence of a CN- and azide-resistant peroxidase for DPNH in extracts of Streptococcus faecalis. The activity of this enzyme was directly proportional to the flavin content. The enzyme has now been isolated as a flavo-protein with an FAD content of 0.66% in the best preparations obtained so far; no hematin component is present. In the oxidized state, the enzyme has

PROGRAM 6000 - BIOLOGY AND MEDICINE (Continued)

a typical flavin spectrum with maxima at 370 and 450  $\mu$ . On the addition of excess DPNH, the 450- $\mu$  band is shifted to about 445  $\mu$ , the extinction at 450  $\mu$  is reduced about 20%, and a new broad absorption band appears in the region 520-600  $\mu$ . On the addition of peroxide, the original spectrum of the oxidized enzyme is regenerated. The addition of excess hydrosulfite to the enzyme in the presence of DPNH results in only a 10% further reduction of the 450- $\mu$  band, however, in the absence of DPNH, hydrosulfite reduces the 450- $\mu$  band about 80% and no new absorption band appears above 520  $\mu$ .

These results may be interpreted as follows: DPNH combines with the flavo-protein to form a complex which is only partially reducible with hydrosulfite, and which is rapidly oxidizable with peroxide but only slowly autoxidizable in the presence of molecular oxygen. The absorption band above 520  $\mu$  in the presence of DPNH may indicate the presence of another component in the prosthetic group, possibly a metal. Neutron activation analysis appears to rule out the presence of molybdenum, copper, and manganese. (AEC Activity 6400)

Radiation Protection - Further studies were made of the effects of protective chemicals ( $\beta$ -mercaptoethanol, cysteamine) on the X-ray-induced reversion rate of several mutant strains of *E. coli*. This work was particularly successful with a phenylalanine-requiring strain *E. coli* 83-5. By use of a preplate treatment technique with yeast extract containing liquid medium, recovery following cysteamine treatment and X irradiation of this strain on minimal medium was produced. These studies clearly show that the recovery process in increasing postirradiation survival also decreases the mutation rate to a corresponding degree and suggest that the phenomena of radiation-induced mutagenesis is indirect and related to the mechanism of killing of cells by X-ray. Efforts are under way to develop a synthetic recovery medium adequate for these studies in order that they might be further extended by a different technique.

Conditions under which *Escherichia coli* B/r are able partially to overcome the damaging effects of X- and  $\gamma$ -radiation have been described. Comparisons of protein and nucleic acid synthesis are now being made on irradiated and nonirradiated cells under the most favorable and least favorable conditions for the recovery process. Preliminary results indicate that the synthesis of deoxyribonucleic acid (DNA) is more sensitive to ionizing radiations than is either ribonucleic acid (RNA) or protein synthesis. There are also indications that the optimal conditions for recovery may influence DNA synthesis more than RNA or protein synthesis.

The investigation of nucleic acid metabolism and its relation to particulate breakdown in *Escherichia coli* following X-ray exposure was continued. In the previous report it was stated that DNA synthesis is completely blocked in exposed cells incubated in a salts-glucose medium. Investigation now shows that if the cells are pretreated with cysteamine and incubated in a salts-glucose medium supplemented with yeast extract, the inhibition in net DNA synthesis is reversed after a brief lag period. Such treatment was found

## PROGRAM 6000 - BIOLOGY AND MEDICINE

by others (ORNL-1766) to markedly increase the survival of X-irradiated E. coli. DNA synthesis remains blocked if the yeast extract is not added. Irradiated cells not pretreated with cysteamine do not show this recovery of ability to synthesize DNA in the presence of yeast extract.

The cysteamine treatment was observed to cause an extension of the lag phase of growth in nonirradiated E. coli suspended in a salts-glucose medium at 37°C, as measured by turbidimetric changes. (AEC Activity 6400)

Biochemistry - Considerable evidence is at hand to indicate that during the process of bacterial virus infection there is both a physical and a functional partition of the virus DNA and the virus protein. The latter exists in two forms, soluble and insoluble (the so-called "ghosts"). The biochemical properties of these virus entities are now being investigated in relation to the function of the whole virus. In this investigation, it was observed that the ghosts, although unable to initiate bacteriophage formation, retain the property of the intact virus to alter profoundly the metabolism of E. coli, in particular to inhibit the synthesis of RNA, to inhibit cell multiplication, and, in sufficient quantity, to cause cell lysis. However, inorganic phosphate is esterified by the cells at a normal rate and both nucleotidic and nonnucleotidic compounds were identified in the medium containing such ghost-treated cells. Further identification of these substances will indicate whether or not the block in RNA synthesis is due to the absence of one or more precursors or of the condensation mechanism. (AEC Activity 6400)

Plant Biochemistry - In the study of the effects of both ultraviolet and  $\gamma$  radiation (cobalt-60 source), the photosynthetic rates are measured by the fixation of  $C^{14}O_2$ . Experiments with Thatcher wheat demonstrated a 70 to 80% reduction in photosynthetic rate with 10-minute exposures to ultraviolet (2537A) (at the particular geometry used) or 100,000 r of  $\gamma$  radiation. Increased exposures up to 30-min ultraviolet or 500,000 r produced no further significant effect on the rate. Paper chromatographic investigation of the distribution of  $C^{14}$  in the photosynthetic products formed directly after irradiation showed a significant increase in glycine and serine and a decrease in sucrose. (AEC Activity 6400)

Biophysics - The techniques of differential gradient centrifugation were applied to the study of the distribution of protein, nucleic acids, and acid soluble nucleotides in liver breis. The distribution of acid-soluble nucleotides which was found suggests that a considerable fraction of these are adsorbed on particulate material in the brei and are desorbed during fractionation. In additional experiments breis of varying concentration (20, 10, 5, and 2-1/2% rat liver) were divided into sedimentable and nonsedimentable fractions by centrifuging three hours at 26,000 x g. Thirty per cent more acid soluble 2600-A-absorbing material per milligram of tissue was obtained in the 2-1/2% brei than in the 20% brei. This gives further evidence that nucleotides are lost from particulates on dilution.

PROGRAM 6000 - BIOLOGY AND MEDICINE (Continued)

In the investigation of the in vivo effect produced after injection of mice with nucleoprotein from ascites tumor cells and their later challenge with tumor cells, two findings are worth reporting at this time. (1) Mice were prepared with protamine and histone from two sources. Challenged with ascites tumor at a later date, these mice do not seem to show a significantly altered mortality rate from that seen in the control unprepared ascites-challenged mice. (2) Mice were prepared with intraperitoneal injections of nucleoprotein at three different dose levels, and groups of these were challenged at four intervals, one week apart, with ascites cells. The earlier death of prepared individuals does not show a direct relation to dosage. Marked differences in mortality rates with the different dose levels are exhibited, however. These differences seem most easily interpretable if an immune reaction is assumed to be involved. (AEC Activity 6400)

Pathology and Physiology - The bone marrow megakaryocytes and the blood platelets of irradiated rats concentrated  $S^{35}O_4$  in a manner similar to that of the nonirradiated controls at 1, 2, 3, 4, and 24 days after 750-r whole body X irradiation ( $LD_{50}/30$  days). Since the uptake of radiosulfate by the surviving megakaryocytes and by platelets was not affected by irradiation, it is probable that platelets continue to be derived from the megakaryocytes remaining viable after irradiation.

The distribution of  $Ca^{45}$  in bone marrow cells and blood platelets was studied in rats. The activity of the platelets declined in a manner parallel to that of the plasma, and the cells of the bone marrow did not concentrate the  $Ca^{45}$ . These results indicate an absence of a firm incorporation of calcium into the structure of platelets or megakaryocytes.

Thyroidectomy by injection of radioiodine was found to enhance significantly ( $p \sim 0.001$ ) the survival of AK mice rendered leukemic by inoculation of AK lymphoid leukemia cells. The beneficial effect afforded by destruction of the thyroid gland was prevented by administration of thyroid hormone. (AEC Activity 6400)

Enzyme Chemistry - Studies on the influence of  $\gamma$  irradiation on nucleic acid synthesis in chick embryos were concluded. It was found that the incorporation of  $C^{14}$  into the adenine of deoxyribonucleic acid (DNA) was not altered by irradiation of the embryos with up to 20,000 r of cobalt-60  $\gamma$  rays when the  $C^{14}$  was administered as adenine-8- $C^{14}$ , glycine-2- $C^{14}$  or formate- $C^{14}$ . On the other hand, the specific activities of the DNA thymine and guanine were lower following treatment with 5000 r or greater doses of radiation. The results suggest that the adenine of DNA may exchange with other adenine independently of new synthesis of DNA, whereas thymine does not enter into DNA except when net synthesis of the polynucleotide takes place. The data do not necessarily require classification of the guanine in the same category as thymine. (AEC Activity 6400)

RADIOISOTOPE SALES AND COSTS

<u>Type of Transaction</u>	<u>December 1954</u>	<u>FY 1955 to Date</u>
Domestic Sales	\$110,204	\$582,978
Foreign Sales	2,150	26,602
Project-Cash Sales	2,141	31,119
Project-Transfer	262	1,720
Technical Cooperation Program Credits	0	1,510
Plant Credits	5,150	20,486
Civilian Defense Credits	0	105
Cancer Program Credits	19,757	121,748
*Miscellaneous	0	52
	<u>139,664</u>	<u>786,323</u>
**Income - No Production Costs Incurred		
Subtract from Total Income	<u>5,023</u>	<u>31,982</u>
Radioisotope Income	\$134,641	\$754,341
Radioisotope Costs	<u>\$ 89,130</u>	<u>\$498,172</u>
Radioisotope Shipments	<u>965</u>	<u>6,024</u>

\*Miscellaneous - Freight and Missing Parts

\*\*Income from H<sup>3</sup>, He<sup>3</sup>, and B<sup>10</sup> and miscellaneous items in excess of handling costs.

GROSS OPERATING COSTS

	<u>Cost for December</u>	<u>FY 1955 Cost to Date</u>
Programmatic Operating Cost - Net	\$2,640,063	\$15,066,988
Plant and Equipment Cost	276,295	1,539,119
Construction Program "H"	19,477	55,344
Work for Other Parties - Transfers	29,362	172,514
Inventory Changes	41,675*	1,698*
Reimbursable Work for Other Parties	186,650	1,020,860
Deferred Charges	<u>7,189*</u>	<u>4,257*</u>
Total Laboratory Cost - Net	<u>\$3,102,983</u>	<u>\$17,848,870</u>
Estimated Cost for Next Month - Net	<u>\$3,100,000</u>	<u>\$20,948,870</u>

\*Credit

[REDACTED]

PERSONNEL SUMMARY

	<u>Number of Employees</u> <u>January, 1955</u>	<u>New Hires</u> <u>January</u>	<u>Terminations</u> <u>January</u>
Administration	61	0	0
Operations*	121	1	0
Engineering, Shops and Mechanical	748	3	2
Laboratory and Research	1895	37	11
Protection	147	0	0
Service	<u>369</u>	<u>4</u>	<u>2</u>
	3341	45	15

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

A total of 778 Laboratory personnel are located in the Y-12 Area.

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Previous reports in this series:

January 1954	ORNL-1676
February 1954	ORNL-1695
March 1954	ORNL-1703
April 1954	ORNL-1719
May 1954	ORNL-1733
June 1954	ORNL-1748
July 1954	ORNL-1760
August 1954	ORNL-1781
September 1954	ORNL-1793
October 1954	ORNL-1805
November 1954	ORNL-1824
December 1954	ORNL-1838