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STATUS AND PROGRESS REPORT

JANUARY 1958

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

January 1958

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January 1958

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STATUS AND PROGRESS REPORT

January 1957

This Status and Progress Report summarizes somewhat more than one-half the activities of the Laboratory. Some of the topics are included every month, but many of them are reported on a bi-monthly schedule. Program 4700 is covered in a separate report.

PROGRAM 2000 — SPECIAL NUCLEAR MATERIALS

Waste Metal Recovery. — ORNL tank-farm waste containing 7 tons of uranium was processed with 99.9% recovery, increasing the total quantity reclaimed during the program to 136 tons. The uranium gross gamma decontamination factor was 3.8×10^3 in one solvent extraction cycle, giving specification-grade product.

The plant was cleaned out, and equipment modifications were made for recovering 42 g of Am^{241} from Los Alamos concentrate. In the first phase of the program, americium, lanthanum, and cerium were separated from iron, chromium, calcium, magnesium, and aluminum by a neutral-extraction flowsheet, with 99.9% americium recovery. The chief flowing-stream loss, 1.6%, was to the spent solvent from the stripping column and was completely recovered by batch water treatment. (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. Approximately 30 lb of uranium, as uranyl chloride, was electrolytically reduced to UCl_4 in 32 hr in the Ionics 18- by 20-in. cell. For 100% reduction, at a rate of 1.2 lb of uranium per hour, the current efficiency was 60%. The current density was 1 amp/in.^{2}.

In a 16-hr run in the 2-in.-dia ion exchange column, iron was removed from an iron-reduced uranium solution by a factor of 5.5, and the product iron concentration was steadily decreasing when the run was terminated. Uranium losses in the waste stream were 1%, probably because of hydrolysis of the uranium to UO_2, which precipitated in the resin. (AEC Activity 2702)

Fluorox Process. — In the Fluorox process, UF_4 is oxidized to UF_6 with oxygen or air at high temperatures. In three continuous fluidized-bed runs at 800 to 820°C, UF_6 recoveries were 40, 47, and 70% of theoretical. The UF_4 feed rate was 1 lb/hr in one run lasting 13 hr. In laboratory studies, the addition of HCl, Cl_2, or NO_2 to the oxygen stream had no significant catalytic effect on the oxidation at 600 or 700°C.

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The compound U_4F_{17}, a UF_4-UF_6 intermediate, was identified in the off-gas. Material collected on the off-gas filter contained corrosion products, and an Inconel thermowell was badly corroded where it was submerged in the bed, but was not corroded where it was in the gas phase.

In two runs in the flame reactor, UF_4 was successfully introduced continuously into a pure CO-O_2 flame without flame instability. (AEC Activity 2702)

Metallex Process. — In the Metallex process a metal chloride is reduced by sodium amalgam to the mercuride, and the metal is recovered by pressure filtration and vacuum distillation. Seven thorium sponge billets, totaling 20 lb, recovered from residual amalgams had good chemical properties except for high iron and nickel content. Low oxygen content, 0.48 to 0.58% ThO_2, and low hydrogen content, 4 ppm, were attributed to drying of the amalgam by amalgamated phase separators prior to retorting. In the reduction step, slow and uniform feeding of UF_6 to the amalgam favored retention of uranium in the mercury phase. The most effective method, of several tried, for removing trace amounts of thorium from recovered mercury was high-shear agitation with finely divided activated carbon followed by washing in 1 M HNO_3. (AEC Activity 2704)

PROGRAM 4000 — REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test. — After the initial critical test, conducted on December 27, the HRT was shut down so that the source could be transferred to the blanket thimble. Concurrently, the core thimble was removed, and a trial installation and removal of the core corrosion specimens was successfully performed with remote-handling equipment.

Leak-checking of the shield tank recommenced and was continued throughout the first week of January. By blanking off the 16-in. shield vent line to the stack, the inleakage to the shield at 7-1/2 psia internal pressure was reduced from 25 to 1/2 scfm. A further reduction to 1/4 cfm was obtained by casting a thermosetting resin into the stainless steel lip to which the galvanized seal pans are welded, at the periphery of the cell and the sides of the girder boxes.

Following a series of no-load heat-loss measurements, low-power critical tests were performed during the period January 8 to 11. Seven tests were made at temperatures ranging from 65 to 281°C, to determine the temperature coefficient of reactivity. Although the data have not yet been analyzed, the coefficient appears to be within a few per cent of the expected value.

Three sets of metallurgical test specimens were then installed in the blanket thimble above the source, and the shield was resealed, pressurized, and charged with helium to 2 vol % to permit searching for leakage with a helium leak detector. Numerous leaks varying in size from 1 to 100 cc/min were found and repaired. After all detectable leaks had been stopped, the leak rate was 7 to 10 liters/min, although no leakage could be found inside the building. In order to reveal the presence of leaks which might have escaped detection in previous searching, approximately 2 liters of 10% ethyl mercaptan was vaporized into the shield on January 27. The resultant concentration in the shield was 40 ppm, approximately 20 times the concentration used in natural gas. Although several other small leaks were located inside the building, it was concluded that the remainder of the leakage (5 to 8 liters/min) must be outside.

Filling of the north bulkhead with a mixture of barytes sand, colemanite (boron ore), and water was completed as one of the final steps in preparation for power generation experiments. A bulk density of 105 lb/ft^3 was attained by first partially filling the bulkhead with water and then pouring the sand-colemanite mixture into the water and vibrating for compaction. (AEC Activity 4103.3)

HRT Chemical Pilot Plant. — The hydroclone loop was operated without difficulty during the final D_2O test run prior to the reactor critical experiments. The 30-liter D_2O inventory was charged preceding the run.

Water leakage into canned refrigeration insulation and the three thermal-probe level indicators during flooding operations of the preceding month necessitated extensive repairs and revamping of the air-pressurization system to prevent similar incidents in the future. (AEC Activity 4103.1)

Fuel Processing. — Silvered Yorkmesh was demonstrated to be an efficient absorber for iodine in the HRT mockup loop. In laboratory tests, iodine absorbed on the silvered Yorkmesh was not displaced by heating to 600°C, by rapid heating to 400°C and cooling, or by immersing Yorkmesh at 170°C in boiling 0.04 m UO_2SO_4—0.02 m H_2SO_4 solution. The rate of absorption decreased tenfold after the bed was 2% loaded, apparently being controlled by the rate of diffusion of absorbed iodine into the mass of the silver. This effect was not observed with silvered Alundum. (AEC Activity 4103.1)

Uranyl Sulfate Blanket Processing. — The results of four runs with plutonium in 1.4 m UO_2SO_4 at 250°C under 350 to 400 psi O_2 in the P-1 loop were similar to those obtained previously with zirconium. When dissolved plutonyl sulfate was injected into circulating 1.4 m UO_2SO_4 at 250°C, most of it stayed in solution until the concentration exceeded 100 mg of Pu per kg of H_2O. At higher concentrations the plutonium was rapidly removed from solution by adsorption on the stainless steel. Less than 1% was removed as solids by the hydroclone. When 850 mg of plutonium as preformed PuO_2 was injected, 20% was removed by the hydroclone, 35% was adsorbed on the stainless steel, and the rest was distributed throughout horizontal sections of the loop as loose solids.

Plutonium adsorption on stainless steel from 1.4 m UO_2SO_4 containing plutonium at a concentration of 2 mg per kg of H_2O was about 0.0004 $\mu g \cdot cm^{-2} \cdot hr^{-1}$ during a 110-hr run. In a 180-hr run, in which the plutonium concentration was gradually increased from 2 to 75 mg per kg of H_2O, plutonium adsorption on type 347 stainless steel averaged 0.005 $\mu g \cdot cm^{-2} \cdot hr^{-1}$. The total adsorption was up to 300 $\mu g/cm^2$ when plutonium concentrations were increased to >100 mg per kg of H_2O, and the amount adsorbed depended on the amount of plutonium added. Total adsorptions of up to 1 mg/cm^2 were obtained.

The hydroclone was apparently effective in removing solids that reached it, but only small amounts of solids actually reached the hydroclone. Less than 1% of the total corrosion products (determined by nickel analysis) was removed as solids by the hydroclone.

Static laboratory tests indicated that the addition of 0.5 m H_2SO_4 to the usual 1.4 m UO_2SO_4 solution decreased the adsorption of plutonium on titanium and Zircaloy-2 to 10% of the value for neutral solutions under the same conditions. (AEC Activity 4103.1)

Thorium Oxide Slurry Development. — The thorium oxide production equipment was modified to permit the preparation of 750 lb per month of thorium oxide of 1 μ average particle size calcined at 1600°C. A capacity of 1500 lb/month is anticipated. About 550 lb of 1600°C calcined oxide and 130 lb of 1400°C calcined oxide, classified so that particles >5 μ would be removed, were produced.

In studies on the effects of the chemical and physical variables, the average particle size of the oxide decreased with decreasing precipitation temperature and increasing reagent concentration. At the lower temperatures, oxides were of more uniform particle size. The fraction of oversize particles decreased with increasing stirring rate and reagent addition rate.

Oxide produced by the 650°C firing of thorium oxalate precipitated in the presence of cellulose was more bulky than the normal form and had lower surface areas but similar x-ray crystallite sizes.

The induction period for thorium oxalate precipitation was pronounced in the presence of 5 M excess HNO_3 (0.1 M $Th(NO_3)_4$, 0.22 M oxalic acid), but oxalate precipitation was essentially complete. Evaporation under a heat lamp and calcination at 650°C of thorium nitrate solution alone or with H_2SO_4, H_2SiO_3, $Al(NO_3)_3$, $Pb(NO_3)_2$, or $Na_4P_2O_7$ additives (at metal/thorium mole ratios from 0.005 to 1) did not produce acceptable slurry material.

The effect of length/diameter ratio on the hindered settling rate in vertical cylinders of slurries of 800 and 1600°C fired thorium oxide in water at thorium concentrations of 200, 400, and 700 g per kg of H_2O was not discernible at L/D ratios less than 10. In general, the 1600°C fired oxide gave more reproducible results than did the 800°C fired oxide.

Studies on the adsorption of sulfuric acid by ThO_2 indicated that for each surface site four hydrogen and two sulfate ions disappear from solution. Data from infrared absorption studies on the recovered solids correlated directly with those from chemical analysis. (AEC Activity 4103.1)

Gaseous-Fission-Product Disposal. — Dynamic studies indicated that the number of theoretical chambers in a long trap for adsorption of xenon and krypton is proportional to the length of the trap under the conditions studied thus far. Iodine was adsorbed effectively from a flowing stream of air by both charcoal and Linde molecular sieve 13X. The adsorption was irreversible on charcoal at 28°C but not on the molecular sieve. (AEC Activity 4103.1A)

Mathematics and Computation: Homogeneous Reactor Development. — The equations for neutron-capture-gamma heating in a semi-infinite slab were formulated, assuming a fast- and a slow-neutron current into the slab and considering the gamma rays to be split into five energy groups. The resulting analytical solution was used as an energy-source term in calculating the temperature distribution in a spherical pressure shell. Oracle codes were written which perform the indicated calculations. (AEC Activity 4103.1)

Reactor Analysis. — The effect of the value of η^{23} in the resonance region upon the breeding ratio in thorium breeder reactors was studied by means of multigroup calculations. It was found that resonance fissions contribute about 10 to 40% of the total fission in reactors containing from 0 to 300 g of Th per liter in the core region. If η^{23} in the resonance region were 0.9 of its value in the thermal region, the breeding ratio in solution-core reactors would be about 0.02 lower than if η^{23} were independent of energy and equal to its thermal value.

Time-dependent studies of slurry-core, slurry-blanket thorium breeder reactors generating about 60 thermal Mw indicate that the core poison fraction is the major variable affecting the breeding ratio. With a core thorium concentration of 100 g/liter, a period of 700 days following startup is required before the core poison fraction reaches 7%, while the corresponding time is 1360 days when the core thorium concentration is 200 g/liter. A period of about 800 days is required before the U^{233} concentration in the blanket reaches 3 g/liter.

Revised calculations were performed to determine the heat generation rates in the HRE-3 core vessel. Values obtained with a core power of 50 Mw were about 10.5, 9.4, and 9.0 w/cc for the cases of blankets containing 0 (D_2O blanket), 500, and 1000 g of Th per liter, respectively. (AEC Activity 4103.1)

Homogeneous Reactor Instrumentation. — A remote disconnect for metal-clad mineral-insulated electrical cable was designed, and a prototype was constructed.

Two test bobbins, simulating the windings used in differential transformers for sensing primary-element motions, were wound with 30-gage anodized aluminum wire and exposed to 6×10^{17} fast neutrons/cm^2 and 1×10^8 r of gamma radiation in the ORNL Graphite Reactor without insulation failure. (AEC Activity 4103.1)

HRP Design. — Analysis of data from flange tests confirms that a mismatch of as much as 0.010 in. between the pitch diameters of ring and groove of a ring-type joint is permissible for HRT service.

Approximately 99% of the vendor's shop drawings for the HRT spare heat exchanger have been checked and approved. It is expected that the delivery date of April 1, 1958, will be met. (AEC Activity 4103.1)

HRP Metallurgy. — In an effort aimed at finding a better alloy for homogeneous reactors than Zircaloy-2, a decision has been made to concentrate on Zr—15% Nb—X and Zr—20% Nb—X alloys, with X equal to 2 or 5 wt % of either molybdenum or palladium. These alloys were selected on the basis of their favorable combination of in-pile corrosion resistance to uranyl sulfate solution and their transformation characteristics, which are favorable for fabrication and welding. A limited amount of scouting work will continue on zirconium-palladium and zirconium-platinum binary alloys.

An effort has been made to substitute metallographic examination for hydrogen analysis of zirconium alloys. It has been shown that present techniques are capable of revealing a hydride layer on a sample containing a total of 500 ppm of hydrogen but are questionable at 100 ppm. For the thin layers expected in-pile, the 500-ppm capability is not considered adequate. (AEC Activity 4103.1)

Laboratory Corrosion Studies. — Two type 17-4 PH stainless steel bolts partially hardened to 37 Rockwell C and stressed at approximately 40,000 psi cracked during a 500-hr exposure at 280°C in the vapor phase above oxygenated, chloride-free 0.04 m UO_2SO_4 solution containing 0.02 m H_2SO_4 and 0.005 m $CuSO_4$. A stressed specimen exposed in the solution developed cracks during a 1000-hr period. This was the second observed incident of cracking of the alloy in the partially hardened condition.

The cracking behavior of Croloy 16-1 stainless steel and Incoloy was examined in boiling 42% $MgCl_2$ solution and in distilled water at 300°C containing 100 ppm chloride. In the former environment, Croloy 16-1 developed small cracks during a 100-hr test, whereas Incoloy did not. In pH 2.8 water containing chloride, cracking was observed on Incoloy during a 500-hr test; no cracking occurred on Croloy 16-1. Both alloys were severely pitted in the distilled-water environment.

Allegheny metal 350, a precipitation-hardening alloy, was tested in four heat-treated conditions. In 0.04 m UO_2SO_4—0.02 m H_2SO_4—0.005 m $CuSO_4$ solution at 100 and 300°C, corrosion rates in all conditions were less than

1 mil/year. At 200°C the corrosion rates ranged from 5 to 11 mils/year. Stressed specimens of the alloy were not subject to cracking in chloride-free uranyl sulfate solution but did crack readily in the boiling solution to which 50 ppm chloride had been added. (AEC Activity 4103.1)

Dynamic Solution Loop Corrosion Tests. — The boiler water in the HRT steam system may contain some oxygen formed by radiolytic decomposition. The effect of oxygen concentration on the corrosion of carbon steel and stainless steel in boiler water was investigated at 250 and 300°C. At 300°C the average corrosion rates of carbon steel grade SA-212-B for 200-hr periods were 4, 12, and 22 mils/year for oxygen concentrations of <0.1, 2, and 10 ppm, respectively. The carbon steel pitted extensively in the presence of oxygen, making the actual penetration greater. Type 347 stainless steel corroded at 1 to 2 mils/year under all conditions, but the corrosion rate would be expected to decrease with time.

An investigation was made to determine whether diluting the uranium concentration or increasing the copper concentration of HRT solution would affect the phase stability of the solution. Circulation of 0.02 m UO_2SO_4 containing 0.02 m H_2SO_4 and 0.03 m $CuSO_4$ in light water at 300°C for 1000 hr gave no precipitation. In the presence of 0.02 m H_2SO_4 there appeared to be no effect upon decreasing the uranium concentration by a factor of 2 or increasing the copper concentration by a factor of 3. (AEC Activity 4103.1)

Small-Scale Dynamic Slurry Corrosion Tests. — In toroid tests, experimental preparations of arc-fired and flame-fired ThO_2 produced high metal attack rates and were degraded during circulation at 250 and 280°C at slurry concentrations of 1000 g of Th per kg of H_2O. Similarly, ThO_2-CaO mixed oxides fired at 1700 and 1800°C were readily degraded during circulation at 250°C with attendant high metal attack rates.

Type 347 stainless steel, Zircaloy-3A, and titanium-75A exhibited moderate attack rates in tests with oxygenated slurries of 1600 and 1800°C fired thoria prepared from jet-precipitated thorium oxalate at a concentration of 1000 g of Th per kg of H_2O; however, the 1800°C calcined ThO_2 was markedly degraded during 300 hr of circulation.

In toroid tests made in order to study the effect of operating temperature, atmosphere, and ThO_2 calcination temperature on the corrosion-erosion attack by circulating slurries, generally higher attack rates of selected alloys occurred with hydrogenated slurries than with oxygenated slurries. In tests with hydrogenated slurries, the attack on type 347 stainless steel increased with increased circulation temperature.

Titanium and zirconium alloys displayed higher corrosion rates in hydrogenated slurries at 150°C than at 100 or 200°C. The properties of some slurries were changed during runs in which the operating temperatures were varied.

Generally, low attack rates were observed with oxygenated slurries of experimental preparations of silica-coated thoria at 280°C. The slurries after circulation were well dispersed and fluid. (AEC Activity 4103.1)

Dynamic Slurry Loop Corrosion Tests. — The improvement of the erosive characteristics of thoria as a result of the removal of large particles by sedimentation classification was demonstrated in loop experiments. Loop circulation tests at 200°C with ~500 g of Th per kg of H_2O (1600°C calcined thoria, prepared by jet precipitation or batch precipitation at 25°C of thorium oxalate) resulted in high erosive attack by slurries containing large-diameter particles (sinters) which were not degraded appreciably during circulation. The large particles were removed from the jet-precipitated 1600°C calcined thoria by sedimentation classification, and, in a subsequent test at 280°C with 323 g of Th per kg of H_2O, the slurry showed low corrosion-erosion rates and had satisfactory handling properties. (AEC Activity 4103.1)

In-Pile Solution Corrosion Loops: LITR. — Loop L-2-17, which had been operated at 300°C with a solution of 0.04 m UO_2SO_4, 0.025 m H_2SO_4, and 0.005 m $CuSO_4$, was dismantled and examined. The corrosion rates observed for Zircaloy-2 specimens were in general agreement with those observed in L-2-10, a previous experiment conducted under similar solution conditions but at the lower temperature of 280°C.

As was observed in all but one of the 280°C experiments in which either 0.17 m or 0.04 m UO_2SO_4 solution was employed, Zircaloy-2 specimens exposed in the low-velocity region of the L-2-17 core exhibited appreciably higher corrosion rates than those of specimens located in the higher-velocity channel. Analysis of two Zircaloy-2 specimens from the core revealed the presence of uranium sorbed on the surfaces in amounts which are probably significant. The amount of uranium per unit area on the low-velocity annulus specimen is about equivalent to the amount in a 30-μ layer of solution adjacent to the specimen, and calculations indicate that about 80% of the fission-fragment recoil energy reaching the specimen surface, from uranium in these sources, originated in the sorbed surface uranium. The analysis of the high-velocity core channel coupon showed an amount of uranium which is lower by a factor of 4 than the amount on the low-velocity specimen. These results are consistent with the interpretation that uranium sorbed on the surface is responsible for an appreciable fraction of the total corrosion attack of a Zircaloy-2 specimen under irradiation. (AEC Activity 4103.1)

In-Pile Solution Corrosion Loop: ORR. — Construction and development of the ORR loop package are being continued. The core section of the loop, now being fabricated, is designed to give flow velocities greater than those in the present LITR in-pile loops in order to increase metal-to-solution heat transfer. All other loop components have been fabricated. Installation of equipment for the exposure facility at the ORR is being continued and is about on schedule. (AEC Activity 4103.1)

In-Pile Autoclave Slurry Tests: LITR. — In the first of a series of in-pile autoclave slurry corrosion experiments, a thoria slurry containing 1000 g of Th per kg of D_2O was irradiated at 280°C for 261 hr in the LITR HB-6 rocking autoclave facility (319 hr at temperature), under 800 psi oxygen, in a Zircaloy-2 autoclave. A parallel out-of-pile experiment lasting 480 hr was made. Both experiments exhibited the same initial corrosion rate of approximately 1 mil/year, as estimated from pressure measurements. The out-of-pile experiment exhibited a slower rate in the latter part of the run. (AEC Activity 4103.1)

Autoclave Radiation Corrosion Studies: LITR. — In several different autoclave exposures to reactor irradiations which employed 0.17 m UO_2SO_4 with excess acid and $CuSO_4$, a Zr—15% Nb—1.5% Sn alloy has corroded at rates which are about 50 to 60% of those observed with Zircaloy-2. In a recent experiment, a Zr—15% Nb alloy and Zircaloy-2 were exposed in 0.17 m UO_2SO_4 containing 0.18 m Li_2SO_4 as well as $CuSO_4$ and H_2SO_4. Zircaloy-2 corroded roughly half as rapidly as in a similar system without the Li_2SO_4, whereas the corrosion of the Zr-Nb alloy appears to have been unaffected by the Li_2SO_4. Samples of loose scale that formed on 15% niobium alloys from three separate exposures indicate that less uranium is absorbed in the scale on these alloys (about 0.1 to 0.5% uranium) than in the scale on Zircaloy-2 (usually a few per cent uranium). Recent autoclave and in-pile loop results are consistent with the interpretation that Li_2SO_4 affects the Zircaloy-2 corrosion, at least in part, through a reduction of the amount of uranium at the Zircaloy-2 surface. Corrosion of the 15% niobium alloys is little affected by the presence of Li_2SO_4, possibly because little uranium is normally absorbed in the scale on these alloys.

Fewer data are available for niobium corrosion (two exposures). One test indicated a corrosion rate about one-third that of Zircaloy-2 in 0.17 m UO_2SO_4 with excess acid and $CuSO_4$; the other test, with a solution containing 0.18 m Li_2SO_4 in addition, indicated that no large change in the corrosion rate was effected by the presence of the Li_2SO_4. In both cases a very heavy scale, about 25% uranium, formed on the niobium. The amount of uranium included in the niobium scales was large but was not affected by the presence of Li_2SO_4. (AEC Activity 4103.1)

CIVILIAN-POWER ADVANCED-TYPE GAS-COOLED REACTOR (GCR)

Gas-Cooled Reactor: Physics. — One of the major topics in the nuclear analysis of the GCR is the reactivity lifetime of the core — that is, the exposure, in megawatt days per metric ton of uranium, that can be achieved before the depletion of fissionable material and the accumulation of fission-product poisons cause the reactor to become subcritical at the operating temperature. Extensive calculations were made in order to establish the dependence of the attainable exposure on such factors as fuel enrichment, lattice pitch, initial multiplication factor, and initial conversion ratio, and, also, to ascertain the composition of the fuel as a function of exposure. The results were used for determining fuel cycle costs, and, together with capital cost figures, as the basis for the selection of an optimum core configuration and fuel enrichment.

A number of different control materials were evaluated, including hafnium, cadmium-silver alloy, silver, rare earths, boron steels, and others. Silver was selected on the basis of effectiveness, longevity, induced radioactivity, fabricability, cost, and availability. There will be sixty-one 2-in.-dia rods, enclosed in stainless steel tubes; they will operate through the pressure vessel openings for fuel charging. The total worth of the rods, in k, will be about 17%.

The possibility of flattening the radial power density distribution in the reactor was examined. The methods considered were variable fuel enrichment (as a function of position in the core), variable lattice pitch, and variable discharge exposure. The last method was considered to be preferable, and it was found to be feasible to reduce the peak-to-average radial power ratio from 1.85 (in the uniform core) to about 1.25 to 1.3, with very little effect on fuel cycle economy. Further reduction of this ratio could be achieved only at the sacrifice of average fuel exposure or at the cost of additional fuel enrichment. (AEC Activity 4119)

Gas-Cooled Reactor: Experimental Engineering. — Equipment for two isothermal static-pot tests of the compatibility of graphite, fuel-element cladding materials, and helium in a stainless steel vessel was assembled, and the initial test is under way. The design of the test system that will provide thermal convection of the helium was completed, and fabrication was started. (AEC Activity 4119)

Gas-Cooled Reactor: Instrumentation and Controls. — Criteria were established for the control-rod drive mechanism. The major requirements are that the drive system must be able to positively position each control rod, that a positive indication of the position must be obtained, and that a failure of an individual rod drive must not jeopardize the operation of the other rod drives. The first requirement is being relaxed to the extent that gravity will be depended upon for insertion of the rod in order to simplify the mechanism and to reduce cost and space requirements.

The normal withdrawal speed and emergency insertion speed that have been selected for the control rods will provide a safe limitation of power in case of a startup accident and yet will provide an acceptable time interval for starting the reactor. The emergency insertion rate will also safely limit the temperature rise of the fuel in case the fuel cooling rate is suddenly reduced from the design-point value to 1% of that value. The normal insertion speed is identical with the normal withdrawal speed, so that a relatively simple actuator can be used.

Numerical data regarding the neutron and gamma-ray flux available to the chambers for sensing the nuclear power were examined. The design of the reactor is such that the thermal-neutron flux incident on the chambers is very much lower than that which would be expected from a consideration of the power level. Means for obtaining an indication of the flux during startup are being investigated.

Layouts for instrumentation and control were completed. (AEC Activity 4119)

Gas-Cooled Reactor: Design. — The last of the mechanical design features of the plant were established or revised for consistency on the basis of a final collation of the design specification. Calculations of pressures and temperatures within the fuel element were extended in order to take into account the burnups of 10,000 Mwd/metric ton, which, from the reactor physics standpoint, now appear to be obtainable. The fuel-element design was modified in order to accommodate the higher fission-gas pressures that will result from such burnup.

The steam generator design and steam cycle were established for 950°F, 950-psi steam at the turbine inlet and a helium temperature at the reactor outlet of 1000°F. The TVA design and cost estimation work was completed. (AEC Activity 4119)

Gas-Cooled Reactor: Radiation Damage. — The installation in the LITR of the apparatus for the study of the release of fission gas from UO_2 was delayed for reprocessing of the UO_2 pellets. Equipment for irradiation of a stressed fuel element was designed and is being fabricated. (AEC Activity 4119)

Gas-Cooled Reactor: Metallurgy. — The creep-buckling characteristics of the stainless steel cans for the fuel elements are being investigated. It was expected that under operating conditions the cladding material would collapse in the annulus that provides the clearance needed between the can and the fuel during assembly. In preliminary tests under simulated operating conditions, buckling occurred evenly and none of the specimens fractured. (AEC Activity 4119)

GENERAL REACTOR RESEARCH

Metallurgical Materials and Processing. — Diffusion experiments have been performed in which solid zirconium was exposed to magnesium vapor in order to establish the depth of grain-boundary penetration of magnesium into zirconium as a function of time at 625°C. The data reveal that 2 to 3 hr at 625°C is sufficient time for complete penetration of 0.030-in. zirconium cladding. Similar diffusion data are being obtained for Zircaloy-2. Various acid solutions are being used to test the susceptibility of the grain-boundary material to selective leaching. (AEC Activity 4203)

Thorex Process. — Thorium and U^{233} were recovered from thorium irradiated to 4000 g of U^{233} per ton and allowed to decay for 30 days. Solvent extraction losses were ~3% for thorium and ~0.5% for uranium, and average gross-gamma decontamination factors across two cycles were 10^4 for thorium and 10^5 for uranium. The run was terminated after 173 hr because of lines becoming plugged, probably as a result of the high irradiation. Solvent

degradation appeared excessive, as measured by higher radiation intensities at the extraction column interface, more rapid deposition on the plates of a gel-like thorium phosphate complex, and decreased partitioning efficiency. In laboratory studies with short-decayed feeds, however, solvent degradation, as measured by interfacial emulsions, did not appear serious.

Laboratory studies on process improvement indicated that the lower product decontamination from ruthenium in the pilot plant as compared with that in the laboratory is the result of insufficient sulfite. In the large volumes of the plant, gamma energy is more efficiently absorbed and sulfite is more rapidly destroyed. At 53°C, with 0.06 M bisulfite in the feed, the decontamination factor was 320, as compared with 2.5 in the control. Temperatures as high as 73°C were reached before the bisulfite was destroyed.

A 0.2 M KOH solution gave about twice the decontamination of used solvent as was obtained with the 0.2 M Na_2CO_3 used previously.

A flowsheet for immediate recycle of the aqueous waste from the runs on short-decayed material to recover additional uranium was demonstrated. This will decrease the isotopic dilution of the U^{232} recovered after protactinium decay.

The off-gas from the tanks in which the waste from the runs on short-decayed material was stored did not contain appreciable hydrogen. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Darex Process. — In the Darex process, stainless-steel-containing fuel elements are dissolved in aqua regia, and the chloride is removed before the uranium is extracted by an organic solvent. Continuous operation of the Darex loop (dissolver, stripper, reflux condenser) was smooth for 25 hr. Partial plugging of the dissolver outlet by flakes of what appeared to be undissolved stainless steel caused subsequent erratic operation, and the run was discontinued after 50 hr. In a 13-hr run, stainless steel dissolved at a rate of 6 g/min. The stripper product contained 250 ppm of chloride. Chlorine and nitrogen losses to the off-gas were, respectively, 0.2 and 1.0 mole per mole of stainless steel dissolved. In batch tests, specification (30 ppm chloride) solvent extraction feed was made by adding an equal volume of 70% HNO_3 to the dissolver product, evaporating to 126°C, and diluting to the original volume.

Yankee Atomic fuel rods (stainless-steel—clad UO_2 pellets) positioned vertically dissolved continuously in 5 M HNO_3—1 M HCl to give a solution containing 112 to 144 g of uranium per liter. The variation in the uranium concentration was caused by the change in the ratio of acid feed rate to pellet surface area, which resulted from dislodging of the pellets as the jacket dissolved. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Materials Evaluation. — Chemfast, an epoxy-resin-base concrete, continued to be resistant to 3 M HNO_3, 3 M HCl, 3 M H_2SO_4, and demineralized water after 30 days. In a 7-day exposure to the

liquid Zircex system (boiling $AlCl_3 \cdot NH_4Cl$ plus HCl), nickel corroded at a rate of 1.2 mils/month, which is low enough to permit the use of nickel as a container material. The rates of corrosion of Nichrome V were 6.2 and 0.13 mils/month in the liquid and vapor phases, respectively.

Fission products were removed from vinyl coatings more readily than from any other coatings tested, with decontamination factors as high as 5.5×10^5, but decontamination was not complete. Decontamination from Pa^{233} was more difficult than that from fission products. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Aqueous Dissolution. — Type 304L stainless steel dissolved at an average rate of 4 $mg \cdot cm^{-2} \cdot min^{-1}$ in refluxing (105 to 110°C) 4 M H_2SO_4, the rate being constant until the acid concentration decreased to 2 M and the stainless steel concentration reached 100 to 110 g/liter (about 2 M). Beyond this point, precipitates formed on cooling, and the dissolution rate decreased rapidly. When the stainless steel cladding of an APPR fuel element (sintered UO_2—stainless steel core) was dissolved in 4 M H_2SO_4 and the core was dissolved in 8 M HNO_3, only 0.033% of the uranium was lost to the residual solids. Contrary to previous results with APPR fuel elements, irradiation increased the uranium loss from Yankee Atomic fuel pins only slightly during sulfuric acid dissolution of the stainless steel. The loss in earlier experiments is considered to be due to the formation of hydrogen peroxide.

The dissolution rate of sintered 96% ThO_2—4% UO_2 pellets in fluoride-catalyzed nitric acid was maximum in 13 M HNO_3—0.04 M NaF. Solutions 1 to 2 M in dissolved thorium were obtained in 1 to 6 hr, depending on the ratio of solution volume to fuel surface area. The dissolution rates dropped markedly between 0.8 and 1.4 M dissolved thorium. A simulated APDA fuel pin (Zr-clad U-Mo alloy) formed a stable solution in 13 M HNO_3—0.5 M HF without added heat.

Hydrofluoric acid, added so that its concentration never exceeded 5 M, dissolved Zircaloy-2 jackets from PWR fuel elements with 0.24% uranium loss. Irradiation did not increase the loss significantly in 2 hr. The increased loss in a longer time is considered to be due to the formation of H_2O_2.

The liquid metal fuel 98.7% bismuth—1.3% uranium dissolved readily in 8 M HNO_3.

In the anodic dissolution of Zircaloy-2 in 3 M HCl, the percentage of metal remaining as sludge decreased with decrease in anode current density and was negligible at 0.01 amp/cm^2; current efficiencies were 93 to 100%. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Ion Exchange. — The uranium in a fluoride solution that had been used for dissolving zirconium cladding was removed by a phosphoric cation exchange resin with a loss of 0.6% and a decontamination factor from zirconium of 28.

The trace of plutonium dissolved by 0.25 to 0.50 M H_2SO_4 solution that had been used for dissolving stainless steel cladding was 94% recovered by sorption on a cation exchange resin and elution with 2 M HNO_3. The product contained 26% of the dissolved stainless steel components. (AEC Activity 4301)

Waste Treatment and Disposal. — The sodium and nitrate concentrations of synthetic aqueous waste were reduced from 0.6 and 0.3 M to 0.06 and 0.02 M, respectively, in two or three stages in a membrane electrolytic cell. (AEC Activity 4305)

Long-Range Planning Studies. — The maximum reactivity addition which would not cause any fuel elements to melt in the proposed enriched graphite reactor was calculated. It was assumed that the control rods would be released within 100 msec following the time at which the reactor power exceeded its nominal level, that the total worth of the rods was 5% Δk_e, that the rods fell freely with an acceleration of 1g, and that the reactivity-worth-vs-position relationship was S-shaped. With the control rods initially completely removed from the reactor core, the maximum permissible reactivity addition was 2.9%; the corresponding value was 3.3% if the control rods were initially inserted 4 ft into the reactor core. (AEC Activity 4510)

Reactor Safety Studies. — Some critical parameters of uranium-aluminum plate-type reactor fuel elements (MTR- and ORR-type) were determined by using elements having a U^{235} content as high as 200 g, the uranium being 93% enriched. No significant source-neutron multiplication was produced by a closely packed 11 by 12 rectangular array of 132 elements, containing a total of 18.6 kg of U^{235}, either with or without an effectively infinite hydrogenous (paraffin) reflector. No moderator was used between the fuel plates in either of these two tests.

The results of another series of experiments, with the elements completely submerged in water, may be summarized as follows: The lowest observed critical mass was 2.5 kg of U^{235} and, within the range studied, was not sensitive to the U^{235} content of individual elements, being only slightly lower for an array of 168-g elements than for those containing either 140 or 200 g. This minimum occurred when the elements were separated in two dimensions by a layer of water about 0.2 in. thick, the masses of closely packed arrays being about 3% greater. As the separations were increased beyond 0.2 in. the reactivity decreased rapidly, an infinitely large array of 168-g elements each separated from its neighbors by 2 in. of water being apparently subcritical. An 11 by 12 rectangular array of 132 elements containing 20.7 kg of U^{235} and having adjacent columns in contact and adjacent rows separated by a 0.02-in. thickness of cadmium was subcritical, showing little if any neutron multiplication. In a study of slab-like arrays of elements, spaced from each other to give maximum reactivity, it was shown that a single row infinitely long would be subcritical, as would be two parallel rows of 140-g elements. Insufficient material was available to ascertain unequivocally that two rows of the more heavily loaded elements could be made critical. It was shown, however, that two rows of 37 elements each, a total of 11.5 kg of U^{235}, was

subcritical, and its further extension with 140-g elements apparently did not increase the neutron multiplication. It is pointed out that the measurement of the multiplication in such extreme geometry is uncertain. (AEC Activity 4580)

PROGRAM 5000 — PHYSICAL RESEARCH

Reactor Operations. — A safeguard report is almost complete for the enriched ORNL Graphite Reactor. This report provides for loading the enriched fuel in increments with the natural fuel. Since the control system cannot be completely revamped in time for the first loading of enriched fuel, it is planned to limit the excess reactivity and the power.

Additional measurements are being made on graphite samples removed from the ORNL Graphite Reactor. The best value for the maximum stored energy found in these samples was approximately 31.5 cal/g (200°C peak). These values were based on x-ray measurements, and samples will be checked by combustion tests at the Bureau of Standards as soon as possible. In order to check reports that irradiated graphite will support combustion at 450°C, combustion tests on irradiated and unirradiated graphite are being run at various temperatures.

ORR Project. — Modifications to the ORR building by the H. K. Ferguson Company are essentially complete inside the building. Work is in progress in the basement of the adjacent change house, where the air-conditioning compressor and associated heat exchangers are being installed.

The two large facility plugs have been received from Paducah, and ORNL forces have installed the aluminum pebble thermal shielding and barytes concrete shielding.

The installation of the reactor tank with its associated piping, beam tubes, and large facilities is proceeding very slowly. A delay of approximately six weeks has been caused by problems encountered during the installation of the large facilities and beam tubes. These problems have been solved, and the installation phase should be completed by February 15, 1958.

Hydraulic tests of the ORR core have been completed, and the results indicate that the flow characteristics are essentially as designed.

Preparations for the critical experiments are essentially complete. Boron-loaded strips for reactivity measurements have been calibrated in the LITR, and step-by-step procedures are being written for the various counting techniques required in making flux traverses. The critical experiment program is presently scheduled to start the last of February 1958.

Thermocouples, instruments, and various special apparatus are being assembled and tested for necessary measurements during the power runs which are scheduled to follow the critical experiment program.

PHYSICS

Neutron Velocity Selector. — The digital speed control equipment for the M1 chopper is now in operation. This equipment, designed and constructed by the Instrumentation and Controls Division, automatically accelerates the rotor to any preset speed up to 15,000 rpm and controls speeds to ±2 rpm. The M1 rotor has been successfully spun at 6000 rpm, and higher speed tests are planned for the near future. Total-cross-section measurements of iodine, silver, tantalum, and gold are now in progress at the LITR 45-m flight station as a check on the performance of this spectrometer. A counting rate of ~4 counts/min per 1-μsec channel is now obtained with a bank of 15 Radiation Counter Laboratories BF_3 counters. (AEC Activity 5220)

High Voltage Program. — It was previously reported that transmission measurements had been made on a number of separated nuclides. The results from these measurements were converted into cross sections. The following is a partial list of the nuclides studied, together with a qualitative description of the behavior of the cross section of each:

Nuclide	Energy Interval (kev)	Resonances (kev)
N^{14}	2—17	*
Ti^{48}	2—13	2.2,** 2.5**
Ti^{49}	2—17	2.3,** 2.55,** 3.7, 7.9**
V^{51}	2.5—17	4.0, 6.3, 10.5,** 12.25, 15.5
Fe^{56}	2.0—17	***
Fe^{57}	2.0—17	3.7, 5.7
Cu^{65}	2.0—17	2.4, 3.7, 4.2,** 6.05, 7.3, 12.4
Rb^{85}	2.0—9	2.25,** 2.8
Rb^{87}	2.0, 4.5, 6.0—12	3.6,** 4.0,** 6.8, 8.1
Zr^{90}	2.9—17	3.6,** 12.5, 15.6

* Falls smoothly from 12.5 to 7 barns.
** Previously unreported.
*** Flat, no resonances.

Coulomb excitation of several states in $_{41}Nb^{93}$ and $_{49}In^{115}$ with 6- to 10-Mev alpha particles was detected. For Nb^{93}, gamma rays of 963, 745, and 140 kev were observed, which correspond to the excitation of states at 963 and 745 kev. From the yield of the 140-kev gamma ray as a function of alpha-particle energy, it follows that this must be a cascade gamma ray from the decay of the 963-kev level. The reduced electric quadrupole transition probabilities, B(E2), for excitation of the states at 745 and 963 kev are 8 and 21 times the

single-particle estimate, respectively. In the case of In^{115}, states were observed at 1075, 1130, and 1285 kev, and the values of B(E2) for excitation are approximately 7, 33, and 18 times the single-particle estimate, respectively. (AEC Activity 5220)

Neutron Diffraction. — Neutron diffraction measurements made on single crystals of $FeCl_2$ and $CoCl_2$ at temperatures down to 4.2°K in an external magnetic field definitely established the antiferromagnetic structures in these compounds below about 25°K. In both compounds the magnetic moments of the metal atoms within a layer are coupled ferromagnetically, and adjacent ferromagnetic layers are antiparallel. The crystal of $FeCl_2$ has atomic magnetic moments of 4.2 ± 0.4 Bohr magnetons directed parallel to the hexagonal c axis, while in $CoCl_2$ the moments are perpendicular to the c axis with a value of 3.2 ± 0.3 Bohr magnetons. Previous investigations on powdered samples had suggested these magnetic structures, but accurate measurements of the magnitude and direction of the magnetic moments could not be obtained because of preferred particle orientation in the samples. The single-crystal measurements on $CoCl_2$ also showed that there are antiferromagnetic domains in this structure, that is, regions which have different directions of antiferromagnetism. The measurements on single crystals of $FeCl_2$ confirmed previous susceptibility measurements at low temperatures which had suggested that magnetic fields along the c axis greater than a critical value would align all the magnetic moments in the direction of the field. (AEC Activity 5220)

Low-Temperature Nuclear and Solid State Physics. — Broad-area germanium n-p junction counters similar to those developed by Gossick and Mayer at Purdue for alpha counting have been used to detect alpha particles and fission fragments at 77°K and in the temperature region between 1.30 and 4.2°K. Counters with effective counting areas as large as 1 cm^2 have shown good resolution and reasonable stability. Under optimum conditions, a resolution of 4% (full width at half maximum) has been obtained for 5-Mev alpha particles. Preliminary results suggest that the response of these counters is nearly linear with particle energy up to the highest energies of fission fragments. A curve taken at 4.2°K of the counting rate as a function of energy for U^{233} fission fragments clearly shows two peaks and is similar to the curve for U^{235} fission fragments obtained by Fowler and Rosen with a gas counter. (AEC Activity 5220)

Thermal Diffusion. — All the argon separated to date has been purified from contaminants and bottled. The inventory now on hand has the following assay:

Quantity (Standard ml)	A^{36} (%)	A^{38} (%)	A^{40} (%)
68	2.81	0.19	97.00
177	8.05		91.95
900	15.5	1.1	83.4
510	19.4	1.6	79.0
16	79.4	1.9	18.7
Normal	0.34	0.063	99.60

The krypton plant contains approximately 100 standard ml of 95.3% Kr^{86}. At the present rate of increase this concentration should reach 99% in about 40 days.

Construction has been started on a new laboratory which will provide adequate space for the thermal diffusion operation; this laboratory should be completed by the end of February. (AEC Activity 5250)

Mass Spectrometry Research and Development. — The Analytical Mass Spectrometry Section has completed and is using a gas-handling system for collecting samples to determine the relative amounts of gaseous components that are baked out of materials at various temperatures up to 1000°C. The system is at present being used in a study of graphite samples for the Gas-Cooled Reactor. Contaminants in xenon and tritium have been determined for the radioisotopes section. Concentration and isotopic abundances are being determined on HRE-2 fuel samples. (AEC Activity 5250)

CHEMISTRY

Raw Materials Chemistry. — Di(2-ethylhexyl)phosphoric acid (D2EHPA) labeled with P^{32} was used for the measurement, with better sensitivity and precision than were previously available, of the distribution losses of the reagent from kerosene solutions to synthetic Dapex process acidic raffinates and alkaline strip solutions. At 25°C the loss from 0.1 M D2EHPA to synthetic leach liquors (0.5 M SO_4, pH 1, 1 g of U per liter) was <1 mg per liter of aqueous phase in batch extractions and <2 mg/liter in continuous countercurrent extractions. At 50°C the batch loss was higher but was <5 mg/liter. These losses are negligible compared with entrainment losses in the raffinate. Batch equilibration losses at 25°C from 0.1 M D2EHPA to neutral and alkaline sodium salt solutions varied inversely and approximately exponentially with the aqueous Na^+ concentration, with little dependence on the choice of aqueous anion. The losses did not exceed 250, 50, and 10 mg per liter of 1, 2, and 3 M Na^+ solutions, respectively, and were between 120 and 180 mg/liter to 1.3 M Na^+ solution in continuous countercurrent stripping. These losses correspond to <0.005 lb D2EHPA (costing <0.5¢) per pound of U_3O_8 recovered in typical stripping with 10% Na_2CO_3 loaded to >40 g of U_3O_8 per liter.

In fundamental studies on the extraction of uranium by synergistic combinations (ORNL-1995, -2355), molecular association between D2EHPA and tri-n-octylphosphine oxide (TOPO) was examined by infrared spectrophotometry. The concentration dependence of the absorbancies in n-octane solution indicated at least two complexes:

$$(D2EHPA)_2 + 2TOPO \rightleftharpoons 2(D2EHPA \cdot TOPO)$$

$$K_1 = [D2EHPA \cdot TOPO] \;/\; [(D2EHPA)_2]^{1/2}\,[TOPO] = 30 \pm 5$$

$$(D2EHPA)_2 + TOPO \rightleftharpoons (D2EHPA)_2 \cdot TOPO$$

$$K_2 = [(D2EHPA)_2 \cdot TOPO] \;/\; [(D2EHPA)_2]\,[TOPO] = 100 \pm 50$$

(AEC Activity 5310)

Extraction Reagent Performance. — Degradation products were formed in both solvent and diluent under irradiation. Dibutyl phenylphosphonate, which has 25% greater extraction power for uranium than does tributyl phosphate (TBP), was six times more radiation-stable alone and twice as stable when diluted with Amsco. Compounds containing a phenyl group or a phosphonate group appeared more stable to radiation than did TBP. Acidic materials in irradiated organic compounds were removed by anion exchange.

Cryoscopic determination of the molecular weight of polymeric material formed by radiolysis of TBP indicated a molecular weight of about 840, suggesting a pentaphosphate structure. (AEC Activity 5310)

High-Level Nuclear Chemistry. — In an investigation of the release of fission products from reactor fuels, Nichrome (Ni-Cr V, 42D) clad fuel coupons containing approximately 81 mg of U^{235} were irradiated in the ORNL Graphite Reactor for one week and were melted in air after 15 days "cooling." The time of heating was approximately 30 sec, and the temperature was approximately 1530°C. Upon melting, 10% of the rare gases, 0.2 to 0.4% of the gross gamma activity, 4.0 to 4.4% of the iodine, and 0.7% of the cesium were liberated. After 10 days "cooling," one sample was melted in air and held at a temperature above the melting point for 3.75 hr. The molten phase was swept with air. The fraction of the activity released was determined by comparing the analyses with those of a duplicate dissolved specimen; 99% of the iodine, 1.6% of the cesium, 0.01% of the strontium, and 77% of the rare gases were released.

Pellets punched from an APPR fuel plate were used for a comparison of the effect of heating time on the release of rare gases and iodine activity. As was expected, the longer the heating time, the more activity was released. For heating times of 17 to 72 sec, the release of iodine varied from 4 to 18%. The release of rare gases varied from 16 to 51%.

Two experiments were designed to determine the diffusion rates of fission products through a 5-mil thickness of type 304L stainless steel. APPR coupons irradiated for one week in the Graphite Reactor and heated at a temperature of 900°C for 7 and 22 days failed to release significant amounts of activity. An experiment is now in progress for a heating period greater than 30 days. (AEC Activity 5330)

Chemistry of Heavy Elements. — A solution of neptunyl ion (7.43×10^{-4} M $RbNp^{237}O_2(NO_3)_3$ and 0.1 M DNO_3 in D_2O at 25°C) was examined spectrophotometrically from 0.6 to 1.3 μ over a period of 45 hr and over a temperature range from 4.5 to 251.9°C. The sample was saturated with ozone, then degassed immediately before introduction into the titanium cell and reservoir assembly which had been pretreated previously at 250°C with 1 M HNO_3.

In this experiment, NpO_2^{++} was found to be reduced irreversibly and quantitatively to NpO_2^{+} as follows (limits of observation: Np(VI), ≧1%; Np(V), ≧0.1%; Np(IV), ≧ 0.1—0.5%; Np(III), ≧0.1—0.5%):

Time After Preparation of Sample (hr)	Temperature (°C)	Np(V) (% of total neptunium)
6.9	25	9
13.4	25	10
20.0	25	11
21.7	25.4	12.5
23.0	4.5	12.5
25.4	109.5	37
32.0	251.9	>98
44.3	26.0	>98

The experiment was completed and the sample was removed without alpha contamination being found exterior to the sample space. Virtual decontamination of the sample space was achieved by very slow flushing with 1 M HNO_3 until the effluent contained $<10^{-3}$ μg of Np^{237} per 100 ml. (AEC Activity 5330)

Chemistry of Corrosion. — The reduction reaction of uranyl ion on the surface of passive stainless steel electrodes in a solution of 0.010 f H_2SO_4 + 0.090 f Na_2SO_4, saturated with oxygen at 44°C, was examined potentiostatically at a number of potentials. The reduction reaction is first order with respect to the concentration of uranyl ions in solution over the whole potential and concentration range studied. The slope of the plot of the electrode potential vs the logarithm of the current density due to the reduction of UO_2^{++} indicates that the reaction involves the transfer of two unit charges across the electrode-solution interphase during each individual act. Experiments run at the lowest potentials studied, in which the reduction of UO_2^{++} is relatively fast, suggest (but do not prove) that uranyl ions are deposited in some form on the surface of the electrode by the reduction process. (AEC Activity 5330)

Chemistry of Technetium. — A study of the reduction products and the equilibria established when $KReO_4$ dissolved in distilled sulfuric acid is reduced by $SnSO_4$ is in progress. The addition of one equivalent of Sn^{++} per mole of rhenium results in the formation of a deep-violet solution; upon further addition of Sn^{++}, the intensity of the violet color is decreased. A sapphire-blue solution of Re(V) is produced when two equivalents of Sn^{++} per mole of rhenium has been added. Further addition of Sn^{++} has no effect. Spectrophotometric titration and dilution studies indicate that at least two equilibria are involved in the reduction to give the violet solution. (AEC Activity 5330)

Chemical Separation of Isotopes. — Deuterium having a very low tritium content is required for certain bubble-chamber work. To provide this material, a batch electrolysis facility has been constructed and operated. Fifty-six liters of D_2O having a T/D ratio of $<5 \times 10^{-16}$ has been prepared to date.

The heat of reaction of BF_3 with di-n-butyl sulfide has been calculated from vapor pressure vs temperature data on mixtures in which the BF_3/Bu_2S mole ratios were 0.229 to 0.984:

$$BF_{3(gas)} + Bu_2S_{(liq)} \longrightarrow BF_3 \cdot Bu_2S_{(liq)}$$

$$\Delta H = -12.76 \text{ kcal/mole}$$

The vapor pressure of the 1:1 complex was measured over the temperature range of -13°C (100 mm) to 25.5°C (1280 mm).

Essentially no isotopic fractionation of oxygen was measured in a five-pass equilibration for a two-phase system consisting of diethyl ether in the upper phase and $LiBr \cdot HgI_2 \cdot 6Et_2O$ in the lower phase. (AEC Activity 5340)

PROGRAM 6000 — BIOLOGY AND MEDICINE

BIOLOGY

Cytology and Genetics: Plants and Fungi. — Difficulties which have prevented certain experiments on genetic recombination and gene action in bacteriophage have apparently been overcome through the development of a new medium. The titration and genetic analysis of progeny phage produced by lysis of infected bacteria in broth at high titer have not been satisfactory because of adsorption of progeny phage onto unlysed bacteria. Use of a broth with lowered salt concentration reduces adsorption, but a selective discrimination against certain phage genotypes (which is essential to the planned experiments) tends to be lost. An enriched nutrient broth in which 0.002 M sodium citrate and 0.007 M NaCl are substituted for the usual 0.085 M NaCl concentration has been found to permit the desired reduction in phage adsorption rate while retaining the selective feature. (AEC Activity 6130)

Cytology and Genetics. — It is well known that the proportion of male to female births in man decreases as the parents grow older, but the exact reason for this has not been exactly determined. This is a matter of some importance for the practical reason that if infant mortality is involved it seems important to determine the cause of such mortality, and for the less practical reason that it is of obvious scientific interest to determine the reason for variation from simple genetic expectations, in this case 50% of each type of birth, irrespective of the origin of such deviations.

It has been possible to obtain from the Bureau of Vital Statistics data which have been classified in such a way as to permit a more thorough analysis than has been possible previously. These data give, simultaneously, the sex of each child at birth, the ages of the parents, and the order of the child in the sibship. A multiple regression analysis has been run on these data, with the help of the Oracle, in such a way as to permit a check for nonlinear as well as interaction regression components. It was found that the effects of the age of the male and of birth order are significant, whereas the effect of the age of the mother is not. It appears, therefore, that these well-known deviations are not caused by mortality in the usual sense, but reflect some other biological reactions not well understood at present. (AEC Activity 6130)

Pathology and Physiology. — A comparative study has been made of the water-soluble proteins in the spleen, thymus, bone marrow, serum, and liver of Sprague-Dawley rats, (101 X C3H)F_1 mice, and rat-mouse chimeras [(101 X C3H)F_1 mice given 950 r of x rays followed by injection of Sprague-Dawley rat bone marrow]. Protein fractions were characterized according to electrophoretic migration in starch gel and to selective staining reactions as being of rat or mouse type. In the chimeras, proteins were found of both rat and mouse types, as indicated by the following. The serum and tissue albumins were of mouse type. The spleen and thymus usually contained protein bands of rat type. The spleen exhibited loss of a pre-albumin fraction characteristic of the normal mouse. The bone marrow contained proteins predominantly of rat type. The serum globulins were apparently exclusively of mouse type; however, the levels of alpha and gamma globulin were increased, and the level of beta globulin was reduced. Proteins of rat type were not found in the liver, duodenum, or muscle. These results appear consistent with, and shed further light on, the transplantation of rat cells into the hematopoietic tissues of irradiated mice. (AEC Activity 6130)

Cell Physiology. — Peptide intermediates in protein synthesis have not previously been isolated from the intracellular sites of protein formation. To attack this problem systematically a number of technical difficulties had to be surmounted. Methods for isolating up to 60 g (wet) of microsomes from up to 32 perfused rat livers in 4 hr have been devised. Peptides, found in this laboratory to be extractable with 1 M NaCl, are now extracted with ammonium formate, which can be removed by sublimation. Peptides are separated from protein by ultrafiltration through cellophane at a pressure of 70 psi. By using chromatography on 100- to 200-cm XE64 ion exchange resin columns, separation into 11 well-defined peaks is obtained. The optical density of the column effluent stream is continuously recorded by using peptide bond absorption in the 2000-Å region. Amino acid composition and end-group analysis are currently being carried out.

Hepatic cell fractions from normal and partially hepatectomized rats are being assayed in partially hepatectomized recipient rats for possible effects on the course of regeneration of the liver. A differential effect appears to exist between cell fractions used when tested singly — notably that nuclear fractions stimulate regrowth of liver, while microsomal particles appear to have inhibitory effects.

A study of the fate of radioisotope-labeled cells and cell fractions is in progress. In preliminary experiments, liver nuclei have been labeled in vitro with radioiodine. Confirmation has been established by autoradiography. Tritiated phenylalanine has been prepared by exchange with tritium, and the labeled amino acid has been administered to rats. Cells and cell fractions have been isolated and injected into rats and mice. Confirmation of adequate labeling, by autoradiography, is in progess. (AEC Activity 6130)

Microbial Protection and Recovery. — Irradiated catalase-negative cells of a hemin-requiring mutant strain of *Escherichia coli* develop an extreme sensitivity to low concentrations of hydrogen peroxide. This sensitivity to hydrogen peroxide can be clearly demonstrated as a postirradiation inactivation. The sensitization process is being investigated under a variety of conditions in an attempt to establish the nature of the cellular constituent being sensitized and the relation between this phenomenon and the immediate effects of ionizing radiation. So far, this process has been studied as a function of dose, postirradiation temperature, and postirradiation hydrogen peroxide concentration. The effects of protective agents on the development of hydrogen peroxide sensitivity are also under investigation. (AEC Activity 6230)

Mammalian Recovery. — Attempts to promote greater long-term survival of irradiated mice treated with foreign bone marrow now show that high protein, high carbohydrate, and high fat diets are of no special advantage. High protein and high fat diets were somewhat detrimental. The long-term survival after treatment with fetal blood-forming tissues indicates that this method is the best currently available to reduce the delayed mortality. More control data, however, are needed.

Animals that survived for prolonged periods with foreign bone marrow and were outwardly "normal" had a greatly reduced amount of lymphatic tissue, compared with mice of the same age treated with isologous bone marrow.

Bone marrow cell separation studies indicate that elements for forming red blood cells do not need to be present in the donor bone marrow in order to promote recovery. (AEC Activity 6230)

Radiation Immunology. — The immune status of mice exposed to 950 r and treated with foreign bone marrow was determined 200 to 300 days posttreatment. The circulating blood cells of these mice, survivors of the "delayed foreign bone marrow reaction," were of the donor type, and grossly the mice appeared healthy. However, they responded subnormally upon sensitization with antigens foreign to both the host and the graft. In contrast, the 950-r mice treated with isologous bone marrow responded normally. These results show that 950-r mice treated with foreign bone marrow are not normal immunologically.

Studies on the antigens responsible for the bone marrow transplantation immunity revealed that the antigens were absent in the serum and the red blood cells (RBC), but were present in nucleated cells. That a minimum of two classes of antigens are present is indicated by the results obtained after various enzyme treatments of cell fractions. One class of antigens appears to be simple or complex polysaccharide-like materials, and the second class appears to be labile DNA(desoxyribonucleic acid)-protein-like material.

Serological distinctions between host and donor RBC when homologous erythropoietic tissues are injected into lethally irradiated mice are being applied to further studies of the replacement of the host RBC population by

RBC of the donor type. Apparent differences between embryonic liver and adult bone marrow as donor materials are being analyzed. Treatments that might be expected specifically to "enhance" the transplantation of tissues, or to render either the host or the graft "tolerant," have so far not been found to suppress the immunological response believed to be involved in the delayed bone marrow reactions. (AEC Activity 6230)

PROGRAM 8000 — WORK FOR OTHERS

Oak Ridge School of Reactor Technology. — University participation in the ORSORT program has been discontinued. Plans for a new educational program which will start in September 1958 are being discussed. (AEC Activity 8712)

MISCELLANEOUS REPORTS

OPEN LITERATURE PUBLICATIONS

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VISITORS

FOREIGN VISITORS:

Fitch, F. T., W. R. Grace Co., Baltimore, Maryland (Citizen of Canada)
Hunt, John W., Ontario Cancer Institute, Toronto, Ontario, Canada
Matsumoto, Iwao, Mitsubishi Company, Tokyo, Japan
Murdock, Robert, United Kingdom Atomic Energy Authority, Harwell, England
Preat, Michel, Bureau d'Etudes Nucleaires (B.E.N.), Detroit, Mich. (Belgian)
Schalscha, Eduardo, University of Chile, Santiago, Chile
Schwartz, M., University of Louisville, Kentucky (Citizen of Canada)
Soelamean Djajoesman, National Police, D'Jakrata, Indonesia
Sowden, Ronald G., United Kingdom Atomic Energy Authority, Harwell, England
Upa-Suparja, Chief of Traffic Division, Dandunga, Indonesia

RADIOISOTOPE SALES AND COSTS

Type of Transaction	December 1957	FY 1958 to Date
Domestic Sales	$123,506	$ 883,417
Foreign Sales	61,769	109,890
Project Transfer	689	12,704
Project Cash Sales	5,844	36,754
Technical Co-operation Program Credits	0	20
Plant Credits	1,410	15,909
AEC Credits	19,373	104,255
Total Radioisotope Income	$212,591	$1,162,949
Total Radioisotope Costs	$181,022	$1,047,530
Total Radioisotope Shipments	1,134	6,920
Helium		
Income	$6,640	$18,152
Costs	$ 608	$ 9,622
Shipments	4	20

GROSS OPERATING COSTS

	December 1957	FY 1958 to Date
Programmatic Operating Cost - Net	$3,752,317	$22,703,631
Equipment	203,114	1,344,770
Construction	58,023	848,206
Work for Others - Transfers	17,166	139,205
Inventory Changes	301,365	1,116,685
Reimbursable Work for Others	195,911	1,299,862
Adjustments to Costs of Prior Years	(152,870)	(213,156)
Deferred Charges	9,816	68,753
Total Laboratory Cost - Net	$4,384,842	$27,170,450

Estimated Cost for January $4,600,000
Estimated FY 1958 Cost through January $31,770,450

() Credit

Reports in this series issued during the past year:

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
November 1957	ORNL-2437
December 1957	ORNL-2458

Approved by Alvin M. Weinberg, Director