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OAK RIDGE NATIONAL LABORATORY

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OAK RIDGE NATIONAL LABORATORY

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

April, 1957

This status and progress report summarizes somewhat less than one-half of the Laboratory's activities. A few of the activities are reported every month but most of them are reported on a bimonthly schedule. Program 4400 is reported separately.

PROGRAM 3000 - WEAPONS

Special Separations - An additional run in the current series of plutonium isotope separations was completed. The feed material for the separation was 73 grams of highly-irradiated plutonium from the NRX reactor at Chalk River, Canada. The isotopic analysis of the feed was 65.4% Pu^{239}, 29.7% Pu^{240}, 4.1% Pu^{241}, and 0.8% Pu^{242}. Product processing is incomplete but 1.7 grams of ~ 90% Pu^{240}, and 0.240 grams of 70-75% Pu^{241} are expected. The ratio of Pu^{+} ions focused at the collector to plutonium vaporized in the ion source was 8%.

The first seven Pu-Al fuel elements were delivered to MTR for irradiation. Four of the seven units are standard elements which will be irradiated for approximately five cycles to give the optimum isotopic distribution for the separation of high purity Pu^{240} and Pu^{241} in gram quantities. Three of the units are shim assemblies which are to be irradiated for 1-1/2 to 2 years for the production of transplutonic elements for UCRL and ANL. Two shim assemblies and one element are now in the MTR. Present indications are that the length of allowable irradiation of the shim elements may be considerably less than the desired period because of reactor safety consideration. The fabrication of four additional elements for the Special Separation program and three additional elements for long-term irradiations was approved. The specifications for the elements for long-term irradiations will be modified in accordance with the experience at MTR. (AEC Activity 3610)

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HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test - Run No. 7 was completed on March 28, 1957, after the accumulation of 625 operating hours at 1700 psi and 270-280°C, of which 527 hr were logged with 10-g/liter depleted uranyl sulfate in the system. After the system was rinsed and the contents of the rinse solution were analyzed, 4703 g of the original 4760-g charge of uranium was accounted for, and the amount of water recovered agreed to within 1% with the amount indicated by the instruments.

When the rinse was completed, the instrument conduit and air lines were pressurized and the shield tank was filled with condensate, to locate leaks in these lines. Several tests of remote underwater-maintenance procedures followed, including the successful removal and replacement of several valve pressurizer heaters and liquid-level indicators. Some of the remote operations were hindered because of water turbidity and inadequate refrigeration for freezing the large pipes, such as the 3-1/2 in. lines of the main circulating loops.

The latter half of the month was devoted to the removal of leak-detector tubing from the high-pressure system and to the opening and inspection of every flanged joint in the system. Nearly 200 flanges have been examined, with fluorescent liquid penetrant. Approximately one-third of the total were rejected on the basis of imperfections, such as deep pits and suspected stress-corrosion cracks, and will be replaced. Another one-third are questionable and must be studied further: the remainder are acceptable in all respects. During this period, operations activities were confined to the testing of the chemical processing plant and the waste evaporator system. (AEC Activity 4103.3)

HRT Chemical Pilot Plant - The HRT Chemical Plant was operated for about 200 hr in conjunction with the reactor during the natural-uranium test runs. Startups and shutdowns were carried out successfully without disturbing the reactor operation. Corrosion in the reactor was not sufficient to produce suspended solids of any consequence, and the underflow receiver collected only 0.25 g of solids, which may have been left from preceding tests.

A 0.56-in.-dia hydroclone performed as predicted from design curves for capacity vs pressure drop. Efficiencies of 25% were recorded for the ThO_2 feed material used and an induced underflow-pot collection system.

The dissolving-equipment checkout has been delayed by difficulties in sealing the tantalum dissolver nozzles to connecting lines of Carpenter-20 stainless steel and by leaks from cracked welds in the junction of the tantalum nozzles to the tantalum liner. Early dissolving tests in a mockup of the dissolving equipment yielded inconsistent results. Apparently, keeping boilup rates low to minimize sulfuric acid entrainment and thus to minimize corrosion of the Carpenter-20 stainless steel connecting lines does not provide sufficient agitation for complete dissolution.

A check of the off-gas absorber beds, based on recent absorption data, indicates that the beds are adequate for the design flow rate, but oxygen purge rates in excess of 500 cc/min, for which the beds were designed, would result in the release of substantial amounts of radioactive materials to the stack. The principal contributor would be Xe^{133}. (AEC Activity 4103.1)

HRT Fuel Processing - Particles of simulated reactor solids containing more than 40% Fe_2O_3 showed a marked tendency to increase in size when heated to 275-300°C in uranyl sulfate solution. Growth was rapid at 300°C; at 275°C an initiation period of about 3 hr, during which little growth occurred, was followed by a short period of very rapid growth. Particles containing 85% ZrO_2 did not grow appreciably even at 300°C.

In studies of dissolution of simulated corrosion-product solids, the solids remaining after three cycles of reflux with 10.8 M H_2SO_4 were 3-8% of those initially charged. Corrosion rates of 120-150 mil/yr on Carpenter-20 condensers were observed.

In simulated fuel solution at 100°C in the presence of Co^{60} radiation, the stability of iodate was measured as a function of the H_2/O_2 ratio in the gas phase above such solutions. For a given temperature, increasing the H_2/O_2 ratio decreased the iodate stability; increasing the uranium concentration increased iodate stability. Increasing the temperature to 120°C markedly lowered the iodate stability, as also did the presence of metallic ions, which catalyze the decomposition of radiation-induced peroxides.

Uranyl sulfate solution processing by UO_4 precipitation gave a decontamination factor of 8.7 from cesium with a 0.3% uranium loss from a starting solution containing 50 g U/liter. Dissolution and decomposition of UO_4 in dilute sulfuric acid was complete in 30 min at 80°C.

Krypton solubility measurements in 0.02 m UO_2SO_4 solutions and water at 100-300°C showed no deviations from predicted values as a result of the low partial pressures of krypton and the presence of solute at low (5 g U/liter) concentrations. (AEC Activity 4103.1)

Uranyl Sulfate Blanket Processing - Plutonium solubility in 1.4 m UO_2SO_4 and specific adsorption on stainless steel were essentially the same for surface area/volume ratios of 0.2, 0.4, and 0.6 cm^2/ml. Plutonium was added batchwise at the rate of about 6 mg/kg H_2O/day to 1.4 m UO_2SO_4 heated to 250°C under 200 psi H_2 and 100 psi O_2. As the plutonium concentration was increased to 45 mg/kg H_2O, essentially all the plutonium remained in solution as Pu(VI). There was a small amount of adsorption, but no plutonium was precipitated. As more plutonium was added, the soluble plutonium decreased to 5 mg/kg H_2O, and plutonium adsorption and precipitation increased rapidly. Since adsorption and solubility are independent of the stainless steel surface area, decreasing the area increases the amount of plutonium in the loose precipitate.

When 1.4 m UO_2SO_4 containing more than 300 mg Pu(IV)/kg H_2O was heated to 250°C in pyrex tubes under 200 psi O_2, approximately 215 mg Pu(VI)/kg H_2O remained in solution.

About 80% of the plutonium was present as Pu(IV) when 1.6 m UO_2SO_4 containing chromium was heated to 250°C under 200 psi O_2 in a Co^{60}-gamma flux of 2 watts/liter; in the absence of irradiation, Pu(VI) was formed when heated under stoichiometric hydrogen and oxygen.

Plutonium formed by LITR irradiation of 1.4 m UO_2SO_4 in a titanium bomb under oxygen was 57% in solution at a concentration of 26 mg/kg H_2O, 42% was adsorbed on the titanium, and only 1% was in the precipitate. Neptunium distribution was similar, 56% in solution, 43% adsorbed, and 1% in the precipitate. Analysis showed that less than 0.1% of the plutonium in solution was in the reduced valence state.

Loop P-1, which is being used to study the removal of precipitated plutonium and fission and corrosion products from uranyl sulphate solution, has been operated for 175 hr at temperature. Some leakage around valve glands was observed. (AEC Activity 4103.1)

Thorium Oxide Blanket Processing - The adsorption of uranium from dilute uranyl sulfate solution on thorium oxide in aqueous slurries at 250°C was investigated. In tests with ThO_2 pretreated with sulfur-saturated alcohol, dilute sulfuric acid, or dilute thorium sulfate, the uranium adsorption was lower by a factor of 10 than on untreated thorium oxide. The lowest uranium adsorption at 250°C on untreated slurries of ThO_2, prepared by calcination at 650°C, in 0.01 m UO_2SO_4 was 2000 ppm.

Uranium adsorption decreased as the ThO_2 calcination temperature increased. Thorium oxide calcined at 650°C adsorbed 3300 to 4400 ppm uranium from 0.05 m UO_2SO_4 containing 0.05 m H_2SO_4 at 250°C, but that calcined at 1100°C adsorbed only 80-190 ppm. (AEC Activity 4103.1)

Homogeneous Reactor Thorium Blanket Studies--Chemical Development - The U/Th ratio of seven ThO_2-enriched uranium oxide slurries did not change from the original value of 0.005 on irradiation at 300°C in the LITR. In these and in two ThO_2 slurries similarly irradiated, corrosion-product pickup agreed with out-of-pile results. Most of the radioactivity appeared with the solids, only cesium being in the supernatant in significant amounts.

The properties of a thorium-uranium oxide (250 g Th/liter) prepared by thermal decomposition of 10°C-coprecipitated oxalates resembled those of a pure oxide fired similarly. The hindered-settling rates and the critical concentration increased with increasing slurry temperature to 1170°C. There was some evidence of gelation at 300°C.

Studies at 100°C with a slurry of 800°C-fired ThO_2 (250 g Th/kg H_2O) and 10,000 ppm SiO_2, based on ThO_2, as $Na_2O \cdot SiO_2$ indicated that equilibrium distribution of silicate is reached in less than 1 hr, the time depending somewhat on the previous heat treatment of the slurry.

Dispersion was evident in thorium-silicon oxide slurries (0.5 and 1 mole % SiO_2, based on ThO_2) autoclaved with an additional 1000-10,000 ppm SiO_2

added as Na_2SiO_3. The thorium-silicon oxide was prepared by firing ThO_2 and H_2SiO_3 at 1000°C for 24 hr.

Thoria sols stabilized with nitrate were unstable at high temperature. Thoria beads in the 100-μ range, prepared from nitrate sols, gelled by hexamethylenetetramine, retained their spherical shape when fired at 1400°C.

In large-scale preparation of ThO_2, a series of filtration studies indicated that a continuous rotary filter will separate thorium oxalate from mother liquors. Filtration rates were up to 8 gal/hr-ft^2 at 40 cm Hg vacuum, with a product loss of less than 0.2%. (AEC Activity 4103.1)

HRP Chemistry--Fuel Studies - Studies of the ability of dissolved cupric salts to catalyze the homogeneous recombination of hydrogen and oxygen have included a comparison between systems involving heavy and light hydrogen. In many of its chemical reactions deuterium is more sluggish than hydrogen and the recombination reaction is no exception. Rate constants were obtained for sulfate systems involving deuterium gas over light-water solvent and deuterium gas over heavy-water solvent for comparison with the rate constants for hydrogen over light-water solvent at a few selected values for $CuSO_4$ concentration and H_2SO_4 concentration and at 175, 200, and 250°C. Although the difference in rates is dependent on the acidity, and possibly on the temperature, in general the copper catalyst is about 50% as effective in recombining deuterium as it is in recombining hydrogen. Thus it appears that heavy-water homogeneous reactor systems will need about twice the concentration of copper catalyst, or twice the deuterium overpressure, to achieve the same rates of gas recombination by means of homogeneous catalysis as the light-water systems. (AEC Activity 4103.1)

Slurry Component Development and Slurry Testing - Run 200-A-11 continued through the report period, accumulating more than 2000 hr of operation. The thoria concentration was raised until erratic circulation occurred, which was at a circulating concentration of about 1600 g Th/kg H_2O at 300°C. Normal circulation was re-established after the charge was reduced. During the run, violent boiling occurred twice when the rupture disc failed and released the pressure to atmospheric. Restarting the run was routine after the lost water was replaced. The handling characteristics and generalized attack rate at 300°C for the sulfated mixed-oxide slurry, U/Th = 0.005, were similar to those for the sulfated thorium oxide slurry. (AEC Activity 4103.1)

Special Slurry Problems - Alternate methods to high-temperature circulation of thorium oxide slurries for achieving particle-size reduction below about 1 micron are being investigated. Of the methods examined so far, the one involving multiple passes of the dry powder through a Mikro-Pulverizer appears to be the most satisfactory.

A method for comparing thorium oxide cakes was developed in which the ease of resuspension of a cake by agitation in water is measured. The method has the advantage of involving a technique similar to that which must be used for disintegrating cakes found in a reactor system. (AEC Activity 4103.1)

Slurry Blanket System Development - The system is undergoing repairs and alterations. (AEC Activity 4103.1)

Blanket Engineering Research - The heat-transfer system was improved in a number of details as a result of the water shakedown runs; the heat balances now regularly check to within a few percent.

The design of the vertical-tube viscometer was altered to provide for operation up to 200°C and 300 psi; it is now ready for construction. (AEC Activity 4103.1)

Fuel Circulating Equipment - The 400A-1 pump has satisfactorily circulated 0.04 m UO_2SO_4 at 255°C for 1200 hr since the last inspection. Operation with this solution now totals 8400 hr since the seal welding of the thermal barrier.

Shutdown of the 400A-2 pump with the modified thermal barrier was necessitated after 758 hr by high pump temperature caused by improper installation of the shaft sleeve.

The 300A-1 pump operated in the HRT mockup for 492 hr with no indication of malfunction.

The 20-cfm blower was operated with a steam-nitrogen mixture at 500 psi and 150°C for 116 hr, and at 1000 psi and 170°C for 66 hr. No measurable wear resulted from the runs.

The feed pump with a Stellite piston was operated for 167 hr on distilled water, pumping 1.2 gpm at 500 psi. During this time, the piston leakage increased steadily from 260 to 960 cc/min.

An oxygen compressor with a water-actuated diaphragm was installed and operated to supply oxygen to the HRT mockup.

One purge-pump diaphragm failed after 4031 hr of operation. Diaphragm endurance testing is being continued, with four heads now pumping 0.04 m UO_2SO_4 solution and four heads pumping water. (AEC Activity 4103.1)

Miscellaneous Equipment - Design of the thermal-cycle test facility was completed, and material orders were placed. The Besler steam generator and the feed-water deaerator should be delivered in May. Titanium 110-AT pipe and caps were ordered for construction of a 400A test-loop pressurizer. (AEC Activity 4103.1)

Heat Removal Equipment - Design of the Babcock and Wilcox HRT replacement heat exchanger was completed. Material procurement and preparation of shop drawings were initiated. (AEC Activity 4103.1)

Solution Systems Development - The HRT mockup operated for 600 hr and underwent a major inspection during this period. The 300 g U/kg H_2O run was concluded, and after an inspection and maintenance period, a 10 g U/kg H_2O run was started. Special tests conducted during this run included operation of a low-pressure recombiner, a test injection of iodine into the loop, and successful use of a method of correcting gas-binding of the feed pumps during operation.

Iodine was found to be strongly adsorbed on the platinized-alumina recombiner, reducing its efficiency somewhat. At high recombiner temperatures, there was some transfer of iodine from the catalyst to the off-gas.

During the period, a feed-pump diaphragm failed after 6750 hr of operation, and a purge-pump diaphragm cracked after 3800 hr of operation.

The major leak which interrupted thermal cycling of the eight ring-joint flanges (see ORNL-2281) was caused by cracked bolts. Magnafluxing revealed that 17 of the 48 bolts were cracked. Many of the ferrules and nuts were also cracked. Results of a metallurgical investigation indicated that the failures were caused by cadmium embrittlement due to the diffusion of cadmium plating into the base metal. The flanges were reassembled with a bolt stress of 45,000 psi. After thermal cycling, the stress remaining in the volts was from 26,000 to 34,000 psi. (AEC Activity 4103.1)

PACKAGE POWER REACTOR PROGRAM

Army Package Power Reactor (APPR-1) - The Laboratory continued to furnish technical support to the Army Reactors Branch (AEC) on the 10-Mw pressurized-water reactor being constructed at Fort Belvoir, Virginia by Alco Products, Inc. The reactor was first made critical on April 8. Operational tests were conducted at various increased power levels, including tests at full power on April 29. It is expected that the 700-hour performance test will begin early in May.

The Laboratory completed fabrication of fuel and control assemblies for APPR-1, including the requested number of spares.

A radiation damage test is being conducted in a full-scale APPR-1 control-rod absorber section. The absorber section was operated as an MTR shim rod for five MTR cycles and has now been removed for visual and metallurgical examination. The boron burnup is expected to be greater than for a complete fuel cycle in the APPR-1. Two miniature samples of absorber plates (APPR specification) were irradiated to approximately 25 x 10^{20} nvt. One sample was badly blistered and the other had disintegrated when removed from the reactor. (AEC Activity 4201.1)

Gas-Cooled Reactor Development - The Laboratory assisted in the evaluation of proposed reactor systems for the Gas-Cooled Reactor Experiment (GCRE) which will be designed and built at NRTS, Idaho, by Aerojet-General Corp.

Design work continued on the gas-cooled materials testing facility which will be installed in the Oak Ridge Research Reactor. An investigation is being made of the suitability of existing computer codes for utilizing Oak Ridge digital computers for gas-cooled reactor calculations. The Prod II multi-group code was obtained, checked, and is now available for use on the IBM 650 machine at K-25. (AEC Activity 4201.1)

GENERAL REACTOR RESEARCH

Radiation Damage--Advanced Engineering and Development - Exposure to reactor radiation increased the tensile strength of three types of impregnated asbestos papers useful in electrical applications. These papers had been impregnated to the extent of 25-30% by weight with styrene, vinylacetate, and silicone resin. The styrene-impregnated paper showed an increase of 25% in tensile strength after exposure to 4×10^{17} thermal n/cm^2-sec and the associated radiation; exposure to 2×10^{18} produced an improvement of 60% over the original strength, but with an accompanying loss in elongation and flexibility. Asbestos impregnated with polyvinylacetate showed an even greater improvement at the lower dose. The change in silicone-impregnated material was less marked.

The molecular weights of previously fractionated polystyrene and polymethyl methacrylate were determined before and after irradiation by solution viscosity measurements. The energies required per cross-link in styrene and per chain scission in methyl methocrylate appear to be independent of initial molecular weight. The measured values for these energies, 2300 ev per cross-link and about 80 ev per scission, are slightly higher than the energies determined by other workers but there is a wide disparity in the earlier data. (AEC Activity 4540)

Basic Reactor Research - The effect of fluctuations in the widths of neutron reactor cross sections are expressed in terms of a single, infinite integral when the widths are distributed in chi-squared distributions. The integral was evaluated in terms of tabulated functions in some simple cases.

The thermal-neutron flux attenuation kernel for a point source in water was obtained from Lid Tank Shielding Facility data. The moments (through the eighth) and the Fourier transform of this kernel were also obtained. The migration area (1/6 of the second moment) obtained from the thermal-neutron kernel agrees with the age to indium resonance of Hill, Roberts, and Fitch (ORNL-181) plus the age from indium resonance to thermal reported by Burkov, Makarin, and Mukhin (J. Nuc. Energy, II, Vol. 4, p. 94, 1957) plus the square of the diffusion length.

A preliminary estimate of the multiplication constant was made by using the above Fourier transform as the nonleakage probability for a series of U^{235}-H_2O cylinders which were made critical for two concentrations. The estimate was too low by about 4%. This error is due largely to the uncertainty in the estimated buckling and to the uncertainty in the experimental data used which affect the Fourier transform. (AEC Activity 4520)

Radiation Detector Development - The spectrum of neutrons from a 1-curie Po-Be source was measured by means of a $Li^6I(Eu)$ scintillation detector operating at liquid nitrogen temperature. The observed neutron spectrum is in agreement with measurements made elsewhere by proton recoil techniques. The gamma-ray background of the Po-Be source was monitored with a $Li^7I(Eu)$ crystal; the contribution of gamma rays to the observed neutron spectrum was found to be completely negligible. It is necessary, however, to apply corrections to the original data to account for competing nuclear reactions and reflected neutrons. (AEC Activity 4570)

Thorex Process - The pilot plant operated at 70% efficiency in processing about 2260 kg of irradiated thorium. The first cycle, including recycle-thorium product feed, was operated at 90% efficiency. About 2200 kg of thorium product was recovered and 4850 g of U^{233} product was sorbed on an ion-exchange column. Solvent extraction losses averaged 1.6 and 0.5% for thorium and uranium, respectively. The final gross gamma decontamination factors for run HD-24 averaged 5.7×10^3 for thorium and 2.8×10^4 for uranium.

Design of the third uranium cycle and installation of the uranium storage facility and the sample conveyor system are about 80% complete.

In laboratory studies on process improvement, mercury was eliminated from the thorium dissolver solution without increasing the total dissolution time. When mercury was used in the dissolution radioactive iodine was removed from the organic-soluble iodide-mercury complex in the extraction step by the addition of iodide to the scrub solution. Ruthenium decontamination factors of greater than 10^3 were obtained with a slightly modified Thorex flowsheet using Decalin as a diluent for TBP.

The uranium loading on a Dowex-50 resin at breakthrough was about 100 g/liter when a synthetic solution, pretreated with $NaNO_2$, was passed at the rate of 8 ml/cm^2-min through an 8-cm-long resin column at room temperature. The uranium loading was increased about 10% when a 30-cm-long column, containing the same volume of resin, was used with the same feed flowrate.

A continuous, interfacial solids-removal system, containing a Fulflo glass fiber filter and a Selas phase separator, is being investigated. The optimum recycle rate through the system was tentatively established at 250 ml/min. The flowsheet for pilot plant evaluation was designed. (AEC Activity 4610)

PROGRAM 5000 - PHYSICAL RESEARCH

ISOTOPE PRODUCTION

Isotope Separation - Processing of iron in the Alpha calutrons continued during this period; monitored ion currents correspond to a total separation of 400 grams of iron isotopes. Processing of the isotopes of ruthenium (masses 96, 98, 99, 100, 101, 102, and 104) in the Beta calutrons was completed with a total collection estimated at 18 grams of isotopes. Separation of the isotopes of iridium (masses 191 and 193) was accomplished in the Beta calutrons with 3 grams being collected. Both ruthenium and iridium required the use of the electron-bombardment source heating technique to obtain the high temperatures required for vaporizing these metallic charges. The separation of the isotopes of titanium (masses 46, 47, 48, 49, and 50) is currently in progress in the Beta units, with emphasis being placed on obtaining Ti^{50} of purity higher than 90%.

Preliminary testing of the operating characteristics of the Alpha-I calutron (source at ground potential) indicates it to be inferior by at least a factor of two as compared with the standard Alpha-2 calutron (source at 35 kilovolts positive); the isotopes of iron were separated in these tests. (AEC Activity 5121)

Isotope Chemistry - Chemical refining was completed for eleven new lots of enriched Li^6, Li^7, Mg^{24}, Ca^{44}, Cd^{106}, Cd^{110}, Ba^{138}, Dy^{164}, and W^{183}, and the samples were added to the inventory. Two returned samples of Fe^{58} were chemically reprocessed and made available for distribution.

Conversions of inventory forms were made as follows: $NaCl^{33}$ to KCl^{37}, $K^{39}Cl$ to $K^{39}I$, and $Ge^{74}O_2$ to Ge^{74}metal. (AEC Activity 5121)

PHYSICS

Scintillation Spectrometry - The accurate location of deep seated brain tumors by scintillation counter techniques requires the use of heavy (~ 100 pound) collimators, which focus on the tumorous area and shield from body background. An improved scanning mechanism is required to support and control the motion of the collimator and detector over the patient. For this reason, a prototype apparatus was built and successfully tested. A servo-control unit regulates both the desired speed and distances of scan. (AEC Activity 5220)

High Voltage Program - Angular distributions of the 3.09-Mev and 3.68-Mev γ-rays from the reaction $C^{13}(p,p'\gamma)C^{13}$ were measured on and between the resonances observed in the γ-ray yield curve. The protons were accelerated by the ORNL 5.5-Mv Van de Graaff generator. The γ-rays were detected by a 3 x 3-in. NaI crystal shielded from the neutrons produced at the target by 11 cm of lithiated paraffin, 3-1/2 cm of boral, 4-1/2 cm of lithiated paraffin and 0.6 cm of lead, with the lead nearest the detector. All the angular distributions of the 3.09-Mev γ-ray were isotropic, in agreement with previously assigned spin to the first excited state in C^{13}.

The location of the second 2^+ state was established for nine even-even medium weight nuclei by means of Coulomb excitation produced by 8-, 9-, and 10-Mev α-particles. The relatively weak excitation of these states is detected by a coincidence measurement of the cascade gamma-rays. The locations of the second 2^+ state are (in kev): Ru^{104}, 893 $\pm$ 7; Ru^{102}, 1100 $\pm$ 9; Ru^{100}, 1355 $\pm$ 16; Pd^{110}, 812 $\pm$ 7; Pd^{108}, 941 $\pm$ 7; Pd^{106}, 1120 $\pm$ 8; Cd^{116}, 1217 $\pm$ 11; Cd^{114}, 1200 $\pm$ 10; and Cd^{112}, 1295 $\pm$ 16. In addition, the B(E2) for excitation of these states were determined. The second 2^+ state in Pd^{106} is very close to the well-known 0^+ state at 1137 kev. This is in agreement with the "near harmonic" model which predicts a close-lying triplet of 0^+, 2^+ and 4^+ states at about twice the excitation of the first 2^+ state. The location of the second 2^+ state in Cd^{114} agrees with the work of Motz (Phys. Rev. 104, 1353, 1956). For Cd^{114} the B(E2) for decay are $(1.6 \pm 0.3) \times 10^{-49}$ and $(2.0 \pm 0.4) \times 10^{-51} e^2 cm^4$ for the cascade and cross-over transitions, respectively. These are 47 and 0.6 times the independent particle estimate (where $R = 1.2 \times 10^{-13} A^{1/3}$ cm). (AEC Activity 5220)

The 86-Inch Cyclotron, Nuclear Physics - Coincidence studies of the Ni(p,2p) reaction were completed. It was shown that the reaction cannot be explained as an inelastic scattering followed by a proton "boil-off", but that both outgoing protons are emitted simultaneously. The reason for the much greater probability of the emission of two protons than a proton and a neutron cannot be explained; the usual explanations for it were shown to be invalid.

The properties and limitations of a previously described fission-frgament mass separator were studied. The resolution was found to be limited by the width of the nuclear charge distribution of fission fragments of a given mass. By detailed studies of this resolution the full width at half maximum of the nuclear charge distribution of mass-97 fragments was found to be 2.3 $\pm$ 0.5.

A systematic investigation of nuclear levels in neutron-deficient rare earth isotopes is being made. The following new isomeric levels were observed: Tb^{156m} (5.5 hr) 88.2 kev (E3); Ho^{160m} (5.0 hr) 60.1 kev (E3); Er^{167m} (2.5 sec) 208 kev (E3); Er^{168m} (10^{-7} sec); and Yb^{171m} (T 1/2 ?) 75.8 kev (E3). Multipolarities are determined by K/L and L_{II}/L_{III} ratios and comparative lifetimes. All the E3 transitions may proceed between levels predicted by Mottelson and Nilsson (Phys. Rev. 99, 1615, 1955). The radioactive nuclides are made by irradiating rare earths with 22-Mev protons. After ion exchange chemistry is performed, conversion electron spectra are obtained in a 180-degree photographic recording instrument. (AEC Activity 5220)

The 86-Inch Cyclotron, Applied Physics - The isotopes As^{74}, Sr^{85}, and W^{181} were produced in service irradiations for outside customers and Kr^{79}, Nb^{90}, and $Te^{121, 123}$ were produced for other Laboratory divisions. Bombardments to determine the yields of Se^{75} and Na^{22} were made. (AEC Activity 5220)

The 86-Inch Cyclotron, Operation - A 3-in. aperture, quadrupole focusing system for the deflected beam was designed and is being constructed. It will replace the existing 2-in. system and should reduce focusing losses and thus provide for a larger deflected beam in the cyclotron pit. (AEC Activity 5220)

The 63-Inch Cyclotron, Physics - The measurements of the energy spectrum of protons from the reaction $Al^{27}(N^{14}, p)Ca^{40}$ were continued. At 30, 60, and 90 deg all spectra give the same value of $\underline{a} = 5$ in the level density formula $w = e^{2\sqrt{aE}}$. The spectrum of alpha particles from the nitrogen bombardment of aluminum was measured at 0, 30, 60, and 90 degrees. It appears that the alpha particles are peaked strongly in the forward direction, unlike the protons. Also, the value of $\underline{a}$ is not constant for all angles, $\underline{a} = 2.7 \pm 0.2$ at 0 deg and approximately 4.2 ± 0.3 at the other angles. Measurements are continuing on this unexpected peaking of the alpha distribution. (AEC Activity 5220)

Spectroscopy Research Laboratory - The infrared vibrational spectra of ND_2T, NDT_2, and of the unsymmetric species NHDT were observed. Corrections for the anharmonicity were introduced into the normal coordinate calculations by use of modified "spectroscopic masses" in computing the elements of the G-matrices with the result that the majority of the normal modes of vibration have now been assigned to observed bands, with a satisfactory agreement between the predicted and observed frequencies.

A reflection-type, 2-mm effective path length, absorption cell, and the associated optics, for use with a Beckman DU Spectrophotometer was designed for high temperature studies of corrosive, molten salts.

Calculations made under extremely pessimistic conditions for the allowable impurity of Hg^{199} in pile-produced Hg^{198}, to be used as a possible primary standard of length, show that the 99.6% or better ORNL Hg^{198} product satisfactorily meets these rigid design criteria. Preliminary testing of an interferometer-Ebert grating optical setup and the data reduction methods, using a Hg^{198} source, was completed. Several components of the instrumentation associated with the development of a high resolution, pressure-scanning Fabry-Perot interferometer were completed; the high voltage power supply, the Wheatstone bridge circuitry for precision pressure recording, the ratio computer, and the magnetic clutch power supply were tested successfully. (AEC Activity 5230)

Electronuclear Machines - Fabrication and assembly of the Cyclotron Analogue I was completed early in March, approximately 10-1/2 months after funds were approved and design was started. The various water-cooling circuits and the many electrical circuits were rechecked and adjusted. Currents in all coils were set at their calculated values, as determined with a high precision potentiometer, the r-f was turned on, and the electron beam was immediately obtained at the maximum radius of the machine. The beam, as observed on a scintillator, was well focused all of the way out from the center of the machine; no beam was lost vertically at any point in the observable range

(1 to 15-in. radius), and there was no detectable attenuation. No beam disturbances were observed at any of the resonances through which the beam passed.

Results of initial observations are clearly most gratifying. The very low threshold obtained (equivalent to 0.2 Mev/turn for protons) and the complete ease with which passage through the various resonances was made very strongly indicate the feasibility of a 900-Mev fixed-frequency proton cyclotron. The fact that the Analogue operates in this fashion with all currents simply set at their calculated values dramatically demonstrates the validity of a large portion of the theoretical work that has been done on the azimuthally varying field (AVF) machine. (AEC Activity 5240)

The 48-Inch Cyclotron - A preliminary design was established for radial magnetic field gradient coils and harmonic coils for the 48-Inch Cyclotron. The radial gradient coils will determine the rate of the magnetic field change with radius, and will be adjustable for optimum beam conditions. The harmonic coils will perform similarly to those on the 86-Inch Cyclotron in moving the effective center of beam rotation to the best position for deflection. (AEC Activity 5240)

Mass Spectrometry Research and Applied Mass Spectrometry - Studies have been continued concerning ion-molecule reactions between ions of CO and the following gases: He, Ne, Kr, A, H_2, D_2, and N_2. The predominant ion resulting from collision dissociation of 5100-ev CO^{++} molecule-ions is C^+, suggesting a charge exchange dissociation reaction. An assumed ion-molecule reaction for A is $CO^{++} + A \rightarrow C^+ + O + A^+$. The A^+ ion cannot be observed directly in the mass spectrometer; however, there is indirect evidence for its existence in that O^+ is not observed from the reaction. The above reaction did not proceed for He and Ne, in opposition to that previously reported for CO^+ (ORNL-2281). This observation suggests that the energy for the reaction is derived completely from the electronic energy of the CO^{++} ions and not from their kinetic energy. (AEC Activity 5250)

Research and Development, Stable Isotopes - It was found that the argon plant described previously (ORNL-2281) was not building up the concentration of A^{36} and A^{38} as rapidly as it should. Since it appeared that poor gas conductance from the bottom end of the hot wire to the adjacent feed system was probably responsible, a new gas inlet system was installed. At present, fresh argon is admitted until the system pressure is 1/4-in. Hg above atmospheric, and this pressure is held for 15 minutes. Then the gas is vented at the inlet point and the system held at zero gage pressure for 5 minutes. This 20-minute cycle is continually repeated. The rate of A^{36} build-up seems to have been improved by this new feed system, but it has not been in operation long enough to permit complete evaluation. At present a total inventory of a few cubic centimeters of 30% A^{36}, about 1.5 liters of 10% A^{36}, and about 1.5 liters of 6% A^{36} is available.

A plant for the separation of krypton isotopes was constructed but has not yet been put into operation. These 20-ft columns differ only in minor details from the argon columns; they are essentially a No. 24 Nichrome hot wire inside of a 7/16-in. ID cold tube. There are six stable isotopes of krypton ranging from mass 78 to 86; the ones most in demand are Kr^{80} and Kr^{84}. While it is relatively easy to take off the end isotopes of a series (as is done with A^{36}) it is more difficult to obtain the isotopes not at the ends of a chain.

Study of the personnel hazards associated with the separation of the isotopes of osmium has shown that $(NH_4)_2OsCl_6$ and $(NH_4)_2OsBr_6$, and possibly $OsCl_4$, are suitable forms for charge recovery chemistry.

Very thin foils (0.00002 in. to 0.0001 in.) of copper and nickel were plated on and then stripped successfully from electropolished and chrome-plated nickel mandrels which had been dipped in aquadag and wiped to give a molecular stripping layer. This procedure was developed for subsequent manufacture of isotopic films of these elements. (AEC Activity 5250)

CHEMISTRY

Raw Materials Chemistry - Di(2-ethylhexyl)phosphoric acid has proved to be an effective extractant for thorium from ore leach liquors. With 0.1 M reagent in kerosene the $E_a^0(Th)$ from 0.5 M sulfate solution at low thorium levels is 20 at pH 1 and ~ 2000 at pH 2. The extraction isotherm at pH 2 has the normal shape, levelling off at ~ 6 g Th/liter in the organic phase (Th:reagent mole ratio ~ 1:4).

Both uranium and molybdenum were successfully recovered from an ore leach liquor by using Amine S-24 as the extraction agent. With 0.1 M amine in kerosene, 99.9% of the uranium and about 85% of the molybdenum were recovered in four extraction stages from a synthetic sulfate leach liquor containing 0.3 g U/liter, 0.3 g Mo/liter, and relatively high concentrations of ferric iron, aluminum, and phosphate. The uranium was stripped completely from the solvent with 1.0 M NaCl while only 1.7% of the molybdenum was removed. The molybdenum was stripped with 5% sodium carbonate.

Rare earths were recovered from sulfuric acid digests of monazite sand by extracting with long-chain primary amines in kerosene. After being stripped from the solvent with acidic nitrate solution and precipitated with ammonia the rare-earth oxide product contained only 0.8% PO_4, whereas the original liquor contained 52 g/liter RE and 33 g/liter PO_4. (AEC Activity 5310)

High Temperature and Structural Chemistry - The method of thermal analysis was substituted for the technique of equilibration and sampling to determine the phase equilibria in the high temperature region of four sodium-sodium halide systems and for redetermining the potassium-potassium fluoride phase diagram. The latter method was found to be unreliable in those cases where

there was only a small difference in specific gravity between the liquid metal and the salt phases. The data thus obtained for consolute compositions and temperatures are as follows: NaF-Na:27 mole % Na, 1183°C; NaCl-Na:52 mole % Na, 1080°C; NaBr-Na:54 mole % Na, 1022°C; NaI-Na:64 mole % Na, 1036°C; KF-K:23 mole % K, 902°C. It is to be noted that the relatively high consolute temperature for NaI-Na deviates from the trend. Also, there are very pronounced asymmetries of the two-liquid phase equilibria in the two fluoride systems and a moderate one in the iodide system. These asymmetries are almost fully explained by the large difference in the molar volume of the metal and the salt in these three cases.

The peculiar trend in the electrical conductivity of sodium metal solutions in molten sodium bromide at low metal concentrations, with the conductivity increasing less and less rapidly with increasing metal concentration, was confirmed by a new series of measurements.

The self-diffusion coefficients of Cs^+ and NO_3^- in molten $CsNO_3$ were measured over the temperature range 425° - 480°C by using Cs^{134} and N^{15} as tracers. The self-diffusion coefficient of the Cs^+ was found approximately 2% higher than that of the NO_3^-. The heats of activation of diffusion are between 5 kcal and 6 kcal, the same as those for the ions in $NaNO_3$ and KNO_3, as determined previously.

The self-diffusion coefficient of the NO_3^- in KNO_3 was previously determined to be about 5% higher than that of the K^+. This result appeared to be anomalous. The experiment was repeated and the self-diffusion coefficient of the NO_3^- was found to be about 10% lower than that of the K^+. The ratios of the self-diffusion coefficients of the cation to anion in $NaNO_3$, KNO_3, and $CsNO_3$, respectively, are 1.6, 1.1, and 1.0. (AEC Activity 5330)

Radio-Organic Chemistry - The rearrangement of diphenyl-o-tolylacetaldehyde in cold, concentrated sulfuric acid was shown, by means of the carbon-14 tracer technique, to proceed in such a manner that the o-tolyl/phenyl migration ratio is about 3:1. In contrast, the nitrous acid deamination of 2,2-diphenyl-2-o-tolylethyl-1-C^{14} amine takes place with an o-tolyl/phenyl migration ratio of about 0.8:1. These data are explained as follows: 1) In the sulfuric acid, the carbonium ions produced from diphenyl-o-tolylacetaldehyde are sufficiently long lived that rotation about the $C-\overset{\oplus}{C}$ bond is fast compared with the rate of migration of the phenyl or o-tolyl groups. Thus the major steric restriction to migration of o-tolyl is not present, and o-tolyl migrates in preference to phenyl. 2) From molecular models of 2,2-diphenyl-2-o-tolylethyl amine it is clear that the conformations in which phenyl is back-side to nitrogen are preferred over those in which o-tolyl is back-side to nitrogen. Since the deamination reaction probably requires very little solvent or neighboring group participation, thus producing a high-energy carbonium ion, it is proposed that aryl migration is fast compared to rotation about the $C-\overset{\oplus}{C}$ bond. Thus, the relative confirmations of the original molecules control aryl migration, and phenyl migrates in preference to o-tolyl.

The study of the rearrangement of phenyl-di-p-tolylacetaldehyde and the three glycols related was completed. Although a simple product ratio of the ketones obtained upon rearrangement of the aldehyde in sulfuric acid would indicate a p-tolyl/phenyl migration ratio of less than unity, it was demonstrated by means of the Hearon equation that the p-tolyl/phenyl migration ratio is, in fact, greater than unity. Thus the mechanism proposed earlier was supported.

The rearrangement of steriospecifically phenyl-labeled (+)-1,1-diphenyl-2-amino-1-propanol in the presence of nitrous acid was carried out. The product of this reaction, (-)-1,2-diphenyl-1-ketopropane, was 25% racemic. The resolution of this product into a completely resolved (-) fraction and into a racemic fraction followed by cleavage and the radioactivity assay of the degradation fragments of each fraction disclosed that whereas the (-)-product possessed all of its radioactivity in the No. 2 phenyl group, the (+)-product possessed all of its radioactivity in the No. 1 phenyl group. Since the configurations of reactant and product were related, it is concluded that the labeled phenyl approached the migration terminus from the opposite side of the carbon originally bonded to nitrogen, whereas the unlabeled phenyl approached the migration terminus on the same side of the carbon originally bonded to nitrogen. These results are best explained in terms of carbonium ion intermediates whose rotation about the $C-C^{\oplus}$ bond is restricted, and whose phenyl groups migrate solely through trans-transition states. (AEC Activity 5330)

Molten Salt Thermodynamics - In connection with activity determinations on $LiCl-FeCl_2$ and $KCl-FeCl_2$ melts, condensed phase diagrams were obtained for these systems. Conventional cooling curves and differential cooling curves were made simultaneously on the same samples, and additional samples were quenched from known temperatures. Phase identifications were made by X-ray analysis and by optical characteristics determined with the petrographic microscope.

LiCl (m p 615°C) which has a cubic lattice, and $FeCl_2$ (m p 675°C) which has a hexagonal layered lattice, formed an almost complete series of solid solutions with a eutectic point of 525°C at 40 mol % $FeCl_2$. The solid solution behavior apparently results from the fact that the chloride ions in both compounds form a close packed cubic lattice with practically the same parameters, and either cation can fit in the available octahedral holes.

KCl (m p 775°C) forms $KCl \cdot FeCl_2$, which melts congruently at 400°C and has a solid transition at 300°C, and also $2KCl \cdot FeCl_2$, which melts incongruently at 385°C and has a solid transition at 300°C. Activities derived from the liquidus curve along which pure KCl precipitated gave excellent agreement with calculated activities based on the assumption of $FeCl_4^{=}$ ions in the liquid state, and similarly, fair agreement was found along the $FeCl_2$ liquidus. (AEC Activity 5330)

Analytical Chemistry Research - Water and mud samples were analyzed for fission-product and cobalt-60 activities by gamma spectrometry, with a 20-channel analyzer. Concentrations as low as 10^{-8} μc/ml were measured.

The activation analysis method, used in determining particle size in thorium oxide samples, has now been extended to include the analysis of mixed oxides of thorium-uranium and of chromium-iron-zirconium. A preliminary investigation of these materials by means of a gamma spectrometer indicates that the particles of each of the particular oxides behave differently. In the actual radioactivity measurements, a 3-channel analyzer is employed and discrimination made for specific gamma energies. The activity at these gamma energies are displayed on a recorder and the percentage undersize for a given particle diameter is determined from this data and the sedimentation of the particles by Stokes' Law.

It is believed that this study is significant in that a method is now possible for analyzing particle systems containing multiple components. A future program using a multichannel gamma spectrometer is being considered.

A further study was made of a pyrolysis technique for the separation of fluoride from materials containing NaF in which the sample, mixed with U_3O_8, is heated to 1035°C in a gas stream. It was found that the removal of fluoride is much more rapid when oxygen saturated with water vapor at room temperature, rather than dry oxygen alone, is passed through the reaction tube. Furthermore, quantitative removal of the fluoride is effected when helium (either dry or water saturated) is substituted for oxygen, although the rate of fluoride removal is lower when helium is used instead of oxygen. Water vapor is apparently essential for the rapid removal of fluoride; but the amount required is much less than that being used in the pyrohydrolytic procedure as now designed. (AEC Activity 5330)

METALLURGY

Ceramics Research - Preliminary tests of the compount 6 $ZrO_2 \cdot Nb_2O_5$ show that it is overfired at 1450°C. Some experiments with specimens fired at lower temperatures will be made to test its reputedly negative coefficient of expansion.

Data have been assembled and a report completed on europium oxide for presentation at the National Convention of the American Ceramic Society in Dallas, Texas, in May.

Four new clays of the Attapulgite type were tested and proved highly absortive. Cone fusion tests, X-ray patterns, and differential thermal analyses were run on these clays.

Twenty-four sinter mixes were prepared from 10 different clays and 3 different tagged Purex solutions. Samples of these mixes were fired at 430°, 540°, 650°, and 870°C and then subjected to static leach tests. Thin films

of each sinter mix were spread on quartz glass cells and weight and count changes were noted as they were fired at the same successive temperatures. Incomplete returns indicate the ball clays are the most promising.

Samples of Al_2O_3-Cr, both fueled and unfueled, were fabricated, then sent to NDA for testing at 2500°F as follows: fission-product retention, diffusion of fuel into the cladding, and compatibility with different atmospheres. Development work continued on fueling SiC-Si.

Unit-cell parameters were determined on powdered samples of TiO_2 which had been fired at various temperatures from 1000° to 1450°C. Hydrostatically pressed compacts of TiO_2 were fired at 1350°C for various lengths of time; thin sections were made from them to determine the time necessary at this temperature to grow crystals in the compacts at least 150 microns in size. (AEC Activity 5420)

Fundamental Physico-Metallurgical Research - Metallic cerium undergoes two phase transformations at temperatures below ambient. The face-centered cubic form, stable at room temperature, transforms to a hexagonal structure with c/a = 3.23 or to another face-centered cubic structure with a volume decrease of 16.5%. The temperatures for the transitions are: f.c.c. → h.c.p. - start 263° ± 10°K, not complete at 77°K; h.c.p. → f.c.c. start 373°K, finish 413° ± 10°K; f.c.c. → f.c.c.' start 96° ± 5°K, not completed at 77°K; f.c.c.' → f.c.c. start 166° ± 5°K, end 197° ± 5°K.

Although the transformation f.c.c. → f.c.c.' does not go to completion at 77°K upon cooling, repeated plastic deformation at this temperature will give a structure which is entirely f.c.c.'

The alpha and beta phases of zirconium were found to dissolve cadmium in excess of 9 at.%; at 900°C the center of the $(\alpha + \beta)$ region is in the vicinity of this composition.

In the silver-zirconium system, preliminary evidence was found for an immiscible liquid region from which the ZrAg phase forms at 1160 ± 7°C. The homogeneous region of the Zr_2Ag phase at 1150°C has been determined more accurately and lies between 33.4 and 33.9 at.% Ag.

In the lead-zirconium system, a diffusion-couple experiment indicates that at 1100°C diffusion of lead proceeds at least as rapidly as cadmium, and more rapidly than indium.

An attempt was made to reduce the grain size of solid zirconium X-ray specimens by lowering the stress-relieving temperature from 800° to 550°C. An expansion of one part in 2500 in the c spacing occurred. This effect may result from hydrogen content since at lower temperatures removal of hydrogen is probably impaired by thin oxide films.

Preliminary measurement of the specific heat of a high purity zirconium specimen in the temperature range 3.3 to 4.4°K indicate that the density of

states is somewhat lower than that previously reported but still within the high range typical of other transition elements. (AEC Activity 5420)

Fundamental Investigations of Radiation Damage in Solids - The minority carrier lifetime of large single-crystal samples of N-type germanium was found to be very sensitive to reactor irradiation and to gamma radiation; a single power law dependence over several orders of magnitude indicates a possible use for lifetime measurements as a monitoring device in the low integrated range. A one-level recombination model serves to explain adequately the experimental data and indicates that recombination may occur at the energy level of the first ionization of the interstitial atom. The cross section for hole capture in this basis is $\sim 4.4 \times 10^{-15}$ cm^2 and 5.1×10^{-16} cm^2 for neutron-irradiated and Co^{60} gamma-irradiated germanium, respectively. An alternative model that indicates recombination at low lying levels is possible but such does not invalidate the experimental results obtained thus far. (AEC Activity 5430)

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STATUS OF CONSTRUCTION

During the period work was started on the installation of the Specialty Welding and Brazing Facility by the H. K. Ferguson Company and Laboratory forces.

Since its inception in 1950, the Welding and Brazing Laboratory of the Metallurgy Division has had to divert an increasingly larger portion of its research effort to the fabrication and/or heat treatment, of complex and highly critical components and sub-assemblies for the various reactor programs at Oak Ridge National Laboratory.

Part of this fabrication entails the development of brazing and welding methods and requires the knowledge and experience derived from the research and developmental activities of the Welding and Brazing Group. It is naturally desirable that the first unit of any particular design be fabricated in the Welding and Brazing Laboratory under the close supervision of that group, functioning as part of the Metallurgy Division, in order to develop the necessary new techniques. After specifications and techniques for the fabrication have become established and are routine, the specialized services of research personnel and laboratory facilities are no longer required. However, due to the lack of other facilities at the Laboratory for the performance of this work, the efforts of this group are being diverted to the routine fabrication of units. This has resulted in delays, interruptions and on some occasions indefinite postponement of important research and developmental programs.

A Specialty Welding and Brazing Facility is being established in the Engineering and Mechanical Division to relieve this research group of routine fabrication and to permit the manpower and equipment of the Welding and Brazing Laboratory to be concentrated on research and development pertaining to welding procedures, brazing alloys, and joining techniques, as was originally intended.

The work will consist of minor alterations to Building 7003, the construction of an electrical substation nearby and the installation of furnaces, welding machines, purification system, and other specialized equipment.

VISITORS

FOREIGN VISITORS:

Adler, K. F., Australian AEC, Sydney, Australia
Bleaney, B., Oxford University, England
Cabala, L. P., University of Concepcion, Chile
Charlesby, A., Tube Investments Res. Laboratory, Cambridge, England
Dekeyser, W. C., CEAN, University of Ghent, Belgium
deLaboulaye, H. L., French AEC, Paris, France
deRaad, B., Royal Duhl Shell, The Hague, Netherlands
deVries, A. E. Holland
Eriksen, E., Oslo, Norway
Fossoul, E., SEEN, Belgium (Wilkinsburg, Pa.)
Franck, U. F., National Institute of Health (German Citizen)
Gandy, A. P., National Bureau of Standards (French Citizen)
Gorodetzky, S., Institut Rechershes Nucleire, Strasborg, France
Graf, P., Reactor, Ltd., Zurich, Switzerland
Grave, G., Phoenix-Rheinrohr, Homberg, Germany
Haeffner, E. A., AB Atomenergi, Sweden
Herzet, G. L., SEEN, Belgium (Sewickley, Pa.)
Hickman, B. S., Australian AEC, Sydney, Australia
Hogan, M. A., Irish AEC, Dublin, Ireland
Hogfeldt, E. H., BNL (Swedish Citizen)
Kelly, A., Northwestern University (British Citizen)
Klein, F. S., BNL (Israel)
Laroche, J., ONIA, France (Princeton University)
Ljogodt, L. K., Oslo, Norway
Maldague, P. E., SEEN, Brussels, Belgium
Nakai, Y., Mitsubishi Co., Tokyo, Japan
Nevin, T. E., Irish AEC, Dublin, Ireland
Pleeck, G. W. P., Syca Corp., Brussels, Belgium
Rabson, S. R., Transvaal and Orange Free State Chamber of Mines, So. Africa
Robertson, R. F. S., AECL, Chalk River, Ontario, Canada
Satchler, G. R., University of Michigan (British Citizen)
Sjoborg, L. T., AB Atomenergi, Stockholm, Sweden
Soman, S. D., A.E.E., Bombay, India
Spaepen, J., CEAN, Belgium
Storebo, H., Norway
Sugata, T., Ohbayashi Gumi, Ltd., Osaka, Japan
Taylor, W. H., Cavendish Laboratory, Mass. (British Citizen)
Van Bekkum, D. W., NDRC, Netherlands
Weill, J., French AEC

RADIOISOTOPE SALES AND COSTS

Type of Transaction	March 1957	FY 1957 to Date
Domestic Sales	$297,586	$1,448,819
Foreign Sales	19,392	105,504
Project-Transfer	1,372	10,709
Project-Cash Sales	10,429	48,125
Technical Co-operation Program Credits	0	3,395
Plant Credits	1,004	27,088
AEC Credits	26,277	158,377
Total Radioisotope Income	$356,060	$1,802,017
Total Radioisotope Costs	$147,671	$1,110,665
Total Radioisotope Shipments	1,284	10,089
Helium		
Income	$6,075	$25,152
Costs	$ 44	$ 3,209*
Shipments	5	25

*Helium cost figures for December, January, and February have been revised as follows to reflect credits:

	Cost	FY 1957 to Date
December	$1,283 Cr.	$1,865
January	496	2,361
February	804	3,165

GROSS OPERATING COSTS

	Cost for March	FY 1957 Cost to Date
Programmic Operating Cost - Net	$4,796,941	$38,706,264
Equipment	207,394	1,925,079
Construction	155,914	1,410,571
Work for Others - Transfers	116,256	511,786
Inventory Changes	(24,184)	(18,166)
Reimbursable Work for Others	55,271	632,504
Deferred Charges	11,199	(253,207)
Total Laboratory Cost - Net	$5,318,791	$42,914,831
Estimated Cost for Next Month	$5,200,000	$48,114,831

() Credit

PERSONNEL SUMMARY

	Number of Employees April, 1957	New Hires April	Terminations April
Administration	72	1	1
Operations*	132	0	0
Engineering, Shops, and Mechanical	861	4	4
Laboratory and Research	2187	18	10
Protection	117	1	1
Service	376	3	1
	3745	27	17

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

938 Laboratory employees are working in the Y-12 Area.

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Reports in this series issued during the past year:

April 1956	ORNL-2082
May 1956	ORNL-2109
June 1956	ORNL-2123
July 1956	ORNL-2144
August 1956	ORNL-2166
September 1956	ORNL-2185
October 1956	ORNL-2205
November 1956	ORNL-2232
December 1956	ORNL-2248
January 1957	ORNL-2261
February 1957	ORNL-2281
March 1957	ORNL-2299

Edited by F. T. Howard

Approved by Alvin M. Weinberg, Director