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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

JUNE 1955

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

June, 1955

W. H Sullivan

and

F. T. Howard

Date Issued: JUL 8 1955

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STATUS AND PROGRESS REPORT

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

June, 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 - SOURCE AND FISSIONABLE MATERIALS

Thorex Process - In four runs in the Thorex pilot plant, about 2.5 tons of irradiated and 1.5 tons of nonirradiated thorium were processed to recover 3.35 tons of thorium and 1.58 kg of uranium. Thorium and uranium losses to the aqueous waste were 1.7% and 0.5%, respectively. Gross gamma decontamination factors were 8×10^3 and 6×10^4 for the thorium and uraniun products, respectively.

Engineering flowsheets and equipment design were completed for a second solvent extraction cycle, which is necessary to achieve sufficient decontamination of the thorium product when irradiated thorium containing 2000-4000 g of U^{233} per ton is processed. The proposed second cycle consists of an extraction-scrub column and a thorium-stripping column. The feed is prepared by evaporating the first-cycle thorium product solution. The same extractant, 42% tributyl phosphate, is used as in the first cycle. Laboratory studies on this proposed second cycle indicate that 3-4 stages at an organic/aqueous flow ratio of 1/1 will strip approximately 99% of the thorium. Approximately 4% of the uranium in the second cycle feed will follow the thorium, which represents a loss of 0.03% of the U^{233} processed. (AEC Activity 2423)

Recovery of U^{235} - Preliminary building and equipment drawings for the U^{235} recovery plant proposed for Savannah River were completed. The dissolvers and the bulk of the feed preparation equipment are located in the directly maintained instead of the remote facility, as reported in ORNL-1886.

There are indications that the core of irradiated Savannah River tubular fuel elements will shatter and displace particles when sheared or folded for placement in the dissolver. The ductility of LITR fuel plates, whose composition is similar, was completely destroyed by irradiation to 23% burnup and was restored only partially by annealing at 975°F.

In a slab dissolver the same width but one-fourth the length approved by the Criticality Committee (ORNL-1886), 4-ft sections of Savannah River type elements (aluminum-clad 16% uranium--84% aluminum alloy) were continuously dissolved at a rate of 113 kg of aluminum, and about 11 kg of uranium, per day. The product was 1.6 M in aluminum and 1.6 M in HNO_3 and contained about 4 g of uranium per liter.

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The flooding rate of a 2-in.-dia solvent extraction pulsed-column (22 ft extraction, 4 ft scrub) was 823 gal/sq ft-hr with the above material adjusted to 1.8 M aluminum and 1.2 M HNO_3, with a feed/extractant/scrub flow ratio of 20/8/4, a pulse amplitude of 1 in., and a pulse frequency of 50 cycles/min. Under these conditions, with a 2-in.-dia column, uranium would be processed at a rate of 2.2 kg/day, with operations at 60% of flooding.

Fifty times the irradiation expected in the extraction column did not increase the emulsifying tendency or uranium retention of the proposed solvent, 6% tributyl phosphate in Amsco Special Naphtha No. 1, when the irradiation was given in five separate exposures to a Co^{60} source and the solvent was washed between exposures with Na_2CO_3, HNO_3, and water. Without washing, a similar irradiation led to a twofold increase in uranium retention, corresponding to a 0.02% stripping loss.

Emulsification in the extraction column was considerably decreased when the raw feed was made 2 M in HNO_3, boiled 2 hr, evaporated to remove excess acid, and diluted to the original volume with water.

Results of solvent extraction runs in the Mini-mixer-settler units, operated with feed 50% as radioactive as that expected in the process, showed that the proposed first-cycle chemical flowsheet (ORNL-1867) should yield gross beta and gamma decontamination factors of 5×10^4 and 1×10^4, respectively.

Washing of used solvent twice with 0.2 M Na_2CO_3 and once with demineralized water in a turbine mixer gave β and γ decontamination factors equal to those obtained in controlled laboratory-scale batch studies, 1.4×10^3 and 3.6×10^3, respectively. Samples of the effluent after each wash showed no solids or aqueous phase. (AEC Activity 2560)

PROGRAM 3000 - WEAPONS

Special Separations - Good enrichments were obtained for plutonium isotopes of masses 240 and 241 in the sixth separation run. While only 76 grams of plutonium was evaporated in the two-arc calutron, the $PuCl_3$ was converted to well-focused Pu^+ ions with a process efficiency of 5.6%. Assays of the Pu^{240} product are incomplete but the purity is expected to exceed 80%. Assay data for two batches of Pu^{241} product and for the irradiated plutonium feed are tabulated below.

	Abundance (At %)				Wt (mg)
	Pu 239	Pu 240	Pu 241	Pu 242	
Feed	87.96	10.8	1.13	0.1	-
Pu-241 Product, A	31.60	15.35	52.37	0.6	49.2
Pu-241 Product, B	32.43	20.22	46.7	0.6	25.8

(AEC Activity 3601)

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test - The HRT construction contractor completed all the work inside the reactor tank, including application of the protective coating (Amercoat 74) to the tank walls. The top shielding plugs are being received on schedule; roof girders and seal sheets are ready for installation. The chemical processing cells are 80% complete, with all the steel in place. All reactor components, except valves, are available for assembly of the low-pressure systems. High-pressure components are being finished on schedule. (AEC Activity 4109.11)

HRP Blanket Engineering Development - About one-third of the mockup of the thorium oxide blanket system for the HRT was completed. A test loop for the 200-gpm slurry pump was completed and successfully passed all "shakedown" tests. It is now ready for a six-month test of the pump.

Calcination of thorium oxide at 800°C produced a slurry with superior flow properties and little,if any change in abrasive properties.

In spite of the expenditure of considerable effort, no proven method was developed for preventing gradual sedimentation of ThO_2 in the 16-ft long horizontal HRT blanket dump tanks. It was tentatively concluded that vertical tanks must be used although several possibilities for the horizontal dump tanks are still being investigated.

A new relationship was developed for predicting the movement of steam through water, and it appears to be confirmed by experimental data covering the pressure range from atmospheric to 600 psi. This relationship indicates that a boiling slurry blanket for a large reactor may be a distinct possibility. (AEC Activity 4109.31)

HRP Chemistry--Fuel Studies - Additional exploratory studies of the solubility of UO_3 in alkali or alkaline earth carbonate solutions at 250°C, as a function of CO_2 partial pressure, indicate that neither the sodium nor magnesium system offers much chance of providing a satisfactory fuel solution. The uranium solubility in the sodium system was adequate (about 1.5 g U per liter) but, in order to achieve this solubility, the mole ratio of Na_2O to UO_3 had to be greater than 20. At all points tested in the magnesium system, the solubility of uranium was less than about 0.1 g per liter. The lithium system provides solubilities as high as 30 to 40 g U per liter with the ratio of Li_2O to UO_3 of about three. These observations offer some encouragement especially if one envisages the use of the lower cross section isotope of lithium. The corrosiveness of such solutions and their behavior under radiation have not been studied.

The study of the four-component system, CuO-UO_3-SO_3-H_2O, at 100° was nearly completed. The contour of the surface of the saturated liquid was determined for solutions containing from 4 to 25% total salt. The solid phase, in equilibrium with solutions from the copper side of the diagram to a line where the mole fraction of UO_3 of the total CuO plus UO_3 is roughly 0.65, is the compound antlerite, $3\ CuO \cdot SO_3 \cdot 2H_2O$. A binary mixture occurs along the line where the

UO_3 mole fraction of the total base is approximately 0.83, the solid phases being antlerite and $UO_3 \cdot H_2O$. Between a UO_3 mole fraction of 0.65 and 0.83 the evidence indicates the existence of a solid solution between antlerite and $UO_3 \cdot H_2O$. Above a UO_3 mole fraction of 0.83 the solid phase is probably α $UO_3 \cdot H_2O$. (AEC Activity 4109.31)

HRP Inorganic Solution Chemistry - In the continuing study of the ion exchange properties of a number of inorganic materials, principal emphasis was placed on the anion exchanger, zirconium hydroxide, and the cation exchanger, zirconium phosphate and zirconium tungstate. In dilute electrolyte solutions, exchange for all three materials appears to be reasonably ideal, i.e., the usual ion exchange mass action expressions are applicable. The capacities of the materials are high, of the order of the commercial organic ion exchangers. The exchangers have considerable acid stability and, at least at low temperature, may be used repeatedly without adverse effects. In some cases the materials show high selectivities. For example, essentially complete separation of rubidium and cesium can easily be effected with about 5-cm columns of both the phosphate and the tungstate. (AEC Activity 4109.31)

HRP Blanket Studies--Chemical Development - Approximately 1100 lb of thorium oxide, previously calcined at 650°C, was recalcined at 950°C in the pilot plant for engineering evaluation and corrosion studies. Approximately 1000 lb of thorium oxide was prepared by oxalic acid precipitation from the nitrate and calcination in three stages, the final temperature being 800°C.

The average particle sizes of oxides, prepared by calcination of thorium oxalate precipitated from nitrate solution, increased from 1 μ to 5 μ with increasing precipitation temperature (10-100°C) but did not change with increasing calcination temperature (400-900°C). The crystallite sizes, as measured by x-ray diffraction, increased with increasing calcination temperature and calcination time and could be correlated directly with the specific surface areas, measured by nitrogen adsorption. Oxides, pumped as slurries at 250-300°C, were degraded from an average particle size of 3-8 μ to less than 1 μ. The size distribution, originally logarithmic, was complex and polymodal after the pumping. The settled solid densities and relative dispersions of slurries, recovered after being autoclaved at 300°C with 0-10,000 ppm of sulfate in the presence and absence of 0.005 M $Na_4P_2O_7$, increased with increasing calcination temperature (650-1000°C) of the original oxides. Marked minima and maxima were observed in the "settled density" and relative dispersion with increasing sulfate concentration and decreasing pH, the effect becoming more pronounced with increasing calcination temperature.

In the presence of a thorium oxide slurry, containing 660 g of thorium per kilogram of H_2O and 0.01 m silver, about 34 moles of hydrogen per hour per liter combined with stoichiometric amount of oxygen at 270°C and 500 psi hydrogen pressure to give water. The addition of 0.5 wt % UO_3 and 0.5 wt % UO_3 plus 5000 ppm of sulfate decreased the catalytic activity of this slurry by about 50 and 75%, respectively.

Thorium oxide slurries irradiated for 30 days at room temperature in the Co^{60} source showed no change in bulk properties. (AEC Activity 4109.31)

HRP Valves and Miscellaneous Equipment - Construction and pre-testing of the valve test loop is essentially complete, and the system is ready for fuel operation with an HRT prototype dump valve.

The HRT mockup loop completed the water phase of its operation and has accumulated over 300 hours operating time with a uranyl sulfate solution. The water operation demonstrated adequate performance of all the system components and of the integrated apparatus. The uranyl sulfate runs were characterized by unexplained uranium losses and relatively high corrosion rates.

The 14-in. gas separator was tested with a new set of vanes larger than the HRT gas separator vanes. These larger vanes have only a single curvature and are, therefore, much easier to fabricate than the doubly curved vanes tested previously. The overall liquid pressure drop was about 2.5 psi (two equivalent inlet velocity heads) for flow rates of 5800 gpm of liquid and 125 cfm of air (standard conditions). The pressure drop from inlet to gas takeoff was 7 psi. The separator was not long enough to provide 100% gas separation but did remove from 90 to 95% of the gas. Due to the short distance between the vanes on this model (5 pipe diameters), the smallest bubbles (less than approx. 1/16-in. dia) did not have time to reach the void. A distance of 10 pipe diameters should provide sufficient time for about 99% gas removal. (AEC Activity 4109.4)

Core and Blanket System Development Studies - The development of a satisfactory procedure for making the final girth weld in the HRT pressure vessel was completed. Fabrication of the vessel is approximately 50% complete.

The Zircaloy-2 core vessel was satisfactorily tested at an internal hydrostatic pressure of 775 psi. (AEC Activity 4109.4)

Gas Handling Equipment - The high-pressure recombiner loop was modified so that the electrolytic gas was diluted with steam at the tops of the electrolytic cells. Although this eliminated the explosion problem, further difficulties were encountered with leaks and the entrainment of caustic. Installation of entrainment separators and replacement of faulty piping was begun.

A 20-cfm canned-rotor gas circulator, suitable for use in a high-pressure recombination system in the HRT, was ordered from the Allis-Chalmers Manufacturing Company, with delivery to be made in approximately seven months. Special features of the circulator include hydrostatic bearings, with the motor end running in water, and top accessibility for maintenance.

Testing of a 5-gpm ORNL pump, converted for use as a gas circulator, was continued for 3900 hours after an electrical failure. The unit accumulated a total of 5400 hours of operating time, circulating building steam at 110 psi and 170°C. (AEC Activity 4109.4)

HRP Fuel Circulating Equipment - All HRT-size development pumps have been received from Westinghouse. The 400A No. 2 volute casing, which was returned to Westinghouse for repair in November, was successfully repaired and is being assembled into a test loop. On the 400A No. 1 pump, an isolation ring and a grooved lower radial bearing were installed to provide adequate cooling. The pump completed a 1000-hour run with 0.13 m uranyl sulfate solution at 300°C. The only evidences of corrosive attack were on 1) the rear of the thermal barrier (old design), 2) the rear hub of the impeller, and 3) slight attack on the shaft where it passed through the shaft seal. No other corrosion or wear damage was observed. Some 220 reverse starts were accumulated on the pump; 100 of these were with 0.13 m uranyl sulfate solution. The pump has accumulated over 2600 hours of operation; about 2200 hours was with fuel solutions, and the balance was with water.

A 300-gpm pump accumulated over 500 hours of HRT mockup operation time on fuel solutions and water. The 230-gpm HRT blanket prototype pump accumulated 900 hours of operation on water in a test loop. "Back-water" injection of loop steam condensate was tested for a few hours, but the system has not yet been "debugged" for continuous operation.

Westinghouse has redesigned the thermal barriers for both the HRT and the development pumps. The thermal barrier design was ineffective in maintaining the region around the bearings at below 100°C while pumping 300°C fluid. The HRT pumps were delayed until new thermal barriers could be designed and fabricated.

Scott and Williams feed pumps were installed on the 4000-gpm loop. Oil traps, to protect the loop against contamination in the event of a rubber pulsator failure, are being installed, after which the loop will again be ready to run with fuel solution.

The HRT feed-pump system on the mockup was tested to determine the capacities and limitations of this feed pump under all HRT operating conditions. The system operated satisfactorily and logged over 1500 hours with only minor difficulties.

The slurry feed pump was tested as a high-pressure source of slurry for valve tests. Efforts are being made to improve the suction characteristics of the pump.

A 2000-psi, 5-gpm, ORNL pump was operated on water for about 1600 hours at 300°C; operation was interrupted several times by leaks. A 1000-psi, 5-gpm, ORNL pump was put back into test with a rewound electrical stator; the stator had failed after 6700 hours of service. The pump has accumulated a total of 6700 hours of operation on water.

An an attempt to increase the life of ORNL pump stators, one pump was put into test with the windings connected in series, rather than in parallel. The pump has run 2100 hours on water. (AEC Activity 4109.5)

HRP Heat Removal Equipment - Fabrication of the first HRT heat exchanger was completed, including a seal-welded channel closure. The unit successfully passed a helium leak test, a hydrostatic test, and 50 thermal cycles. The second exchanger is almost complete. Thermal cycling of the second unit is expected to start in early July.

A tube-joint welding procedure was developed and qualified by the Foster Wheeler Company and approved by ORNL. Cracking of the tube joint welds was experienced with the first exchanger. The trouble was studied, and a remedy was found by adding additional filler metal to the crater of the joint. The Foster Wheeler Company used a quality control program including re-qualification of welders at short intervals during the tube joint welding. ORNL inspectors observed almost all of the tube joint welds.

During fabrication of the second exchanger, a tube expander was broken during rolling. In removing the expander, the tube was damaged. Although the damage was not great, the tube was plugged to assure the integrity of the unit. (AEC Activity 4109.5)

HR Fuel Reprocessing - In dynamic loop studies the degree to which neodymium sulfate scaled out of a simulated fuel solution (0.02 m UO_2SO_4-0.005 m H_2SO_4) was a function of the wall temperature rather than of the temperature differential between the wall and solution as previously thought. The solubility of neodymium sulfate obtained under these conditions was 160 mg/kg H_2O at 285°C, which is considerably higher than the value reported (ORNL-1895) under static conditions.

ThO_2, used to simulate insoluble fission-product sulfates, remained suspended in a circulating test loop at room temperature, but at 300°C only about 1% of the solid remained in suspension. This indicates that the circulating loop is capable of trapping a sizable quantity of solids.

The performance of a full-scale HRT chemical processing plant evaporator was satisfactory in an extended series of runs in which the uranium concentration was increased from 10 to 875 g/kg H_2O.

Oxidized forms of iodine (hepta- and pentavalent) were rapidly reduced to the elemental state at 250°C in stainless steel or quartz systems. In stainless steel at equilibrium the concentration of iodine in the pentavalent and elemental states was about the same. In quartz the distribution was 7:1 in favor of the elemental form. With silver in the vapor phase above such solutions the half-time for transfer of iodine from the solution was only a few minutes.

In studies on blanket processing, up to 94% of the protactinium was leached from irradiated ThO_2 (prepared by oxalate calcination at 650°C) by refluxing with 14 N H_2SO_4 for 2 hr, filtering while hot, and washing with hot 14 N H_2SO_4. Although this procedure converted most of the ThO_2 to $Th(SO_4)_2$, only about 1% of the thorium was dissolved. In one experiment the sulfate content

of the ThO_2-$Th(SO_4)_2$ residue was reduced from 32% to 0.12% by calcining at 900°C for 16 hr. Calcination at lower temperatures was less effective; for example, in 2-hr calcinations, the sulfate content of one such residue was reduced from 14.9% to 0.56% at 870°C but only to 7.8% at 700°C. (AEC Activity 4109.81)

PACKAGE REACTOR DEVELOPMENT

Army Package Power Reactor - Fabrication of the fuel assemblies and control rods for the critical experiment is now in progress. Engineering drawings for the remaining structural elements were completed; fabrication should be completed in August. A program to check the kinetics of the reactor was completed for core constants proposed by the contractor, the American Locomotive Company. A final report will be released shortly. Two fuel irradiation experiments were placed in the MTR on June 20. The first is a set of small fuel plates each with different fuel particle sizes and the second a complete stainless steel fuel assembly adapted to fit into the MTR core. The two experiments will remain in the MTR a sufficient time to obtain a fuel burn-up similar to that expected from the APPR. The irradiated fuel plates will then be examined metallographically. (AEC Activity 4250

GENERAL REACTOR RESEARCH

General Reactor Radiation Damage - An optical absorption band in the ultraviolet region appears in Corning high-purity vitreous silica as a result of irradiation. Optical bleaching studies show that the broad band consists of two single absorption peaks, one of which bleaches more readily than the other. These peaks have been resolved approximately to give one at about 2120 Å and one, much more stable to ultraviolet light, at about 2570 Å. Before the sample was bleached the longer wave-length band appeared only as a slight bump on the absorption curve. The build-up of absorption at 2120 Å as a result of irradiation (x-rays, Co^{60} gammas, 1.8-Mev electrons, and probably pile neutrons) appears to follow a first-order growth law.

Continued fast-neutron bombardment of a group of natural crystals containing hybrid covalent-ionic binding gives increasing evidence for the wide differences in stability of various cation-oxygen bonds under neutron irradiation. In the order of decreasing stability under irradiation the bonds are (1) beryllium-oxygen, (2) aluminum-oxygen, (3) zirconium-oxygen, and (4) silicon-oxygen. This is also the order of decreasing ionic-bond character. (AEC Activity 4540)

Reactor Theory - A series of Oak Ridge Research Reactor calculations recently initiated will include calculations of (1) the flux distribution throughout the reactor for various fuel loadings, (2) beam hole currents, (3) critical masses, (4) control-rod effectiveness, and (5) poison effects. Thus far, the flux distribution for the proposed fuel loading and for asymmetric loadings has been determined.

Some investigations utilizing phenomenological theories of nuclei for reactor calculations were also initiated. These include: (1) applications of the "clouded crystal ball" model of the nucleus, in particular, calculations of inelastic scattering cross sections; (2) a calculation of the average absorption cross sections in the epithermal region; (3) a calculation of the temperature dependence of effective resonance integrals introduced by Doppler broadening of nuclear resonances; and (4) calculations of neutron-deuteron scattering lengths.

Improved multigroup calculations on the Oracle are being developed. Monte Carlo calculations of reactor parameters are in the coding stage. A master cross section tape for general use in Oracle calculations is in preparation. (AEC Activity 4570)

Basic Reactor and Shielding Research - Critical tests for the Pennsylvania State University Reactor were performed in the grid of the Bulk Shielding Reactor (BSR). A total of three water-reflected configurations were tested, in each of which the four proposed control rod positions were simulated. Except for the four partial elements through which the control rods moved, the basic configuration contained all full fuel elements (13). The total U^{235} content of this lattice was approximately 2.67 kg and the excess reactivity was about 0.5%.

The preliminary critical tests for the Aquarium reactor were performed in the grid of the BSR with BSR control rods and rod elements. The resulting configuration was essentially a 5 x 5 fuel element array, with two corners vacant; i.e., 20 full Aquarium fuel elements and three BSR rod elements. The total U^{235} content of this lattice was 3615 g and the excess reactivity was about 0.4%, as indicated by the regulating rod position. (AEC Activity 4570)

Dissolution Studies - In studies on dissolution of uranium and thorium in mercury as a means of recovering metal scrap without recourse to the usual nitric acid dissolution, solvent extraction, and bomb-reduction procedures, both uranium and thorium metals dissolved in boiling mercury. The dissolution of uranium was limited by its solubility, 1 atom %, in mercury at 360°C. No such limit has yet been established for the thorium-mercury system. In both the uranium and thorium systems, a crust of mercuride formed on the metals after prolonged digestion. The crusts were $U(Hg)_4$ and $Th(Hg)_3$, respectively, according to chemical and x-ray data. (AEC Activity 4581)

ISOTOPE PRODUCTION

Stable Isotope Production - Nitrogen isotopes (masses 14 and 15) were successfully separated by collecting the isotopes on either magnesium, uranium, aluminum, or sodium placed in the collector pocket. Retention of nitrogen on these materials is still unsatisfactory, being only about 10%. The surface temperature at the point of ion impact is not favorable to the formation of stable nitrides with the metals tried.

The processing of tellurium isotopes (masses 120, 122, 123, 124, 125, 126, 128, and 130) was completed. An estimates 213 grams of separated isotopes was collected. Both copper and aluminum pockets were used; retention of tellurium is better in the aluminum pocket.

Exploratory separations were performed with argon, molybdenum, and vanadium to evaluate charge materials and collectors.

Separation of high-purity lithium isotopes (masses 6 and 7) is in progress. These are "second-pass" separations, using enriched charge materials, from which products having less than one part in 10^5 isotopic contamination are anticipated. These highly enriched lots will be used for mass analysis standards.

Both Ru^{98} and Ru^{104} were placed in the inventory for the first time. New lots of Ru^{98}, Ru^{99}, Ca^{48}, Rb^{85}, Ta^{180}, Cr^{50}, Cr^{52}, Cr^{53}, and Cr^{54} were added to the inventory. (AEC Activity 5121)

PHYSICS

Scintillation Spectrometry for Nuclear Energy Level Determinations - The nuclear level structure of Sr^{88} was studied through measurements of the gamma radiation following the decay of 17.8-min Rb^{88} and 104-day Y^{88}. Three gamma rays in Y^{88} were found with energies of 1.850 ± 0.008, 0.909 ± 0.004 and 2.76 Mev and with relative intensities $1.09 \pm 0.05 : 1 : 0.005 \pm 0.003$. Besides these transitions, gamma rays of 1.39, 2.11, 2.68, 3.01, 3.24, 3.52, 3.68 and 4.87 Mev from Rb^{88} were resolved and fitted into a level scheme with the assistance of coincidence spectroscopy with the cylindrical 3 by 3 in. NaI(Tl) crystals, in conjunction with the multichannel analyzers. By comparison of the intensity of the total number of beta rays to the intensity of the 1.85-Mev gamma ray, it was determined that $75.9 \pm 5\%$ of the beta ray transitions from Rb^{88} went directly to the ground state of Sr^{88}. Parity assignments were made to all the levels in Sr^{88} from the comparative half-lives of the beta ray transitions, as determined from the gamma-ray intensities. The spins of the first two excited states of ${}_{38}Sr^{88}_{50}$, at 1.85 and 2.76 Mev, seem to be consistent with single particle configurations of $(p^{-1}_{3/2}\ p_{1/2})_{2+}$ and $(p^{-1}_{3/2}\ g_{9/2})_{3-}$ for the last two protons. In addition, the energy separation between these levels is very nearly that of the $p_{1/2}$-$g_{9/2}$ levels in the neighboring odd proton nucleus ${}_{39}Y^{89}_{50}$. (AEC Activity 5200)

Scintillation Spectrometry for Medical Use - Transmission measurements were made on the focussing collimator which was developed for the medical spectrometer and described in a previous report. This collimator, designed for a 2-in. NaI crystal and a 2-in. working distance, gives a transmission of 58% at a distance of 2-in. from the end of the collimator and 52% at the maximum counting rate distance of 1-1/2 in. Another focussing collimator was designed and constructed for a working distance of 3 in. It was necessary to design this collimator for a 3-in. NaI crystal in order to reduce the number of holes to a practical value; the collimator has 61 tapered hexagonal holes. The transmission is expected to be about 46% at the 3-in. working distance with a sensitive circle about one centimeter in diameter. The medical spectrometer has been in continuous successful use at the ORINS medical hospital and has given good results for both scanning and iodine uptake measurements.

A scintillation surgical probe was designed and constructed by using the sub-miniature filamentary tube technique; its first use in an actual operation produced very sharp localization. The probe is 1/4 in. in diameter and 3-3/8 in. long. The response is a variable frequency audio note which varies (with counting rate) over a range of 75 to 1. This method of indication was found satisfactory to all the surgeons who were present at the operation. (AEC Activity 5200)

High Voltage Physics - The experiment for detecting fission neutrons in coincidence with fission fragments (ORNL-1715) was continued with runs at several neutron energies in the range 0 - 5 Mev. For this set of runs a 10-mil cadmium sheet was installed between the recoil counter and the fission counter. This prevents those background neutrons which give recoil pulses from being slowed down below 0.5 ev and producing fissions; at this reduced energy the probability of fission is higher. Also, the thermal calibration was made with 100-kev T(p,n) neutrons partially moderated with a 3/4-in. layer of water and Lucite. The ratio of $\nu(E)$ to ν_{th} at 1, 4, and 5 Mev was found to be 1.15 $\pm$ 0.12, 1.26 $\pm$ 0.14, and 1.31 $\pm$ 0.14, where the errors are statistical. Since these results are somewhat lower than the preliminary results reported previously (Reactor Science and Technology, Vol. 4, 141, 1954), there may have been an effect due to the slowing down of recoil neutrons. The new data are in good agreement with the original theoretical estimate of the variation of ν with energy (ORNL-1374).

Neutrons were produced in the $T(d,n)He^4$ reaction by bombardment of a tritium gas target with deuterons from the 5.5-Mv electrostatic generator. The monoenergetic neutron spectrum was observed in a radiator-type triple-coincidence spectrometer consisting of two proportional counters and a NaI crystal. With both a target thickness and deuteron energy increment of 50-100 kev the 0-deg cross section was measured from E_d = 0.9 to 5.8 Mev. No sharp resonance was observed within this energy range. In the center of mass system (c.m.) the cross section continues to drop with increasing energy from the well-known resonance at 107 kev up to 3 Mev and then rises steadily, increasing by 30% from 3 to 5.8 Mev. Angular distributions were measured from 0 deg to 150

deg at E_d = 0.98, 1.53, 2.20, 3.05, 3.97, 4.98, and 5.79 Mev. A forward peak, which is slight at the lower energies, becomes steadily sharper with increasing energy. At 5.79 Mev the peak (0-deg) to valley (100-deg) cross section ratio is 5:1 in the c.m. system. Beyond 100-deg the cross section rises by less than a factor of two. At no energy is there symmetry about 90-deg.

The $Li^6(He^3,p)Be^8$ reaction is being studied in an attempt to find any weak low-lying levels in Be^8 which may have been missed in earlier work. A target having 92% Li^6 and 7.5% Li^7, in sulfate form, was bombarded with 1-Mev He^3 ions. Particle groups were studied with a CsI crystal and a 100-channel serial memory analyser. In addition to the ground state and 3-Mev state in Be^8, weak lines arising from the $Li^7(He^3,p)Be^9$ contamination reaction were observed. Targets having lower Li^7 content will be available in the near future. Nothing attributable to levels in Be^8 other than the ground state and the 3-Mev state has been found so far.

Further work was done on the angular distributions of the gamma-rays excited by Coulomb excitation in the nuclei of cadmium. The spin of 2 for the first excited state of Cd^{116}, Cd^{114}, Cd^{112}, and Cd^{110} was established. The angular distribution of the γ-rays from Cd^{114} was measured at six different incident proton energies to provide more extensive information on the variation of angular distribution with incident proton energy.

The Coulomb excitation of the palladium isotopes was measured by using targets made of enriched stable isotopes. The following γ-rays were observed: Pd^{110}, 374 kev; Pd^{108}, 433 kev; Pd^{106}, 513 kev; Pd^{105}, 440, 322 and 280 kev; and Pd^{104}, 555 kev. The reduced transition probabilities for quadrupole excitation were determined for the four even-even nuclei.

The threshold for excitation of the 0.8-sec isomeric state in Zr^{90} was measured with neutrons from the T(p,n) and Li(p,n) reactions. The values are in close agreement and give the threshold as 2.35-Mev. The γ-ray energy spectrum was measured with an anthracene scintillation detector. A single γ-ray of 2.32-Mev was found. This is additional evidence that the 0.8-sec activity results from excitation of a state at 2.32-Mev by inelastic neutron scattering.

The cross section for the reaction $Be^9(n,\alpha)He^6$ was measured from threshold (E_n = 700-kev) to 3.0 Mev. The absolute cross section at one energy was determined to an accuracy of $\pm$ 20%. The cross section rises smoothly and attains the value of 100 millibarns at 3.0-Mev neutron energy. The cross section for this reaction is of interest in reactor work since it is a possible mechanism by which a reactor may become poisoned. (AEC Activity 5200)

<u>The 86-Inch Cyclotron, Operation</u> - In the original design of the beam deflector system the magnetic channel was placed so as to intercept the deflected beam 4 in. closer to the edge of the poles. An attempt to shim the magnetic field to compensate for the disturbances introduced by the channel and to provide the desired radial fall off near the channel was unsuccessful due to space limitations. The channel was then raised 2 in. to obtain a more

desirable radial fall off in the magnetic field, and the field was shimmed to minimize the first harmonic. Orbit tests were repeated with a current-carrying wire, in tension, to simulate a proton beam in the magnetic field. The change in channel position and the reduction in current in the channel coil from 5000 amperes to 4000 amperes increased the estimated radial width of the proton beam 80% at the intermediate target chamber. Magnetic field tests were completed, and vacuum testing and installation of r-f components are in progress. (AEC Activity 5200)

Electronuclear Machines - A magnet to be used in analyzing reaction products produced by the ORNL 63-Inch Cyclotron is being constructed. The yoke and pole assembly, complete with three sets of pole tips, is being fabricated by the Permanent Magnet Company of Indianapolis; delivery is expected in July. The coils, regulating equipment and vacuum system were designed and are now being fabricated and assembled. The motor-generator set is already installed. (AEC Activity 5200)

The 63-Inch Cyclotron--Physics - The measurements of the angular distribution of N^{13} from the reaction $N^{14} + N^{14} \rightarrow N^{13} + N^{15}$ were completed at energies of 16 Mev, 19 Mev, and 23 Mev. As is expected from the effect of neutron crossover, the peak of the angular distribution moves forward with increasing energy. Differential cross sections of the elastic scattering of nitrogen on nitrogen, neon, argon, and krypton were measured. A NaI scintillation particle spectrometer was developed for experiments involving light particles produced by nitrogen bombardment; it has a resolution of 3.5% for 8-Mev alpha particles. The excitation functions for nitrogen-induced reactions in aluminum are being investigated; chemical separation methods are required. (AEC Activity 5200)

Spectroscopy Research Laboratory - Molecular parameters for vinyl fluoride were determined; the C=C bond distance is 1.338 A, C-F distance 1.327 A, and dipole moment 1.416 Debye. A 130-curie T_2O sample was synthesized and its three fundamental molecular vibrations observed; results agree approximately with theoretical calculations of W. F. Libby. The Zeeman effect of a sample of Po^{210}, prepared at the Mount Laboratory, was observed at 20,000 oerstads, and new information on quantum properties of the atomic energy states obtained. Methods of attaining fields up to 40,000 oersteds with low pressure discharge type sources were perfected. K x-ray wavelengths of eleven elements from Br through Ag were used to calibrate a GE XRD-3 unit from 1043 to 564 X units; L spectra of uranium were measured to better than 0.05 X units. Crystal spacings of LiH and LiD were measured as 4.085 and 4.065 A, respectively. (AEC Activity 5200)

Research and Development--Stable Isotopes - Special services included preparation of approximately 30 grams each of $H_3B^{10}O_3$ and $H_3B^{11}O_3$ by conversion of the $BF_3 \cdot CaF_2$ complex to BCl_3, followed by hydrolysis of the BCl_3 and crystallization of the resulting H_3BO_3. In order to fill a special request, thirty grams of elemental B-10 was converted to B_2O_3 by oxidation with HNO_3, crystallization of the resulting H_3BO_3, and dehydration of the H_3BO_3.

Preliminary investigations of the methods for obtaining targets of elemental tungsten and titanium indicated that a suitable procedure could be worked out for each: (1) a powder metallurgical technique for the tungsten, involving reduction of WO_3 with hydrogen before pressing; (2) a reduction of $TiCl_3$ with magnesium to give metallic titanium, followed by an acid extraction of any excess magnesium before drying and pressing the resulting powder. (AEC Activity 5200)

Mass Spectrometer Laboratory - The isotopic abundances of technetium isotopes formed by cyclotron bombardment of natural molybdenum were determined in the mass spectrometer and found to be:

Mass	Abundance (%)	Limit of Error, 95% (%)
95	(0.05)	
97	56.0	0.4
98	17.3	0.2
99	26.7	0.2

The presence of Tc^{98} after 270 days cooling proves the existence of a long-lived Tc^{98} which was suspected but previously unproved.

The isotope dilution method of analysis was used to measure the Ru^{100} which had grown in a sample of Tc^{99} which had been irradiated in the MTR for one year. It was found that the Ru^{100} present was 2.0% of the technetium originally present.

A method of isotopic analysis was perfected for C^{13}. The carbon sample is oxidized to CO_2 for the analysis; the primary problem was to obtain a supply of oxygen free from CO_2. The problem was solved by decomposing mercuric oxide and combining it with the carbon sample in quartz equipment.

The program of renovation of the existing 8-in. radius mass spectrometer is 70% complete. (AEC Activity 5200)

CHEMISTRY

Nuclear Chemistry - Quantitative measurements were completed on two short-lived fission product isotopes: 17.8-min Rb^{88} and 15.4-min Rb^{89}. Gamma-rays of energies 0.908, 1.39, 1.85, 2.11, 2.68, 3.01, 3.24, 3.52, 3.68, and 4.87 Mev were resolved and fitted into a level scheme for Sr^{88}, with the assistance of gamma-gamma coincidence spectroscopy. The decay of 15.4-min Rb^{89} was found to excite gamma-ray transitions in Sr^{89} of 0.13, 0.69, 1.03, 1.23, 1.54, 2.26, and 2.65 Mev energy. The 4.87-Mev gamma-ray in the decay of 17.8-min Rb^{88} is of interest in that it appears to be the most energetic gamma-ray yet observed in the decay of a uranium fission product. (AEC Activity 5300)

Chemical Physics - The studies of surface ionization of alkali metals on tungsten and platinum were extended to include lithium, rubidium, and cesium. These elements appear to follow the Saha-Langmuir equation on tungsten but seem to be partially reflected from platinum. They are thus like potassium but unlike sodium, which on platinum appears to follow the Saha-Langmuir equation with no reflection.

A series of measurements of the low-temperature heat capacities of various technetium and rhenium compounds was initiated with the calorimetric apparatus described in detail in ORNL-1828. Recently, Re_2O_7 was measured over the temperature range 15° to 300°K. No anomalies were observed in the heat capacity variations. This measurement is of interest in that it constitutes the first of such determinations on any stable heptoxide. Technetium heptoxide is scheduled for measurement in the near future. (AEC Activity 5300)

Radio-Organic Chemistry - A previously reported anomolous p-tolyl/phenyl migration ratio of <1 in the deamination of 2-phenyl-2-p-tolylethyl amine was shown to be incorrect. The new ratio, determined by two independent methods, is 1.22-1.25.

The alpha and beta forms of 1,2-diphenyl-1-p-tolylethylene glycol were shown to rearrange in formic acid to yield 88% of p-tolyldesoxy-benzoin and 12% p-tolylbenzhydryl ketone. The yields of these same products were 85% and 15%, respectively, when concentrated sulfuric acid was used as the catalyst. Less than 5% secondary hydroxyl removal occurred under either of these conditions. (AEC Activity 5300)

Radiation Chemistry - An experiment on the alpha particle-induced polymerization of benzene vapor at 100°C is in progress. The logarithm of total gas pressure decreases as a straight line function of the quantity of radon remaining until the pressure is about 1/3 of the original pressure. The pressure continues to drop at a decreasing rate until the total pressure is about 1/10 of the original pressure after which there is a slow pressure increase. This would indicate that the polymerization of benzene is accompanies by a gas evolution which becomes more pronounced as the benzene pressure is decreased. The evolved gas is largely if not completely uncondensed in liquid nitrogen.

The polymer is a yellow liquid when first formed and progressively changes into a dark brown material, thence into a white solid.

The velocity constant, based on total pressure drop, is 36.1, which compares with a value of 40.4, obtained by Mund in 1925. (AEC Activity 5300)

Chemistry of Fused Salts - The density and specific electrical conductance for molten sodium bromide and cesium iodide were measured over somewhat more than 200°C temperature ranges. The heats and entropies of activation for equivalent conductance were calculated from the experimental data for these two salts. A survey of all data obtained to date for alkali halides shows

that in general the heat of activation for equivalent conductance varies linearly with temperature. The sign of this variation depends upon the cation while its magnitude depends upon the anion. The entropy of activation for all alkali halides is nearly temperature independent and in the range of -6 to -7 cal./mole·deg.$^{-1}$. Reasonably satisfying interpretations of these effects have been evolved.

Further work was done on determining the dissociative and associative equilibria in dilute solutions of cadmium chloride and lead chloride in molten sodium nitrate and potassium nitrate. The common ion effect was amply substantiated in these molten salt solutions. It was demonstrated that a chlorocadmium complex exists which contains at least four chlorines per cadmium. (AEC Activity 5300)

Chemistry Math and Computation - The parameters in the osmotic coefficient equation were estimated by a direct least-squares fitting of molality as a function of log activity of H_2O (by Deming's method). The code for the Oracle accepts isopiestic data and initial estimates, and punches out final estimates, sum of squares, and inverse matrix of normal equations. (AEC Activity 5300)

Uranium Chemistry of Raw Materials - In a previously described process for recovering uranium from acid sulfate leach liquors, the uranium was extracted with di(2-ethylhexyl) phosphoric acid in 98% kerosene - 2% capryl alcohol and subsequently stripped with a sodium carbonate solution. Although the presence of alcohol caused an appreciable reduction in the uranium extraction coefficient, it was included in the solvent to prevent formation of a third liquid phase, containing the sodium salt of the extractant, during the stripping operation. In recent tests, it was observed that tributylphosphate can be used, in place of alcohol, to prevent third-phase formation during stripping. In addition, the uranium extraction coefficients are higher when tributylphosphate is present than when the di(2-ethylhexyl)-phosphoric acid is used alone.

In continued studies on amines as solvent extraction agents, it was found that uranium can be separated effectively from thorium in sulfate liquors by extracting the uranium with a symmetrical tertiary amine. Good separations were also obtained with secondary amines.

A preliminary comparison of stripping agents for the amine extraction process was made. Considering the reaction rate, reagent requirement and number of stages, the estimated cost of a sodium chloride stripping operation is 7¢/lb U_3O_8 less than a sodium carbonate stripping procedure. (AEC Activity 5300)

Equipment Decontamination Studies - The scale which resulted from contact of acidic uranyl sulfate solutions on type-347 stainless steel at 250°C was readily removed by hot solutions of oxalic acid, with the rate of removal being dependent on the oxalic acid concentration. For essentially complete scale removal at 87°C, a 6-hr contact with 8% oxalic acid or 18-hr contact

with 0.5% oxalic acid was required. The corrosion of an unscaled sample of type-347 stainless steel in 5% oxalic acid at 87°C for 52 hr was less than 1 mil per year.

After oxalic acid is used to descale and decontaminate stainless steel it can be destroyed with H_2O_2. Since the reaction products are CO_2 and H_2O, the resulting solution can be greatly reduced in volume to minimize waste storage. The reaction rate constant for oxalic acid decomposition at 86°C was determined as 0.013 per minute per mole of H_2O_2, or, in other words, the half time of decomposition is 50 min in 1 M H_2O_2. (AEC Activity 5300)

Power Reactor Fuel Element Dissolution - STR-type fuel elements, which consist of a core of zirconium-uranium alloy clad with Zircaloy-2, were attacked by molten (800°C) zinc at a penetration rate of 10 mils/hr when the Zn/Zr atom ratio was 10/1. With a ratio of 5/1, the penetration rate was slower. The resultant metal mixture appeared homogeneous on cooling and in both cases was brittle. Both mixtures dissolved readily in nitric acid, but when the atom ratio was 5/1 an insoluble residue remained.

Zirconium was dissolved in hydrofluoric acid by a process in which the fluoride complex formed initially was reacted with a second complexing agent, oxalic acid, thereby releasing the fluoride ion for further dissolution. Zircaloy-2 dissolved at a rate of 0.172 mg/cm^2-min to give a solution 3 M in oxalic acid, 0.054 M in hydrofluoric acid, and 0.16 M in zirconium. The dissolution rate decreased as the oxalic acid concentration of the dissolvent decreased. With citric, tartaric, and sulfuric acids and with 2, 4-pentanedione, the dissolution rate was much less than with oxalic acid.

Nichrome alloy was reported previously (ORNL-1886, p. 19) to be readily dissolved in concentrated nitric acid by anodic electrolysis. Further studies indicated that dissolution takes place with a 100% current efficiency in nitric acid between 10 M and 0.5 M. Electrolytic dissolution in chromic acid was also demonstrated; the resistance of this electrolyte was higher than that of the nitric acid. (AEC Activity 5300)

Analytical Research - In connection with the work of the HR corrosion group, the difference in the spectral absorption of dichromate and chromic ions was utilized satisfactorily for the simultaneous determinations of hexavalent and trivalent chromium in nitric acid solutions. The large differences in the molar absorbancy indexes for Cr^{+6} and Cr^{+3} at wavelengths of 350, 480 and 576 mμ, respectively, make it possible to calculate the ion constants for the mutual interferences of the two species, thus obviating the necessity of using simultaneous equations to make this evaluation. By means of this procedure, concentrations as low as 5 μg of Cr^{+6} and 10 μg of Cr^{+3}/ml can be determined simultaneously. The interferences of aluminum, trivalent iron, divalent nickel, and hexavalent manganese were also evaluated.

A method was developed for the spectrophotometric estimation of 5 to 60 μg/ml of disodium ethylene diamine tetra-acetate in aqueous medium. It was found

that in a buffer solution of 0.1 M Na_2HPO_4, at pH 11, the intensity of the color of the complex obeys Beer's law at a wavelength of 250 mμ. The degrees of interference of such diverse ions as Ni^{++}, Co^{+}, Cr^{+6}, Cr^{+3}, Fe^{+3}, Fe^{++}, Ca^{++} and Mg were also established. This procedure is being applied in following the entrainment problems associated with the testing of components for the HR project.

Of a number of methods examined for the determination of low concentrations of nitrite in mixed solutions of nitric and sulfuric acids, the spectrophotometric method of Shinn (Ind. Eng. Chem., Anal. Ed., 13, 33, 1941) as modified by Keshaw and Chamberlain (Ind. Eng. Chem., Anal. Ed., 14, 312, 1942) proved to be quite satisfactory. Sulfanilamide and n-napthylethylenediamine dihydrochloric are used to develop the color which has a maximum absorbance at a wavelength of 550 mμ. In mixed solutions of 1 M sulfuric acid and 0.1 M nitric acid, concentrations of nitrite as low as 0.1 μg/ml can be determined with a coefficient of variation of about 1%.

It was shown that boron in concentrations of the order of 5 to 30 μg/ml in aqueous solutions, containing five times as much fluoride as boron, can be determined accurately by the application of the spectrophotometric, carminic acid method of Hatcher and Wilcox (Anal. Chem., 22, 567, 1950). Boron in water extracts of solutions of BF_3 in organic solvents can be estimated directly without the necessity of refluxation to complete hydrolysis of fluroborates or of the distillation to isolate the boron. The coefficient of variation is of the order of 5%.

A polarographic method for determination of europium in strontium ores was developed and a series of such ores are being examined for the presence of this element. The method uses direct polarography on the samples at pH 5 and is sensitive to 0.005% europium. The ores are dissolved either in HCl, or fused with Na_2CO_3, then dissolved in HCl. The excess HCl is neutralized with NH_4OH prior to polarographing.

METALLURGY

Ceramics Research - Compatibility tests between hydrogen at 0.15 Mach number and high density graphite (1.8 gm/cc) at approximately 2400°C interface temperature show a corrosion-erosion loss of only 0.0001 gm/sq in.-cc. The corrosion-erosion loss was substantially the same for helium as for hydrogen under similar test conditions. Test control rod shapes 1 in. long by 1.275 in. I.D. and 1 in. long x 1.275 in. O.D. - 0.775 in. I.D. were prepared from a mixture of Gd_2O_3-Sm_2O_3 by cold pressing and firing to 1500°C for one hour followed by precision grinding. Dielectric constant measurements, made on Sm_2O_3 and Al_2O_3 or Fe_2O_3 and Ca_2O_3 and Al_2O_3 or Fe_2O_3 (equal weights) pressed into 1/2-in. discs 20 mils thick and fired to 1500°C, gave values in the range 6.0-22.5; power factor values range from 0.1 to 8.6. Eu_2O_3 discs 1/2-in. in diameter, 20 mils thick, fired at 1200°C and 1500°C showed an increase in density from 4 to 7 gm/cc. Heat experiments indicate energy requirements

of about 0.01 watts/cc would be necessary to bring a ceramic mass to 850°C in an insulated pit 20 ft dia. by 10 ft deep. This information is of interest in a scheme to dispose of radioactive waste by mixing it into a ceramic body and sintering it in place in such a pit. (AEC Activity 5400)

Physical Metallurgy of Reactor Materials - In connection with a study of the effect of fast-neutron bombardment on the magnetic properties of semiconductors, it was found by fitting curves of the carrier contribution of the susceptibility vs reciprocal temperature that, for unirradiated n-type germanium, a statistical weight of four best describes the data in the range of transition from classical to Fermi-Dirac statistics. Cyclotron resonance studies have established that energy surfaces in the conduction band of germanium can be represented as ellipsoids of revolution oriented along the [111] directions in k space. Since there are eight equivalent [111] directions, there would be eight ellipsoids if the energy minima fall within the Brillouin zone, but only four if the minima lie near a zone boundary. This result is taken as tentative evidence that four ellipsoids best describe the states of the conduction band in germanium.

A low-temperature facility for the study of radiation damage was installed in the ORNL Graphite Reactor. The cryostat can be operated indefinitely at 20°K with an A. D. Little Co. helium refrigerator to provide helium gas as the coolant. A study was made of the effect of reactor bombardment on the electrical resistivity of copper single crystals. It was found that, to a high degree of precision, the change in resistivity is directly proportional to the neutron flux. From values of the rate of change of resistivity, the fast-neutron flux, and the calculated resistivity of vacancy-interstitial pairs it was determined that about 20 displacements are produced per knocked-on atom, a factor of 5 smaller than the computed results of Snyder and Neufeld. Low-temperature annealing studies indicated that 45% of the change in resistivity was recovered at 35°K. There are indications from the shape of the annealing curve that this low-temperature annealing is the result of the motion of interstitial atoms. Approximately 50% of the resistivity appears to be associated with the movement of interstitial atoms as evidenced by the recovery at 35°K; about 25% of the change is associated with vacant lattice sites (further recovery at 243°K); the remainder of the resistivity change anneals at 700°K and is associated with interstitial atoms and vacant lattice sites trapped at dislocations. (AEC Activity 5400)

Fundamental Physico-Metallurgical Research - A high degree of purification of zirconium was achieved by zone refining Grade 1 crystal bar. Neutron activation analyses for nickel and iron were made at various positions along the length of the rod, and refining factors of 2 to 3 were observed. Isothermal annealing in the vicinity of the α/β transition temperature confirms the purification reported by analyses; for example, it was sufficient in one lot of zirconium to reduce the temperature range of the transition from 40 to 15°C.

Recent results in the study of phase diagrams are as follows:

1. In Zr-Ag, the higher solubility of silver in α zirconium with increased zirconium purity is supported by a new determination of the $\alpha/\alpha+\beta$ boundary from 0% Ag at 857°C to 1.0% Ag at 810°C.

2. In Zr-In, the solubility limit of the alpha phase at 555°C was found to be 5 $\pm$ 1 at. % In. An x-ray spectrometric investigation of the alpha phase alloys showed that the lattice spacing varied approximately linearly with indium content, and without an inflection such as has been reported for Ti-Al and Ti-Ga.

3. In Zr-Pb the α/β boundaries were found to be convex upwards. The slope decreases appreciably at about 1% Pb. A similar but smaller change in slope in the α/β boundaries of Zr-In occurs at about 2% In. This curvature is the opposite of that observed in Ti-Al.

4. In view of the normal behavior of the Zr-In spacings and the different nature of the curvature of phase boundaries, it would appear that the Brillouin Zone effect hypothesized for titanium does not occur at the same electron concentration in zirconium as in titanium.

The fiber axis distributions were determined for aluminum rods extruded at 850°F and at the rates of 0.3 and 738 fpm. The most preferred crystallographic directions of the fiber axis in the rod extruded at the slower rate were <111> and <001>, the former component constituting 30% and the latter 70% of the volume. The most preferred direction of the fiber axis in the rod extruded at the faster rate was 2 deg from the <118>; this rod was completely recrystallized as-extruded.

The fiber axis distributions of aluminum rods extruded at slow rates (0.1 - 0.3 fpm) at temperatures of 450°, 650°, and 850°F were independent of temperature. Specimens taken from the back sections of these rods had duplex <111> - <001> textures with 25 to 30% of the volume being associated with the <111> component. There appears to be a strong temperature dependence of the fiber texture in aluminum rods extruded at fast rates (615 - 738 fpm) at the same temperatures. The back section of the rod extruded at 450°F had a duplex texture of 50% <111> and 50% <001>. A specimen taken at a comparable position from the rod extruded at 850°F was completely recrystallized and had a <118> fiber axis. (AEC Activity 5400)

PROGRAM 6000 - BIOLOGY AND MEDICINE

BIOPHYSICS

Radiation Dosimetry - In a monoatomic substance it is considered that a moving atom of energy E displaces an atom of the medium if upon collision the energy loss y exceeds a threshold $\alpha \sim 25$ ev but that the striking atom replaces it if $E - y < \alpha$. Thus the number of vacancies is not equal to the number of atoms displaced or "knocked out" from their original sites. The number of displaced atoms has been calculated by the authors (Phys. Rev. 97, pp 1637-46) and the methods used there were applied to calculate the number of vacancies. It is found that, in general, the number of vacancies is about 2/3 the number of displaced atoms and is, for velocities of the initial atom $< e^2/\hbar$, given by $E/3\alpha$. (AEC Activity 6520)

Education, Training and Consultation - The 20 students who have AEC Fellowships in Radiological Physics completed their academic training at Vanderbilt University and reported to the Laboratory on June 7 to begin their field training in the Health Physics Division. (AEC Activity 6720)

RADIOISOTOPE SALES AND COSTS

TYPE OF TRANSACTION	MAY 1955	FY 1955 TO DATE
Domestic Sales	$135,040	$1,129,603
Foreign Sales	16,352	58,483
Project-Cash Sales	3,260	54,844
Project-Transfer	12	1,743
Technical Cooperation Program Credits	0	1,510
Plant Credits	2,695	28,592
Civilian Defense Credits	130	235
Cancer Program Credits	23,089	226,929
*Miscellaneous	0	58
Total Income	$180,578	$1,501,997
**Income - No production costs incurred Subtract from total income	*** 13,386	55,541
Radioisotope Income	$167,192	$1,446,456
Radioisotope Costs	76,080	900,150
Radioisotope Shipments	1,203	11,678

* Miscellaneous - Freight and Missing Parts

** Income from H^3, He^3, B^{10} and miscellaneous items in excess of handling costs.

***$3,797 subtracted from total income due to error in April Report.

GROSS OPERATING COSTS

	Cost for May	FY 1955 Cost to Date
Programmatic Operating Cost - Net	$3,083,263	$28,686,404
Plant and Equipment Cost	278,418	2,934,839
Program "H"	51,864	287,272
Work for Other Parties - Transfers	38,734	410,527
Inventory Changes	48,262*	217,840*
Reimbursable Work for Other Parties	237,589	1,964,317
Deferred Charges	15,148*	9,093*
Total Laboratory Cost - Net	$3,626,458	$34,056,426
Estimated Cost for Next Month - Net	$4,350,000	$38,406,426

*Credit

[redacted]

PERSONNEL SUMMARY

	Number of Employees June, 1955	New Hires June	Terminations June
Administration	66	4	0
Operations*	125	3	1
Engineering, Shops and Mechanical	739	15	4
Laboratory and Research	2075	160	26
Protection	143	0	0
Service	379	8	0
	3527	190	31

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

A total of 868 Laboratory personnel are located in the Y-12 Area.

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Previous reports in this series:

June 1954	ORNL-1748
July 1954	ORNL-1760
August 1954	ORNL-1781
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

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