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OAK RIDGE NATIONAL LABORATORY
STATUS AND PROGRESS REPORT

SEPTEMBER 1954

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OAK RIDGE NATIONAL LABORATORY
STATUS AND PROGRESS REPORT

September, 1954

F. T. Howard

and

W. H. Sullivan

Date Issued: OCT 7 1954

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OAK RIDGE NATIONAL LABORATORY

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September, 1954

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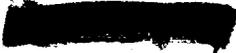
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OAK RIDGE NATIONAL LABORATORY

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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 - The Hanford reduction crucible waste recovery program was completed on September 11, with a total of about 66.5 kg of plutonium and about 10 g of americium recovered from 17 tons of waste. The plutonium recovery, based on losses, was 99.7%, and the product was satisfactorily processed at Rocky Flats.

Since the presence of lanthanum in the Hanford crucible waste was not suspected, the Amex process was not designed originally to separate americium from lanthanum, and the 10-g americium product was contaminated with 3000 g of lanthanum. Sorption of this material on Dowex-50 resin and elution with 12.8 M HCl gave, in 90% yield, a product with a La/Am ratio of 2/1. A portion of purified product containing about 1 g of americium was shipped to the University of California Radiation Laboratory at Livermore to meet an October 1 commitment.

The Metal Recovery Plant has begun operation on recovery of plutonium and americium from the Los Alamos Clementine reactor fuel elements. (AEC Activity 2344)

Excer Program - Pellets of $UO_3 \cdot xH_2O$ containing 40% $UO_2(NO_3)_2 \cdot 6H_2O$, for use in the Excer-Moving Bed process for converting uranyl nitrate to UF_4 , were prepared by extruding and crumbling a mixture of the salts at 80° to 120°C. The pellets were stable when dehydrated and denitrated to UO_3 in a slow stream of air at 450°C in a tube furnace. Pellets prepared in the 80°-120°C range were stronger, after reduction in hydrogen at 500°C, than those prepared at higher temperatures (up to 240°C).

Pellets of $UO_3 \cdot xH_2O$, for use in studying the reduction and hydrofluorination steps, were produced in a size range of 3 to 8 mesh at a rate of 1000 lb/hr with a yield of about 50%. The powdered oxide was mixed in a hammer mill with 12% water and extruded and aged on a belt before being sized in an oscillating granulator. These pellets were reduced and hydrofluorinated, with NH_3 and HF, in a single moving bed reactor to produce UF_4 in 90% yield. The Inconel reactor which was used showed very little evidence of attack by the chemicals when examined metallographically. The product nickel contamination would be less than 10 ppm from a large-scale reactor. (AEC Activity 2602)

PROGRAM 4000 - REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

HR Design - The designs of all major equipment items for the high pressure and low pressure core and blanket systems of the Homogeneous Reactor Test were reviewed, and final construction drawings were completed or are in preparation. Preliminary process piping layouts were drawn. After review of these drawings, the final layouts and the detailed construction drawings can be prepared.

Structural details for the modification of Building 7500 and for the chemical processing cells are nearing completion. Work on the design of the heat removal system and other reactor auxiliaries is proceeding at a minimum rate until bids are received from vendors and specific equipment has been selected. (AEC Activity 4109.1)

Homogeneous Reactor Test (HRT) - Excavation work for the shielding pit was completed during the month, and concrete pouring was begun in the control room area. The installation of the new transformer bank was completed; it will be connected to the building at a later time.

The first aluminum mock-up of the reactor core tank was tested for stress measurements at Newport News Shipbuilding and Drydock Company, and a second mock-up tank was completed. These tests are intended to verify the design of the zirconium tank, which will be used in the reactor. Zircaloy-2 plates are being formed for the core vessel. The Zircaloy-2 screens which act as diffusers at the inlet of the core were received but are unacceptable because of brittleness. Additional screens will have to be procured, but no significant delay is expected in the completion of the core pressure vessel contract.

Design activities during the month were devoted to revisions of existing component drawings. It was learned during tests of the fuel dump tanks that flooding of the entrainment separator occurred at evaporation rates slightly above the design point of 1/2 gal/min. The installation of baffles and a second vapor outlet connection corrected this difficulty.

Hydraulic experiments with the pressurizer design have shown that the design will not be satisfactory for use with a slurry blanket because of collection and settling of slurry in the pressurizer. Experiments are in progress to determine the changes necessary to correct the situation. (AEC Activity 4109.11)

HR Analysis, Math and Computation - Recent measurements of the neutron absorption cross section of U^{233} made at Brookhaven by Harvey and Palevsky give $\sigma_a(23) = 590 \pm 10$ b for 2200 m/sec neutrons which checks very well with the old measurement of 564 ± 10 b corrected for the new value of the boron cross section. This gives $\eta(23) = 2.29 \pm .03$, which the above authors have recently shown to be constant up to 0.2 ev, within an experimental error of 1%.

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

Preliminary results at Brookhaven indicate a rather large resonance integral, ~1500 b, for infinite dilution of U²³³ in moderator. Multi-group calculations using these data indicate that 10% of the fissions are resonance fissions for a U²³³ concentration of 3 g/kg of D₂O. There is still some uncertainty in the breeding ratio due to lack of data on α (σ_c/σ_f) in the resonance region.

The best estimates of the neutron losses in two-region breeders with the following characteristics are summarized below: core diameter - 5 ft, critical concentration - 2.5 g U²³³/kg D₂O, core power - 363 Mw, blanket power - 85 Mw, core tank - 1/2-inch Zircaloy-2, average temperature - 280°C, 1000 g Th/liter as ThO₂ in D₂O, and 3 g U²³³/kg Th.

Neutron Losses

Normalized to one neutron absorbed in U²³³

Blanket thickness	3 ft	2 ft
<u>Blanket</u>		
Pa	.0283	.0394
D ₂ O	.0028	.0027
Poison	.0078	.0081
<u>Core</u>		
Poison	.0500	.0500
D ₂ O	.0168	.0169
S	.0023	.0024
<u>Core Tank</u>		
Fast Leakage	.0305	.0305
Slow Leakage	.0050	.0160
	<u>.0030</u>	<u>.0111</u>
Total	0.15	0.18

(AEC Activity 4109.2)

HR Chemistry--Radiation Studies - Studies of the effect of reactor radiations on the corrosion of Zircaloy-2 by uranyl sulfate solutions at 250°C were initiated. The experimental methods and techniques employed are essentially those used previously in similar studies with 347 stainless steel. In two of the three in-pile experiments that have been made, the solutions were approximately 0.16 m in UO₂SO₄. The estimated fission power density was 6 to 8 watts/ml when the LTR was operating at 3 Mw. The results of oxygen consumption measurements in these experiments indicate corrosion rates of 8 to 10 mils/yr during irradiation at the maximum pile power. For each experiment, the total oxygen which was lost at any time was roughly proportional to the total fission energy which was dissipated within the bomb. Pin corrosion specimens from one of the bombs were examined; the results of weight measure-

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

ments indicate a total corrosive penetration in near agreement with that calculated from oxygen data.

The third in-pile experiment was with a solution approximately 0.32 m in UO_2SO_4 . The estimated fission power density was 12 to 16 watts/ml when the pile was operating at 2.5 Mw. Oxygen consumption measurements indicate an initial corrosion rate of about 6 mils/yr. The apparent corrosion rate increased to 7.5 mils/yr in the latter part of the exposure.

Out-of-pile experiments were made with solutions of the same concentrations as those used in the in-pile experiments. The results of oxygen consumption measurements indicate corrosion rates of 0.5 mils/yr, or less, for each solution.

The possibility that uranium contained in the zirconium oxide film is responsible for a majority of the radiation effect on corrosion is being explored. (AEC Activity 4109.31)

Dynamic Loop Tests - At flow rates of 15 fps (less than the critical velocity) the corrosion rate of type 347 stainless steel in 0.06 m uranyl sulfate containing 0.006 m sulfuric acid at 200°C was less than one mil/yr and at 225°C, two mils/yr. At flow rates in excess of the critical velocity, where a protective oxide film does not form, the corrosion rates at 200°C and 225°C were 25 and 55 mils/yr, respectively. The critical velocity was about 20 fps at 200°C and 30 fps at 225°C.

Experimental tests are being made to determine the minimum oxygen concentration necessary to stabilize uranyl sulfate solutions at high temperatures. The first run indicated that a 0.17 m uranyl sulfate solution containing 40 to 70 ppm oxygen is stable at 250°C in a dynamic system. (AEC Activity 4109.4)

Laboratory Service Corrosion Tests - No acceleration of corrosion by electrochemical couples between various Stellites and type 347 stainless steel was observed at 100°C in oxygen-pressurized 0.17 m uranyl sulfate solutions, some of which contained 0.01 m cupric sulfate. Stellite 98M2 showed a diminishing rate of attack of 1 to 2 mils/yr, while Stellite 6 and Stellite 12 showed no significant attack. Stellite 12 and particularly Stellite 6 in the form of torch-applied hard facing on type 347 stainless steel exhibited extremely severe pitting attack in a number of cases, while no attack occurred on similar specimens from other sources. Heliarc-applied hard facing by Stellite 6 and Stellite 12 on type 347 stainless steel showed no significant attack. In general, attack appeared to be slightly but not appreciably greater in solutions containing copper.

Thoria slurries prepared from Ames 100-mesh thorium oxide have been circulated in small toroids of type 347 stainless steel. Suitable oscillation of the toroids causes circulating slurry slugs to impinge on pin specimens

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

inserted across the flow. Tests at 250°C and 25 ft/sec with slurry concentrations of 90 to 1000 g Th/kg water showed little effect on titanium 75-A and Zircaloy-2, with small weight gains generally being observed. The corrosion rate of type 347 stainless steel under these conditions was twice as great under a helium atmosphere as that observed when 40 ppm oxygen was present. The rate decreases further with increasing oxygen concentration up to 600 ppm.

Thermocouple materials attached to type 347 stainless steel were exposed for 100 hours in aerated tap water at room temperature, simulating conditions expected in the HRT tank when flooded during shutdown for maintenance. Corrosion data, quantitative and visual, showed the iron-Constantan couple to be unsatisfactory, while Chromel-Alumel and copper-Constantan couples exhibited satisfactory performance. (AEC Activity 4109.4)

HR In-Pile Loop - A third in-pile loop assembly was completed and tested in the mock-up test facility in the Y-12 Area. A standard check-out procedure was used, which consists of operational checks on all component parts of the loop, including a calibration of all thermocouples, followed by cleaning and pretreatment of the loop and corrosion specimens prior to exposure in the LITR. A total operating time of ~70 hours was accumulated in the mock-up.

This loop (designated as "DD") is now at the LITR ready for installation in Hole HB-4 as soon as operational tests of the auxiliary equipment and calibration of all instruments are complete. It contains type 347 stainless steel corrosion specimens in Zircaloy-2 tapered specimen holders. In addition, specimens of Zircaloy-2 for impact testing are contained in the core for exposure to the maximum neutron flux.

One in-pile loop has now been satisfactorily disassembled in the remote dismantling facility in Building 4501. It appears that the procedures for in-pile loop corrosion specimen removal and inspection are adequate for handling these specimens after exposure in the LITR. (AEC Activity 4109.4)

HR Metallurgy - Dynamic tests on all weld-metal type-347 stainless steel specimens, containing varying amounts of ferrite, at concentrations up to 0.17 μ UO₂SO₄, indicate that the extent of corrosion is not necessarily related directly to ferrite content of the weld metal, as appeared to be the case in similar tests in higher concentration, 1.34 μ UO₂SO₄. The corrosion of different weld metal specimens did vary considerably, however, and more extensive work in evaluating the possible effects of other micro-constituents and the chemical compositions of weld deposits is being conducted.

The welding development group has evaluated the preplaced consumable insert, inert-gas-shielded tungsten electrode, method of welding the root pass in stainless steel piping. The results have been excellent, and a program is in progress to qualify the procedure and establish operator qualification standards.

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

Procedural specifications were established for the rolling of Zircaloy-2 plate, and for its forming and welding into the HRT core tank. (AEC Activity 4109.4)

Homogeneous Reactor Instrumentation - The design of controlling and measuring instrument systems for the HRT was completed with the issuance of instrument engineering flowsheets and descriptive tabulations of all items. Designs for the 1/8-inch, 1/2-inch, and 1-inch high pressure valves were completed. Preliminary corrosion data on the selected Chromel-Alumel thermocouple materials in aerated tap water indicate that satisfactory performance can be expected. (AEC Activity 4109.6)

AIRCRAFT NUCLEAR PROPULSION PROJECT

Aircraft Reactor Experiment - Filling of the sodium system of the ARE was started on September 25, and by 4:00 a.m. September 26, the sodium pumps were operating at capacity flow and the operating temperature of 1200°F had been reached. No particular difficulties were encountered during filling, and the electromagnetic flowmeters, which were at first inoperative, functioned properly after sufficient time had elapsed for wetting to occur. About 3:00 p.m. on September 27, a small leak in a tube bend in the sodium purification system was found. Therefore, the sodium was dumped into the fill tanks. The tube bend is being repaired. The leak occurred at a crack in the tubing on the outer radius of the bend rather than at a weld. As soon as the repair has been made, sodium will be recharged to the system, and this phase of the test will be resumed. (AEC Activity 4401.1)

Circulating-Fuel Reactor Experiment (CFRE) - Hydrodynamic tests on full-scale plastic models of CFRE pump-volute-core configurations continued. No arrangement tested to date that is designed for straight-through flow in the core gives a good velocity distribution with one pump out of operation. From this standpoint, the most promising arrangement is one in which the pumps discharge tangentially into the core inlet to give a high swirl velocity in the core.

The swirl-chamber type of expansion tank designed to remove xenon was developed further. Preliminary tests indicate that a circular expansion tank between the two pumps works well with the swirling fluid driven by jets from the pumps. Fluid scooped from the swirl chamber is returned to the main fluid stream through centrifuges on the backs of the impellers. A full-scale plastic model of the system is being built for thorough evaluation.

A one-half scale wood and plastic model of the reactor-heat exchanger-pump assembly is about 60% completed in the shop. This model was designed to permit the installation of a variety of detailed designs of the principal components, as an aid in evaluating fabrication problems.

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

A number of preliminary designs for the CFRE installation were prepared to permit an early evaluation of several representative approaches. Work is proceeding as rapidly as possible on the major elements in the systems to give a more complete picture of the problems. (AEC Activity 4401.1)

ANP Experimental Engineering--Basic Developments - One large-scale, high-turbulence, high-temperature-difference test loop was installed, pretested with water, precleaned with NaF-ZrF_5 , filled with $\text{NaF-ZrF}_4\text{-UF}_4$ (50-46-4 mole %), and operated about 24 hours at a Reynolds number of 10,000, a maximum temperature of 1400°F, and a minimum temperature of 1200°F. Operation was stopped because of a salt leak, and each attempt to restart after repairing was stopped by a leak. A second, duplicate unit was constructed and calibrated with water; it is to be operated with a lower temperature differential.

A high-turbulence, high-temperature-difference test unit for testing the corrosion of beryllium by sodium in an Inconel system was operated about 24 hours and stopped because of a sodium leak. The leak was repaired and the unit restarted on a 1000-hr run at a maximum temperature of 1300°F, a minimum temperature of 1000°F, and a Reynolds number of more than 100,000 at the beryllium throat.

At the completion of 2000 hours of operation of the large-scale loop for isothermally (1375°F) circulating a fluoride mixture in ARE components, test samples of the heat exchanger and reactor hairpin tube were removed and submitted for metallurgical examination. The unit has been reassembled and is to be placed in operation again as a pump test.

Critical speed tests of the rotary element in the ARE pump indicated that the range 2800 to 3200 rpm should be avoided, rather than the range 2400 to 3000 rpm as tentatively reported last month. Harmonic vibrations occur in this critical speed range.

In the development of gas burning furnaces as an alternate heat source for electricity, one test unit put 24 kw of heat into water flowing at 2.5 gpm in a 1/30 ft³ furnace chamber volume from a 72 kw (theoretical) supply of natural gas (based on 1050 Btu/ft³ gas). Developmental work is continuing. (AEC Activity 4401.1)

ANP Experimental Engineering--In-Pile Components - Tests of a plastic model of the proposed in-pile turbine-type pump have shown satisfactory head, capacity, and degassing characteristics. Study is continuing on the effects of modifications, including filling techniques, impeller and clearance limitations, and labyrinth-seal leakage control.

A horizontal-shaft, air-turbine-driven, centrifugal pump has accumulated 1000 hours of operation at 4000 to 6000 rpm and pumping NaF-ZrF_4 at 1 to 1.5 gpm, 1300 to 1400°F (maximum), and 40- to 70-psi head. On the three occasions that flow was stopped, restarting was accomplished with little difficulty.

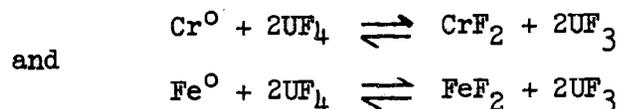
PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

A similar pump incorporating a priming device has operated about 250 hours at 1400°F (maximum), 3000 rpm, 1.0 gpm, and 20-psi head with NaF-ZrF₄ as the pumped fluid. Restarting after stopping was accomplished without difficulty. (AEC Activity 4401.1)

ANP Math and Computation - Data from multi-group calculations on three possible CFRE reactors were analyzed for several basic constants. The reactors were 1) the 18-in.-dia core circulating-fuel type with Inconel cladding in the moderator coolant passages; 2) the same reactor with the Inconel cladding removed; and 3) the second reactor with niobium core shells clad with 0.010 in. of Inconel on each side. The net $\Delta k/\Delta T$ values for both the fast response effects, involving fuel expansion only, and the slow response effects, involving overall reactor expansion under a uniform reactor temperature change, were negative and of the order of 3×10^{-5} to 4×10^{-5} . The neutron life-times were computed to be 430 microseconds. Control rod calculations indicated that a relatively small rod could produce 2 to 4% change in k_{eff} . Larger changes would result from using a lower absorption material than Inconel for the core shells. A radial reactivity distribution for fuel density changes was computed. Values of $\Delta k/\Delta V$ varied from 4×10^{-5} at the island to about 7×10^{-5} at the outer core shell. (AEC Activity 4401.2)

ANP Reactor Chemistry - Final preparations for loading and for sampling the ARE are essentially complete. It is anticipated that assembly of the apparatus will be completed, testing will be finished, and actual transfer of the molten salts into the ARE storage tanks will begin by October 15. Loading of the fuel solvent and the fuel concentrate should be completed by November 1 unless major difficulties are encountered.

Experimental study of equilibrium concentrations for the reactions



in molten NaZrF₅ at elevated temperatures is nearly complete. The most recent data show the equilibrium constant for the reaction of Fe⁰ with UF₄ to be about 1.3×10^{-6} at 600°C and 2.9×10^{-7} at 800°C.

Similar studies of various reactions in which the NaF-KF-LiF eutectic is the solvent were initiated. Preliminary data indicate that FeF₃ is partially reduced to FeF₂ by Ni⁰ and that CrF₃ is quite stable to reduction by Ni⁰ in this solvent. Reduction of both FeF₃ and CrF₃ to the divalent fluoride in nickel equipment was essentially complete in molten NaZrF₅.

Experiments to determine the extent to which UF₄ can be reduced to UF₃ in various molten fluoride mixtures showed that essentially complete reduction can be obtained as long as KF is absent. In salt mixtures containing 50 mole % KF, about one-third of the UF₄ remains unreduced.

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

Experimental evaluation of the solubility of xenon in molten salts is under way. The NaF-KF-LiF eutectic and normal xenon are being used for the study. The molten salt is saturated with xenon and transferred without contamination by the vapor phase to another section of the apparatus. Xenon is stripped from the molten salt by sparging with helium, and the xenon, after separation from the helium, is measured in a modified McLeod Gauge. Preliminary measurements show that the solubility of xenon in this salt mixture is about 5×10^{-7} moles of xenon per cubic centimeter of salt at 540°C under 1 atmosphere pressure of xenon.

The vapor pressure of rubidium was determined over the range 428° to 540°C by the same technique as that used for fused salt mixtures. The data are represented by the equation

$$\log P(\text{mm Hg}) = - \frac{4024}{T(^{\circ}\text{K})} + 7.091.$$

The extrapolated boiling point (683°C) and the heat of vaporation (18.5 kcal/mole) agree closely with values found in Kelley's (US Bur. Mines Bull. 383, 1935) compilation (679°C and 18.5 to 18.8 kcal/mole). The quartz apparatus used for the vapor pressure determinations apparently was attacked by the metal. Although it did not fail during the experiments, it was so brittle that it broke very easily during the disassembly operation. (AEC Activity 4401.5)

ANP Corrosion Research - The fluoride fuel NaF-ZrF₄-UF₄ (50-46-4 mole %) was circulated in thermal convection loops constructed of Hastelloy B and of Hastelloy C. After 1000 hr of operation at a hot-leg temperature of 1500°F , the Hastelloy B loop appeared to be the same as after 500 hr of operation. A loop constructed of over-aged material showed slightly more attack than did a loop of as-received material. On the basis of these tests, Hastelloy B, which has strength properties superior to those of Inconel, appears to be resistant to both impurity attack and to mass transfer. The attack found in Hastelloy C under the same conditions was deeper but it was still only about one-half that found in Inconel.

The purification treatment now being used for the alkali-metal-base fluoride mixtures has slowed down but not prevented the plugging of stainless steel loops. A type 316 stainless steel loop plugged in 350 hours, rather than in the 50 hours previously found with the more impure mixtures.

Although neither hot-leg attack nor deposits were found in one Inconel thermal convection loop after circulation of an alkali-metal-base fluoride mixture containing UF₃ and UF₄, no reproducibility in results could be obtained. The loop tests with alkali-metal-base fluoride mixtures was stopped until chemical study of the system has been completed in more detail.

Several brazing alloys on T-joints of type 304 stainless steel were corrosion tested in sodium. An alloy containing 10.2% P-13% Cr-balance Ni showed satis-

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

factory resistance to attack by sodium. As the chromium content was increased from 2% to the 13% level, the corrosion resistance of the alloys improved. (AEC Activity 4401.5)

ANP Metallurgy--Welding and Brazing - The tube-to-fin section of a stainless-steel-fin, sodium-to-air radiator for 1/2-Mw operation was furnace brazed. All the tubes were shown to be leak tight after brazing, that is, they could be evacuated to less than 0.5 micron. The Microbraz alloy used was applied as flat, punched washers. The desirability of using controlled amounts of brazing alloys, as is possible with washers of this type, was again emphasized, since no excess was noted on any of the 22,500 tube-to-fin joints. Two previous attempts at brazing assemblies of this type by applying the alloy as a slurry or with a medicine dropper were unsuccessful; leaks were formed in the tubes within the radiator core because of excessive dilution which was associated with localized excesses of the brazing alloy.

A method was developed for extruding brazing alloy powder held together with a Castolite binder. Thus, the various brazing alloys can be produced in wire form and a controlled amount of brazing alloy can always be placed on a joint. The brazing alloy powder is mixed with the binder, and the mixture is allowed to age prior to extrusion. The mixture can then be extruded at approximately 180°F. No binder residue has been found in small test specimens, but large assemblies must be examined with respect to atmospheric contamination and flowability. (AEC Activity 4401.5)

ANP Metallurgy--Fabrication - Nickel-molybdenum alloys containing 24, 32, and 38% molybdenum were melted. Studies of their working characteristics indicate that severe work hardening occurs in the alloys containing more than 24% molybdenum.

Creep tests of type 310 stainless-steel-clad copper at 1500°F were completed. For the stresses up to 1000 psi for a 1000-hour period at 1500°F the copper core is not embrittled. (AEC Activity 4401.5)

ANP Metallurgy--Mechanical Properties - One purpose of the creep testing program has been to study the effect of various environments on the high-temperature properties of Inconel. In order to magnify any effect that might occur, a type of specimen was chosen which would expose a large surface area compared to the volume of metal being tested. The 3-in.-long and 1/2-in.-wide specimens were milled from 1/16-in. sheet. A comparison of the data obtained by testing this type of specimen with data reported by other laboratories led to the speculation that the geometry of the specimen could also influence the creep properties of Inconel. In order to test this hypothesis, specimens were machined from a wrought bar to the following dimensions: a round bar with a 0.20 in.² cross-sectional area, a square bar with a 0.20 in.² cross-sectional area, and a round bar with a 0.05 in.² cross-sectional area. These specimens are being tested in argon and hydrogen. Preliminary results indicate that thickness may be an important factor in the

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

life expectancy of Inconel at high temperatures. Bars of large cross section stressed at 3500 psi show much longer life than bars or sheet of small cross section: for example, a time to rupture (in argon) of 4900 hr for the 0.20 in.² cross section square bar compared with 1400 hr for the 0.05 in.² cross section round bar. (AEC Activity 4401.5)

ANP Shielding--Lid Tank Shielding Facility (LTSF) - The measurements of neutron transmission through an array of GE-ANP helical air ducts, were continued with a system of 35 ducts (3 in. ID) arranged so that there is 5 in. between their center lines. Measurements in plain water show that the flux is increased by a factor of approximately 150 with the ducts in place. It has not been determined whether this difference is due to the reduced density of the medium or to streaming in the ducts. (AEC Activity 4401.7)

ANP Shielding--Tower Shielding Facility (TSF) - Various analyses of the TSF differential experiments have used both single- and multiple-scattering theories to determine the contribution of the ground-scattered radiation at the high altitudes. In all cases, an isotropic source was assumed. As previously reported (report ORNL-1781), these analyses indicated that the ground-scattered contribution in the differential experiments was 2 to 5% at the 200-ft altitude. However, the results obtained from experiments with the reactor in the GE-ANP R-1 reactor shield showed that the anisotropies of the sources must be considered. The importance of multiple scattering is still unresolved, but work so far accomplished indicates that a single-scattering theory which includes the anisotropies of the sources may fit the data of both the differential and the GE experiments. If this proves to be true, the ground-scattered contribution in the differential experiments will be reduced to 1% and that in the GE experiment to 5%.

Radiation measurements made around the GE-ANP R-1 reactor shield in the TSF handling pool agree, in general, with similar measurements made at the Bulk Shielding Facility (BSF).

Thermal-neutron measurements were made with a BF₃ counter in the TSF detector tank located 64 ft from the GE-ANP R-1 reactor shield at an altitude of 195 ft. A 5-in. thickness of lead was placed in the detector tank 1 ft from the rear (reactor side), and the attenuation of the neutrons by the lead was surprisingly large. This would indicate that the majority of the neutrons were fast and were penetrating the lead at a slant angle after air scattering. Relaxation lengths were measured as follows:

Near rear of tank	~4.8 cm
First 15 cm in front of lead	~4.8 cm
Near right, left, bottom, and top sides of tank	4.3 cm (av)
Near front of tank	4 cm (av)

(AEC Activity 4401.7)

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

ANP Fuel Recovery - In earlier studies (report ORNL-1703, p. 14) on recovery of uranium from ARE-type fuel ($\text{NaF-ZrF}_4\text{-UF}_4$) by fluorination of the molten salt with excess elemental fluorine, overall gross beta decontamination factors of 5000 were obtained by resubliming the UF_6 volatilized in the process. In further experiments, this UF_6 , in the absence of excess fluorine, was found to be soluble in molten NaF-ZrF_4 , probably according to the reaction $\text{UF}_6 + \text{NaF} \longrightarrow \text{NaF}\cdot\text{UF}_6 \longrightarrow \text{NaF}\cdot\text{UF}_4 + \text{F}_2$. By means of this reaction, aircraft reactor fuel could be refabricated directly from the resublimed UF_6 .

If the uranium is to be returned to a diffusion plant or to a heterogeneous reactor, more decontamination is needed. A decontamination factor of approximately 20,000, with a uranium loss of less than 0.001%, was obtained by scrubbing the mixture of fluorine and volatilized uranium hexafluoride, as it came from the fluorinated fuel, with a molten NaF-ZrF_4 salt bath at 650°C , in which the UF_6 is insoluble in the presence of excess fluorine. Fractional distillation of the UF_6 to obtain complete decontamination could be carried out in only lightly shielded equipment. (AEC Activity 4401.81)

GENERAL REACTOR RESEARCH

School of Reactor Technology - Nine design problems were undertaken by the 1953-54 session of the Oak Ridge School of Reactor Technology, as "group theses" with group leaders selected by the ORSQRT faculty. Final results were reported to the Laboratory in meetings on August 23 and 24. The titles of the design problems are: "Fast Reactor for Power", "MTR" Converter with Aqueous Blanket", "Rubidium-Vapor Aircraft Reactor", "Ceramics Gas-Cooled Power Breeder", "Boiling Homogeneous Reactor for Power and Plutonium Production", "Boiling Homogeneous Reactor for Power and U^{233} Production", "Homogeneous Reactor for Ship Propulsion", "Ultimate Homogeneous Reactor", and "Heterogeneous Boiling Package Reactor".

Selections for the 1954-55 session of ORSQRT were completed, and classes for the new session began September 13, 1954, with an enrollment of 85 (33 new student-employees and 52 sponsored students). (AEC Activity 4841)

PROGRAM 5000 - PHYSICAL RESEARCH

Reactor Operations - Two ruptured slugs were found in the graphite reactor on July 19; these were the first ruptures to occur since October 12, 1953. Both slugs were of the bonded type and the uranium was 100% beta transformed. One slug had been in the reactor for 826 days at a temperature of 238°C; the other, 819 days at a temperature of 153°C. Both ends were off of one slug; one end was off of the other and there was a longitudinal split in the jacket; there were also a number of blisters. Measurements were taken, but no significant increase in slug length was found.

Lightning damage from storms has been much greater than usual this year. Lightning struck twice during July and August, severely damaging a 900-hp motor and associated control boxes.

It has been established that the Np^{239} consistently found in the LITR cooling water must be selectively diffusing through the aluminum jacket on the fuel pieces, since only very small quantities of fission products and no trace of U^{239} have been found in the cooling water.

The Oak Ridge Reactor (ORR) - Approval for the definitive design and construction of the reactor, reactor tanks, control system, etc., was received from the AEC on August 25, 1954, and the design work is now underway. Design criteria on nearly all phases of the work were transmitted to the McPherson Company and preliminary drawings were received from them on the architectural-structural phase of the design. These drawings are now being reviewed by ORNL and the AEC.

ISOTOPE PRODUCTION

Radioisotope Production - The first cobalt wafers which were irradiated in the MTR for use in teletherapy units were received; the specific activity was found to be 56 curies/g. One teletherapy source containing 1600 curies of Co^{60} was loaded. The newly-planned high level manipulator cell has not yet been constructed, so it was necessary to perform these operations in the existing remote manipulator cell. Personnel were rotated during the operations and no radiation over-exposures occurred. This emergency-type loading will be continued until the most urgent requests have been filled. It is expected that the high level manipulator cell will be finished by January 1, 1955.

Methods were worked out to produce routinely small pressed pellets of Cs^{137}Cl in a manner similar to that reported for the recently made 1500-curie source. There is a brisk demand for these smaller sources for radiographic work.
(AEC Activity 5111)

Radioisotopes, Process Development - Test runs were completed on the new I^{131} plant and it was put into routine operation September 15. Production of iodine for the radioisotope program (10-20 curies per week) now requires

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

only one part-time operator. The new cold water scrubbers (4°C operating temperatures) have proved to be very efficient, passing <0.1% of the I^{131} to the final scrubbers containing sodium hydroxide.

Approval was received to start design on a new pilot plant to produce kilocurie fission product sources. The design capacity of the plant will be 200,000 curies of the Cs^{137} per year; it is scheduled for completion in late 1956.

A study of methods for large-scale production of fission-product technetium has resulted in a method of separating technetium from the phenyl arsonium permanganate precipitate, which carries technetium by dissolving it in acidic acetone and passing the solution through an anion exchange column where technetium is selectively taken up. Technetium is then eluted with HCl. Yields are only moderate, 65% per step, but plant-type recycling operations make the method feasible for use in large-scale operations. (AEC Activity 5112)

PHYSICS

Recoil Spectrometry - The chlorine-37 ions that recoil as the result of neutrino emission from K-capturing Argon 37 were subjected to energy analysis by means of 90-degree electric deflection. A spectrometer fitted with deflecting plates, that are portions of spherical surfaces, was used to give two-directional focusing. The larger aperture of this instrument together with increased differential pumping enhanced the ion peaks by a factor of 3 relative to the background, as compared with the previous situation in which the recoils were observed under magnetic analysis. The recoil peak pertaining to doubly-charged ions was studied with particular attention. The recoil energy is 9.5 ± 0.2 ev, which is the value to be expected for a weightless neutrino emitted with the known transition energy, 814 kev. The peak is completely resolved, and has a width about that expected from the result of thermal motion and recoil from Auger emission. The peaks from triply, quadruply, and quintuply charged recoils are not well resolved from one another in the electric deflection. The singly-charged ion peak was again looked for but not found. (AEC Activity 5200)

Neutron Diffraction - The magnetic structure of Mn_2Sb was investigated by neutron diffraction techniques which employed single crystals of the compound. This material is a ferrimagnetic substance in which the two manganese atoms possess different magnetic moments that are coupled in an antiparallel arrangement. Investigations were previously performed on powdered samples, and the magnetic structure was found to agree in general with a model suggested by Guillaud. However, the complexity of the powder diffraction patterns and the difficulties of analysis did not permit a straightforward determination of the magnetic scattering amplitudes and the corresponding atomic magnetic moments. These values were readily determined by a study of single crystal reflectivities with magnetized and unmagnetized samples.

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

Satisfactory agreement was obtained for the magnetic scattering amplitudes measured for various magnetic reflections from several crystals. (AEC Activity 5200)

Low Temperature, Nuclear, and Solid State Physics - Previous measurements, made at this Laboratory, of the magnetic susceptibility of uranium tri-iodide indicated an antiferromagnetic transition near 3°K and, in addition, a type of weak ferromagnetism near 1.5°K . In a search for the thermal effects associated with these magnetic transitions, the specific heat of UI_3 was measured from 1.2°K to 4.2°K by means of low temperature adiabatic calorimetry. These measurements show a sharp λ -type specific heat anomaly of magnitude 10 joules/degree-mole at 2.61°K , which is interpreted as arising from the onset of long-range antiferromagnetic ordering. Above 3°K the magnetic specific heat falls very slowly with increasing temperature, suggesting the slow decay of short range order. A plot of entropy vs temperature, obtained by integrating the specific heat data, shows that only one-fourth of the available spin entropy has been achieved at 2.61°K . No irregularity in the specific heat was found in the neighborhood of 1.5°K , showing that the weak ferromagnetism observed in the magnetic susceptibility measurements must be due to the action of a very small fraction of the available electrons. This ferromagnetic behavior is interpreted as arising from thin ferromagnetic walls separating antiferromagnetic domains. (AEC Activity 5200)

Heavy Ion Physics - The program for the study of capture and loss of electrons by fast (20 to 250 kev) atomic particles passing through gases was continued. The cross sections for electron capture by protons are measured by observing the attenuation of a proton beam which passes through gas in a region of homogeneous magnetic field. A hydrogen atom formed by electron capture leaves, tangentially, the path prescribed by defining apertures and the magnetic field, and so is lost. This attenuation is related to the cross section and the gas pressure by the formula

$$\frac{I}{I_0} = e^{-kp\ell}$$

where I and I_0 are, respectively, the transmitted proton current with and without gas in the charge exchange chamber, p is the pressure and ℓ the capture cross section. The constant k is calculated from the path length and the nature of the gas. The directly measured cross sections for electron capture by protons appear to be in good agreement with those calculated from the previously determined cross sections for electron loss by fast hydrogen atoms and the ratios of loss to capture cross sections. Because separate equipment and techniques were employed, this agreement establishes a reliability of the data which is uncommon in this field.

It is found that in the energy range 80 to 250 kev, both the electron capture and the loss cross sections are well represented by formula of the type

$$\ell = A e^{-bv}$$

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

where σ is the cross section, v the particle velocity, and A and b are empirically determined constants. At the lower energies, the cross sections depart from the exponential behavior, tending toward maximum values. (AEC Activity 5200)

High Voltage Program - A theoretical analysis of the experimental results on elastic scattering of neutrons from nitrogen was made. In one series of experiments, a proton-recoil neutron detector was used to measure scattered neutrons as a function of angle. In another, the angular distribution of neutrons was deduced from the energy distribution of recoil nitrogen nuclei. Comparison of the two types of experiments showed that the nitrogen recoil data needed correction in the region $\cos \phi = 0.1$ to $\cos \phi = 0.5$ (ϕ = center of mass angle). The combined data allow one to calculate the potential phase shifts from 0 to 1.8 Mev neutron energy. The following J-value and parity assignments fit the resonance scattering:

<u>E_n</u>	<u>J</u>	<u>Parity</u>
1.12	3/2	odd
1.35	--	even
1.40	3/2	odd
1.60	5/2	odd
1.80	5/2	even
2.25	--	odd

Preliminary yield curves for the gamma rays resulting from the proton bombardment of B^{10} were extended to 5.5 Mev by use of the magnetically analyzed beam of the ORNL 5.5-Mev Van de Graaff. The gamma rays were detected at 90° to the proton beam by means of a 3 by 3 in. NaI crystal used in conjunction with a 20-channel pulse height analyzer. The targets consisted of thin (30-kev) evaporated layers of B^{10} on tantalum backings. The reactions investigated were $B^{10}(p,p')B^{10}$ and $B^{10}(p,\alpha\gamma)Be^7$. The 0.78-Mev inelastic scattering gamma ray shows only a broad (half Mev) level at about 4.4-Mev proton energy. The 0.43-Mev gamma ray resulting from excitation of the 0.430-Mev level in Be^7 by the (p,α) reaction indicates levels at proton bombarding energies of about 3.0 and 4.4 Mev.

The cross section for the excitation of the 0.8-sec isomeric state in Pb^{207} , produced by inelastic scattering of neutrons from the 5.5-Mev Van de Graaff and detected by measuring the delayed γ -ray activity, was measured from threshold to 3.2 Mev. The cross section was interpreted by the use of the strong interaction theory of nuclear reactions. It was found that the theory correctly predicts the shape and absolute cross section from threshold (1.61 Mev) to 3.20 Mev. In making the calculations, the levels in Pb^{207} at 2.34- and 2.75-Mev were taken as $h_{9/2}$ and $g_{9/2}$, respectively. The success of the theory in this case furnishes additional support for the validity of this approach (theory plus knowledge of energy levels) for the determination of inelastic neutron scattering cross sections. (AEC Activity 5200)

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

CHEMISTRY

Chemical Separation of Isotopes - A series of column runs were made to determine the effective nitrogen-isotope separation factor for the ammonia(gas) vs ammonium-carbonated(aqueous) closed-cycle system. Countercurrent gas-liquid exchange was carried out in a packed column and isotopic samples taken until equilibrium was attained. A solution, simultaneously saturated with commercial ammonium carbonate and gaseous ammonia, was used to prepare feed solutions that were $\sim 18M$ in total nitrogen. Reflux was accomplished at one end of the column by the addition of NaOH to convert NH_4^+ to $NH_3(g)$. A series of identical runs were made at atmospheric pressure and $30^\circ C$ with different constant withdrawal rates for the product. This was done by allowing $NH_3(g)$ to escape from the N^{15} end of the system at a constant rate through a flowmeter. From this series of runs calculations were made by using the formulas of Shacter and Garrett (AECD-1940). The effective single-stage separation factor for the system was found to be ~ 1.015 and the stage height to be ~ 6 inches in the exchange column. This column value may be compared with the fractionation factor obtained from a single stage batch determination which gave 1.017 at $32^\circ C$. Because of the favorable fractionation factor at atmospheric pressure, the high concentration of total ammonia in the aqueous phase, and the closed reflux cycle, it is believed that the ammonium carbonate system offers considerable promise for the low cost production of N^{15} . (AEC Activity 5300)

Instrumentation for Chemical Research - A prototype model of the DD2 double-delay-line linear amplifier was produced. This amplifier was designed to operate under conditions of very high counting rates (100,000 counts per second) and with large overloads, without blocking. The device is useful in obtaining spectra of low energy x-rays in the presence of a high-energy, high-rate gamma background. The clipping time of the amplifier is 1 microsecond, and the output is linear to 0.5% for 100 volts output. The instrument has a gain control range of 1000 to 1.

The design work on a Williams-type storage system for use with a multi-channel pulse-height analyzer was completed and construction has begun on a test model. The present model will have 30 storage channels with a capacity of 10^6 counts per channel. The resolving time of the system is approximately 240 microseconds with a regeneration rate of 10 per second. (AEC Activity 53XX)

Hot Laboratory Research - The method of anion exchange was shown to have considerable advantage over alternate techniques as a method for separating the synthetic elements, neptunium and technetium. For the recovery of neptunium from mixed fission-product sources use was made of the strong adsorption of the chloride complexes of U(VI), Np(IV) and Pu(IV) in $12 N HCl$. This technique permits the separation of these elements from essentially all contaminants, except a few (like iron) which are also adsorbed under these conditions. Since these few contaminants are adsorbed more readily in $5 N HCl$,

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

it is also possible to remove them. Plutonium was removed by reduction to Pu(III). Purity of the Np²³⁷ thus obtained on the 100-mg scale was of the order of 98%.

Technetium, as the TcO₄⁻ ion, was found to adsorb readily on Dowex A-1, even in 2 to 3 N HNO₃. In one loading experiment breakthrough occurred after treating 30 column volumes of a 3 N HNO₃ solution. The amount of technetium contained in this solution nearly equalled the capacity of the resin. Elution was accomplished with NaClO₄. The method promises to be more widely applicable and to permit a more economic recovery of this element. (AEC Activity 5300)

General Reactor Chemistry - A series of measurements of the potential of the silver-silver chloride and the mercury-mercurous chloride electrode combination was made. The temperature was varied from 25° to 263°C and the acid concentration from 0.01 to 1.0 molar. The potentials obtained at given temperatures were compared with those predicted on the basis of thermodynamic calculations for this cell combination by using heat capacity data from the literature. It was found that in 1.0 M HCl the measured potentials agreed with the calculated values up to 240°C, in 0.5 M HCl up to 190°C, and in 0.1 M HCl up to 100°C. A mechanism involving disproportionation and hydrolysis of the calomel to Hg and HgO was postulated to explain the deviation between the measured and calculated potentials at low acid concentrations and high temperatures.

A preliminary measurement of the Np²³⁹ capture cross section for neutrons was made by irradiating uranium slugs for varying lengths of time in the LITR and analyzing mass-spectrographically the plutonium product for Pu²⁴⁰ content. The tentative value obtained from the first four irradiations was 80 ± 30 barns. (AEC Activity 5300)

Chemistry of Corrosion - The electrode potential of type 347 stainless steel was determined in sulfuric acid-sodium sulfate mixtures at several pH's and with various atmospheres in the apparatus. The formal potential of hydrogen on a platinized platinum electrode was determined under similar experimental conditions. These measurements make it possible to interpret the previously observed fact that when air is present and other conditions are suitably controlled, the potential of the steel rises abruptly after reaching a value of approximately -295 mv with reference to the saturated calomel electrode. This is only a few millivolts removed from the potential found for the hydrogen electrode. It, therefore, becomes possible to interpret the great decrease in corrosion rate observed at this potential as arising from the displacement of a hydrogen-saturated surface on the steel by an oxygenated surface. It was also shown that, if carbon monoxide is passed through the solution during the measurements, the corrosion rate is somewhat diminished, but the electrode potential shifts only slightly from its value in an atmosphere of hydrogen or of an indifferent gas. No recovery of potential and no great reduction in corrosion rate is induced by carbon monoxide under these conditions, as is the case when air is present in the flask. (AEC Activity 5300)

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

Hope Project - As a part of the Hope project for decreasing radiochemical processing costs, equipment for continuously charging Savannah River slugs to the dissolver at a rate of two per minute was designed and constructed. The slugs are raised one at a time from the bottom of the canal, through 8 ft of water and the 12 ft of air inside the cell, to the top of the dissolver. This procedure eliminates the lead-shielded carriers and heavy equipment that would be required if a number of slugs were raised together in a carrier and held above the dissolver while one slug at a time was dropped. In a short-term test the charger operated with an efficiency of 90%, i.e., 108 slugs were charged per hour. A color movie showing the operation of the continuous charger was prepared. (AEC Activity 5300)

Ion Exchange Technology - Tests were made to determine optimum operating conditions for the recovery of uranium from unfiltered sulfuric acid ore-leach slurries with the Higgins continuous ion exchange contactor. Uranium was stripped more readily from the anion exchanger Permutit SK-1 (10 to 50 mesh) with 1 M NH_4NO_3 than from other ion exchangers tested, for example, Dowex 1 and Amberlite IRA-400. The kinetic exchange characteristics of a resin varying in size from 10 to 50 mesh were superior to those of a uniform 20-mesh resin, a feature which overshadowed the disadvantage of the higher pressure drop imposed in the column by the finer resin. Results of demonstration runs with this system in a 6-in.-dia. column indicated that such a unit would be able to process 2.5 to 3.0 tons of Colorado Plateau ore per day. The demonstration runs were made with a synthetic water slurry. Stripping of the uranium from the anion exchange resin by conversion from the uranyl sulfate to the uranyl chloride form with 10 M HCl followed by elution with water was highly efficient.

An ion exchange method using Amberlite IR-105 resin and 0.5 M $(\text{NH}_4)_2\text{CO}_3$ as the eluant was developed for the preparation of rubidium chloride containing 99% RbCl, 0.1% CsCl, and less than 1% KCl from crude material containing approximately 80% RbCl, 19% CsCl, and 1% KCl. This material was suitable for use in preparation of rubidium metal. The ammonium carbonate was easily removed from the product by heating it to form CO_2 and NH_3 . (AEC Activity 5300)

Chemical Engineering Research - In the Higgins ion exchange contactor the movement of the resin is considered continuous, but actually it is intermittent, with instantaneous pauses at intervals. An ion exchange column was designed in which there is no break in the movement. The resin flows upward and the liquid downward, instead of the reverse as in the Higgins column, and fluidization of the resin bed is prevented by a hydraulic ram. In performance tests on a 4-in.-diameter column, operation was satisfactory and coefficient-of-friction data were obtained for use in further design studies. (AEC Activity 5300)

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

Economic Studies - The distribution of the costs incurred in the design, construction, and placing in operation of the Idaho Chemical Processing Plant (for recovering enriched uranium from reactor-irradiated uranium slugs) was analyzed. The complete cost (but not including development costs) to the customer, the Atomic Energy Commission, was \$31,105,899. The percentage of land costs and improvements thereon charged to the Atomic Energy Commission include a prorated share of the IDO Central Facilities, which are shared by all installations at the National Reactor Testing Station. A complete breakdown of the costs is given in ORNL-1791 (Secret) and ORNL-1792 (Official Use Only).

Volatility processes for separating the uranium and plutonium in irradiated slugs and for directly converting the uranium to the hexafluoride have been proposed. A cost estimate of the chlorine trifluoride volatility process indicated that the fixed investment cost of a directly maintained plant to process 3 metric tons of uranium per day would be \$32,900,000. The feed was assumed to contain 550 g of plutonium per metric ton of uranium (cooled 120 days after irradiation), and the products were assumed to be uranium hexafluoride and a concentrated aqueous plutonium nitrate solution. The annual operating cost of such a plant, including amortization in 6-2/3 years and 2% for cost of money, but excluding SF inventory, would be \$9,259,000 or \$15.40 per gram of plutonium.

Costs for a bromine trifluoride--bromine pentafluoride volatility plant would be practically the same as the corresponding costs for the chlorine trifluoride plant. Installation and operating costs for a Purex plant of the same capacity, plus an estimated charge of \$1.24 per pound of uranium for converting the uranyl nitrate produced in the Purex process to uranium hexafluoride by conventional methods, would be \$11,490,000 per year or \$19.10 per gram of plutonium. Either of the volatility processes would be approximately \$2,231,000 per year or \$3.70 per gram of plutonium cheaper than the Purex process. (AEC Activity 5300)

Criticality Studies - A general criticality study on cylinders and infinite slabs was made for enriched U^{235} aqueous solutions. The data were used to prepare a series of curves from which criticality conditions for various cylinder dimensions and U^{235} aqueous concentrations can be rapidly determined. A nomograph was prepared from which, for a given H/U^{235} ratio, it is possible to determine, from one set of known critical dimensions, the dimensions of any other critical cylinder, sphere, or cube. (AEC Activity 5300)

Feed Materials - The Metallex process, based on alkali metal reduction of $ThCl_4$, is being evaluated for the preparation of thorium metal. The process includes preparation of a propylenediamine solution of $ThCl_4$; reduction of the $ThCl_4$ to thorium by sodium amalgam, during which the reduced thorium forms a quasi-amalgam with the mercury; and recovery of the thorium from the amalgam phase. Preliminary conservative cost estimates indicate that the

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

process, including conversion of powdered metal to massive form will cost \$1.28 per pound, excluding the cost of the ThCl_4 .

In laboratory-scale studies of the Metallex process, ThCl_4 was prepared by carburizing and chlorinating thorium oxide or oxalate in a single step. The thorium oxide or oxalate was mixed with carbon; then chlorine, CCl_4 , or a mixture of the two was passed over the mixture in a fixed bed at 550°C for 5.5 hr. In another test the product was chlorinated 30 times faster if the carburization was performed as a separate step, prior to the chlorination, at 2000 to 2200°C in a hydrogen atmosphere. Solutions of ThCl_4 up to 0.55 M were prepared by leaching the chlorination product with boiling anhydrous propylenediamine. Up to 85% of the thorium was then reduced by agitation with either lithium or sodium amalgam at about 100°C . The metal and the mercury formed a quasi-amalgam, from which a concentrate 10 times richer in thorium was separated by centrifugation. When the mercury was distilled off under 1 mm Hg argon pressure at 800°C , a pyrophoric thorium powder containing 5% residual mercury remained. A button of thorium metal, ~15 g, was prepared by evaporating the mercury from a simulated thorium quasi-amalgam in an induction furnace. (AEC Activity 5300)

OTHER PHYSICAL RESEARCH PROJECTS

The Oracle - During the months of August and September, a total of 698 hours of good computing time was used for problem solution (as compared to 393 hours for June and July). The total scheduled computing time during this period was 734 hours, of which 36 were lost due to machine breakdown. By the common definition, the operating efficiency for this period was 95%.

The Oracle is now operated on a regularly scheduled two-shift basis, five days per week. The third shift is made available on a voluntary basis with no maintenance personnel present. A machine breakdown during the third shift thus ends operations until the regular day shift personnel arrives. (AEC Activity 5511)

Instrument Development - A pulse integrator for the neutron dosimeter was built to supersede the model Q-1179 dual-channel dosimeter. The new model employs the binary system of weighing and integrating pulses. The device consists of four scales of 32, mixed to prevent coincidence from a single pulse and fed into a scale of 32,000 to give a total storage capacity of 1,056,000. The thirteen discriminators in the design divide pulses into channels having mid-channel amplitudes of 8, 12, 16, 24, 28, 32, 40, 48, 56, 64, 80 and 96 volts, respectively. The outputs from the discriminators are fed into the binary pairs in such a manner as to produce one pulse in the storage system for each amplitude of 4 volts.

The Serial Memory Multi-Channel Analyzer, described in the July report, ORNL-1760, was installed in the High Voltage Laboratory and a spectrum was

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

run on Cs¹³⁷; a resolution of 8.1% was obtained. With an alpha chamber and a monoenergetic alpha source, a resolution of 3% was obtained. The chamber resolution was 2%.

A 625-kv accelerator is being assembled for the High Voltage Laboratory. The power supply was furnished by General Electric, and is called by them a Cascade Generator. It is composed of five nearly identical stages, stacked vertically. At the terminal there is available (1) the high voltage, variable to a maximum of 625 kv, at 25 ma, and (2) 5 kva of isolated power to operate the ion source. A precision resistor for operation of a voltmeter is a part of the machine. Installation of this power supply was completed, and the supply was satisfactorily tested at rated maximum output. The construction of the accelerator tube and supplementary equipment is proceeding.

PROGRAM 6000 - BIOLOGY AND MEDICINE

BIOLOGY

Cytogenetics - The dose curve for mutations in Paramecium has now been established for neutrons produced in the 86-inch cyclotron. The curve is nearly identical in form to that for X-rays with an RBE (relative biological effectiveness) for neutrons of 2.3. Both curves depart from the form expected on the simplest assumptions. A priori, this departure could be attributed either to the inclusion of many two-hit chromosome aberrations in the "mutations" or to an interaction between single-event mutations such that only when two or more segregate together is there a detectable effect. The latter hypothesis is favored by most of the previous evidence and is supported by the results with neutrons since a marked difference in the form of the two curves would be anticipated if the first hypothesis were true. If the second hypothesis is accepted, the data show that the mutations produced by X-rays and neutrons do not differ appreciably in the magnitude of their action. The major differences between neutrons and X-rays is that with the former more cases of multiple mutations in the same nucleus are found, as might be expected on the basis of the differences in the distribution of ionization. (AEC Activity 6400)

Microbiology - The relation between growth rate and nuclear ratio was studied in obligate heterokaryons between biochemical mutants of Neurospora. It was found that nuclear ratios do not adjust automatically in a direction leading toward optimal growth. Apparently, the growth rate of terminal hyphae is influenced by the nuclear ratio in the culture as a whole, but not by their

PROGRAM 6000 - BIOLOGY AND MEDICINE (Continued)

local nuclear ratios. This knowledge makes possible the quantitative study of the efficiency of gene action, since growth rates with limiting proportions of the wild-type allele of a biochemical mutant can be compared with rates for the mutant on limiting amounts of the growth factor.

A simplified approximation formula for finding the nuclear ratio in heterokaryons by plating macroconidia was devised and experimentally tested. An orderly relation was found between the input ratio of nuclei in conidial mixtures and the ratio in conidia of the resultant cultures, as estimated by the approximation. This result shows that the nuclear ratios in Neurospora heterokaryons can be experimentally controlled. (AEC Activity 6400)

Radiation Protection - Previous reports from this group (ORNL-1766) presented evidence for partial reversal of radiation damage in Escherichia coli B/r by additions of known chemical compounds to a chemically defined medium. The reported studies were based on cells cultured on beef extract broth before irradiation. It has now been found that the requirement for the added factors varies, depending on the medium on which the cells were originally cultured. Different chemically defined media were used for culturing cells. The results to date indicate that the requirement for added factors after irradiation increases as the complexity of the culture medium increases. It is logical to assume that the cells cultured on the simple media have, of necessity, a fuller complement of enzymes than those cells supplied with many preformed intermediates in their natural forms, as in beef extract. If such is the case, it should be possible to demonstrate that the factors found to stimulate recovery in cells cultured on beef extract and then plated on a minimal medium after irradiations are involved in stimulating the synthesis of new enzymes.

A previous report indicated that a large part of the protection afforded E. coli from the lethal effects of radiation by cysteamine (β -mercaptoethylamine) is due to a remarkable postirradiation recovery of the irradiated bacteria on the surface of nutrient agar plates. A modified approach to the study of the recovery process in cysteamine-treated cells was carried out by testing the ability of various liquid media to support recovery of cysteamine-protected E. coli in varying lengths of time. These studies show that the stimulus to recovery afforded by liquid medium containing yeast extract is transferred to the bacteria within a few minutes, giving a level of recovery equivalent to that obtained on yeast extract plates. However, a chemically defined medium (containing uracil, guanine, and glutamine, in addition to salts and glucose) was developed which, while effective in promoting recovery when added to the solid agar plate, was ineffective in promoting recovery of cysteamine-treated cells in a liquid medium, even after an exposure of several hours. From these studies it seems probable that yeast extract contains an additional factor (or factors) more directly involved in or necessary to a rapid recovery process than the nutritional factors present in the chemically defined medium mentioned above.

PROGRAM 6000 - BIOLOGY AND MEDICINE (Continued)

Further studies have shown that the nutritional circumstances under which cells to be irradiated are grown, is highly important to the demonstration of nutritional requirements for the recovery process of cysteamine-treated cells. Only cells grown on nutrient media (containing yeast extract or other natural extracts) demonstrate definite nutritional requirements for survival following irradiation. Cells grown on a simple salts-glucose medium apparently contain all the enzymes or other factors necessary for the recovery process to take place. (AEC Activity 6400)

Biochemistry - Recent experiments in other laboratories have demonstrated the presence in T₄ bacteriophage of a reducing sugar, tentatively identified as glucose and apparently covalently bound into the deoxynucleic acid moiety of the phage. This is one of the three phages (T₂, T₄, T₆) in which the complete replacement of cytosine by 5-hydroxymethylcytosine (HMC) was demonstrated a year or two ago. It was proved that this sugar is indeed glucose, by means of the borate chromatography developed in this laboratory as well as by specific enzymic degradations. It was also demonstrated that glucose and HMC are present in equimolar amounts in all of the fragments or groups of fragments isolated by ion exchange from digests with deoxyribonuclease and diesterases (intestinal phosphatase, snake venom). Unfortunately, complete digestion to mononucleotides cannot be achieved, apparently due to an inhibition of diesterase activity by the glucose-HMC moiety. From the ease with which acid removes the glucose from phage DNA (100°, 1 N HCl, 1 hour), it is concluded that the glucose is bound as an O-glycoside to the 5-hydroxymethyl group of HMC and not as an N-glycoside to the 3-N position in place of deoxyribose.

The biochemical effects of the irradiation of a growing tissue could be exerted on the biosynthesis of the small "building blocks" or could be manifested as an interference in the assembly of the "building blocks". Data gathered to date in this and in other laboratories indicate that the latter possibility is the most likely. Further light was thrown on these alternatives by studying the effects of various inhibitors of nucleic acid synthesis on the incorporation of formate into the nucleic acid purines and thymine of bone marrow. Nitrogen mustard, which resembles X radiation in its action, was found to inhibit the incorporation of formate C¹⁴ into each of the bases to an equal degree. On the other hand, aminopterin, which is known to reduce the formation of individual nucleotides had an unequal effect on the bases, inhibiting incorporation of C¹⁴ into thymine to the greatest degree. Thus, in the latter case, nucleic acid synthesis must have taken place in spite of the presence of the inhibitor, i.e., the assembly of the "building blocks" continued even though the new formation of thymine nucleotide was stopped. A series of purine analogues are now being tested for their effects. Compounds already examined are: 2,6-diaminopurine, 6-mercaptapurine, 2-mercaptoazahypoxanthine, 5-amino-7-mercapto-1-v-triazolopyrimidine, 5,7-dimercaptotriazolopyrimidine, and 2-mercaptoazaadenine. These compounds will be classified according to whether they resemble nitrogen mustard or aminopterin in their effects. (AEC Activity 6400)

PROGRAM 6000 - BIOLOGY AND MEDICINE (Continued)

Biophysics - Investigations of the effects of temperature on the X-ray sensitivity of Tradescantia dry pollen were completed. No differences in aberration frequencies were found for material exposed in the range 15° to 26°C. This temperature independence is quite different from the situation for Tradescantia inflorescences where a definite temperature dependence for chromosomal aberration has been well established by other investigators.

The effects of radiation intensity (X-rays) on aberration frequencies in growing pollen tubes was investigated; no intensity effects were found. This is in agreement with previous findings in the case of dry pollen but differ from the results for inflorescences determined by Sax and others. (AEC Activity 6400)

Pathology and Physiology - Rats injected with S³⁵-labeled sodium sulfate three days after 750-r whole-body X irradiation (LD₅₀/30 days) had a plasma radioactivity level on the following day approximately one-half that of the unirradiated controls. A greatly increased excretion of sulfate in the urine of the irradiated animals was also noted. These findings indicate the production of a marked disturbance of sulfate metabolism by the radiation.

An attempt was made to assay organ-specific proteins through the use of C¹⁴-labeled mouse proteins. Some indication of localization of proteins from specific organs was obtained in the homologous organs of young injected mice. Fractionation of the injected material is underway to determine, if possible, a more precise source of the specificity.

The isolation of DNA-H and histone from Ehrlich mouse ascites tumor cells was accomplished and a median lethal dose was established for the histone; the dose is comparable to that published by others in earlier studies. The effects of these substances on ascites tumor growth are being tested.

The development of quantitative high-resolution techniques for the isolation of cell components by centrifugation was continued. A sector-shaped glass centrifuge tube of 65-ml capacity was designed and built; it eliminates wall effects and allows a more ideal separation of cell particulates.

Basic proteins of the nucleus (histones) obtained from chicken erythrocytes have been previously studied electrophoretically and shown to consist of at least five components. The application of the Linde Molecular Sieve to protein fractionation was investigated. Clean separations of bovine serum albumin and hemoglobin were readily obtained through the use of phosphate buffers (pH 6.4) of varying ionic strengths. Preliminary experiments indicate that this material is suitable for the column fractionation of fowl histones. (AEC Activity 6400)

PROGRAM 6000 - BIOLOGY AND MEDICINE (Continued)

Enzyme Chemistry - Work on the nature of the prosthetic group of DPNH (reduced diphosphopyridine nucleotide) peroxidase was continued. By the technique of zone electrophoresis on starch blocks, it was demonstrated that the peroxidase activity in successive fractions along the entire isolated peroxidase peak is directly proportional to the flavin content of the enzyme. This is in confirmation of previous work, which indicated that the peroxidase in flavin-deficient vacuum-dried cells could be activated by FAD (flavinadenine dinucleotide). Thus the evidence is now quite strong that DPNH peroxidase is a flavoprotein whose physiological oxidant is peroxide. It may now be possible, by using zone electrophoresis in conjunction with the fractionation method previously worked out, to prepare a nearly pure enzyme whose physical and chemical properties can be studied. (AEC Activity 6400)

RADIOISOTOPE SALES AND COSTS

<u>Type of Transaction</u>	<u>August</u>	<u>FY to Date</u>
Domestic Sales	\$ 93,387	\$173,066
Foreign Sales	3,626	10,560
Project-Cash Sales	6,955	14,170
Project-Transfer Credits	-0-	305
Technical Cooperation Program Credits	1,510	1,510
Plant Credits	2,243	6,285
Civilian Defense Credits	-0-	-0-
Cancer Program Credits	19,717	38,346
*Miscellaneous Income	<u>16</u>	<u>39</u>
 Total Income	 \$127,454	 \$244,281
 **Income-No production costs incurred Subtract from Total Income	 <u>-5,613</u>	 <u>-5,464</u>
 Net Radioisotope Income	 <u>\$121,841</u>	 <u>\$238,817</u>
 Radioisotope Costs	 <u>\$ 87,272</u>	 <u>\$153,690</u>
 Radioisotope Shipments	 <u>1,058</u>	 <u>2,035</u>

*Miscellaneous Income - D₂O, Freight, Miss Parts, TCP.

**Income from H³, He³, B¹⁰, and miscellaneous items in excess of handling costs.

GROSS OPERATING COSTS

	<u>Cost for August</u>	<u>FY 1955 Cost to Date</u>
Programmatic Operating Cost - Net	\$2,710,865	\$5,380,580
Plant and Equipment Cost	230,505	405,254
Construction Program "H"	4,996	10,639
Work for Other Parties - Transfers	27,850	50,648
Inventory Changes	23,265	8,421*
Reimbursable Work for Other Parties	161,570	299,634
Deferred Charges	<u>1,609*</u>	<u>1,781*</u>
 Total Laboratory Cost - Net	 <u>\$3,157,442</u>	 <u>\$6,136,533</u>
 Estimated Cost for Next Month - Net	 <u>\$3,050,000</u>	 <u>\$9,186,553</u>

*Credit

[REDACTED]

PERSONNEL SUMMARY

	<u>Number of Employees</u> <u>September, 1954</u>	<u>New Hires</u> <u>September</u>	<u>Terminations</u> <u>September</u>
Administration	60	0	1
Operations*	118	1	3
Engineering, Shops and Mechanical	819	7	7
Laboratory and Research	1847	76	132
Protection	147	0	0
Service	<u>375</u>	<u>4</u>	<u>8</u>
	3366	88	151

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

A total of 737 Laboratory personnel are located in the Y-12 Area.

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May 1954	ORNL-1733
June 1954	ORNL-1748
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