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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

November 1957

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

TABLE OF CONTENTS

	Page
PROGRAM 2000 - SPECIAL NUCLEAR MATERIALS	6
Waste Metal Recovery	6
Excer Process	6
Fluorox Process	7
Metallex Process	7
PROGRAM 4000 - REACTOR DEVELOPMENT	7
HOMOGENEOUS REACTOR PROJECT	7
Homogeneous Reactor Test	7
HRT Chemical Pilot Plant	8
Mathematics and Computation: Homogeneous Reactor Development	8
Reactor Analysis	8
Homogeneous Reactor Instrumentation	9
HRP Design	10
HRP Metallurgy	10
Laboratory Corrosion Studies	11
Dynamic Solution Loop Corrosion Tests	11
Small-Scale Dynamic Slurry Corrosion Tests	11
Dynamic Slurry Loop Corrosion Tests	12
In-Pile Solution Corrosion Loops: LITR	13
Supporting Radiation Corrosion Studies	13
Adsorption and Radiation Studies	13
GENERAL REACTOR RESEARCH	14
Civilian-Power Advanced-Type Gas-Cooled Reactor (GCR)	14
Metallurgical Materials and Processing	15
Power Reactor Fuel Reprocessing: Darex Process	15
Power Reactor Fuel Reprocessing: Zircex Process	15
Power Reactor Fuel Reprocessing: Alternate Aqueous Dissolution Studies	16
Power Reactor Fuel Reprocessing: Druhm Process	16
Power Reactor Fuel Reprocessing: Electrolytic Dissolution	17
Power Reactor Fuel Reprocessing: Corrosion Studies	17
Power Reactor Fuel Reprocessing: Liquid Metal Fuel	17
Fused Salt—Fluoride Volatility Processing	17
Waste Treatment and Disposal	18
PROGRAM 5000 - PHYSICAL RESEARCH	19
Reactor Operations	19
The Oak Ridge Research Reactor (ORR)	19

[redacted]

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TABLE OF CONTENTS (Continued)

	Page
(Program 5000, Continued)	
PHYSICS	20
Neutron Velocity Selector	20
High Voltage Program	20
Theoretical Physics	20
Neutron Diffraction	21
Low-Temperature Nuclear and Solid State Physics	21
High-Energy Accelerator Studies	22
CHEMISTRY	22
Chemistry of Corrosion	22
Ion Exchange Studies	23
Technetium and Rhenium Chemistry	23
Characterization of Short-Lived Fission Products	24
Chemical Separation of Isotopes	24
METALLURGY	25
High-Temperature Reactions of Metals and Ceramics	25
PROGRAM 6000 - BIOLOGY AND MEDICINE	25
BIOLOGY	25
Cytology and Genetics: Plants and Fungi	25
Cytology and Genetics: Insects	26
Pathology and Physiology	26
Enzymology and Photosynthesis	26
Research Participation and Traveling Lecture Program	27
Microbial Protection and Recovery	27
Mammalian Recovery	27
Radiation Immunology	28
OPEN LITERATURE PUBLICATIONS	29
VISITORS	32

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

November 1957

This status and progress report summarizes somewhat less than one-half the activities of the Laboratory. A few of the activities are reported every month, but most of them are reported on a bimonthly schedule. Program 4700 is reported separately.

PROGRAM 2000 - SPECIAL NUCLEAR MATERIALS

Waste Metal Recovery - The processing of the plutonium-aluminum alloy rod from the Chalk River NRX reactor was completed. A total of 181.82 g of plutonium was isolated as purified product, which represents 99.86% recovery. Two cycles of solvent extraction were required to obtain a gross-gamma decontamination factor of 4.7×10^5.

The recovery of 110 g of Np^{237} and 5.7 tons of uranium from 9.5 tons of Paducah fluorinator ash was completed. The uranium and neptunium product recoveries were 99.9 and 99.3%, respectively, with major neptunium losses in the extraction column waste (0.04%) and in the uranium product (0.5%). (AEC Activity 2350)

Excer Process - In the Excer process, uranium in an ore concentrate is converted by ion exchange to a form suitable for reduction, is reduced, and is precipitated as UF_4 hydrate. A UF_4 hydrate product with a bulk density of 3.8 g/cc was prepared in the continuous precipitation unit operated at a temperature near 100°C. The ammonium oxalate-insoluble content of the UF_4 did not change significantly during dehydration at temperatures of 350 to 550°C in a 42-hr continuous run.

In a flowsheet test run, ore concentrate was dissolved in the waste acid from UF_4 precipitation; the UO_2Cl_2 was processed in the 2-in.-dia Higgins continuous ion exchange column with 99.9% recovery and then was reduced electrolytically, the extent of reduction being 88% and the current efficiency being 79%. (AEC Activity 2702)

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Fluorox Process - At temperatures below 900°C, uranyl fluoride decomposed in dry helium at atmospheric pressure according to the equation $3\ UO_2F_2 \longrightarrow 2/3\ U_3O_8 + UF_6 + 1/3\ O_2$. This stoichiometry was confirmed by x-ray and chemical analyses of the solid decomposition products. Above 900°C, UO_2 was one of the solid products; it was undoubtedly formed by the slow decomposition of U_3O_8.

In further tests on the flame reactor for oxidation of UF_4 to UF_6 with oxygen at temperatures above 1000°C, the carbon monoxide flame used for heating the reactor to initiate the reaction was extinguished when fluidized UF_4 was introduced. This was probably the result of the quenching effect of the cold powder. Analytical results indicated that UF_4 reacted with oxygen to produce UO_2F_2, U_3O_8, UO_2, and UF_6 in a carbon monoxide—oxygen flame. In further tests on the 3-in.-dia fluidized-bed reactor, UO_2F_2, a by-product of the oxidation, was fluidized at 800°C with nitrogen for 2 hr without agglomeration. Carbon monoxide was completely burned in oxygen in this reactor, but the temperature could not be maintained at the desired 840°C at the carbon monoxide flow rate of 3 to 6 ft^3/hr used. (AEC Activity 2702)

Metallex Process - Washing of thorium amalgams, produced by sodium amalgam reduction of $ThCl_4$, with 1% Versene decreased the oxide content of sintered billets by a factor of 82. Thorium was removed from freshly prepared amalgams to a residual concentration of less than 100 ppm by centrifugation for 30 min at 726 g. The average diameter of residual particles when 7-day-old amalgams were centrifuged was half that of 30-day-old centrifugations.

In mercury recovery studies the thorium in dilute amalgams was decreased from 3000 to 60 ppm by anodic treatment in 1 M Na_2CO_3 for 8 hr at 8 v; 15% of the mercury was lost to the aqueous phase. (AEC Activity 2704)

PROGRAM 4000 - REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test - In order to test for leaks in the piping of the reactor and the chemical processing plant, 40 curies of Kr^{85} was injected into the combined systems while sufficient nitrogen was being added to raise the internal pressure to 500 psig. After the two systems had been allowed to stand pressurized for five days with the shield tanks sealed, the shield atmosphere was sampled for determination of krypton in the cell atmosphere.

Unexpected difficulties with the analytical determination of krypton in the samples made it necessary to resort to helium pressurization for the leak test. Helium had been avoided initially because of complications with other test procedures. However, it was subsequently shown that the total detectable leakage from the process piping was less than 0.2 cc/day. An extremely sensitive helium detector, one capable of sensing approximately 1 ppm of helium, was used.

Pressure-checking for leaks in valve-operator air lines and service piping was also carried out as a part of the establishing of leak-tightness of the external container. Preparations for the final test of the container are nearly complete. During the last three weeks of November, effort was concentrated on final revisions and preparations for the critical experiments. Several valves were removed for seal-welding of the bellows, spare fuel feed lines were installed between the reactor and chemical plant, a new refrigeration system was completed, insulation was applied to all process piping, and numerous improvements and additions were made to the instrumentation and control systems.

The iodine extractor in the fuel recombiner was cut open, and the silver-coated ceramic rings in the iodine bed were replaced with silver-plated stainless steel mesh. The completed assembly was installed temporarily at the waste evaporator for a period of operation. After it is shown that no leaching of the bed occurs, the assembly will be reinstalled in the reactor. (AEC Activity 4103.3)

HRT Chemical Pilot Plant - Leak checks in preparation for final closure of the processing cell are in progress. The process piping was examined, in conjunction with the testing of the reactor, with helium at a pressure of 300 psi and a mass spectrograph type of detector. Two possible indications of leakage are to be rechecked. Testing of the over-all shield containment system is in progress. Maintenance preparatory to closure of the cell is nearing completion. (AEC Activity 4103.1)

Mathematics and Computation: Homogeneous Reactor Development - The standard two-region, two-group reactor code was altered so that it could accept additional input parameters, including reactor power, and compute additional output answers. The output format was changed to a more conventional form. An Oracle code was written for calculating the critical concentration within a bare reactor having annular-cylindrical geometry. A two-group model was assumed. (AEC Activity 4103.1)

Reactor Analysis - The safety of the HRE-3 was investigated as a function of the vapor volume of the pressurizer and of the length and inside diameter of the piping between the core and the pressurizer. For an instantaneous reactivity addition of 2%, the maximum core pressure rise would be about 400 psi if the piping between the core and the pressurizer were 12 in. in diameter and 40 ft long and if the vapor volume of the pressurizer were 20 ft^3.

Heat generation rates in the core tank of reactors of the HRE-3 type were calculated for various core and blanket compositions. With a solution-type core and a D_2O blanket, the heat generation rate would be about 15 w/ml. If the D_2O blanket were replaced by a ThO_2-D_2O slurry containing 1000 g of thorium per liter, the corresponding rate would be about 11 w/ml. If this latter reactor had a core region containing 200 g of thorium per liter, the heat generation rate within the core tank would be about 7 w/ml.

The effect of core length and diameter upon the breeding ratio, wall power density, and critical concentration of cylindrical two-region reactors of the HRE-3 type has been studied. The core diameters were varied from 2 1/2 to 3 1/2 ft and the core lengths from 3 1/2 to 12 ft. The blanket was considered to be 2 ft thick and to contain 1000 g of thorium per liter. For the cases studied, the breeding ratio varied from 1.10 to 1.13, and the critical concentration varied from 2.5 to 6.5 g of U^{233} per liter. For a 3-ft-dia core, increasing the core length from 4.8 to 8 ft decreased the power density by 36%. (AEC Activity 4103.1)

Homogeneous Reactor Instrumentation - The HRT nuclear instrumentation system was installed and is now being tested at the reactor site.

As a part of the program to develop linear variable differential transformers which will be suitable for sensing instrument primary-element motions and which will be more resistant to radiation, a transformer wound with 30-gage anodized aluminum wire was tested at 300°C without insulation failure. The only electrical insulation on the wire is that afforded by the oxide film on the aluminum, which could be expected to be highly resistant to temperature and radiation.

A survey of pressure and differential-pressure instrument types suitable for a reactor slurry system was made as an aid in the planning of an instrument development program. A conceptual design of a flush-diaphragm transmitter incorporating a pressure reference to a liquid system was made, and the feasibility of liquid-metal-filled volumetric-type systems is being studied.

Two bellows, having an effective area of 123 in.^{2} and rated at 100 psi, have been assembled in a tandem yoke with an opposing spring to be tested as a pneumatically powered actuator for a 3-in., 2000-psi control valve.

Satisfactory gold platings for the stainless steel bellows used for control-valve stem seals have not been achieved. The platings were intended to provide good corrosion resistance, but they cracked upon flexing or else cracked or pitted when exposed to boiling HCl. (AEC Activity 4103.1)

HRP Design - A spray system was designed for providing a water spray inside the HRT shield as a means of reducing the temperature and pressure in the event of a gross failure of the reactor system. The spray system will serve also as a scavenging system for withdrawing contaminated water from the flanges being opened during underwater maintenance operations.

Bolts and nuts for the HRT were tested to determine asymptotic torque-stress relationships. They were found to yield consistent results within ±15% after about 12 tightening cycles.

The design of tooling and facilities for the replacement of the HRT core and blanket corrosion-specimen holders and the pressure-balancing-system rupture-disk assembly was completed. The tools can be used with the cell dry or flooded.

The Raschig rings purchased for the HRT iodine removal bed were found to produce a large amount of soluble solids and to increase the pH of the system when leached. The bed was redesigned to contain stainless steel mesh coated with silver.

A special insulation can was designed for installation on the HRT flanges. The can is removable to permit access to the flanges.

The conceptual studies preliminary to the design of the HRE-3 continue. These studies, including flowsheets reflecting the latest thinking in regard to process design and tabulations of design data, are being extended to layout studies for analysis of maintenance, containment, and design philosophies.

Sites in the Oak Ridge area are being studied to determine the best location for the HRE-3. (AEC Activity 4103.1)

HRP Metallurgy - Considerable anisotropy in the mechanical properties of Zircaloy-2 has been found in material fabricated by conventional techniques. The differences were most pronounced in impact tests of notched speciments. The poorest impact properties were found in samples cut at right angles to the plate rolling direction and with the notch in the rolling plane. The best properties were found in a longitudinal sample with a vertical notch. While apparent transition regions were found in the impact curves, no differences were apparent in the fractures. In some cases shear lips were found on the breaks made at low temperatures, which must indicate that in spite of the low energy values some ductility was still present in the metal.

Tensile specimens of Zircaloy-2, Zircaloy-3A, and crystal-bar zirconium were exposed in three in-pile corrosion loops. Under the limited exposure levels and times in these loops, no changes in the tensile properties of the zirconium alloys were found. A small amount of embrittling was noted, however, for titanium alloys A-55 and A-110AT contained in the same loops. (AEC Activity 4103.1)

Laboratory Corrosion Studies - Films formed on stressed type 347 stainless steel by exposure for 500 hr in boiling chloride-free fuel solution (0.04 m UO_2SO_4 — 0.02 m H_2SO_4 — 0.005 m $CuSO_4$) were found to prevent stress-corrosion cracking for periods up to 1000 hr (the length of the tests) after the addition of 50 ppm chloride to the solution. In the absence of a preformed film, specimens in chloride-containing solutions cracked in periods of 400 hr and less, usually during the first 25 hr.

Preliminary data indicate that chloride-induced cracking can occur in stressed type 347 stainless steel exposed in oxygen-free distilled water at 300°C. Distilled water containing 100 ppm chloride was degassed by repeated freezing and evacuation, and upon heating to 300°C, specimens cracked during a 200- to 400-hr exposure interval.

Type 202 stainless steel that was sensitized for 1 hr at 1250°F developed severe blisters and showed evidence of severe intergranular attack upon exposure in boiling 0.04 m UO_2SO_4 — 0.02 m H_2SO_4 — 0.005 m $CuSO_4$ solution. As-welded specimens of the annealed material, however, did not exhibit either type of attack when exposed to the same conditions. (AEC Activity 4103.1)

Dynamic Solution Loop Corrosion Tests - A solution similar to that to be used in the HRT, 0.04 m UO_2SO_4 containing 0.025 m D_2SO_4 and 0.01 m $CuSO_4$ in heavy water, was circulated for 2736 hr at 300°C. The solution was completely phase-stable throughout the run. Corrosion of the 300-series stainless steel specimens was 1 to 2 mils/year or less at velocities up to about 40 fps. Stress specimens of several stainless steels and of two titanium alloys showed neither cracks nor acceleration of general attack.

In the course of readying an all-titanium loop for a run, oxygen at a pressure of about 175 psig was applied to the loop at room temperature to force out a piece of Teflon wedged into a 3/8-in. titanium nipple. When the piece of Teflon was being pried out with a short file, a spark was observed, and suddenly the end of the nipple burned off in a flash of flame and smoke. The accident underscores again the possibility of titanium-oxygen reactions even at moderate pressures at room temperature. (AEC Activity 4103.1)

Small-Scale Dynamic Slurry Corrosion Tests - Normal corrosion rates of type 347 stainless steel (0.2 to 2 mils/year), titanium-75A (0 to 4 mils/year), and Zircaloy-3A (0 to 0.6 mil/year) were observed in tests made in toroids at 250°C and 26 fps to study the effect of the addition of 0.02 m uranyl sulfate to aqueous oxygenated slurries (500 and 1000 g of thorium per kilogram of water) of 800°C-calcined thoria. Attack of SA-212-B mild steel was increased from 2 to 5 mils/year to 14 to 17 mils/year.

In toroid tests made in order to determine the effect of hydrogen and oxygen atmospheres on the attack by slurries of 1600°C-calcined thoria, attack rates for type 347 stainless steel, titanium-75A, and Zircaloy-3A were increased, and for SA-212-B carbon steel were decreased markedly when hydrogen was substituted for oxygen. With the hydrogenated slurries, which contained 0.08 m N_2H_4 as an oxygen scavenger, attack rates at 250°C and 26 fps at concentrations of 500 and 1000 g of thorium per kilogram of water, respectively, were (in mils/year) as follows: type 347 stainless steel, 8 and 13; titanium-75A, 2 and 2; Zircaloy-3A, 0.4 and 0.4; and SA-212-B steel, 2 and 4. The corrosion rate of SA-212-B steel in the oxygenated system was 110 to 120 mils/year.

In a series of tests made at 250°C in order to compare slurries prepared of 800°C-calcined thoria before and after degrading of the oxide in a Mikropulverizer from a mean particle size of 4 μ to 1 μ, no notable reduction of attack was apparent as a result of using the micropulverized thoria. (AEC Activity 4103.1)

Dynamic Slurry Loop Corrosion Tests - An attack rate of 2 mils/year was observed in a 100A loop system test of 1007 hr duration, made at 300°C with an oxygenated previously pumped slurry of 1600°C-calcined thoria of 1.3-μ mean particle size and having an average circulating concentration of 630 g of thorium per kilogram of water. The average attack rates of pin corrosion specimens exposed during the run at relative velocities of 21 and 42 ft/sec, respectively, were (in mils/year) as follows: austenitic stainless steels, 2 and 21; titanium alloys, 1 and 11; and Zircaloy-2, 0.5 and 10. The greatly increased attack at the higher velocity was due primarily to erosion.

In a 300-hr loop test, carried out at 200°C with sulfated 800°C-calcined thoria slurry previously circulated in the slurry blanket mockup, moderate specimen attack rates were observed (except for carbon steel), but the corrosion of pump components was high. The corrosion test paralleled as closely as possible the conditions of the mockup test, that is, steam-pressurized operation and low (60-ppm) oxygen concentration. At an average concentration of 488 g of thorium per kilogram of water, austenitic stainless steels displayed rates of 0.3 to 27 mils/year over the velocity range 19 to 71 fps. Rates of ferritic stainless steels exposed at velocities of 23 and 42 fps ranged from 2 to 10 mils/year, and carbon steel ranged from 100 to 560 mils/year. Zircaloy-2 and titanium alloys showed corrosion rates from 0.1 to 1 mil/year over the velocity range 19 to 42 fps. The average system attack rate was 3 mils/year. Pronounced pitting attack, 12 to 24 mils in depth, was noted on the type 347 stainless steel impeller.

The attack rates of field-test corrosion coupon specimens exposed at ~20 fps to sulfated 800°C-calcined thoria slurry for 678 hr at 170 to 200°C in run SM-3 of the slurry blanket mockup test were (in mils/year) as follows:

type 347 stainless steel, 0.3 to 2; titanium RC-55, 0.2 to 0.3; Zircaloy-2, 0.1 to 0.2; and SA-212-B carbon steel, 455 to 637. The high attack of SA-212-B carbon steel appeared to be due in part to the presence of sulfuric acid (~3700 ppm SO_4^{--} based on thorium) and to galvanic action between the specimens and their stainless steel holder. Stressed specimens of types 347 and AM-350 stainless steels, titanium—6% Al—4% V, and Zircaloy-2 exposed in both the liquid and gas-vapor space of the mockup pressurizer showed no evidence of pitting or cracking. (AEC Activity 4103.1)

In-Pile Solution Corrosion Loops: LITR - Irradiation of HB-4 loop L-4-18 and HB-2 loop L-2-19 was completed. These loops were constructed of stainless steel and contained zirconium, titanium, and steel specimens. The solution employed in experiment L-4-18, the second experiment in which the solvent was D_2O, was 0.17 m UO_2SO_4, 0.07 m $CuSO_4$, and 0.02 m H_2SO_4. The main-stream temperature, 235°C, was lower than in any previous experiment. The main-stream temperature in experiment L-2-19 was 280°C, and the solution was 0.17 m UO_2SO_4, 0.02 m $CuSO_4$, 0.1 m H_2SO_4, and 0.2 m Li_2SO_4. Previous experiments had indicated that the addition of a sulfate such as Li_2SO_4 might beneficially affect the corrosion rate of Zircaloy-2. The total circulation time with enriched solution was 860 hr in L-4-18 and 1149 hr in L-2-19. The energy output of the LITR during the inserted times was 1926 and 2705 Mwhr, respectively. As determined from cesium analyses of the solutions, the fission power in the experiments when the reactor was at 3 Mw was 694 and 1959 w, respectively. The over-all steel corrosion rates based on oxygen data were 0.7 mil/year in experiment L-4-18 and 1.3 mils/year in experiment L-2-19. (AEC Activity 4103.1)

Supporting Radiation Corrosion Studies - The electrochemical polarization method of measuring corrosion rates of metals has been studied in the Chemistry Division at this Laboratory and by others elsewhere and has been shown to be a valid and useful method of measurement in some cases. A study is being made by this group to determine whether the method can be applied to the measurement of corrosion rates of stainless steel and other metals in uranyl sulfate solutions at 250°C and above.

In preliminary studies the method was staisfactorily demonstrated with stainless steel specimens in an all-glass system at temperatures from 25 to 80°C in oxygen- or helium-saturated 0.1 N H_2SO_4 solutions. The apparent corrosion rates for the various steel alloys tested ranged from 4×10^2 to 4×10^{-4} mils/year. Apparatus for carrying out these studies in UO_2SO_4 solutions at the elevated temperatures was designed and constructed. (AEC Activity 4103.1)

Adsorption and Radiation Studies - Fission-gas holdup tests on the HRT charcoal beds under simulated operating conditions were completed. A radioactive-tracer technique developed for use in the laboratory adsorption study was utilized in these tests. A pulse of Kr^{85} was injected at the entrance to the charcoal bed

and then swept through the bed by a controlled oxygen stream. Gases leaving the bed were then monitored for krypton activity. The efficiency of the charcoal beds, in regard to retention or holdup of fission gases, exceeded design specifications. On the basis of these tests the existing charcoal beds should perform satisfactorily with the HRT operating at design conditions.

Experimental and theoretical work is being continued on the factors which influence adsorption of gaseous fission products, such as krypton, xenon, and iodine, by activated charcoal and other adsorber materials. (AEC Activity 4103.1)

GENERAL REACTOR RESEARCH

Civilian-Power Advanced-Type Gas-Cooled Reactor (GCR) - Physics calculations indicate that a reactor core 30 ft in diameter and 20 ft high with a 2.5-ft-thick reflector is required to keep neutron leakage losses to a reasonable level (about 4%). With stainless-steel-clad UO_2 fuel elements arranged in clusters of seven 3/4-in.-dia rods, the optimum lattice spacing is close to 8 in. and the fuel enrichment required is approximately 1.25% U^{235}. The conversion ratio with this arrangement will be approximately 0.6. Analyses of fuel costs, including fuel reprocessing, indicate that burnups of at least 2000 Mwd/ton will be achievable, so that fuel costs will be less than 4 mills/kwhr.

Over-all cost studies indicate that the capital cost can be minimized by maximizing the specific output of the reactor core. This in turn implies that the highest possible pressure should be used in the system. Analyses indicate that a 50-ft-dia spherical pressure vessel with a 3-in.-thick wall will permit a 300-psi pressure. The 50-ft-dia pressure vessel includes space for fuel charging and discharging operations, space for the structure to support the graphite, and space for the various gas passages.

Gas heat transfer and flow considerations, coupled with optimization of over-all net power output, indicate that mean helium velocities of the order of 250 ft/sec through the core will be close to optimum. This leads to a reactor output of the order of 700 Mw with a net electrical output of the order of 200 Mw. The design is converging on the tentative values indicated below:

Gas coolant	Helium
Gas system pressure	300 psi
Fuel enrichment	1.25%
Fuel	UO_2
Fuel element can	Type 304L stainless steel
Moderator	Graphite
Reactor heat output	700 Mw
Peak metal surface temperature	1500°F
Peak helium temperature	950°F

Helium temperature rise through reactor	525°F
Steam temperature out of superheater	750, 850, and 950°F
Steam pressure out of superheater	600, 900, and 1200 psia

Studies are under way for methods of controlling the reactor control rods, the gas coolant flow, and the steam pressure and temperature. Preliminary control room and console layouts are being made for use in cost estimating, and the costs of certain of the instruments known to be needed are being obtained.

Equipment is being designed and fabricated for testing the compatibility of graphite, various fuel element cladding materials, and helium when contained in a stainless steel vessel at high temperatures (up to 1500°F) for extended periods (in excess of 1000 hr). Fuel element specimens are being prepared for in-pile studies of fission-gas release. The first specimens will be 0.156 in. in diameter and will contain 15 wt % U^{235}. These UO_2 specimens will be hot-pressed to 95% of theoretical density. Specimens 0.450 in. in diameter and canned in stainless steel are being prepared for the second test. These specimens will contain 2 wt % U^{235}. Dimensional stability will be measured, as well as fission-gas release. (AEC Activity 4119)

Metallurgical Materials and Processing - Diffusion experiments have been performed with solid zirconium and magnesium vapor, since the vapor is more easily adapted to treating fuel elements of irregular configuration. The diffusion data have been inconsistent, but a grain boundary penetration of 0.02 in. was observed in specimens heat-treated for 2 hr at 625°C. Optimization of the experimental technique may yield increased diffusion rates. (AEC Activity 4203)

Power Reactor Fuel Reprocessing: Darex Process - In engineering-scale tests on the Darex process (aqua regia dissolution of stainless-steel-containing fuel elements), pure water was not obtained in the rectifier overhead. With 12 plates, rectification of 5 M HNO_3 — 2 M HCl, both with and without oxygen, produced overhead containing more than 3.5 M H^+. An attempt to rectify 1.5 M HNO_3 — 0.5 M HCl produced overhead containing 0.6 M H^+. The rectifier has now been replaced with a downdraft condenser.

In laboratory tests the initial dissolution rate of UO_2 in 3 to 6 M HNO_3 containing 1 and 2 M HCl varied from 21 to 51 $mg \cdot cm^{-2} \cdot min^{-1}$. In a continuous dissolution of simulated Yankee Atomic fuel with 5 M HNO_3 — 2 M HCl, a steady state was not reached owing to the difference in the reaction rates of the stainless steel shell and the UO_2 pellets. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Zircex Process - A specimen of U — 10% Nb reacted with HCl at 405°C at a rate of 0.67 $mg \cdot cm^{-2} \cdot min^{-1}$ and a uranium loss of 0.016% to the sublimate. About two-thirds of a 3600-g section of a 12-plate Submarine Thermal Reactor subassembly reacted with HCl in 15.5 hr at 500°C. There were no finely divided metallic residues. Small amounts of impurities in the HCl did not affect the hydrochlorination. Uranium losses

were 1.1% to the sublimate and 0.40% as material insoluble in 10 M HNO_3. There were no violent reactions during the nitric acid dissolution. In a run on a specimen of a U-Zr-Nb alloy having a high uranium content, during which air and moisture were excluded, uranium losses in the nitric acid — insoluble residue were only 0.005%.

In preliminary experiments in the system $3ZrCl_4.2POCl_3$, chlorination rates were favorable, especially for a U-Zr-Nb alloy having a high uranium content. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Alternate Aqueous Dissolution Studies - The presence of H_2O_2, CrO_3, MnO_2, or $Na_2Cr_2O_7$ contributed to uranium losses of up to 95% during sulfuric acid dissolution of stainless steel claddings. Small amounts of uranium were quantitatively recovered on Dowex 1 anion exchange resin from a simulated sulfate decladding solution; plutonium was not sorbed.

Essentially all the radioactivity in a sulfuric acid solution of the cladding of an irradiated fuel element was due to activated components of the stainless steel. A total of 2.4% of the beta activity and 9.1% of the gamma activity from mixed fission products was leached from a calcium sulfate cake made by neutralizing a sulfuric acid decladding solution with lime.

Zirconium and Zircaloy-2 dissolved in 2, 5, 9, and 12 M HF at 90°C at practical rates even when the acid was 75% saturated with dissolved zirconium. The dissolution rates for U—10% Mo and U—10% Nb alloys under these conditions were 0.11 to 0.58 and 0.13 to 0 $mg \cdot cm^{-2} \cdot min^{-1}$, respectively. The compound $ZrF_4.3H_2O$ was precipitated from these solutions almost quantitatively by the addition of acetone.

A uranium dioxide fuel element clad with Zircaloy-2 was stripped by 9 M HF with a uranium loss of 0.5%. The zirconium was separated from the uranium by a factor of 28 when a fluoride decladding solution was treated with Duolite C-65 cation exchange resin. Eighty-four per cent of the uranium was recovered.

The dissolution rates of sintered 96% ThO_2—4% UO_2 pellets were fairly constant, 5.4 to 6.2 $mg \cdot cm^{-2} \cdot min^{-1}$, in 13 M HNO_3 containing 0.05 to 0.5 M fluoride ion. At lower fluoride concentrations, insoluble ThF_4 formed and adhered to the pellets, interfering with the dissolution. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Druhm Process - Direct reduction of uranium hexafluoride to metal (Druhm) appears to be feasible. A small button or uranium metal was produced by the reaction of UF_6 with sodium vapor. Alundum was not a suitable material for the crucible that contains the product, but graphite was satisfactory for test purposes. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Electrolytic Dissolution - The amount of metallic zirconium in the sludge from the anodic dissolution of Zircaloy-2 was roughly 12% with 3 M HCl electrolyte, 10% with 3 M HCl—0.1 M HF, and 8% with 0.5 M NH_4Cl—1.0 M $(NH_4)_2C_2O_4$. When the last solution was allowed to stand, the dissolved zirconium precipitated completely as a result of hydrolysis. An increase in the concentration of dissolved zirconium increased the percentage in the sludge.

In 3 M HCl neither the tin nor the zirconium of Zircaloy-2 was preferentially attacked. Graphite was a satisfactory anode in 3 M HCl electrolyte. A platinum anode showed a negligible weight loss after the dissolution of 1 to 1.5 kg of zirconium or Zircaloy-2 and 2 kg of stainless steel in the 3 M HCl.

A simulated Yankee Atomic fuel element had 82% of its stainless steel jacket and 5% of its UO_2 core dissolved upon electrolysis for 6 hr at 50°C in 3 M HNO_3 containing 1.1 M stainless steel. The current efficiency was 71%. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Corrosion Studies - The tensile properties of the alloys Haynes-25, S-816, Inconel, Hastelloy C, Illium R, and Carpenter 20 were not adversely affected by the HCl-H_2 atmosphere during Zircex hydrochlorination. Haynes-25 was slightly superior to S-816 for construction of the Zircex hydrochlorinator-dissolver when the liquid phase was nitric acid at a concentration of 5 M or less.

In 24-hr tests, the corrosion rates of molybdenum were approximately 0.5 mil/month in both the vapor and liquid phases of boiling $AlCl_3 \cdot NH_4Cl$. Hastelloy B was corroded at rates of 2.0 and 11.4 mils/month.

In chemical resistance tests on protective coatings with 3 M HNO_3, 3 M HCl, 3 M H_2SO_4, 3 M NaOH, and demineralized water at 81 and 120°F, vinyl-base coatings were the most resistant materials tested. Chemfast, an epoxy-base resin, showed excellent resistance at room temperature for two weeks. Glascote, a polyester coating for concrete surfaces, blistered when irradiated to 10^9 r in water. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Liquid Metal Fuel - The use of molten $BiCl_3$-KCl-LiCl to extract uranium and fission products from uranium-bismuth liquid metal fuels is being investigated as a possible head-end method for solvent extraction. In equilibrations at 550°C of a 30 wt % solution of $BiCl_3$ in KCl-LiCl eutectic with a 0.7 wt % solution of uranium in bismuth, the uranium separation factors averaged 250. (AEC Activity 4301)

Fused Salt—Fluoride Volatility Processing - In seven volatility runs in the pilot plant, 84% of the uranium entering the system as UF_6 was recovered in the product cylinders. The recoverable losses were 11% and the nonrecoverable losses 0.03%, for a material balance of 95%.

The hydrofluorinator was installed, and a flowsheet was designed for the dissolution of zirconium-uranium fuel in the pilot plant. Minor modifications indicated by preliminary leak tests are being made.

In laboratory studies, further evidence was obtained that an NaF bed at 400°C acts as a scavenger for various contaminant fluorides in the UF_6 product stream. A 1-in.-dia bed was more effective than a 1/2-in.-dia bed of the same length. Uranium recovery was much lower with nitrogen desorption than with fluorine desorption. Formation of the nonvolatile uranium(V) complex in the NaF absorption traps increased with temperatures up to 450°C.

In corrosion experiments, Inconel specimens exposed to 10 g of HF per hour in $NaF-ZrF_4$ at 650°C for 30 and 100 hr were penetrated at rates of 15 and 25 mils/month, respectively.

The installation of the initial portion of the High-Activity-Level Volatility Laboratory was completed. Equipment is being designed and fabricated for introducing an irradiated Pressurized Water Reactor fuel element into the cell for eventual charging into the hydrofluorinator. A handling device for small shielded carriers is also being designed.

In initial work on the separation of fission products and heavy elements from fused salt fuels, CaO scavenged a significant amount of rare-earth activity from eutectic LiF-NaF-KF but not from $NaF-ZrF_4$. Hydrogen sparging and partial salt crystallization were somewhat successful with $NaF-ZrF_4$. (AEC Activity 4302)

Waste Treatment and Disposal - In preliminary runs in the 1.5-in.-dia Higgins continuous ion exchange contactor, synthetic alkaline waste was decontaminated from Cs^{137} and Sr^{90} by factors of 10^4 to 10^5 at rates of 2000 $gal \cdot hr^{-1} \cdot ft^{-2}$. The cesium product was separated from sodium by a factor of 10^4.

In the first stage of a three-stage acid-base cell for the recovery of nitric acid and caustic from synthetic waste, current efficiencies were 75% and the power consumption was 6.2 kwhr per pound of caustic produced. Nitric acid having a concentration of 1.3 N and sodium hydroxide having a concentration of 1.5 N were produced. (AEC Activity 4305)

Reactor Operations - Work is proceeding on the enrichment of the ORNL Graphite Reactor. Testing of fuel elements is under way, safety calculations are nearly complete, and estimates are being made of the exact fuel loading and neutron flux distribution. Completion of a control system for the enriched reactor is being delayed because of a lack of design personnel.

Since the stock of spare fuel has decreased to about one year's usage, it is proposed to determine whether the enriched fuel could be used with the present control system. By limiting the excess reactivity it may be feasible to begin loading the new fuel next summer. When the control system is revamped, the excess reactivity and power could be increased.

Lattice measurements have been made on graphite samples scraped from the inside surface of fuel channels. These have indicated stored energy values up to approximately 38 cal/g (200°C peak) on the east side where the graphite operates below 100°C. In the center and on the west side, where the graphite temperature is higher, the stored energy is less.

The Oak Ridge Research Reactor (ORR) - Blount Brothers Construction Company has nearly completed work on the several remaining items which were not acceptable, that is, truck doors, ventilation louvers, etc.

Modifications to the ORR building by the H. K. Ferguson Company are proceeding satisfactorily. Installation of the air conditioning system is the controlling item of work and is presently scheduled for completion on February 1, 1958.

Difficulty has been encountered in the fabrication of the north large facility plug at the Paducah plant. During final testing of the plug, a number of leaks were found in welded joints, and it has been necessary to make design modifications to allow more space for welding around the small penetrations. It is now anticipated that the plug will be tested and shipped by January 1, 1958. Pennsylvania Advanced Reactor representatives state that the south large facility plug is scheduled for delivery on December 15, 1957.

Hydraulic testing of the ORR cooling system was begun in November. The main water system was operated at varying flow rates. Testing was concentrated mainly on the core, where pressure drop and direct velocity measurements were made with different core configurations. Analysis of the results is not yet complete; however, preliminary calculations indicate that the design criteria have in general been satisfied. Further analysis of the data will be necessary in order to determine the specifications of the orifices to be installed in the various tank passages to proportion properly the cooling water flow.

Detailed procedures are being reviewed for the neutron testing phase, and preliminary procedures are being worked up for the approach to the power phase of reactor testing. It is now anticipated that critical experiments will be started around the end of December.

PHYSICS

Neutron Velocity Selector - Neutron transmission measurements have been made for two sample thicknesses of fission-product Pm^{147} (2.5-year half life) over the energy range from 0.2 to 50 ev. The transmission measurements indicate an abundant resonant structure in Pm^{147}, and the six resonances observed below 20 ev at 1.04, 5.12, 5.92, 6.71, 15.0, and 18.7 ev have been analyzed to obtain resonance parameters. These parameters result in a strength function of $\overline{\Gamma}_n^o/D = (3.0 \pm 1.1) \times 10^{-4}$ for Pm^{147}. The installation of the new high-intensity chopper at the LITR has just been completed. (AEC Activity 5220)

High Voltage Program - A large neutron detector, employing a 5-ft-dia graphite sphere and BF_3 counters, has been constructed. Its efficiency is essentially constant from 1 kev to 2 Mev. Measurements have been made of total absolute (p,n) cross sections from threshold to 5 Mev for thin targets of Be^9, B^{10}, B^{11}, and C^{13}.

By use of the apparatus described above, total absolute cross sections have been measured from threshold to 5 Mev for the following reactions: (1) $H^2(p,p')pn$, (2) $H^3(p,n)He^3$, and (3) $Li^7(p,n)Be^7$. The yield near threshold in reaction (1) indicates the importance of coulomb effects. From reaction (2) the $He^3(n,p)H^3$ reaction cross section has been calculated by reciprocity.

The $S^{32}(n,\alpha)Si^{29}$ cross section has been measured as a function of energy in the range above 1.4 Mev. A double back-to-back ionization chamber was used with krypton gas. Monoenergetic neutrons from the $H^3(p,n)He^3$ reaction were incident on lead sulfide and U^{238} deposits, situated back-to-back in the center plate of the chamber; fragments from the neutron-induced fission of the U^{238} were counted to determine the number of incident neutrons. Alpha-particle yields were determined separately in the forward and backward hemispheres, that is, at 0 to 90 deg and 90 to 180 deg in the laboratory system; the total (n,α) cross section was obtained from the sum. The cross section in general increases with increasing energy above 1.4 Mev, although several strong peaks are observed. The results agree qualitatively, in the region of overlap, with those of Hurlimann and Huber (Helv. Phys. Acta 28, 33, 1955). (AEC Activity 5220)

Theoretical Physics - A formulation of relativistic quantum mechanics has been devised in which field quantization is neither necessary nor required in order to obtain the results of conventional calculation. In this new theory, simple commutation relations between coordinate operators can be introduced, which effectively impose a smallest length, without any assumption of an arbitrary form factor. New expressions for interparticle forces and self-energies have been obtained in the photon-electron and pion-nucleon cases. A crucial experiment would be the electron-electron scattering at high relative energy, and cross-section predictions for this case are being calculated. (AEC Activity 5220)

Neutron Diffraction - The antiferromagnetic structure properties of the trifluorides of V, Cr, Fe, Co, and Mn have been studied by neutron diffraction techniques. The crystal structure of these trifluorides can be considered for purposes of the magnetic study as distortions of simple cubes in which the metal ions lie at the cube corners and the flourine ions lie on the cube edges. This disposition of anions and magnetic cations is similar to that found in certain perovskite-type compounds for which the magnetic properties have already been studied. It was found in this investigation that in the Cr, Fe, and Co compounds the magnetic ion is antiferromagnetically coupled via the intervening fluorine ions to each of its six nearest neighbors. This same arrangement was previously found in the perovskite compounds of Cr and Fe, in which the intervening anion was oxygen. In the case of MnF_3 a different antiferromagnetic structure was observed. Here a given manganese ion is coupled ferromagnetically via the intervening fluorine ions to its four neighbors in a given plane and is coupled antiferromagnetically to its two neighbors in adjacent planes. This is also similar to the situation found in the perovskite-type compound, $LaMnO_3$. The Néel temperatures in these trifluorides cover the range from about $40^{\circ}K$ for MnF_3 up to about $450^{\circ}K$ for CoF_3. Since these flourides are distorted from cubic symmetry, it was also possible to determine the crystal axes along which the spins were aligned. In the Fe and Cr compounds the spins were found to be parallel to (111) planes of the pseudo cube, and in the Co compounds the spins were found to lie perpendicular to this direction. These fluorides and the corresponding perovskite-type oxides are of the simplest type involving the mechanism of indirect magnetic exchange and are hence very useful for the study of features of this mechanism. (AEC Activity 5220)

Low-Temperature Nuclear and Solid State Physics - In an experiment on the thermal-neutron fission of aligned U^{233} nuclei, it was found that, although there was a substantial anisotropy in the angular distribution of the U^{233} alpha-particle emission, the fission-fragment emission was almost isotropic. There are a number of possible qualitative explanations of this. However, the only fission model of current interest which may be formulated to provide a quantitative description of the U^{233} experiment is that of Bohr. The relevant calculations have been performed, and it is found that it is possible to correlate the experimental results with Bohr's picture. Further, within the assumption that thermal fission goes by approximately one channel, a suggested assignment can be given for this channel, namely, $I = 3$, $K = 2$.

To extend these fission results, a counter was needed which would function reliably near $1^{\circ}K$ and which would give a linear response from the energies of alpha particles near 5 Mev up to energies of fission fragments near 100 Mev. Germanium crystal counters have been prepared, and preliminary results over this energy range show a good signal-to-noise ratio and strongly indicate a suitably linear response. Life tests are now being made. An interesting note is that the counter voltage is very low, near 0.1 v.

Uranium-235 nuclei have been oriented at low temperatures, and the anisotropy of the alpha emission has been observed. This is found to be of

the same sign and of approximately the same magnitude as was found earlier for U^{233} and Np^{237}. A preliminary effort to orient Am^{241} gave, in a sense, a negative result. The alpha-particle emission was found to be isotropic at all temperatures from 1.1 to 300°K. Angular momentum considerations strongly suggest that the alpha emission from oriented Am^{241} nuclei should have an observable anisotropy. Thus it is suggested that this isotropic emission corresponds to no nuclear orientation, possibly as a result of radiation damage. (AEC Activity 5220)

High-Energy Accelerator Studies - The AVF (spiral-sector) cyclotron being developed at ORNL is designed to accelerate protons with fixed orbital frequency up to the integral radial resonance $\nu_r = 2$ (~850 Mev). For an eight-sector machine, this point coincides with the 8/4 nonlinear essential resonance which leads to radial instability. An investigation has been carried out to determine the feasibility of utilizing this instability to achieve efficient beam extraction. Extensive phase-space maps of orbit invariants appropriate to this resonance have been obtained from numerical computations. These results show that this resonance will provide large radial amplitude growth rates without mutilating the radial phase area occupied by the beam. The maximum growth rate attainable in practice is limited by the effects of the $\nu_r = 2\nu_z$ coupling resonance. A growth rate of 4 cm per turn has been obtained without significant deterioration in the vertical motion. Beam extraction can be effected by small cos 2θ field bumps which "steer" the beam into the 8/4 resonance, which then rapidly builds up the amplitude until the beam enters the exit channel.

A procedure for obtaining many-turn injection from an AVF cyclotron into an alternating-gradient synchrotron has been developed. Suppose that the radial frequency is made a quarter-odd integer and that certain frequency relations are maintained between the synchrotron and cyclotron oscillators during injection. Successive pulses from the cyclotron can then be introduced parallel to the equilibrium orbit with large amplitude, by use of a conventional magnetic channel. A cavity with radial electric field and sextupole shape, and with frequency one-quarter that of the accelerating cavity, can then cause steady reduction of radial amplitude, by a simple resonance effect, and thus cause the beam to clear the channel wall. High efficiency in filling the synchrotron phase space is expected, with rather simple apparatus. Detailed calculations are nearly complete which allow simple estimation of the number of turns of injected beam which can be accepted. (AEC Activity 5240)

CHEMISTRY

Chemistry of Corrosion - Improved techniques were used to measure rates of corrosion and kinetic constants of crystal-bar zirconium in oxygenated acid sulfate solutions at 25°C as a function of time and potential. The α factors (fraction of potential applied to the rate-determining charge-transfer reaction) for both the reduction of oxygen and the oxidation of zirconium are

close to 0.25. The rapid attainment of noble potentials and low corrosion rates (about 10^{-8} amp/cm^2) is due largely to the rapid changing of factors which decrease the potential-independent portion of the rate expression of the anodic process. The potential-independent portion of the cathodic (reduction) process is approximately constant with time, and, consequently, the determination of the cathodic kinetic constants and the measurement of the potential allow an estimate to be made of the corrosion rate. (AEC Activity 5330)

Ion Exchange Studies - A series of variable-capacity strong-base anion exchangers was employed in measurements of the bromide-chloride ion exchange equilibrium. These new exchangers are copolymers of styrene and dimethylaminostyrene cross-linked with divinylbenzene and treated with methyl iodide to form quaternary ammonium salts. The selectivity coefficient, D, for the uptake of bromide ion from 0.1 M aqueous solutions was found to decrease with increasing exchange capacity. Analogous variations of D with capacity have been observed with the alkali-metal cations in the case of variable-capacity sulfonic acid cation exchangers.

Distribution coefficients were measured for the partition of trace quantities of zinc(II) between various concentrations of hydrochloric acid and lithium chloride and two monofunctional weak-base ion exchangers. The distribution coefficient showed a maximum with hydrochloric acid concentration at 3 M; a nearly identical behavior was observed with Dowex 1 (a strong-base anion exchanger). The uptake of Zn(II) from LiCl solutions increased sharply with the concentration of the latter. Strong-base anion exchangers show this same behavior. (AEC Activity 5330)

Technetium and Rhenium Chemistry - Rhenium trichloride dissolved in 12 M HCl was found to be reduced to Re(II) by vanadous ion, V^{++}. Protected from oxygen in the air and with excess V^{++} present, the solution of Re(II) is stable. The Re(II) solution is violet in color and its spectrum has a broad absorption band in the visible region with a maximum at 5600 Å. The extinction coefficient at this maximum is 400. Oxygen oxidizes the Re(II) back to $ReCl_3$. Rhenium trichloride dissolved in 2 M H_2SO_4 containing V^{++} in excess of that required to reduce the $ReCl_3$ produces an unstable violet solution which, in a few minutes, undergoes decomposition to a dark colloidal solution. The instability of this solution and the stability of the solution in more concentrated HCl suggest that excess chloride ion is required for stabilization of the Re(II).

The low-temperature calorimeter designed for use with liquid helium has been successfully operated from 60°K to room temperature by measuring the heat capacity of an empty calorimeter. The precision of the measurements was better than 0.1%. The first attempt to use liquid helium was not successful due to a freeze-up. Modifications have been made in order to prevent such a difficulty in the future.

The ice calorimeter used in the high-temperature "drop" calorimeter has been prepared for use by charging the calorimeter with air-free distilled water and mercury. An ice mantle has been grown successfully in the ice calorimeter, and the apparatus will soon be ready for preliminary testing. (AEC Activity 5330)

Characterization of Short-Lived Fission Products - Irradiation of germanium metal containing 97.7% Ge^{74} with 14-Mev neutrons produced a radionuclide whose integral gamma-ray activity, as observed with an NaI scintillation detector, decayed with a 7.5 ± 0.4-min half life. The gamma-ray spectrum showed an intense 0.60-Mev line as well as transitions with energies of 0.86, 1.9, 2.3, and possibly 1.1 and 1.5 Mev. The 0.60-Mev transition corresponds to the decay of the first excited state of Ge^{74}, which has also been found by means of coulomb excitation. This fact, coupled with the high degree of enrichment of the target material used, indicates that the 7.5-min nuclide is Ga^{74} produced by an (n,p) reaction on Ge^{74}. This mass assignment is in general agreement with the results of others on the irradiation of natural germanium with fast neutrons.

The radiations emitted by 86-sec I^{136} have been studied with both single-crystal and coincidence scintillation spectrometers. The spectrum obtained with a 3 x 3 in. NaI crystal spectrometer showed gamma rays with energies of 3.18, 2.84, 2.61, 2.32, 1.89, 1.55, 1.32, 0.870, 0.493, 0.388, 0.270, and 0.210 Mev. Of these, the 1.32-Mev gamma ray was most intense. With an anthracene crystal spectrometer, two high-energy beta rays were found with energies of 5.6 ± 0.1 and 7.0 ± 0.1 Mev. In coincidence with the 1.32-Mev gamma-ray peak were beta rays of 5.60 ± 0.15 and 4.23 ± 0.20 Mev, and possibly a third component at about 2.7 Mev. Also coincident with this prominent peak at 1.32 Mev were gamma rays of 0.19, 0.28, 0.39, 0.56, 0.87, and 1.32 Mev, the last of which is the most intense. The above data indicate that the first two excited states in Xe^{136} are at 1.32 and 2.64 Mev, with a pair of 1.32-Mev gamma rays involved in the cascade process.

The gamma-ray spectrum of 16-sec Tc^{100} exhibits an intense doublet of 0.542 ± 0.006 and 0.600 ± 0.009 Mev energy. Weaker gamma rays of 0.71, 0.81, 0.89, 1.01, 1.14, 1.31, 1.49, and 1.8 Mev, as well as unresolved low-energy components, are also present. The 0.542-Mev gamma ray, which represents the decay from the first excited level of Ru^{100}, is coincident with the 0.600-Mev gamma ray and thus establishes an excited state at 1.14 Mev. Scintillation beta-ray spectra were resolved into components of 3.38 ± 0.06 and 2.88 ± 0.07 Mev, which decay to the ground and first excited states of Ru^{100}, respectively. A beta-ray group of about 2.2 Mev is in coincidence with the gamma-ray doublet of 0.542 and 0.600 Mev, as was expected for the beta rays feeding the 1.14-Mev level of Ru^{100}. (AEC Activity 5330)

Chemical Separation of Isotopes - Fractionation of sulfur isotopes was measured at several temperatures for the exchange between SO_2 gas and SO_2 dissolved in an aqueous solution of KH_2PO_4. Use of this buffer solution permits regeneration of the SO_2 by boiling the solution and thus affords a simple refluxing mechanism for this exchange reaction. The isotopic exchange was

studied with the use of a 30-bubble-plate column. Raising the column temperature increased the fraction of HSO_3^- (the enriching species) in the saturated solution, but the separation factor between SO_2 gas and HSO_3^- was decreased by the higher temperature. Total separations, R(top)/R(bottom), where R is the abundance ratio S^{32}/S^{34}, were found to be 1.070, 1.067, and 1.059 at 30, 40, and 58°C, respectively.

Total separations were also measured for the exchange between SO_2 gas and a number of SO_2-amine addition compounds with the use of the bubble-plate column referred to above. Corrections were made for dissolved uncomplexed SO_2. The experiments were performed at room temperature, and S^{34} enriched in the organic phase. The single-stage separation factors calculated from the column data for the systems containing aniline, triethyl amine, pyridine, and dimethyl aniline were 1.0027, 1.0026, 1.0017, and 1.0014, respectively. (AEC Activity 5340)

METALLURGY

High-Temperature Reactions of Metals and Ceramics - In order to determine the effect of cation environment and temperature on the electronic behavior of anions in a fused salt, a study is being made of the ultraviolet absorption spectrum of nitrate ions in fused salts. The lowest-energy electronic band is assigned to a transition which is forbidden for the free ion at absolute zero. Hence, the integrated intensity of the absorption band is a measure of the perturbing influence of environment and thermal motion.

Measurements were made on the fused nitrates of the alkali metals from lithium through cesium at temperatures near 600°K. The energy of the transition corresponding to the band maximum was found to shift to progressively lower values in going from lithium (4.3 ev) to cesium (4.0 ev). The perturbing effect was greatest for lithium and least for cesium, being 9.1 and 1.6 integrated molar absorbancy index units, respectively. The change of the perturbing effect between adjacent alkali nitrates was greatest for the change from lithium to sodium and decreased progressively, becoming least for the change from rubidium to cesium. The effects of changes in temperature were small. With increasing temperature the band maximum shifted to lower energies and the perturbing effect decreased. (AEC Activity 5420)

PROGRAM 6000 — BIOLOGY AND MEDICINE

BIOLOGY

Cytology and Genetics: Plants and Fungi - Experiments were initiated to test the basic assumption that the number of ad-3 mutants induced in a given population of treated nuclei can be counted directly, following mutagenic

treatment, on the basis of the color and/or morphology of the colony formed by purple adenine mutants plated on complete medium or on medium supplemented with growth-rate-limiting levels of adenine.

By the use of uninucleate conidia from a wild-type strain of colonial morphology, several presumptive ad-3 mutants were recovered after treatment with doses of about 15,000 to 20,000 r. In these experiments the forward mutation rate of the complex is of the order of 1×10^5. (AEC Activity 6130)

Cytology and Genetics: Insects - It is well known that Drosophila males without a complete Y chromosome are sterile, although the determination of this sterility is as yet unknown. Stern and Hadorn (1938) suggested that the sterility is not determined by the genotype of the gametes but is determined early in the diploid phase or is determined by the tissues that surround and nurture the germ cells. The recent discovery of a somatically unstable ring Y chromosome makes possible a reinvestigation of this problem. This work has been facilitated by the further discovery of a genetic factor that causes a high frequency of elimination of this ring Y from the germinal tissue.

The results of studies with this material indicate that fertility is determined at some early stage in the formation of the germinal tissue and that loss of the Y chromosome subsequent to this time does not impair the fertility of the XO tissue. Other studies indicate that the XO tissue can comprise a significant proportion of the germinal tissue. These observations are being extended by the use of cytological techniques, and the inheritance of the factor causing a high frequency of elimination of the ring Y is being investigated. (AEC Activity 6130)

Pathology and Physiology - The earlier death of mice acutely exposed to neutrons, as compared with x rays or gamma rays, has been traditionally ascribed to relatively greater intestinal injury. This explanation is now supported by the observation that the relative biological effectiveness (RBE) of fast neutrons for the production of intestinal weight loss in the mouse is appreciably higher than that for acute lethality. For intestinal weight loss, the RBE of 14-Mev neutrons, 250-kvp x rays, and Co^{60} gamma rays is 2.0, 1.5, and 1.0, respectively, whereas for 30-day lethality the corresponding RBE is 1.5, 1.4, and 1.0. (AEC Activity 6130)

Enzymology and Photosynthesis - Studies were continued on the phenomenon of light emission from dried chloroplast films when they are heated. Previously, these films were charged by exposure to visible light. It has now been shown that the films may be charged chemically by exposing them in the dark to air which is irradiated by short ultraviolet rays. A number of gases were tried: nitrogen, helium, oxygen, and air. Only air and oxygen produced a charge. It seems likely that ozone is the activating gas. The light emitted from plates charged in this manner is of the same wavelength as that given off by plates charged by visible light. (AEC Activity 6130)

Research Participation and Traveling Lecture Program - The Research Participants who spent the summer at the Laboratory have completed their assignments and have returned to their home universities. Of the 53 participants representing 44 universities, 12 were engaged in biological and biophysical research. There are presently two participants in the Biology Division.

The Traveling Lecture Program for the academic year 1957-1958 has begun, with 48 lectures already scheduled, 14 under Program 6000. (AEC Activity 6130)

Microbial Protection and Recovery - The involvement of extracellular H_2O_2 on inactivation of a catalase- and cytochrome-negative hemin-requiring mutant strain of *Escherichia coli* is clearly demonstrable as an after effect (i.e., inactivation continues after the end of exposure). The lethal effect on a population of these cells appears at present to involve three separable processes: (1) an immediate rapid inactivation of a fraction of the population, (2) a "sensitization" of some target material in the surviving cells, and (3) a resulting abnormal sensitivity of the surviving cells to the toxic action of H_2O_2 produced by x rays in the extracellular medium. The possibility that the immediate lethal effect also involves the toxicity of H_2O_2 is being investigated.

A mutant strain (15_{T-}) of *Escherichia coli* is being investigated for radiation sensitivity as a function of nucleic acid and protein synthesis. Synchronous cultures of this organism are being used for studying the relationship of cell division to radiation sensitivity. This organism, incubated in a simple chemically defined medium in the absence of added thymine, synthesizes ribonucleic acid and protein but no deoxyribonucleic acid for a period of time. Continued incubation in the absence of thymine results in a logarithmic death rate as a function of time. If thymine is added just before the onset of death, the culture shows an abrupt and rapid synthesis of deoxyribonucleic acid and later an abrupt increase in cell numbers (synchronous division). Irradiation of such cultures at frequent intervals permits a demonstration of striking changes in radiosensitivity which can be correlated with the biochemical activity of the cell. (AEC Activity 6230)

Mammalian Recovery - Isologous spleen treatment after lethal irradiation was compared with isologous bone marrow treatment. The lymphatic tissues recovered much more quickly when spleen was used than when bone marrow was used.

More detailed studies on the effect of delaying the injection of foreign bone marrow after irradiation now indicate that delayed injections are not particularly effective in overcoming the delayed reaction to foreign bone marrow.

Life-span studies in the mouse of normal mouse, normal rat, and mouse-grown rat erythrocytes indicate that normal rat and mouse-grown rat erythrocytes have a maximum life span in the mouse of about 2 to 3 days. Normal mouse red blood cells, however, have a maximum life span in the mouse of about 50 days. (AEC Activity 6230)

Radiation Immunology - Further studies on the antibody response of mice during the maximum depression period following varying doses of total-body x irradiation showed that the curvilinear relation between irradiation dose and antibody response is, in part, a function of the antigen-host genetic relationship.

Lethally irradiated mice were injected with homologous bone marrow, and, at varying intervals, blood samples were analyzed for the appearance of donor-type red blood cells. It was found that within 14 days there was an almost complete replacement of the host-type red blood cells. In contrast, it took about 50 days for the heterologous red blood cells to attain this level in lethally irradiated mice treated with rat bone marrow. (AEC Activity 6230)

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November 1956	ORNL-2232
December 1956	ORNL-2248
January 1957	ORNL-2261
February 1957	ORNL-2281
March 1957	ORNL-2299
April 1957	ORNL-2316
May 1957	ORNL-2342
June 1957	ORNL-2355
July 1957	ORNL-2370
August 1957	ORNL-2393
September 1957	ORNL-2411
October 1957	ORNL-2426

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