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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

September, 1955

F. T. Howard

and

W. H Sullivan

Date Issued: OCT 7 1955

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

September, 1955

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

PROGRAM 2000 - SPECIAL NUCLEAR MATERIALS

Metallurgical Materials and Processing - Two billets of thorium, 26 pounds total weight, were prepared by consolidating the small compacts from the retorting cycle of the Metallex process. The consolidation was accomplished by hot pressing the thorium in a suitably evacuated container. An attempt to condition the surface of one billet by arc melting the surface was not successful due to the combined effects of outgassing and the presence of oxide particles. Both billets will be extruded as rods. (AEC Activity 2132)

Waste Metal Recovery - Approximately 18-1/2 tons of uranium and 1393 g of plutonium were recovered from uranium slugs from the ORNL Graphite Reactor. Processing was continuous. Uranium and plutonium solvent extraction losses were 1.9 and 2.4%, respectively. The plant was shut down for one day to permit equipment modifications and repairs. (AEC Activity 2350)

Metallex Process - A product containing more than 98% $ThCl_4$ was prepared by preheating 300 g of pelletized thorium oxalate in an inert gas for 0.5 hr at 250-300°C and then chlorinating at 350-400°C for 2 hr with 4.8 moles each of CO and Cl_2 per mole of thorium and then at 675-700°C for 2 hr with 2.0 moles of CCl_4 and 5.0 moles of Cl_2 per mole of thorium.

Carburization of thorium oxide prepared by evaporating and denitrating 2 M $Th(NO_3)_4$ solution at temperatures up to 350°C took place more rapidly and at lower temperatures than that of thorium oxide prepared at temperatures above 350°C. The carburization reaction, accomplished at 1500-2000°C with a C/Th mole ratio of 4.4/1, was 99% complete in 3 hr and gave a product of ~50% each ThC and ThC_2. The carbides were chlorinated exothermally in fluidized and flame reactor apparatus at temperatures above 200°C, but the reaction was difficult to control.

Reduction yields of 95% were obtained when dry, sublimed $ThCl_4$ was reduced with 3-4 M sodium amalgam at 230°C for 30 min, with high-shear agitation. About 85% of the thorium was recovered as a quasi-amalgam by filtration. The sintered thorium product from the dry process compared favorably with that from the solvent process in all respects except that the acid-insoluble content averaged 2-3%; this is about twice the amount specified. Kinetic studies showed the dry reduction reaction to be diffusion-controlled and

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hence very dependent on rate of exposure of new reactant surfaces. In studies on vapor phase contacting of $ThCl_4$, sodium, and mercury, the products indicated the presence of the desired thorium amalgam, but recovery of the thorium as amalgam was very low.

Titanium quasi-amalgam from the sodium amalgam reduction of $TiCl_4$ was cold-pressed and sintered to a titanium metal compact with an oxygen content of 0.139%. (AEC Activity 2704)

Power-Reactor Fuel Reprocessing - In studies on methods of dissolving various fuel element components, type-304 stainless steel dissolved at a rate of 0.5 mg/min-cm^2 in 65% nitric acid containing 0.2 M chromate ion. Nichrome-V dissolved at a rate of 0.45 mg/min-cm^2 in 15.5 M nitric acid containing 0.1 M chromate ion. Type-316L stainless steel dissolved in molten aluminum at an initial rate of 16 mg/min-cm^2 and at a rate of 7 mg/min-cm^2 when the melt contained 40-50% stainless steel. An unexplained minimum dissolution rate of 0.35 mg/min-cm^2 occurred with molten aluminum containing 10% stainless steel. Because of the large amount of aluminum required, this does not appear to be an economical process.

Preliminary studies indicate that, with minor modifications, the tributyl phosphate solvent extraction process, "25 process", developed for recovering U^{235} from Savannah River 7.5% uranium--92.5% aluminum alloy is practicable for recovering highly enriched uranium from nitric acid solutions of various power-reactor fuel elements. Macro amounts of iron, chromium, nickel, or zinc did not significantly affect the process. In initial tests, a modified Purex flowsheet, for recovering uranium and plutonium from elements moderately enriched with U^{235}, was used without difficulty in processing 10% molybdenum--90% uranium alloy. (AEC Activity 2XXX)

PROGRAM 3000 - WEAPONS

RaLa Production - A very successful large run was completed during the last week in August and approximately 20,000 curies of product was shipped September 2. The next run is scheduled for October. (AEC Activity 3641)

PROGRAM 4000 - REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test - The reactor cell roof structure was finished and leak tested. A preliminary hydrostatic test indicated that several structural steel members in the north shielding wall would require strengthening before the design pressure of the cell could be raised to 30 psig. The required reinforcements were installed in preparation for a hydrostatic pressure test.

The low-pressure fuel-system assembly was operated on a test stand to check the performance of the dump tank evaporators, entrainment separators, etc. Performance was satisfactory, and the testing will continue through October.

The reactor core tank - pressure vessel - blast shield assembly was completed by the Newport News Shipbuilding and Dry Dock Company and the assembly was safely transported to Oak Ridge.

During acceptance tests of the HRT heat exchangers, at the Foster Wheeler Corp. plant, thermal cycling resulted in leakage of fluid past the head gasket. It was decided to use 12-in.-longer bolts on the flanges, with extension ferrules, to obtain more spring action on the gasket. Failure of several tube joints in the heat exchanger was also noted after the thermal cycling; these failures, all in the first 200 tubes welded, were repaired. Subsequent to the installation of the first 200 tubes the welding quality was more carefully controlled. A decision was made to have the Nooter Co. of St. Louis, Missouri, install blast shields around the heat exchangers.

The over-all HRT construction is 800 man days behind schedule; this is equivalent to only 3.3 working weeks. (AEC Activity 4103.1)

HRT Chemical Pilot Plant - The cell shielding walls were poured, the cell liner was tested, and the exposed surface of the liner is being painted with protective paint to minimize oxidation of the tank walls, which would add turbidity to the shielding water and make observation difficult during underwater maintenance. The contractor began the building extension that will house the chemical processing area. (AEC Activity 4103.1)

HR Physical Chemistry--Aqueous Reactor Systems - Efforts to maintain an unsaturated solution (no solid phase present) at 250°C which contains more than 10 g U/liter in the system UO_3-Li_2O-CO_2-H_2O failed even though data for saturated solutions indicated that the unsaturated solution should be possible. With 8 g U/liter, an unsaturated solution was held at 250°C for several days, however, with no evidence of a precipitate. Efforts to dissolve UO_3 in the NH_3-CO_2-H_2O system at 250°C with CO_2 pressures as high as 1300 psi disclosed no measurable uranium in solution. The solid phase appears to be an ammonium uranate rather than a carbonate.

Further work in the system $CuO-UO_3-SO_3-H_2O$ at 100°C on the uranium-rich side and at salt concentrations higher than previously reported disclosed further complexity. Among the solid phases produced, greenish crystals having the same composition and X-ray diffraction pattern as the mineral johannite, $CuO \cdot 2UO_3 \cdot 2SO_3 \cdot 7H_2O$, were obtained. Both optical and electron microscopy verify their identity.

Studies of the equilibrium between Cr^{III}, in the form of an aqueous suspension of $Cr(OH)_3$, and Cr^{VI}, in solution, at 250°C as a function of pH and oxygen pressure indicated the following: Above a pH of 2, and with an O_2 pressure of 300 psi (measured at room temperature), the Cr^{VI} concentration increased quickly to reach a stable value, where it remained constant for at least several hours. At pH's below 2 the Cr^{VI} concentration decreased. The solid left as a residue appeared, by X-ray examination, to be the equilibrium phase, CrO(OH), expected at this temperature. (AEC Activity 4103.1)

Homogeneous Reactor Analysis - The safety of one- and two-region reactors was investigated for the case of sudden increases in reactivity resulting from injection of cool fluid into the reactor core. For the same cooling incident, the one-region reactor had the higher degree of safety, as indicated by a smaller rise in core pressure. The results indicate that increasing the size of a reactor (eigher one- or two-region), and thereby lowering the absolute value of the temperature coefficient, is desirable, from the standpoint of reactor safety, if the most dangerous situation corresponds to reactivity addition by means of the temperature coefficient itself.

Calculations were performed to determine the behavior of the TBR under certain conditions involving interruption of normal operation. If fluid circulation in the core circuit suddenly stops, the temperature of the core fluid rises over 40°C in the first minute and then rises at a much lower rate. If the core heat exchanger suddenly fails to remove energy from the core fluid, the core temperature rises over 30°C in the first minute and then rises at a much lower rate. If the core circulating pump fails, the core temperature rises about 6°C but returns to normal operating temperature in less than one minute. After the short transient period the core remains critical at about 60-Mw power level, with heat removal by means of natural convective circulation of the fluid fuel.

A preliminary study was made of the effect of the fuel removal method upon the breeding ratio. The results obtained for batch fuel reprocessing are compared with those for continuous fuel reprocessing, by using, for the purpose of this calculation, the same average cycle time for each case. In the two specific reactors considered, the breeding ratio appeared to be ~0.01 to 0.03 higher if the fuel fluid was removed from the reactor on a batch basis. (AEC Activity 4103.1)

Homogeneous Reactor Instrumentation - All steam system valves were received, checked for leakage, adjusted, and sent to the site for installation. The tank weighing systems on the first low-pressure system assembly were installed

and are being tested. All process valve drawings were received from the vendor and are being circulated for final approval. The drawings showing electrical conduit runs and cold-trap refrigeration system instrumentation and control were completed and sent to the field. The completed drawings for the sample station and control circuitry are awaiting approval. (AEC Activity 4103.1)

HR Design - The design of the temporary and permanent freezer units for closing HRT process lines by freezing sections of liquid in place were completed and prototype equipment is being built for testing. Specifications for the heat exchanger blast shields were prepared and submitted for bids. Approximately 85% of all final drawings of HRT equipment, building, and services are now approved for construction. These include, in addition to final drawings reported in July, the refrigeration piping, leak detector system, thermal shield, instrument air lines, instrument installations in the west instrument cubicle, and the air monitor for the cell.

In the design study for the 440-Mw homogeneous reactor, the advantages of a system which depends entirely upon high pressure recombination are being considered. Two other features considered so far are: (1) the use of mechanical pipe joints and closures on removable equipment, instead of all-welded construction, and (2) a high-pressure, fast-dumping system which will result in reasonable wear on equipment, reduce heat exchanger requirements, and will protect the core vessel from damage. The operation of the station under partial load is being studied to determine the economic advantage of developing means for prompt replacement of the heat exchanger in event of failure. (AEC Activity 4103.1)

HR Metallurgy - Zircaloy-2 specimens were hydrogenated to contents of 500, 1,000, 2,000, and 3,000 ppm and submitted for in-pile corrosion testing.

It was suggested that a study of the oxidation of zirconium and its alloys might reveal why corrosion under radiation is more severe than normal corrosion. An examination of the results of neutron damage to zirconium oxides suggested that under irradiation the cubic phase may be more stable than the monoclinic. Tests were made in which small amounts of various oxides were added to ZrO_2 to determine their effectiveness in stabilizing the cubic phase. CaO, Cb_2O_5, and Y_2O_3 proved to be the most effective additions. Of these the most attractive for addition to zirconium metal would be columbium. Alloys made by the additions of 15 wt% columbium to zirconium metal contained oxides with as much as 80% of the cubic phase present. Such an alloy may be fabricated by cold rolling. Tests to determine its physical properties and corrosion resistance are being made.

It was shown that the conversion of the ferrite found in commercial 347 stainless steel weld metal to the sigma phase did not result in a reduction in corrosion resistance or in ductility. (AEC Activity 4103.1)

HR In-Pile Autoclave Tests - The new facility for opening corrosion test bombs was put in operation and bombs Z-5, Z-10, and Z-12 were opened. Pins from these bombs were defilmed, and the corrosion, as measured by weight loss, agreed satisfactorily with that measured by oxygen consumption. The greatest difference observed was about 11%. Two of the pins from Z-5 were of a Zircaloy-3 alloy, composed of 0.45% Sn, 0.72% Fe, and 0.73% Cr, and the remainder zirconium. These Zircaloy-3 pins showed slightly more corrosion than the conventional Zircaloy-2 pins.

As another method of obtaining experimental values for the neutron flux to which the bombs were subjected, the induced Zr^{95}-Nb^{95} activity of the pins was measured.

The experiment Z-10, which was reported in progress in ORNL-1905, was completed. The corrosion rate for this bomb at 280°C was about 10 mils/yr. At 290°C the corrosion rate was about 12 mils/yr. The results of Z-5 and Z-10 indicate an activation energy of 12,000 ± 500 calories/mole.

Four additional "rocking-bomb" experiments in the LITR were completed. Two of these experiments were with type-347 stainless steel, exposed in the HB-6 beam hole. The other two were with Zircaloy-2, exposed in the HB-5 beam hole.

Two rocking-bomb corrosion experiments at the MTR were completed. The bomb material in each case was Zircaloy-2, and the approximate solution composition was the following: UO_2SO_4, 0.04 m; $CuSO_4$, 0.05 m; and H_2SO_4, 0.02 m. The use of U^{235} enriched to 1.7% in the first and 93.2% in the second gave estimated fission power densities of 0.6 and 35 w/ml, respectively. The estimated power density in the solution resulting from the absorption of γ-rays and fast neutrons was 4 w/ml. The temperature maintained during exposure was about 280°C. The corrosion rate determined from oxygen depletion measurements was approximately 8 mils/yr in the first experiment and 45 mils/yr in the second. For comparison, the corrosion rate determined in the LITR experiment, Z-12, was about 10 mils/yr. The estimated fission power density in Z-12 was 3 w/ml and the estimated γ-ray and fast neutron power density was 1 w/ml. Other experimental conditions were essentially the same as those for the MTR experiments. (AEC Activity 4103.1)

HR In-Pile Loop Tests - In-pile operation of the fifth loop, designated L-4-8, was completed after a total of 1676 hours, and the loop is now being dismantled. It contained stress, coupon, and sleeve-type specimens of five different materials, Zircaloy-2, titanium, and types 347, 17-4 PH and 309 SCb stainless steel, which were positioned in four different sections of the loop. These sections were: the core, the pressurizer, the regular in-line position, and a special in-line position. The pump for this loop was equipped with bearings and journals of sintered aluminum oxide; this is the first time that this bearing combination has been used for an in-pile experiment. The performance of the pump was superior to that of previous pumps which had been equipped with a bearing combination of Graphitar 14 and type 17-4 PH stainless steel. (AEC Activity 4103.1)

HR Laboratory Service Corrosion - Cast specimens of zirconium, alloyed with tin, niobium, cerium, cesium, yttrium, and silver were exposed at 300°C in an oxygenated 0.04 m uranyl sulfate solution containing 0.02 m sulfuric acid and 0.005 m copper sulfate. The tests were concerned with improving the protective nature of the oxide film formed on zirconium in contact with uranyl sulfate solution at elevated temperature. With the exception of a 1.5% tin alloy (Zircaloy-2) and a 15% niobium alloy, preliminary results indicated that all other agents caused a marked decrease in the corrosion resistance of zirconium. After a 50-hr exposure, corrosion attack on the 1.5% tin and the 15% niobium alloys was negligible.

Thorium oxide produced at ORNL, calcined at 650°C, was re-calcined at temperatures up to 1600°C. The size of the thorium oxide particles, as determined by gravitational sedimentation with tetrasodium pyrophosphate as dispersant, increased with calcination temperature (40% larger than 3 μ for the 650°C calcined thoria, 60% larger than 3 μ for the 1600°C calcined thoria). Slurries of these oxides at a concentration of 1 kg Th/kg H_2O were circulated in stainless steel toroids at 26 ft/sec, 250°C, and with an oxygen atmosphere. The rate of attack on type-347 stainless steel, titanium 75A, and Zircaloy-2 corrosion pin specimens was generally less than 5 mils/yr under all conditions. Slurries of Fernald thorium oxide re-calcined at 800°C (45% larger than 3 μ) showed slightly lower rates of attack on these metals than those given by slurries of the ORNL thorium oxide also re-calcined at 800°C. (AEC Activity 4103.1)

HR Dynamic Loop Tests - A corrosion test was completed in which 0.04 m urnayl sulfate containing 0.006 m sulfuric acid and 0.005 m copper sulfate was circulated at 300°C for 8515 hr. Corrosion damage to the loop and to the corrosion specimens was very slight. Stainless steel types 347, 304 L, and 309 SCb corroded at the rate of 0.10 to 0.16 mils/yr. in the velocity range of 9 to 37 ft/sec. The critical velocity for onset of rapid corrosion of the system was greater than 50 ft/sec. Both zirconium and titanium showed practically no corrosion damage; zirconium specimens showed slight weight gains and titanium specimens, slight weight losses.

The solution used in the above test was not completely stable, and for a period of several thousand hours uranium and copper slowly precipitated from solution. As a result, it was necessary to add more acid to the solution. Preliminary tests indicated that 0.01 m sulfuric acid is sufficient to prevent precipitation of uranium and copper. Tests are now in progress to determine the corrosiveness of such a solution.

Previously reported data showed that the addition of either lithium or magnesium sulfate to dilute uranyl sulfate solutions substantially decreased their corrosiveness to stainless steel. Further studies showed that the addition of equimolal quantities of lithium sulfate to uranyl sulfate solutions in concentration of 1.3 to 2.0 m reduces the corrosiveness of such solutions by about a factor of ten. Furthermore, the presence of lithium sulfate increases the temperature at which a second phase appears to greater than 325°C. AEC Activity 4103.1)

HR Dynamic Slurry Tests - Corrosion studies with thorium oxide slurries were performed in a 100 gal/min circulating loop at 300°C, 120 lb/in^2 oxygen pressure (room temperature), and at an average slurry concentration of 1030 g Th/kg H_2O; the thoria was calcined by ORNL at 800°C. The following corrosion rates were observed on pin-type specimens in a 75-hr run at a velocity of 70 ft/sec; type-347 stainless steel, 110 mils/yr; titanium 75A, 50 mils/yr; Zircaloy-2, 30 mils/yr; gold, 40 mils/yr; platinum, 50 mils/yr; and various Stellites, 200 to 600 mils/yr. (AEC Activity 4103.1)

Math and Computation--HR Development - The two-group, two-region Oracle code for spherical reactors was improved and modified to comply with changes in Oracle operation. The revised code allows one to calculate temperature coefficients of reactivity and reactivity changes associated with changes in parameter values.

A two-group, two-region Oracle code for cylindrical reactors was completed except for the Bessel function routine. The code calculates critical concentration, neutron bookkeeping, and various coefficients of reactivity. (AEC Activity 4103.1)

GENERAL REACTOR RESEARCH

Basic Reactor and Shielding Research - The WADC duct tests proposed in ORNL-1935 were completed at the Bulk Shielding Facility (BSF). Essentially, these tests consisted of determining the effect produced on reactivity by a large void placed against a face of the BSR. It was recognized that the possible flooding of an air void of such large dimensions could result in a large excess reactivity, and thus represents a potential hazard for a reactor of the WADC type.

The reactor loading was a 5 by 7 fuel element array with the void located adjacent to the front 7-element face. Because of the large excess reactivity required for this experiment, two additional boron carbide safety rods were installed in the lattice. The void was made of 1/2 in. thick aluminum plate welded to form an air-tight chamber with outside dimensions 26 by 22-1/2 by 36 in. The chamber was rigidly clamped to the reactor frame during each phase of the experiment. The water level inside the void was controlled by air pressure, and the water level information was transferred through a float and pulley arrangement to an indicating device at the side of the pool.

In addition to measurements of the increased reactivity due to the flooding of the void, tests were made with two different neutron-absorbing curtains between the reactor and the void. It was hoped that these curtains (a 100-mil thick cadmium curtain and a 1/4-in. thick boral curtain) would shield the reactor from the effect of the filling the void with water. Since it was also desirable to determine, if possible, the effect on reactivity of experimental equipment inserted in the duct, iron slabs of different thicknesses were inserted between the chamber and each of the absorbing curtains,

to simulate equipment in the void. The results are tabulated below:

Experimental Condition	Change in Reactivity Resulting from Flooding the Void with Water (%Δ k/k)
No curtain	+ 2.61
Cadmium curtain	+ 0.60
Boral curtain	+ 0.42
Cadmium curtain + 3 in. iron slab	+ 0.15
Cadmium curtain + 1/2 in. iron slab	+ 0.49
Boral curtain + 1/2 in. iron slab	+ 0.33

An experiment was performed to determine whether the fast neutron spectrum of a large, high-intensity, polonium-beryllium source might be different from the spectra of the usual sources. The fast neutron spectrum of the Biology Division's source was measured between 1.3 and 10 Mev with the proton-recoil neutron spectrometer at the BSF. The source intensity of 118 curies was such that the statistical error of the measurement was less than the errors associated with previous Po-Be source spectra. The measurements agreed, within statistical limits, with those determined earlier with smaller sources (R. G. Cochran, K. M. Henry, RST 26, 763, 1955). (AEC Activity 4570)

Reactor Theory - The program for the calculation of solutions to the one-velocity transport equation by means of the S_n method of approximation was coded. It was found that N may take even values up through and including eighteen. The number of space points was set at 255. Simple preliminary problems are being prepared in order to "debug" the program.

A theory of α-spectra was formulated, and a code for the Oracle was written and "debugged" for performing the necessary numerical computations. Production runs on the Oracle were begun.

An analysis of accumulated Oracle computations of ORR fluxes for various loadings and the preparation of a report which includes all computations made so far was begun. A first report of ORR fluxes was issued jointly with the ORR Project. (AEC Activity 4570)

Oak Ridge School of Reactor Technology - Twenty summer projects were undertaken by the 1954-55 class at ORSORT. Twelve of these were group projects on reactor design problems, and eight were individual projects involving reactor design, reactor calculations, or reactor operations. Reports on the studies were presented to the Laboratory on August 23 and 24.

The 1954-55 class completed their work on August 26. On September 12, the 1955-56 session began with an enrollment of 75 industry-sponsored students and 19 student employees. (AEC Activity 4704)

PROGRAM 5000 - PHYSICAL RESEARCH

Reactor Operations - Operation of the graphite reactor and LITR was routine. A total of thirteen slugs have ruptured in the graphite reactor since January 1, but no serious difficulty has resulted from these incidents.

The No. 2 graphite reactor fan failed, because of two broken bars in the rotor, and was replaced with a spare; the old motor is being repaired.

The installation of the remote control panel for operating the LITR from the graphite reactor control room is 75% complete.

The Geneva reactor fuel element was removed from its test position in the LITR lattice during July and was found to have suffered no noticeable damage.

Downtime on the LITR was reduced to 7.5% (from an average of ~20%), partly as a result of fewer scheduled shutdowns.

The Oak Ridge Research Reactor (ORR) - Blount Brothers Construction Company, contractor for the building and cooling system, maintained work on a three-shift basis on the excavation of rock and clay. This phase of the work is essentially complete and excavation for building foundations is in progress. A delay of two weeks was occasioned by walkouts of the operating crafts; the present scheduled date for completion of the building is May 1, 1956.

Drawings were sent to a number of firms for bids on fabricating the aluminum reactor tank, and the replies are being evaluated.

ISOTOPE PRODUCTION

Radioisotope Production - The sale of C^{14}-labeled compounds was completed; total sales amounted to about $9,000.

All radioisotope price revisions were approved by the AEC except for C^{14} and I^{131}. These await the results of a study on pricing by the Comptroller's Office, for which complete sales and production cost data were submitted in September.

All orders for Kr^{85} were filled. New equipment for purifying and dispensing Kr^{85} is working well, but the supply of crude gas from ICPP is somewhat uncertain.

The new multikilocurie cell was used in loading over 30,000 curies of Co^{60} into teletherapy and industrial radiation sources. No significant radiation leakage was observed when the cell contained 11,000 curies of Co^{60}.

The equipment for separating and purifying fission-product rare earths is being overhauled for the first time in three years of operation. (AEC Activity 5111)

Radioisotopes, Process Development - A source containing 80 millicuries of Cd^{109} was fabricated for use in a portable X-ray machine at ORINS. The source output was 2.1 r/hr at 3 cm.

Negotiations were completed with the Phillips Petroleum Company for erecting loading facilities for handling the 15-ton shielded transfer tank to be used in shipping hot waste to ORNL.

Tests made by irradiating sulfur in the LITR showed that a 300-fold increase in P^{32} production can be obtained over that in the graphite reactor.

A successful test run for separating the Xe^{131} daughter from I^{131} was made by treating NaI^{131} with cadmium metal and pumping the Xe^{131} off for recovery in a cold trap. Twenty-five microcuries of Xe^{131} was obtained from 100 mc of I^{131}.

Fission product Eu^{155} was thoroughly purified by ion exchange, and its gamma ray spectrum was examined. It appears that the product contains up to 40% Eu^{154}, formed by neutron capture in the stable fission product Eu^{153}. This destroys the usefulness of the pure 85-kev radiation from Eu^{155}.

Excavation was completed by ORNL for the Fission Product Pilot Plant (F3P), and the contractor should start construction October 1. Equipment design is 75% complete. Arrangements were completed for coordination between F3P and HOPE operations; F3P will process all hot waste from HOPE operations and return dilute HNO_3 for concentration and re-use. (AEC Activity 5112)

PHYSICS

Neutron Diffraction - Neutron diffraction data obtained for $MnBr_2$ show the existence of antiferromagnetic ordering in these compounds at low temperatures. The bromides of iron and manganese crystallize in the hexagonal layer structure characteristic of CdI_2. In the case of $MnBr_2$ the neutron diffraction data, taken down to 1.5°K, show that the manganese ion moments are aligned ferromagnetically within each hexagonal layer, that moments in adjacent layers are aligned antiferromagnetically, and that the orientation of the moments is normal to the hexagonal axis of the crystal.

The temperature dependence of the (001) magnetic reflection in $MnBr_2$ was studied in detail; it tends to follow a Brillouin-type curve below about 2.2°K. Above this point the intensity falls off slowly with increasing temperature, and this intensity fall-off is accompanied by pronounced line broadening. These results can be correlated with specific heat measurements (J. W. Stout, Institute for the Study of Metals, Chicago, Illinois) which show a sharp anomaly at 2.18°K. Diffraction data obtained for $FeBr_2$ at 4.2°K show the same sheet structure for $MnBr_2$ except that in this case the moments are parallel to the hexagonal axis. (AEC Activity 5220)

Heavy Ion Physics - As a continuation of the study of electron capture and loss, the cross section for the loss of an electron was determined for fast helium atoms passing through gases. The energy range studied was from 30 to 200 kev and the stopping gases investigated were hydrogen, helium, nitrogen, oxygen, neon, and argon. It was found that, as the fast neutral atoms are formed by electron capture, an appreciable number are left in the metastable state. Subsequent collisions produce an equilibrium distribution between the ion, metastable-state atom, and ground-state atom components. The electron loss cross sections were determined for the neutral component of such an equilibrium beam. Similar behavior was observed for fast neon atoms, but not for hydrogen or nitrogen atoms. This indicates the existence of strong metastable states in H or N. The cross sections for electron loss increase rapidly as the velocity of the helium atom is increased. The cross sections at 200 kev are 6.0, 10.0, 19.8, 23.0, 23.0, 37.2 x 10^{-17} cm^2/atom for H_2, He, Ne, N_2, O_2, and A, respectively. (AEC Activity 5220)

Physical Research Math and Computation - The internal conversion coefficients are the (branching) ratios of the number of bound electrons ejected by a nucleus, in making a transition to a state of lower energy, to the number of gamma ray quanta emitted in the same type of transition. The comparison of the calculated and measured coefficients is a valuable tool in nuclear spectroscopy. The coefficients for the K shell were calculated several years ago on the Harvard Mark I computer; those for the L shell which require much more complicated formulas, are now being computed on the SEAC at the National Bureau of Standards. These were recomputed on the Oracle by using less exact formulas; the coefficients for the M shell were also computed. (AEC Activity 5220)

Isotope Neutron Cross Sections - Because of α-contamination (Am^{241}), the graphite parts and ionization chamber of the pile oscillator were replaced. The new chamber yields as much current as the old, but the signal strength is more sensitive to the placement of the sample than before; errors of up to 20% may be introduced if the sample is not uniformly distributed in the container. Care in relative sample placement should reduce this error to less than 5%.

An isotopically and chemically pure sample of fission-product Tc^{99}, in the form of 1.1 g of $KTcO_4$, was measured in this new arrangement, and was found to have a thermal neutron capture cross section of 19 $\pm$ 2 barns relative to 98 barns for gold. This may be compared with two earlier measurements (CF-55-1-61, pp 7-8). An MTR burnout irradiation reported previously gave a value of 2 barns, which was dependent, however, on a flux value furnished by the MTR operations group, since the actual flux was unmonitored. A fast chopper measurement made on the same sample as that used in the present measurement yielded a value of 44 barns. This measurement was not reproducible enough in the near-thermal range to allow for a precise breakdown into a constant scattering cross section and a 1/v capture cross section; however, analysis of the lowest resonance yields a contribution at thermal energies of about 15 barns. (AEC Activity 5220)

High Voltage Program - An electronic timer and an electrostatic deflector were built to modulate the ion beam from the 5.5 Mv Van de Graaff generator. The electrostatic deflector is able to remove the ion beam from the target in two or three microseconds. The time required to re-establish the ion beam on the target is approximately twenty microseconds. The electronic timer also gates the pulses from the detector, i.e., the scaler can register pulses from the counter during only specified time intervals. Two variations of the irradiation and counting time sequences were used. In the first, the ion beam was alternately turned on and off the target for approximately equal time intervals, T. The pulses from the counter were alternately gated on and off with approximately equal time intervals, T. The "on time" for the beam was the "off time" for the scaler and vice versa. In the second sequence, the ion beam was again alternately turned on and off the target for time intervals, T, but the pulses from the counter were fed into each of ten different scalers for time intervals of T/10. By the use of a beam of fast protons and a tritium gas target it was possible to produce bursts of fast neutrons and subsequently to detect activities in samples exposed to the neutron bursts. A 20-microsecond activity in tantalum and a 150-microsecond activity in lead were identified. It is planned to measure the cross sections for production of these activities as a function of neutron energies.

A method was developed for determining the absolute differential elastic cross section for scattering of neutrons from nuclei in a gas. The gas is contained in a proportional counter upon which neutrons are incident, and scattered neutrons are detected by an anthracene crystal. Real coincidence between proton recoils in the anthracene crystal and nuclei recoils in the proportional counter give a measure of the scattering cross section. The method was used for preliminary measurements of the differential cross section of neon as a function of angle for the non-resonance neutron energies, 1.56 and 1.78 Mev. The neutron source was the T(p,n) reaction produced by protons from the 5.5 Mv Van de Graaff generator. The results show that in the center-of-mass system the differential cross section for forward neutron scattering is about twice that for backward scattering.

The study of the level structure of Be^8 for the case of $Li^6(He^3,p)Be^8$ was completed. A new Li^6 sample assaying 99.96% isotopic purity was used in a careful search for levels in Be^8 which might have been missed in preliminary work. Proton groups corresponding to the ground state, a 2.9-Mev state, and a 12.3-Mev state in Be^8 were observed. Transitions to sharp levels in the region from zero to 10 Mev in Be^8 would have been observed if their intensity had been as high as 1% of the intensity of the transition to the ground state. If the various levels reported for Be^8 in this energy region do exist, it is difficult to explain their absence in the reactions $Li^6(He^3,p)Be^8$, $B^{10}(d,\alpha)Be^8$, $B^{11}(p,\alpha)Be^8$, and $Li^7(d,n)Be^8$, all of which have been studied carefully within the past year. (AEC Activity 5220)

Theoretical Physics - A procedure was finally found for getting convergent results in those aspects of quantum field theories where virtual pair production plays an essential role. The photon self-energy never appears, the

charge renormalization vanished by an obvious prescription, and the observable effects in quantum electrodynamics are correctly predicted. An important application is to meson theory, where the life-times of the neutral and charged pions are conventionally grossly incorrect and divergent, respectively. In addition the divergence of the meson-meson scattering is a serious difficulty. The new formulation is now being applied to all these problems, which seem most appropriate for a strong check of the method.

Further calculations and analytical work were done on the linearized stability of proton orbits in high-energy fixed-frequency cyclotrons. Field specifications were developed for several interesting electron models, as well as for possible conversions of existing synchrocyclotrons to fixed-frequency operation. A preliminary analytical study of an essential non-linear limitation on beam intensity was completed; it is to be supplemented by numerical calculations. A review and criticism of existing convenient analytical procedures for stability calculation was performed by comparing approximate results with exact numerical results. (AEC Activity 5220)

CHEMISTRY

Volatility Studies - In further studies on recovery of uranium by volatilization of UF_6, decontamination factors of 10^5 were obtained by use of two NaF absorber beds. The volatilized UF_6 was passed through the first bed at 100°C, at which temperature ruthenium fluorides were not absorbed; the UF_6 was then desorbed with F_2 sparging at 100-400°C. The effluent was passed through a second NaF trap at 100-400°C, which absorbed any remaining ruthenium fluorides. Niobium fluorides in the gas stream were absorbed in the first trap at 100°C and not desorbed at the higher temperature. A second method, in which a single NaF bed was used at 650°C, gave a decontamination factor of only 10^4 and was more corrosive. In this method both the niobium and the ruthenium fluorides were absorbed by the NaF, while the UF_6 passed on through.

Based on equipment corrosion rates and fission product removal, disodium dihydrogen versenate and 3 M HNO_3 were the most satisfactory reagents studied for decontamination of the fluorinator. (AEC Activity 5310)

Ion Exchange Technology - In a fixed-bed, ion-exchange (Dowex-50) column, the distribution coefficients for cesium, strontium, and rare earths in a 1.6 M dibasic aluminum nitrate system were determined to be 5, 6, and 9, respectively. A preliminary flowsheet for a process to reduce storage volumes of highly radioactive wastes containing $Al(NO_3)_3$ was drawn up. The waste is heated to ~160°C, to convert the Al^{3+} ion to $Al(OH)_2^+$, and then passed through an ion exchange column to remove the fission products. The highly radioactive elements are thus concentrated in a small volume; the effluent has very low activity and can be stored in open pits or discharged. (AEC Activity 5310)

Chemical Engineering Research Studies - In development studies on the use of freeze plugs for normal and emergency line closures in radiochemical processing plants, such plugs held against large pressure differences. The plugs could be formed, however, only when the liquid to be frozen was stagnant or was flowing very slowly.

Pressure drops of 16,000 psi were held for 5 min or more by 1-1/4-in.-long plugs frozen from stagnant water in 1/8-in.-dia schedule-80 pipe and by 1-7/8-in.-long plugs in 1/2-in.-dia schedule-80 pipe. In the same pipes, plugs of 7/8 to 1-1/4 in. length frozen from UO_2SO_4 at 9 g U/kg H_2O held 8000 psi pressure differences for 10 min or longer. The UO_2SO_4 solution plugs failed with pressure differences above 13,000 psi. All plugs lost their ability to hold any pressure difference within 15 to 45 sec after the refrigerant (Freon-12) was cut off. (AEC Activity 5310)

Feed Materials Processing - Dense metallic uranium was prepared from the spongy uranium metal obtained by volatilizing off the mercury from uranium quasi-amalgam and melting the residue. The uranium quasi-amalgam was prepared both by reduction of UF_6 with sodium amalgam and by dissolution of metallic uranium in boiling mercury. There was no difference in the mercury volatilization or uranium melting behavior of the two preparations.

In studies on the Excer process, 3500 g of $UF_4 \cdot 0.4NH_4F$ was prepared by electrodialysis of a 0.25 M UO_2F_2--0.6 M HF--0.23 M NH_4F--0.23 M H_2SO_4 solution. The product was separated from various ionic and radioactive impurities by factors, for example, of 9 for gross γ, 45 for gross β, 10-2000 for iron, and 30-320 for aluminum. Corrosion of the lead anode, which was protected from the fluoride electrolyte by an ion exchange membrane, was negligible.

Preliminary cost estimates for the Fluorox moving-bed process to convert UO_3 to UF_6 indicated that one-year savings resulting from increased HF utilization and elimination of large-scale fluorine production would more than compensate for the cost of installing Fluorox equipment in existing plants.

The UO_3 in UO_3-starch-H_2O pellets was simultaneously reduced by carbon formed from the starch and hydrofluorinated by 110% stoichiometric HF in the 4-in.-dia continuous moving-bed reactor to produce UF_4 at a rate of 65 lb/ft^3 of reactor volume. About 60% of the HF was injected into the upper reaction zone at room temperature and 40% was fed to the bottom of the reactor at 650°C. The temperature of the bed decreased from 650°C at the bottom to 300°C at the gas outlet. The carbon content of the UF_4 product decreased as the off-gas temperature increased, and was <0.2% at 300°C. Substitution of H_2 or NH_3 for 15% of the starch reductant did not decrease the carbon content of the product. In laboratory tests, carbon was removed from UF_4 pellets containing 0.5% carbon by O_2, air, or CO_2 at 400-500°C, but the UF_4 was oxidized above 500°C.

To prevent corrosion of the oxidation reactor for converting the UF_4 to UF_6, an insulating liner of U_3O_8 bricks was developed. These bricks were formed by calcining pre-cast blocks made from U_3O_8 aggregate and UO_3-H_2O cement, and were reinforced with Inconel wire. The bricks were temperate cycled in air from 20 to 1200°C and back again in a 2-hr period without damage. (AEC Activity 5310)

Neptunium Recovery - The chemical feasibility and mechanical operability of a solvent extraction process (ORNL-1936) for recovering Np^{237} and uranium from high burn-up MTR fuel elements was demonstrated in 1/2-in. pulsed columns. In this Neptex process solvent extraction losses were about 0.1% of the neptunium and 0.01% of the uranium. No difficulties with emulsion formation were encountered in the pulsed column tests when the fuel solution was boiled to coagulate silicon compounds before being extracted. In the laboratory batch countercurrent runs, the addition of 0.01 M oxalic acid to the extraction column feed and scrub solutions increased the zirconium decontamination factor from about 20 to $>2 \times 10^4$. With this modification, an overall fission product decontamination factor of 10^5 was obtained in one cycle. (AEC Activity 5310)

Extraction Reagent Performance - Purified, dry Special Naphtha No. 1, which is used as the diluent for tributyl phosphate in radiochemical solvent extraction processes, showed ultraviolet absorption at 220-250 mμ after a radiation dosage of 1.2 β watt-hr/liter. Irradiation to 595 β watt-hr/liter increased the absorption by a factor of about 20, but there were no characteristic maxima or minima in the spectrum. The grouping responsible for the absorption was tentatively identified, by infrared spectra, as $R_2C{=}CH_2$. Iodine number and chromyl chloride tests confirmed the presence of unsaturated compounds. Commercial Special Naphtha No. 1 showed intense ultraviolet absorption, but material purified with oleum and silica gel gave the ultraviolet transparency expected for an alkane mixture. (AEC Activity 5310)

Hot Laboratory Research - Recent ORNL Metal Recovery Plant adaptations of acid conservation which involve the recycling of final wastes of both the plutonium (2AW) and uranium (1DW) streams were found to result in an almost quantitative partitioning of Np^{237} with the first plutonium (1BP) stream. Further tracing in the plant revealed that less than half of the neptunium continued to follow plutonium to the ion-exchange column. The remaining neptunium is recycled in the acid recovery step. Most of the adsorbed neptunium was observed to elute as a complex with sulfuric acid during the uranium stripping.

For the three most recent lots of approximately 500 grams of plutonium, more than 200 milligrams of neptunium was found in each of the sulfuric acid eluants. These fractions were held for final isolation of the neptunium by a simple ion exchange method. During the column loading and elution cycles, the plutonium alpha activity was reduced to a level of only a few hundred counts per milliliter; as a result is was possible by direct alpha pulse analysis to detect less than one-tenth milligram of neptunium in 100 gallons

of this waste. This discovery of the occurrence of neptunium in an essentially pure state as a waste product may permit its rather widescale recovery from other Purex-type radiochemical plant processes. (AEC Activity 5330)

Chemistry of Corrosion - Technetium dioxide cathodically deposited on platinum was reoxidized to pertechnic acid upon exposure to aerated water. It was shown that hydrogen simultaneously deposited on the platinum greatly accelerated this oxidation. The active hydrogen reacted rapidly with oxygen to give peroxy compounds, such as HO_2, which oxidized the technetium dioxide more rapidly than molecular oxygen alone. This observation supports the interpretation previously given to the sudden ennobling of stainless steel by air when its potential rises above the "critical recovery potential" in aerated sulfuric acid.

Further study was made of the effect of added electrolytes upon the electrode potential of electrolytic iron in the presence of molybdate, tungstate, pertechnetate, and chromate ions as inhibitors. The measurements were made at 58°C and substantiated the general behavior observed with the pertechnetate ion in measurements made at 24°C. Molybdate and tungstate ions ennobled the potential only in the presence of oxygen. All the potentials were debased when sufficient concentrations of sulfate or chloride ions were added, though differences in detail were observed which are of importance in the theory of the action of the inhibitors. (AEC Activity 5330)

Ion-Exchange Studies - A complete and thermodynamically rigorous computation of cation exchanger selectivities was accomplished for the first time by using measurements of only the variation of exchanger density with water content and the variation of exchanger water content with water activity. These computed ion-exchange equilibrium "constants" agreed with those experimentally determined within the errors involved, except for the most highly cross-linked exchangers were significant discrepancies appeared. This departure can be explained if these cation exchangers contain more than one type of sulfonic acid group, so that they are not unifunctional. A computation of anion exchanger selectivities is now being attempted. If this effort should also prove successful, it is believed that a considerable advance in the basic understanding of the equilibrium behavior of ion-exchangers will have been established. (AEC Activity 5330)

Chemistry of Technetium - Final evaluation of the low-temperature heat capacity data on rhenium heptoxide, Re_2O_7, was completed. The entropy of the heptoxide is 49.54 $\pm$ 0.05 e.u., of which 0.52 e.u. is estimated for the entropy below 15°K by means of a Debye-T^3 extrapolation. This entropy determination is of importance in the correlation of the chemistry of technetium with that of rhenium and manganese. Low-temperature heat capacity measurements on potassium hexachlororhenate, K_2ReCl_6, are in progress. This compound shows three second-order transitions at the approximate temperatures of 76°, 103°, and 111°K. The characteristics of these heat capacity anomalies are being studied further. (AEC Activity 5330)

Characterization of Short-Lived Fission Products - Measurements on the decay chain Ca^{49}-Sc^{49}-Ti^{49} were completed. The most energetic beta-ray group of Ca^{49} has an energy of 1.95 ± 0.05 Mev. Gamma-rays following the decay of Ca^{49} were observed, corresponding to the deexcitation of levels in Sc^{49} at 3.10 ± 0.03, 4.05 ± 0.05, and 4.68 ± 0.05 Mev; the relative populations of the levels were calculated from the gamma-ray intensities. It was established that Sc^{49} is a pure beta emitter, with a beta-ray energy of 2.05 ± 0.05 Mev.

Studies on the complex decay scheme of Rb^{89} were completed. Energies and intensities of 10 gamma-rays per disintegration following the decay of Rb^{89} were measured and a decay scheme was established with the help of gamma-gamma coincidence spectroscopy, which proposes levels in Sr^{89} at 1.05, 2.32, 2.57, 2.75, 3.27, and 3.52 Mev. The ground state beta-ray transition was measured as 3.92 ± 0.10 Mev.

The radiations emitted by long-lived Tc^{98} were detected in four different technetium sources. In all cases detection was accomplished by means of gamma-gamma coincidence spectroscopy between the two cascade gamma-rays of 0.66 and 0.75 Mev energy. Preliminary measurements indicate a half-life for Tc^{98} of about 10^4-10^5 years so that it is highly unlikely that this isotope has persisted in the crust of the Earth.

It was possible to detect Tc^{98} in a 3.12-gram source of fission product technetium and, assuming a half-life of 1.0×10^5 years for Tc^{98}, it is estimated that the ratio of Tc^{98} to Tc^{99} formed in fission is about 1.4×10^{-9}. (AEC Activity 5330)

Chemical Separation of Isotopes - A small amount of 4% nitrogen-15 (natural abundance - 0.37%) was produced with the Nitrox system for isotope concentration. This system (report ORNL-1905) uses the exchange between aqueous nitric acid and gaseous NO and NO_2 to effect isotopic separation. Operation of the product reflux unit was satisfactory and less than 5 ppm of the nitrogen entering the refluxer was found in the by-product sulfuric acid. The 7-foot exchange column and associated reflux equipment operated automatically, with very few adjustments being necessary, during a 60-hour period, at which time an unscheduled shut-down occurred. Isotopic analyses of the enriched samples indicated that equilibrium was not attained at the time of the shut-down. Longer operation of the equipment can be expected to produce greater enrichment of nitrogen-15.

The heat of reaction between BF_3 and anisole to form $BF_3 \cdot$anisole complex was measured calorimetrically and found to be 14 ± 1 kilocalories per mole. This value was used for design calculations on the Anco system (BF_3 vs $BF_3 \cdot$anisole) for boron isotope separation. (AEC Activity 5340)

METALLURGY

Metallurgical Materials and Processing - Work on the controlled addition of carbon to stainless steel as an aid to chemical dissolution was continued. A full-size APPR fuel element assembly containing UO_2 was carburized to a carbon level of 2.5%, a value that previous work indicated is necessary for satisfactory dissolution rates. Dissolution tests are to be made. (AEC Activity 5420)

PROGRAM 6000 - BIOLOGY AND MEDICINE

BIOLOGY

Cytology and Genetics - Two major inheritable effects of radiation on the nuclei of *Paramecium aurelia* have been established by previous work, i.e., recessive lethal mutations and inhibition of nuclear exchange at conjugation. The former has been shown to be sensitive to oxygen tension during irradiation, while the latter is not. It has now been shown that they also differ in that the recessive lethals are decreased by the presence of cysteine during irradiation and by low temperature afterward, whereas the inhibition of exchange is unaffected by these two treatments. Both effects are very much less, however, when the irradiation is made shortly before cell division than when it is made shortly after. Thus, the factors which determine stage sensitivity must be quite different from those which are involved in modification by oxygen concentration, cysteine, and postirradiation temperature.

When *Habrobracon* eggs are irradiated in the first meiotic metaphase, terminal deletions are incurred which result in bridges in the second meiotic anaphase and bridge breakage during cleavage. Consequent gene imbalance has been considered as the source of dominant lethality. Since the breakage-fusion-bridge cycle does not appear to become established in eggs irradiated in the first meiotic prophase, the question arises as to the cause of dominant lethality in these eggs. Examination of dead embryos shows that approximately 80% have been blocked in development at the 6th or 7th cleavage and that the nuclei are Feulgen negative. Thus, it appears that dominant lethality in these eggs is associated with interruption of deoxyribonucleic acid synthesis. To test whether this action is caused by induced chromosomal deletions of fixed extent, the dead embryos from unirradiated triploids were examined. The chromosome complements of such embryos comprise a variety of aneuploid types. Since eggs from triploids died during later development, it appears likely that the radi-

ation effect on deoxyribonucleic acid synthesis is not necessarily brought about by the induction of chromosomal deficiencies.

Time-intensity experiments on the production of two-hit chromosome aberrations by 250-kvp X-rays indicate that in the seed of Vicia faba the radiation-induced breaks remain open for the relatively long period of two hours. This plus the fact that a source of energy is needed for the breaks to close has led to the conclusion that the breaks are at covalent bonds. Recent reports in the literature have hypothesized, however, that chromosome breaks are breaks of ionic bonds. Other reports have postulated the existence of two types of breaks, one of which would stay open for only relatively short periods of time.

Consequently, a time-intensity experiment was performed at high X-ray intensities. The shape of the resultant curves indicate that, in addition to the type of break that stays open for two hours, there is indeed another type of break that closes in the relatively rapid time of less than three minutes. Furthermore, this second type of break begins to close immediately after it first opens so that the number of this type is being decreased from time zero. Other experiments with chelating agents such as Versene indicate that the removal of metallic ions is capable of breaking the chromosomes.

The data accumulated so far for the rapidly closing breaks are consistent with the hypothesis that breaks of ionic bonds are produced. This is in contrast to the data on the breaks which stay open for relatively long times and which are more likely covalent. These experiments have demonstrated clearly the existence of two types of breaks, and they permit preliminary postulations to be made in regard to the chemical definition of the breaks. (AEC Activity 6130)

Biochemistry - The generalizations on the structure necessary for maximum radiation protective activity (ORNL-1905) were further substantiated by the preparation and testing of a new series of thiuronium compounds. In addition, an excellent correlation was found between chemical tests for labile sulfhydryl groups and radiation-protective activity. Another promising protective compound, S, γ-aminopropylisothiuronium·Br·HBr (APT), was examined extensively for its biological activity. It appears to have about the same toxicity as S, β-aminoethylisothiuronium·Br·HBr (AET) and to be equally effective over a fourfold range of dose (2.3-9 mg/mouse) against a lethal radiation dose. Both AET and APT gave effective protection to mice when administered intraperitoneally up to two hours before the radiation dose. (AEC Activity 6130)

Pathology and Physiology - In an attempt to study the mechanism whereby transfused nonirradiated bone marrow enables the survival of otherwise lethally irradiated animals, rats irradiated with 750 r of X-rays were subsequently injected with homologous nonexposed bone marrow carrying an immunogenetic marker. Erythrocytes carrying the genetic label were detected in the peripheral circulation within 2-3 weeks, whereas controls injected with unirradiated marrow did not show erythrocytes derived from the implanted marrow.

At the time of writing, marrow implants have been observed to persist and function as long as 110 days, contributing up to 80% of the peripheral erythrocytes. These experiments suggest that the protective action of transfused bone marrow may result from the implantation and proliferation of the nonirradiated hemopoietic cells in the irradiated hosts. (AEC Activity 6130)

Tracer Studies in Microbial Metabolism - A previous report (ORNL-1878) on succinic acid decarboxylase studies described an enzyme system from combined cell extracts of Propionibacterium and Veillonella, which fixed a C_1 fragment (from the decarboxylation of succinyl-CoA) into malate. This transfer was dependent on the presence of DPNH (reduced diphosphopyridine nucleotide) and pyruvate. It was proposed that the C_1 fragment was combining with pyruvate to form OAA (oxalacetate) by a unique carboxylation mechanism, and that this product (OAA) was converted to malate by the malic dehydrogenase system.

Additional support for this hypothesis was obtained from tracer experiments employing succinyl-1,2,3,4-C^{14}-CoA as a substrate, performed in the presence of malonate to inhibit the direct conversion of succinyl-CoA to malate through fumarate. The data obtained demonstrate the inhibition of CO_2 (but not propionate) production by addition of pyruvate and DPNH, and the accompanying increased labelling of the malate carboxyl. Only negligible amounts of labelled lactate were formed. In addition, it was observed that catalytic amounts of malate will replace the requirement for succinyl-CoA during DPNH oxidation with this system.

Tracer experiments with the same system show that pyruvate-2-C^{14} is converted to lactate in the presence of catalytic amounts of malate and substrate quantities of DPNH. The spectrophotometric and tracer experiments can probably be interpreted most simply as indicating that with DPNH present, pyruvate is converted to lactate on a pathway through OAA and malate; catalytic amounts of the C_1 fragment from malate decarboxylation furnish the (carboxyl) carbon required to initiate the cyclic process. The proof of the existence of the pyruvate to OAA step (and its requirement for malate) establishes the link for the malate-dependent conversion of pyruvate to lactate through OAA. (AEC Activity 6130)

Enzyme Chemistry - In a continuation of studies on the relation of free radicals to the production of light, the relative rates of reactions of phenylhydrazine, hydrazine, phenylhydroxylamine, and hydroxylamine with oxyhemoglobin and methemoglobin were compared; the production of H_2O_2 was detected in these reactions by measuring the light given off when luminol was present. When reacting with oxyhemoglobin, all the reducing agents mentioned, except hydrazine, produced H_2O_2 rapidly. Phenylhydrazine and phenylhydroxylamine were found to react much faster with oxyhemoglobin or methemoglobin than did hydroxylamine or hydrazine, the latter two being the least reactive. Although phenylhydroxylamine produced a large amount of H_2O_2 when reacting with oxyhemoglobin, no verdoglobin was formed, as is the case with the other reducing agents. This lack of verdoglobin formation was explained by the formation of

of nitrosobenzene, a product of the reaction of phenylhydroxylamine with oxyhemoglobin, which combines with hemoglobin forming nitrosobenzenehemoglobin. Hydrogen peroxide probably cannot displace the nitrosobenzene from hemoglobin, the formation of the complex preventing the oxidation of hemoglobin with the subsequent production of verdoglobin. (AEC Activity 6130)

Mammalian Radiation Recovery - The screening of tissues and agents for their effect on recovery from lethal body irradiation demonstrated that small intestine, urinary bladder, and subcellular particulates of adult rat liver are ineffective. A suspension of rat chloroleukemia cells was given to 28 irradiated mice and 2 were living on the 18th day whereas all 5 X-ray control mice were dead by the 12th day. This degree of survival is probably significant. Studies on the mechanism of action of bone marrow treatment after total-body irradiation showed that the recovered mice that received isologous (same mouse strain) bone marrow have a nearly normal immunologic response to rat red blood cell antigens and sheep red blood cell antigens. Recovered mice that received heterologous (rat) bone marrow showed no immunologic response to rat red blood cell antigens. Quantitative biologic studies demonstrated that recovery from irradiated bone marrow is proportional to the dose of injected isologous bone marrow cells irrespective of the percentage of mice surviving a lethal X-ray exposure. The therapeutic action of leukemoid blood (very high white blood cell count) after irradiation resides in the white blood cell mass injected. (AEC Activity 6230)

RADIOISOTOPE SALES AND COSTS

Type of Transaction	August 1955	FY 1956 to Date
Domestic Sales	$96,618	$195,904
Foreign Sales	4,105	6,753
Project-Cash Sales	5,389	7,648
Project-Transfer	241	304
Technical Cooperation Program Credits	55	465
Plant Credits	239	1,437
AEC Credits	9,119	13,667
Total Radioisotope Income	$115,766	$226,178
Total Radioisotope Costs*	$73,531	$134,457
Total Radioisotope Shipments	1,044	2,012
Boron and Helium		
Income	$7,930	$8,471
Costs	$ 89	$ 310
Shipments	4	7

*Includes some costs incurred but not reported during July 1955.

GROSS OPERATING COSTS

	Cost for August	FY 1956 Cost to Date
Programmatic Operating Cost - Net	$3,193,028	$6,009,510
Plant and Equipment Cost	361,935	633,032
Program "H"	19,541*	20,022
Work for Other Parties - Transfers	11,267*	2,163
Inventory Changes	32,388	17,716*
Reimbursable Work for Other Parties	260,907	412,104
Deferred Charges	75,273*	81,296*
Total Laboratory Cost - Net	$3,742,177	$6,977,819
Estimated Cost for Next Month - Net	$3,700,000	$10,677,819

*Credit

[redacted]

PERSONNEL SUMMARY

	Number of Employees September, 1955	New Hires September	Terminations September
Administration	63	0	3
Operations*	120	2	3
Engineering, Shops, and Mechanical	769	24	17
Laboratory and Research	1959	62	141
Protection	142	1	1
Service	371	3	7
	3424	92	172

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

A total of 841 Laboratory personnel are located in the Y-12 Area.

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Reports in this series issued during the past year:

September 1954	ORNL-1793
October 1954	ORNL-1805
November 1954	ORNL-1824
December 1954	ORNL-1838
January 1955	ORNL-1849
February 1955	ORNL-1867
March 1955	ORNL-1878
April 1955	ORNL-1886
May 1955	ORNL-1905
June 1955	ORNL-1920
July 1955	ORNL-1936
August 1955	ORNL-1968

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