

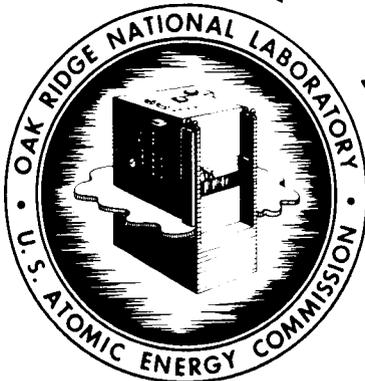
# AEC RESEARCH AND DEVELOPMENT REPORT

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OAK RIDGE NATIONAL LABORATORY  
STATUS AND PROGRESS REPORT  
OCTOBER 1956



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STATUS AND PROGRESS REPORT

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

October, 1956

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 2000 - SPECIAL NUCLEAR MATERIALS

ORNL Health Physics Research--Boston - On the basis of preliminary data obtained from six patients injected to date with soluble U<sup>233</sup> compounds, it has been shown that the relationship between the body burden of uranium (q) and the uranium excretion rate (q̇) can be expressed as a power law of the form

$$\dot{q} = -\lambda q^n$$

The parameters of this expression,  $\lambda$  and  $n$ , have been determined to give a best fit to the human data. This equation is now being used on a routine basis to interpret the urinary excretion data of production workers exposed continuously to high inhalation levels of soluble compounds of uranium in air. (AEC Activity 2120)

Thorex Process - The design of a new U<sup>233</sup> isolation system for the thorex pilot plant was completed. It incorporates a new upflow sorption--downflow elution ion exchange flowsheet together with improved criticality, shielding, and sampling features.

Development work was continued on the thorex coextraction flowsheet (ORNL-2166), in which uranium and thorium are extracted and stripped together in the first cycle and partitioned in the second. Decontamination of thorium was almost as high as in a conventional two-cycle flowsheet and uranium decontamination was much better than in the one-cycle uranium flowsheet. No difficulties were encountered during laboratory-scale, counter-current batch extractions. A sand filter in combination with a glass wool filter removed solids that formed during extraction and agglomerated and removed the dispersed phase. The addition of recycled thorium nitrate to the scrub solution increased the saturation of the TPB and improved the decontamination.

Used solvent that had been washed with carbonate was decontaminated by a factor of 2 by passage through a column of 14-28 mesh alumina. When unwashed used solvent was treated similarly, the alumina removed contaminants normally removed by the carbonate. Solvent that was used repeatedly with I<sup>131</sup>-containing feeds and treated after each use did not build up an iodine content after the first use.

PROGRAM 2000 - SPECIAL NUCLEAR MATERIALS (Continued)

In laboratory experiments the Thorex U<sup>233</sup> product was decontaminated from ruthenium by a factor of 75-100 by ion exchange following nitrite treatment. The addition of 0.1 N NaNO<sub>2</sub> to a uranyl nitrate solution containing fission products, followed by heating at 70-80°C for 0.5 hr, converted the ruthenium to a form that was not sorbed on cation-exchange resin but did not affect uranium sorption. The decontamination factor was only 2 in a control run in which the nitrite treatment was omitted. (AEC Activity 2423)

PROGRAM 3000 - WEAPONS

Special Separations - Purification and assay of the products from the tenth separation of plutonium isotopes were completed. A summary of the results is as follows:

	Isotopic Abundance (at.%)				Wt (g Pu)
	Pu <sup>239</sup>	Pu <sup>240</sup>	Pu <sup>241</sup>	Pu <sup>242</sup>	
Feed	87.0	11.5	1.3	0.2	83.0
Pu <sup>240</sup> Products					
Batch-1	19.1	79.7	1.0	0.2	0.348
Batch-2	29.0	69.2	1.6	0.2	0.020
Pu <sup>241</sup> Products					
Batch-1	37.8	16.7	43.9	1.5	0.057
Batch-2	38.2	36.9	23.9	1.0	0.003

Two more plutonium isotope separations were made; the feed for the first was 143 gram of plutonium assaying 13.1% Pu<sup>240</sup>, and 1.61% Pu<sup>241</sup>; and for the second, 150 grams of very highly irradiated plutonium assaying 29.7% Pu<sup>240</sup>, 4.3% Pu<sup>241</sup>, and 0.9% Pu<sup>242</sup>. The products are being analyzed. The process efficiency was considerably lower than usual (1% vs 5-7%) but information obtained should permit improvements in future operations.

The fabrication of plutonium fuel elements for irradiation in the MTR is proceeding satisfactorily. One control-rod-type assembly for long-time irradiation was shipped to Idaho. The fuel bearing sections for two more were completed and the finished control rods will be shipped by December 1. Production of the four fuel elements for short-term irradiation is proceeding as scheduled. These elements should be completed by mid-January. (AEC Activity 3610)

## PROGRAM 4000 - REACTOR DEVELOPMENT

### HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test - The reactor system was test-operated with oxygenated water on a 7-day, 24-hour-per-day schedule for the entire month. The reactor system was operated for the purpose of performing tests on the dump control system. Two dumps were made; one with the system at 210°C and 750 psig, and the other at 235°C and 1500 psig. As a result of these measurements, it is expected that the time required to bleed off overpressure from a system temperature of 280°C will be approximately 15 min. This time compares favorably with the results recently obtained from the dump test with the mockup but is several minutes longer than had been previously predicted.

In the course of this operation, much difficulty was experienced with the performance of the diaphragm-type purge pumps. The reactor system was shut down to make extensive revisions in the piping associated with these pumps, as well as to make repairs in the high-pressure steam heating system. Following these repairs, the system was operated at the design point of 280°C and 2000 psig. (AEC Activity 4103.3)

HRT Chemical Pilot Plant - Operation of the high-pressure system with oxygenated water at 250°C and 1250 psi was begun and proceeded normally during six two-day periods of continuous operation; proposed procedures for operation in conjunction with the reactor were simulated. A series of runs is under way with uranyl sulfate solution at a nominal concentration of 10 g/liter.

Delivery of the tantalum-lined dissolver is scheduled in two weeks. Design of the low-pressure-system modifications, which includes, besides the dissolver, two decay storage tanks and a sampler, is 65% completed. Shop fabrication of components for this system is under way. (SEC Activity 4103.1)

HRT Fuel Processing - The hydroclone circuit effectively removed solids from the HRT mockup loop. Solids were concentrated in the underflow by factors of ~1000, and concentrations of about 1 mg/kg H<sub>2</sub>O were maintained in the loop for long periods of time. The concentration of solids injected into the loop was halved in 1.2 hr; 2.5 hr was required when the hydroclone was not operating.

In a full-scale power reactor, neutron poisons must be removed from the hydroclone underflow prior to recycle of the uranium. Scouting tests indicated the feasibility of (1) removing precipitated fission and corrosion products at 25°C, (2) recovering and decontaminating uranium by precipitation as UO<sub>4</sub>, and (3) dissolving the UO<sub>4</sub> in D<sub>2</sub>SO<sub>4</sub>. This could be done in a heavy-water system. In laboratory tests, 99.9% of the uranium was precipitated as UO<sub>4</sub> from 0.17 m UO<sub>2</sub>SO<sub>4</sub>--0.35 m NiSO<sub>4</sub>--0.1 m H<sub>2</sub>SO<sub>4</sub> with H<sub>2</sub>O<sub>2</sub> at pH 1.5-2.0. Decontamination from Nd<sup>147</sup> tracer in mixed rare earths was 16; the UO<sub>4</sub> contained about 1% Ni. UO<sub>4</sub> was also precipitated with Na<sub>2</sub>O<sub>2</sub>, but a pH of 2.5 was required for 99.9% recovery. The Nd<sup>147</sup> decontamination factor was 7.6; the UO<sub>4</sub> contained 4% Ni.

In laboratory experiments, simulated HRT Chemical Plant solids were dissolved without mechanical agitation in two complete cycles of digestion with

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

10.8 M  $\text{H}_2\text{SO}_4$ , dilution, and digestion with 4 M  $\text{H}_2\text{SO}_4$ . Three cycles were needed on a unit operations scale. Dissolution in 85%  $\text{H}_3\text{PO}_4$  was satisfactory on a small scale with volume ratios that can be used in the HRT.

The equilibrium valence distribution of iodine in simulated  $\text{UO}_2\text{SO}_4$  fuel at  $100^\circ\text{C}$  was affected by the irradiation intensity and the gas-phase composition. Increasing the irradiation intensity or the mole fraction of  $\text{H}_2$  in the gas increased the proportion of elemental iodine in the solution. At Vitro Laboratories, in a loop so constructed that iodine could be stripped from a circulating  $\text{UO}_2\text{SO}_4$  solution at  $230^\circ\text{C}$  and 1000 psi by a gas stream, 13-15 min was required to halve the iodine concentration of the aqueous phase. The half-time for reduction of iodate to free iodine was 0.1 min. At  $100^\circ\text{C}$  the elemental-iodine distribution coefficient between vapor and liquid was 0.005 for water at pH 4.15 and 0.31 for fuel solutions. There was some evidence that ferric ion or ruthenium affected the distribution. (AEC Activity 4103.1)

Plutonium Producer Blanket Processing - Gradual addition of plutonium to 1.4 m  $\text{UO}_2\text{SO}_4$  at  $250^\circ$  in a pyrex-lined autoclave under 100 psi  $\text{O}_2$  and 200 psi  $\text{H}_2$  confirmed previous results in that no  $\text{PuO}_2$  precipitated while the plutonium concentration was gradually increased to 26 mg/kg  $\text{H}_2\text{O}$ . When the concentration reached 28 mg/kg  $\text{H}_2\text{O}$ , however, partial precipitation occurred, leaving 22 mg/kg  $\text{H}_2\text{O}$  in solution, mostly as Pu(IV). In a titanium container there was no precipitation as the concentration was increased to 21 mg/kg  $\text{H}_2\text{O}$  in solution. In type-347 stainless steel, no  $\text{PuO}_2$  precipitated up to 33 mg/kg  $\text{H}_2\text{O}$ , and the plutonium was all oxidized to Pu(VI). However, at 37 mg/kg  $\text{H}_2\text{O}$ ,  $\text{PuO}_2$  precipitated, leaving only 7.5 mg/kg  $\text{H}_2\text{O}$  [all Pu(VI)] in solution. Apparently, the Cr(VI) present from stainless steel corrosion oxidized the plutonium.

Pu(IV) in 1.4 m  $\text{UO}_2\text{SO}_4$  at  $25^\circ\text{C}$  is stable; however, when heated to  $90^\circ\text{C}$ , about 30% of the plutonium disproportionated to Pu(III) and Pu(VI). It therefore seems unlikely that appreciable concentrations of Pu(IV) can exist in 1.4 m  $\text{UO}_2\text{SO}_4$  at  $250^\circ\text{C}$ .

A Westinghouse pump (A13-A 1, 1 gpm - 100 ft head, the HRT Chemical Plant prototype) has performed satisfactorily in 1400 hr operation. Explosion tests of the P-1 loop pressurizer demonstrated that rupture would not result from a  $\text{H}_2\text{-O}_2$  explosion with 66% steam--34% stoichiometric  $\text{H}_2\text{-O}_2$  at  $265^\circ\text{C}$  and 1700 psig. (AEC Activity 4103.1)

Thermal Breeder Blanket Processing - Scouting tests indicated that irradiated  $\text{ThO}_2$  may be processed by dissolving it in concentrated phosphoric acid at  $230^\circ\text{C}$  and then passing the diluted solution (4.5 M  $\text{H}_3\text{PO}_4$ ) through a cation exchanger to sorb the rare earths. Upon dilution to 3.5 M  $\text{H}_3\text{PO}_4$  both thorium and protactinium were precipitated, leaving uranium in solution. When these solids were dissolved in dilute nitric acid and a small amount of zirconium nitrate was added, zirconium phosphate precipitated and carried the protactinium. (AEC Activity 4103.1)

## PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

Homogeneous Reactor Thorium Blanket Studies - A slurry of mixed thorium-uranium oxide, 750 g Th/kg H<sub>2</sub>O, 0.5 mole % U<sup>235</sup>O<sub>3</sub>, prepared by calcining the coprecipitated oxalates at 800°C, containing 0.15 m MoO<sub>3</sub> was irradiated in the LITR at 300°C for 314 hr at a radiation power density of 7 watts/g ThO<sub>2</sub>. The viscosity, 13 centistokes, was constant and there were no stirring difficulties. The viscosities of unirradiated thorium and thorium-uranium oxide slurries, determined in the dash-pot-stirred bomb, were essentially independent of temperature from 25 to 300°C but increased from 13 to 19 centistokes with increasing sulfate concentration to 3000 ppm.

A radiolytic-gas recombination rate of ~10 moles H<sub>2</sub>/hr-liter of slurry is required to hold the blanket pressure at 2000 psi. Addition of 0.05 m MoO<sub>3</sub> to a thorium-uranium oxide slurry and activation with H<sub>2</sub> at elevated temperatures increased the combination rate of a H<sub>2</sub>-O<sub>2</sub> mixture over the slurry from a very low value to >30 moles H<sub>2</sub>/hr-liter of slurry at 225°C and 500 psi H<sub>2</sub> partial pressure. Addition of 1000 ppm iron (based on ThO<sub>2</sub>), as the oxide, to the slurry decreased the combination rate at 150°C, but rates were satisfactory at slightly higher temperatures. With 1500 ppm iron, the combination rate was 3 moles H<sub>2</sub>/hr-liter. The rate increased greatly when this slurry was treated with H<sub>2</sub> at elevated temperatures, but decreased on subsequent treatment with O<sub>2</sub>.

Sulfuric acid titration curves of the "standard" slurry (pumped thorium oxide, 500 g Th/kg H<sub>2</sub>O) showed no increase in specific surface activities as a result of the pumping, although the surface area was almost doubled. Mild stirring in laboratory glassware at 98°C readily degraded the microspheres characteristic of this material and markedly increased the slurry conductivity.

The settling rate of a ThO<sub>2</sub> slurry is an exponential function of the thorium concentration. A calculated Stokes diameter for settling particles which did not change with temperature was obtained by extrapolating to zero concentration curves of settling rate vs slurry concentration obtained with the "standard" slurry for a series of temperatures. Sulfate, 500-1000 and 5000 ppm, greatly increased the hindered settling rate of the standard slurry at 150-200°C. In sulfate titration curves the regions of temperature instability bracketed the break in the pH curve, and at pH 7, in the presence of sulfate, settling rates were relatively low and temperature stability was good. (AEC Activity 4103.1)

HRP Chemistry--Fuel Studies - By means of experiments carried out in sealed quartz tubes, the number and types of phases present in the system CuO-UO<sub>3</sub>-SO<sub>3</sub>-H<sub>2</sub>O at 304°C are being ascertained. The work has been completed for solutions containing no excess H<sub>2</sub>SO<sub>4</sub>.

Experiments with dilute solutions in the system UO<sub>2</sub>SO<sub>4</sub>-CuSO<sub>4</sub>-NiSO<sub>4</sub>-H<sub>2</sub>SO<sub>4</sub>-H<sub>2</sub>O in titanium bombs disclosed that at least 20 hr is required to establish equilibrium in the "green precipitate" region at about 200°C. Previously reported temperatures of initial precipitation obtained in quartz-tube experiments in which equilibration times were limited to only about 15 min were too high by as much as 20 to 50°C. (AEC Activity 4103.1)

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

Slurry Component Development and Slurry Testing - Examination of samples of "standard" slurry withdrawn from the 200-A loop during initial circulation revealed progressive growth of small spheres of about 8 to 20  $\mu$  in diameter during the first 100 hr of circulation.

Chemical analysis of the cake removed from the 200-A pump at the end of run 200-A-9D indicated the presence of very little sulfate in the part of the cake near the wall, leading to the conclusion that some caking in the pump scroll must have occurred prior to the addition of sulfate.

Design of a test facility for development of high-pressure diaphragm-type pumps for use with slurry was completed. (AEC Activity 4103.1)

Special Slurry Problems - A 750 g Th/kg  $H_2O$  slurry containing 0.3 wt % sodium silicate (based on total weight of slurry) was boiled for one month without adverse effect on its fluidity or resuspendability. Slurry of this composition was also circulated in a T-loop at 300°C for 92 hr and found to be easily resuspendable on starting the pump after a shutdown of several days. (AEC Activity 4103.1)

Slurry Blanket System Development - The blanket test system, converted to low-pressure operation with the blanket vessel and low-pressure heat exchanger in place, was subjected to about 300 hr of water shakedown runs. During this time personnel were trained in operating the system, and various corrections and improvements were made in the system. Provisions were made to estimate the  $ThO_2$  distribution in the blanket by measuring the radiation attenuation from a gamma source placed centrally in the core and scanned along part of a meridian on the outside of the pressure vessel.

Heat transfer from core to blanket with water circulation was measured as 212 Btu/hr-ft<sup>2</sup>-°F. (AEC Activity 4103.1)

Fuel Circulating Equipment - The 400A-1 pump with a titanium impeller and a titanium insert in the thermal barrier has been operated for 4400 hr without trouble since the thermal barrier was seal-welded. This operation has been at 250°C with a solution of 0.04 m  $UO_2SO_4$ , 0.005 m  $CuSO_4$ , and 50 mole % excess  $H_2SO_4$ . The pump has now been operated for a total of about 9700 hr.

The 300A-1 pump has been operated for approximately 4983 hr since both the thermal barrier and the main flange were seal-welded. This operation has included 4590 hr with uranyl sulfate solution at 280 to 300°C. An increase in solution concentration in the motor cavity was noted, indicating possible leakage around the seal weld or excessive shaft seal wear or corrosion.

The 400A-2 pump was fitted with a 1/16-in.-wide, gold-plated, solid stainless steel thermal-barrier gasket. The pump was subjected to a series of ten thermal cycles on water with no indication of leakage.

The 20-scfm canned-motor blower passed the specified performance test at Allis-Chalmers and is now ready for installation in a loop at ORNL.

## PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

An annealed 0.019-in. diaphragm and a 1/4-hard 0.031-in. diaphragm, both type-347 stainless steel, have operated on water for 1541 and 611 hr, respectively, in feed pump loop No. 1.

A prototype HRT purge pump has accumulated 5330 hr during a current endurance run while operating continuously at 200 psi and 200 strokes per minute. (AEC Activity 4103.1)

Miscellaneous Equipment - The freeze-jacket test equipment was operated to determine maximum leak rates at 2000 psi pressure and at temperatures below 300°C.

The prototype HRT sampler limit switches for flask-holder position and isolation-chamber stem position were found to operate satisfactorily.

Preliminary design has begun on a 400-gpm titanium test loop. (AEC Activity 4103.1)

Heat Removal Equipment - A contract for fabrication of the spare HRT heat exchanger was awarded to Babcock and Wilcox Co. The vendor was given permission to increase fuel holdup to 31 gal if, by so doing, the accessibility of the tubes can be increased and the tube stresses can be reduced.

A program was initiated to investigate the effects of different tube-joint designs on the stress-corrosion problem. (AEC Activity 4103.1)

Gas Handling Equipment - The high-pressure recombiner loop was operated for 90 hr as part of a study of the effect of H<sub>2</sub> adsorption on titanium and Zircaloy-2. (AEC Activity 4103.1)

Solution Systems Development - The HRT mockup has operated for 1353 hr during the current run at 280°C and 1400 psi without requiring maintenance shutdowns. (AEC Activity 4105.1)

### PACKAGE POWER REACTOR PROGRAM

Army Package Power Reactor (APPR-1) - The Laboratory continued to furnish technical support to the Army Reactors Branch on the APPR-1 plant being constructed at Fort Belvoir, Virginia, by Alco Products, Inc. Overall construction is approximately 70% complete. Installation of the secondary system is essentially finished, and delivery of the reactor pressure vessel and other components of the primary system is expected soon.

It was discovered that the stainless-steel clad on the first loading of fuel assemblies had become sensitized during fabrication and that some assemblies had been attacked intergranularly by HNO<sub>3</sub>-HF cleaning solution. Corrosion tests indicate that sensitized clad is adequate for conditions encountered in the APPR-1 reactor provided it has not been subjected to intergranular attack by other chemical agents. Since it is not possible to determine conclusively which of the completed assemblies were subjected

## PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

to the corrosive cleaning solution during fabrication, it was decided to fabricate additional fuel assemblies for the initial reactor loading. Fabrication of these assemblies by the Laboratory is proceeding satisfactorily, with completion of the initial loading scheduled by December 1.

Critical experiments performed by Alco Products, Inc. with APPR-1 fuel assembled indicated that the clean reactor has about 4% more reactivity than anticipated. Consideration was given to increasing the boron content of the fuel matrix, but it was decided by Alco that a change in specifications was not necessary.

Irradiation of APPR-1 fuel and control-rod absorber samples in the Materials Testing Reactor continued. One absorber sample which had been irradiated to about 50% burn-up showed a small but significant increase in thickness (0.155 in. to 0.161 in.). A full-scale APPR-1-type control rod absorber section was prepared for irradiation in an MTR fuel-shim position beginning in November. (AEC Activity 4201.1)

Gas-Cooled Reactor Development - Design of the proposed gas-cooled loop for use in the Oak Ridge Research Reactor is about 50% complete. Equipment layouts were started, and work is continuing on design provisions for insertion and removal of samples. An alternate design of the in-pile section is being investigated which may make possible the elimination of the secondary helium coolant system.

Nineteen industrial firms submitted proposals for design and construction of the AEC Gas-Cooled Reactor Experiment. The Contractor Selection Board, to which the Laboratory provided technical assistance, selected Aerojet-General Corporation of Azusa, California, and a contract is currently being negotiated. (AEC Activity 4201.1)

### GENERAL REACTOR RESEARCH

Radiation Damage -- Advanced Engineering and Development - Copper single crystals were subjected to irradiation with 1.2 Mev  $\text{Co}^{60}$  gamma rays at room temperature. This irradiation causes an increase in the Young's modulus and a decrease in the internal friction. These effects are quantitatively consistent with an interpretation based on the pinning of dislocation lines by lattice defects which migrate to the dislocation line from the point where they were originally produced by Compton electrons and photoelectrons resulting from the incident gamma rays. Comparison with previous work shows that for each primary displaced lattice atom only one-eightieth as many pinning points result from the gamma-ray bombardment as from bombardment with fast neutrons; this result is in satisfactory agreement with the calculations of higher-order displacements for the two cases. (AEC Activity 4540)

Basic Reactor Research -- Experimental and Theoretical - Plans are now being formulated for a critical assembly, in the new bay of the Critical Experiment Facility, which will operate with resonance energy (variable from about 1 to 100 kev) neutrons. Research will include measurements of fission-product poisoning, nuclear properties of fissile elements, and other nuclear properties of interest in this energy region. Moderation will probably be

## PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

achieved with fluorine and carbon; highly enriched uranium will be used. Considerable effort is being made to design a simple system by the elimination of reflector and control-rod inhomogeneities in so far as possible.

Revised calculations for the proposed stainless steel core for the Bulk Shielding Reactor show that the clean, cold critical mass for a 5 by 5 in. lattice, using 20-plate elements with 20-mil meat and 5-mil cladding, would be 5.62 kg. This weight corresponds to a uranium content of 13.4 wt %  $UO_2$  in the meat. The critical mass for a 7.56-mil meat, which corresponds to 25 wt %  $UO_2$ , would be 4.1 kg.

An automatic "start" feature and automatic safety devices for unattended reactor operation were added to the BSR controls. (AEC Activity 4520)

Radiation Detector Development - Measurements of the response of a 9.4-in.-dia. NaI(Tl) crystal to 2.76-Mev gamma rays incident normally on its conical end showed unexplained anomalies in the pulse height spectrum. In order to determine if these effects are due to the conical geometry, a 2-in.-dia. replica of the large crystal was cut for another measurement with lower energy gamma rays. The large crystal is intended for use in a new gamma-ray spectrometer of high sensitivity. (AEC Activity 4370)

Power Reactor Waste Disposal Engineering Studies - To measure the concentration of condensation nuclei produced by boiling radioactive wastes at the Aerosol Entrainment Well, a General Electric Condensation Nuclei Meter was tested against the condensation nuclei cloud chamber developed at ORNL. A heterogeneous NaCl aerosol containing particles from  $10^{-7}$  cm to  $10^{-4}$  cm in diameter was used for the tests and the G. E. Condensation Nuclei Meter readings were reproducible to  $\pm 20\%$ . The advantages of using this instrument are (1) it is portable, (2) requires no electric power, and (3) reads directly the concentration of nuclei per cubic centimeter of air in the concentration range of  $2 \times 10^2$  to  $1 \times 10^7$  nuclei/cc. (AEC Activity 4630)

## PROGRAM 5000 - PHYSICAL RESEARCH

### ISOTOPE PRODUCTION

Isotope Separation - The processing of calcium (masses 40 and 48) and boron (masses 10 and 11) was completed. Each of these was a special type of separation.  $Ca^{40}$  of purity in excess of 99.995% was produced from normal calcium feed in a single-pass operation; 8.25 grams was produced. The processing of high purity boron-10 and boron-11 was accomplished separately by using previously enriched feed ( $BF_3 \cdot CaF_2$ ) for each isotope. The purity has not been determined; estimated quantities of  $B^{10}$  and  $B^{11}$  collected are 3.7 grams and 6.5 grams, respectively. Palladium (masses 102, 104, 105, 106, 108, and 110)

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

is being separated; the metal is heated to approximately 1700°C in an ion source heated by electron bombardment. Li<sup>6</sup> of 99.999% purity is being separated in multi-gram quantities from feed enriched in Li<sup>6</sup>; a similar separation of Li<sup>7</sup> is beginning. (AEC Activity 5121)

Isotope Chemistry - New lots of enriched S<sup>33</sup>, Ca<sup>40</sup>, Rb<sup>87</sup>, Sr<sup>86</sup>, Sr<sup>88</sup>, Cd<sup>114</sup>, Te<sup>123</sup>, Te<sup>125</sup>, Te<sup>126</sup>, Te<sup>128</sup>, Te<sup>130</sup>, Ba<sup>130</sup>, Ba<sup>132</sup>, Ba<sup>134</sup>, Ba<sup>135</sup>, Ba<sup>136</sup>, Ba<sup>137</sup>, Ba<sup>138</sup>, Dy<sup>161</sup>, and Dy<sup>165</sup> were chemically refined and added to the inventory. Returned samples of enriched Sr<sup>88</sup>, Ba<sup>135</sup>, Ba<sup>137</sup>, Ba<sup>138</sup>, and Sm<sup>148</sup> were chemically reprocessed and made available for distribution.

Targets of Sr<sup>86</sup>, Sr<sup>88</sup>, and Rb<sup>85F</sup> were encapsulated in silver containers for cross section measurements by the Laboratory's Van de Graaff time-of-flight group. (AEC Activity 5121)

PHYSICS

Scintillation Spectrometry and Instrument Development - A new amplifier was developed for scintillation spectrometry; it has overload characteristics suitable for use with very large detectors. This amplifier, called the A-8, recovers from a 4000-times overload signal in about 8 μsec. There is no positive base line excursion after the main pulse. It uses the double delay line differentiation principle, has a gain of 13,500 in the main amplifier and an extra factor of 1, 3, or 10 in the preamplifier. The gain control range is by factors of 2 over a total range of 64. Rise time is about 0.18 μsec. The output stage is capable of driving a 1000-ohm load to greater than 100 volts in both directions. The power requirement is about the same as for an A1 amplifier.

The intrinsic peak efficiencies of the following NaI(Tl) crystals were measured for the energy range 0.320 - 1.18 Mev.

<u>Diameter</u>	<u>Length</u>	<u>Well Diameter</u>	<u>Well Depth</u>
3"	1"	-	-
3"	2"	-	-
3"	3"	-	-
2"	2"	-	-
1 3/4"	2"	5/8"	1 1/2"
3"	3"	1/2"	1 1/2"

This is a continuation of a program of efficiency measurements. The detailed efficiency vs energy curves are given in the Physics Division Semiannual Progress Report for period ending September 20, 1956, ORNL-2204. (AEC Activity 5220)

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

Scintillation Spectrometry - Experimental - The radiations from the decay of  $\text{Nb}^{90}$  were studied with coincidence scintillation spectrometers and a magnetic spectrometer. The information obtained together with published data yields a level scheme showing states at 1.75 Mev ( $0^+$ ), 2.19 Mev ( $2^+$ ), 2.32 Mev (probably  $5^-$ ), 3.07 Mev, 3.45 Mev, and 3.59 Mev. By using an independent particle model, and assuming a delta function interaction between the protons outside the closed shell of 40 nucleons, it is possible to calculate the energy levels for this nucleus; there is qualitative agreement between the predicted and experimental level order if the last three states above have the spins and parities  $4^+$ ,  $6^+$  and  $8^+$ . These assignments are consistent with the experimental branching ratios for transitions from these states. Work is in progress to attempt to establish, experimentally, the spins of these states. (AEC Activity 5220)

High Voltage Program - Doubly ionized helium ions were accelerated to 9 and 10 Mev with the ORNL electrostatic generator to attempt Coulomb excitation of the even isotopes of tin and the states of  $\text{Zr}^{92}$  and  $\text{Zr}^{94}$  known to be at 920 keV. Weak excitation was observed. The transition probabilities for decay of the 920-keV states of  $\text{Zr}^{92}$  +  $\text{Zr}^{94}$  is 6 times the independent particle estimate for an E2 transition. The average transition probability for the even isotopes of tin (excitation energy  $\sim 1200$  keV) is 12 times the independent particle estimate for an E2 transition.

By use of a calibrated assembly of  $\text{BF}_3$  counters, the absolute p,n cross sections of  $\text{Cl}^{37}$ ,  $\text{Cr}^{53}$ ,  $\text{Co}^{59}$ , and  $\text{Se}^{77}$  were measured for threshold to 500 keV above threshold. At 100 keV above threshold the average cross sections of these four reactions are 4, 0.3, 0.3, and 0.32 mb, respectively. The  $\text{Se}^{82}(\text{p},\text{n})\text{Br}^{82}$  threshold is less than 970 keV, and the  $\text{Nb}^{93}(\text{p},\text{n})\text{Mo}^{93}$  threshold is less than 1310 keV.

Two Sb-Be photoneutron sources which had been calibrated against the National Bureau of Standards Ra-Be photoneutron source on dates separated by 265 days were compared by observing the activity produced by each in a  $\text{MnSO}_4$  solution. This comparison indicates an  $\text{Sb}^{124}$  half-life of  $60.1 \pm 0.5$  days.

A 5-ft graphite sphere was constructed for use as a flat-response neutron detector. The neutron producing reaction or source is placed at the center of the sphere and thermal neutrons are counted near the surface with  $\text{B}^{10}\text{F}_3$  proportional counters. The inverse relation of source and counters was not used because of concern over the energy dependence of air and room scattering. A 4 by 4 in. hole used to introduce proton beams from the Van de Graaff was shown by a plugging test to have a  $+0.55 \pm 0.68\%$  effect on the counting rate from a central source. Displacements of a central source affected the counting rate by  $+0.14 \pm 0.08\%$ /cm. As the neutron mean free path is about 2.1 cm, this indicates that source or reaction asymmetries should not change the efficiency appreciably. The gamma ray sensitivity is low enough to permit counting a half-curie,  $10^6$  n/sec, antimony beryllium source at the center (though not near the surface) of the sphere. Intercomparison of two Sb-Be sources standardized at the Bureau of Standards on different dates gave a half-life of  $60.3 \pm 0.5$  days for the antimony. Most of the error derives from the NBS results. The indicated efficiency from these calibrated sources is  $2.5 \pm 0.1$  percent.

## PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

From data obtained with protons on thin targets of LiF and ZrT, the response of a bare  $B^{10}F_3$  counter was compared to that of the flat efficiency detector for neutrons in a narrow forward cone produced near threshold. The comparison indicated a  $1/v$  or slightly steeper dependence of the  $B^{10}(n,\alpha)$  cross section from 30 to 70 kev within a few percent. Yield curves near threshold were also observed for the two targets. The shape of the  $Li^7(p,n)$  yield is suggestive of another weak resonance at 4 or 5 kev above threshold. (AEC Activity 5220)

86-In. Cyclotron, Nuclear Physics - Studies of inelastic scattering of 23-Mev protons were continued. The upper 4 Mev of the spectra of all elements of atomic number 40-52 were resolved into three energy groups; the regularity of energy and cross section vs atomic number was pronounced. The spectra for Pb and Bi were found to be identical up to  $-Q = 7$  Mev. Six groups were resolved and found to have essentially identical energies, cross sections, and angular distributions.

Studies of the  $Ni(p,2p)$  reaction revealed that the outgoing protons are mostly of very low energy ( $\leq 5$  Mev); angular correlations between the two outgoing protons are not large. (AEC Activity 5220)

86-In. Cyclotron, Applied Physics - Energy measurements made with stacked copper foils indicate that the energy of the protons on an internal target at a radius of 30.5 in. is 20.8 Mev, with the full width at half maximum 1.0 Mev. The isotopes  $Al^{26}$ ,  $As^{74}$ ,  $Ce^{139}$ ,  $Be^7$ , and  $Sr^{85}$  were produced in service bombardments for outside customers. In addition,  $F^{18}$ ,  $Bi^{207}$ ,  $Mn^{54}$ ,  $Sr^{85}$ , and  $Y^{88}$  were produced for use within the Laboratory. (AEC Activity 5220)

86-In. Cyclotron, Operations - An analyzing magnet was installed in the path of the 23-Mev protons deflected from the 86-in. cyclotron. The magnet bends the beam 15 deg before it enters the reaction room; thus, a second external target installations is available in the room. At the new position the energy gradient is 1.2 Mev/in.

The cyclotron now operates "beam on target" slightly more than 50% of the scheduled 80-hr week. This includes one or more changes per day from internal to external (deflected) beam operation. (AEC Activity 5220)

63-In. Cyclotron, Physics - Spectra of  $\alpha$ -particles, tritons, deuterons, and protons from the nitrogen bombardment of lithium-6 were measured. The yield-energy relationships for light products from nuclear reactions which result in the residual nucleus  $F^{19}$  have now been determined for three different reactions,  $Be^9(N^{14},\alpha)F^{19}$ ,  $Li^7(N^{14},\alpha)F^{19}$ , and  $Li^6(N^{14},p)F^{19}$ . The results are being compared with predictions of the statistical theory of nuclear reactions. The importance of excited states in the angular distribution of  $N^{13}$  from the reactions  $Mg^{25}(N^{14},N^{13})Mg^{26}$  was investigated; it was found, for example, that at 80 deg in the barycentric system about 20% of the reactions proceed to a state of  $Mg^{26}$  higher than 5 Mev. (AEC Activity 5220)

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

Spectroscopy Research Laboratory - A Perkin-Elmer Model-21 double-beam infrared spectrophotometer was received, tested, and calibrated over the range 0.5 to 40 microns. A simple vapor fractometer, for infrared and microwave studies of gas fractions, was constructed and tested successfully with adsorption type (silica gel, molecular sieve) and partition type (Tide, Formamide) columns of 4-foot lengths. New measurements of the hyperfine splittings of  $\lambda$  5915 Å in  $U^{233}$  and  $U^{235}$  yielded a magnetic moment ratio  $\mu^{233}/\mu^{235} = 1.63$  and an electric quadrupole ratio  $Q^{233}/Q^{235} = +0.802$ . Design tests, using an optical analog, were made on the 33-ft gamma-ray collimators for reactor components; it was concluded that the alignment may be resolved by optical procedures and is not as critical as had been supposed. An experiment to investigate the internal bremsstrahlung of pile produced  $Ga^{71}$  from a 200-mg sample of  $GeO_2$  containing 96%  $Ge^{70}$  was concluded; self-excited K lines of  $Ga^{71}$  were detected but the continuum was too weak to measure.

Two additional spectral regions of the Echelle-Littrow spectrograph, Quartz 4 (2700 to 4000 Å) and Quartz 2 (3200 to 6500 Å), were calibrated; zero field spectra of Te I and Te II, with  $Te^{130}$  in an electrodeless discharge tube, were measured in the range 2700 to 6500 Å. Landé g factors were obtained for an additional 10 levels of  $Th^+$  with MIT Zeeman data. The Zeeman study of plutonium was extended to over 340 measured patterns; 7 of the 13 low energy levels from the electron configuration  $5f^6(7F)7s(8,6F)$  were positively identified by the Landé g factors. (AEC Activity 5230)

48-Inch Cyclotron - Testing of the resonant system for the 48-in. cyclotron was continued on a limited basis; the tests are being made in a "Beta" magnet. At this field the cyclotron is in resonance for protons. Over 10 ma of protons was obtained at 1 Mev, and 8 ma at 2.8 Mev. Investigation at higher energies has been restricted because of lack of shielding. Under normal conditions beam attenuation is as low as 10%. (AEC Activity 5240)

Research and Development, Stable Isotopes - The hot-central-wire thermal diffusion columns are now leak-tight. Several attempts to make separations were interrupted because of failure of the d-c supply. The mercury vapor rectifier tubes would not perform satisfactorily although they were being operated well within the manufacturer's rating. These tubes were replaced with Thyratrons, diode connected, and the current supply is now operating dependably. The columns are operating with argon for a separation run as a final check on their operating fitness.

A technique was worked out for plating thin foils of those isotopically enriched metals which can be reduced from aqueous solution. A molybdenum electrode is coated with a thin layer of Aquadag, on which the metal (Cu, Ni, etc.) is plated. The lubricating effect of the Aquadag permits ready removal of the metal foil.

External reflux equipment was added to the extraction-column pilot plant used for rare-earth separation. Analyses from preliminary separation indicate a large increase in the separation of ytterbium and lutetium from other rare earths. (AEC Activity 5250)

## CHEMISTRY

Raw Materials Chemistry - Of 15 quaternary ammonium compounds tested for ability to extract uranium from carbonate solutions, the best diluent compatibility and extraction power have been shown by dimethyldodecylammonium carbonate (Rohm and Haas B-104 converted from chloride to carbonate salt). Third phase formation occurred with a 0.1 M solution in unmodified kerosene, but was prevented by addition of a high molecular weight alcohol. Uranium extraction power increased with alcohol content: the extraction coefficient  $E_a^O(U)$  from 0.5 M  $\text{Na}_2\text{CO}_3$  solution was 6 and 30 with 5 and 25 v % tridecanol in kerosene diluent, and 2, 7, and 30 with 0, 5 and 25 v % tridecanol in Amsco G diluent. The extracted uranium was stripped effectively with 1 M NaCl solution, and stripping was also obtained in preliminary tests with NaOH solution.

After extraction of thorium with Primene JM-T/kerosene (as previously described, ORNL-1838) and extraction of uranium with tri-n-octylamine/kerosene from a sulfuric acid digest of monazite sand, effective rare earth extraction was achieved with Primene JM-T/kerosene. Of several practicable stripping methods, the use of  $\text{Na}_2\text{CO}_3$  solution is attractive in that it offers some separation of light from heavy rare earths during stripping.

The formation of uranyl-di(2-ethylhexyl) phosphate complex aggregates in hydrocarbon solution at high uranium loadings, previously reported (ORNL-2166) on the basis of isopiestic vapor pressure measurements, has been confirmed by measurement of viscosity. The viscosity of 0.1 M HX/n-hexane (X = di(2-ethylhexyl)phosphate) increased gradually from 0.35 to 0.4 centipoise as the U:X ratio was increased from 0 to 0.45, and then increased rapidly to 50 centipoises at a U:X  $\approx$  0.499, consistent with the formation of very long chain aggregates as the U:X ratio approaches the stoichiometric limit of 0.5. (AEC Activity 5310)

Chemical Physics - Neutron diffraction study showed that the protons in  $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$  form discrete water molecules coplanar with Cu and Cl; the O-H distance is 0.95 Å and the H-O-H angle is  $108^\circ$ . (AEC Activity 5330)

High Temperature and Structural Chemistry - The continued study of the electrical conductance of potassium metal solutions in molten potassium chloride showed that the steep increase in conductivity at low metal concentration, which, as reported earlier, appeared to be proportional to the third power of that concentration, was in error and caused by experimental difficulties that have now been overcome. The results of the latest measurements may be summarized and interpreted as follows: At ca.  $820^\circ\text{C}$  the specific conductivity increases at an increasing rate from  $2.25 \text{ ohm}^{-1} \text{ cm.}^{-1}$  for pure KCl to  $145 \text{ ohm}^{-1} \text{ cm.}^{-1}$ , i.e., more than sixtyfold, for a solution of 19 mole percent K. The equivalent conductance,  $\lambda_2$ , for the potassium in solution, as calculated from the specific conductivity with the somewhat simplifying assumptions of additivity in volume (indicated in preliminary observations), and of no change in the equivalent conductance of the salt in the solution, appears, below approximately one mole percent K, to be rather independent of the mole fraction  $x_2$  of the metal. A plot of  $\log \lambda_2$  vs  $\log x_2$  further shows a rapid change between

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

$x_2 = 0.01$  and  $x_2 = 0.02$ , from constancy to approximately linear dependence on concentration. Tentatively, the low concentration region of constant equivalent conductance of the metal is considered the range in which the electronic component of the conductance is semi-conduction, i.e., temperature-activated conductance. At higher concentrations the gradual establishment of a new conduction band by the increasing overlap of the wave functions of the valence electrons of the added metal is probably the principal cause for the accelerated increase in conductivity. (AEC Activity 5330)

Radio-Organic Chemistry - Continued work on organo-phosphorus compounds for solvent extraction led to the synthesis of dibutyl phosphonoacetic acid,  $(\text{BuO})_2\text{P}(\text{O})\text{CH}_2\text{COOH}$ . This compound extracts uranium from uranyl nitrate solution by exchanging hydrogen for uranium, forming the uranyl salt that is complexed by the phosphoryl grouping in the molecule. The properties of this acid will be studied with emphasis on stability and complex formation with cations. (AEC Activity 5330)

Radiation Chemistry - A kinetic study of the effect of the thallos ion on the photo-oxidation of water, sensitized by ceric ion, yielded convincing evidence for the intermediate formation of OH radical. A preliminary study of the effect of formic acid confirmed the reaction of OH radical with sulfuric acid.

Uranyl ion decreases the yield for ferrous oxidation and increases the yield for ceric reduction by  $\gamma$ -rays. It was also shown that uranyl ion lowers the yield of hydrogen in the decomposition of water. All of these observations can be explained by reaction of uranyl ion with the H atoms produced by decomposition of the water. (AEC Activity 5330)

Molten Salt Thermodynamics - A polarographic technique has been applied to the quantitative analysis of  $\text{Ni}^{++}$ ,  $\text{Fe}^{+++}$  and  $\text{Cr}^{+++}$  in molten  $\text{LiF}\cdot\text{NaF}\cdot\text{KF}$  eutectic. The cathode was a thin silver wire which barely protruded from the bottom of a dip tube through which inert gas passed. When immersed in a melt, the escaping bubbles caused an intermittent contact of the wire with the melt, and thus provided a periodic renewal of the conducting layer. A nickel crucible served as container and anode. The assembly was operated in an inert atmosphere furnace and enclosed by a chamber equipped with glove ports, window and electrical leads.

The wave heights for a given ion changed linearly with concentration up to saturation, and then abruptly increased rapidly as the melt became turbid with excess solute. Presumably colloidal particles of undissolved solute provided a reservoir of conducting ions.

Because the anode was nickel, the polarographic wave for  $\text{Ni}^{++}$  occurred below 0.1 volt; the solubility of  $\text{NiF}_2$  was 0.42 wt. % at  $550^\circ$ , and 0.146 wt. % at  $500^\circ\text{C}$ . For  $\text{CrF}_3$ , the wave was found at 0.9 volt; for  $\text{FeF}_3$  the wave was at 0.4 volts, and the solubility at  $550^\circ$  was 0.19 wt. %. The course of the reaction  $\text{Ni} + 2\text{FeF}_3 \rightarrow 2\text{FeF}_2 + \text{NiF}_2$  was followed as increments of  $\text{FeF}_3$  were added to the molten  $\text{LiF}\cdot\text{NaF}\cdot\text{KF}$  eutectic. (AEC Activity 5330)

## PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

Analytical Chemistry - A colorimetric method was developed for the determination of microgram quantities of thorium in which quercetin (3,3',4',5,7-pentahydroxyflavone) is used as the chromogenic reagent. Within the pH range, 2.7 to 3.5, this reagent forms a yellow-colored complex with maximum absorption between 420 to 425 m $\mu$ . Beer's law is adhered to over the range 0.4 to 6  $\mu$ g of thorium per ml. The molar absorbance index of the complex is approximately 25,000 as compared to 15,000 for the Thoron complex. Many ions interfere in the application of this method; however, a separation procedure has been devised to eliminate the interferences of milligram quantities of Fe<sup>+3</sup>, Ni<sup>+2</sup>, Cr<sup>+6</sup>, U<sup>+6</sup>, Al, Ti, V<sup>+5</sup>, Mn<sup>+2</sup>, So<sub>4</sub><sup>=</sup>, F<sup>-</sup>, and Po<sub>4</sub><sup>=</sup>. In this procedure, two separation processes are utilized; namely, ion exchange absorption and extraction by thenoyltrifluoroacetone (TTA). From 10 to 200  $\mu$ g of thorium can be estimated by this method with a coefficient of variation of the order of 5%.

A sensitive, spectrophotometric method has been developed for the determination of uranium in an extraction solvent composed of a mixture of cyclohexane and trioctylphosphine oxide (TOPO). After uranium has been extracted from a nitrate or chloride system with TOPO, an ethanolic solution of dibenzoylmethane, 0.5 w/v percent, is mixed directly with the solution of the uranium-TOPO complex in cyclohexane. Sufficient pyridine is added to make the solution 0.05 v/v percent with respect to pyridine, after which the absorbance of the solution is measured at 405 m $\mu$ . The molar absorbance index is of the order of 18,000, as compared to 1330 for the ascorbic acid complex of uranium, and to 2000 for the thiocyanate complex.

A technique developed for measuring the concentration of Pu<sup>+3</sup>, Pu<sup>+4</sup>, and Pu<sup>+6</sup> concentrations in uranyl sulfate solutions is based on measurements of light absorption at eight wavelengths. Application of this technique to solutions of Pu<sup>+4</sup> in 1.4 M UO<sub>2</sub>SO<sub>4</sub> at 90°C showed considerable disproportionation to Pu<sup>+3</sup> and Pu<sup>+6</sup>.

Boron is now being determined spectrographically at the 0.5% level in a 100 microgram sample. Microdrill samples weighing 10-100 micrograms are transferred to a quartz 0.5 - 2.0 ml volumetric flask. During dissolution of the sample, this flask can be attached to a small reflux condenser if necessary for the retention of volatile constituents (e.g., boron). (AEC Activity 5330)

### METALLURGY

Ceramics Research - Development was started on Si-SiC coated graphite fuel element, and work continues on fueling the Si-SiC element.

UO<sub>4</sub> is being studied to obtain control of materials entering the UO<sub>3</sub> crystal growing process.

Twenty-six new clay-flux compositions were mixed with Hope or Purex solution tagged with CsBa<sup>137</sup> and mixed fission products, then fired at various temperatures and placed in leach water.

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

The properties of  $Y_2(CO_3)_3 \cdot 3H_2O$ , which forms at room temperature in the presence of  $CO_2$  and water, are being compiled.

A series of mixtures of  $UO_2$  and  $ThO_2$  are being sintered in argon to check the effects of atmosphere on the sintering characteristics of this system.

In an attempt to isolate the adsorbed ions which determine the settling behavior of  $ThO_2$  suspensions in water, spectroscopic analysis of dialyzed slurries is being continued. (AEC Activity 5420)

Fundamental Physico-Metallurgical Research - Recent results in the study of binary phase diagrams of zirconium are as follows:

- a. The peritectic reaction temperatures in In-Zr and Sb-Zr may be specified more accurately as  $1003 \pm 20^\circ C$  and  $876 \pm 5^\circ C$ .
- b. The compositions of the two intermediate phases in the Cd-Zr system at  $581^\circ C$  are approximately  $Zr_3Cd$  and  $ZrCd_2$ . The crystal structures of these phases are both simple face-centered cubic with  $a = 4.43 \text{ \AA}$  and  $a = 4.37 \text{ \AA}$ , respectively.
- c. A eutectic reaction occurred in the cadmium-rich end of the above system forming cadmium and an unidentified intermediate phase.
- d. Three at. % lead raises the transformation temperature of zirconium so that the transition takes place over the range  $885 - 898^\circ C$ .
- e. Tests of the resistance of the graphite thermometer in the low temperature calorimeter show that temperature can not be measured closer than  $0.005^\circ K$  if the thermometer is cycled to room temperature after calibration.

Fiber axis distribution charts for aluminum rods extruded slowly at room temperature and at a temperature below  $0^\circ C$  showed duplex  $\langle 111 \rangle - \langle 001 \rangle$  textures. In the rod extruded at room temperature, 76% of the material had the  $\langle 111 \rangle$  texture and 24% of the  $\langle 001 \rangle$ , and in the rod extruded at the lower temperature the relative amounts were 85% and 15%, respectively. There was evidence of recrystallized grains in each specimen. (AEC Activity 5420)

Fundamental Investigation of Radiation Damage in Solids - Three samples of silicon, one high-resistivity p-type, one low-resistivity p-type, and one low-resistivity n-type, were irradiated in Hole 51 of the ORNL Graphite Reactor for a total estimated irradiation of  $1.7 \times 10^{18} \text{ nvt}_f$ . The level of bombardment was chosen so that, on the basis of the stated carrier concentrations, all the carriers in the low-resistivity samples would be expected to be trapped out. Magnet-susceptibility measurements were made on the irradiated cube specimens and on comparison unirradiated cubes. On the basis of the results obtained, some general observations are apparent. Holes trapped out,

## PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

as a result of fast-neutron bombardment, disappear magnetically, as did the trapped electrons in irradiated germanium. The carrier contribution in the n-type silicon sample changed from diamagnetic to paramagnetic upon irradiation - a result which cannot be interpreted conclusively because Hall or conductivity curves for the irradiated specimen were not available. Irradiation of near-intrinsic silicon increases its diamagnetic susceptibility at room temperature and alters the temperature dependence of the susceptibility slightly. It is postulated that this alteration of temperature dependence in the irradiated intrinsic specimen results from a radiation-induced change in the Van Vleck paramagnetism, a concept which was originally invoked by Krumhansl and Brooks to explain the temperature dependence of the susceptibility of pure unirradiated silicon and germanium.

The curve of the magnetic susceptibility as a function of temperature for a crystal of barium titanate was determined in the temperature range 67 to 405°K. The room-temperature value of the specific susceptibility was found to be  $-8.47 \times 10^8$  cgs. The four phase transitions were visible as discontinuities in the curve. The over-all temperature dependence was equivalent to approximately  $5 \times 10^{19}$  s-like paramagnetic centers per cubic centimeter. (AEC Activity 5430)

### OTHER PHYSICAL RESEARCH PROJECTS

The Oracle - On September 24 Oracle operations were started on a round-the-clock, seven-day week basis with five operators. In September good computing time was approximately 450 hours, and for October good computing time was a record 550 hours. There was no "available" or scheduled idle time in the month of October as opposed to 80 hours scheduled idle time in September.

## PROGRAM 6000 - BIOLOGY AND MEDICINE

### BIOPHYSICS

Professional Health Physics Training Program - The Education and Training Section of the Health Physics Division presented a 10-hour course in Health Physics for members of the Chemical Technology Division during the month of October. (AEC Activity 6690)

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## STATUS OF CONSTRUCTION

### Miscellaneous Small Construction Projects

In planning the construction program to keep pace with the Laboratory's varied and expanding research programs a definite gap appeared between major construction projects which were clearly defined to be performed by lump-sum contractors and the minor construction jobs estimated to cost less than \$2,000, which are performed by Laboratory forces. To perform the construction work falling within this gap the Atomic Energy Commission negotiated a cost-plus-fixed-fee contract with the H. K. Ferguson Company. The Ferguson forces started work on projects at the Laboratory in October, 1955, and since that date have had an average of approximately ten jobs in progress at all times.

The scope and cost of projects performed or proposed vary from construction of a fence costing approximately \$2,000 at the Metallurgy Laboratory, to the installation of the process equipment for the Fission Products Pilot Plant, estimated to cost approximately \$190,000. The value of work completed to October 1, 1956, is \$345,000. Some of the more important construction projects completed or in progress by the Ferguson forces and their approximate costs are as follows:

<u>PROJECT</u>	<u>APPROXIMATE COST</u>
Alterations to Health Physics Waste Research Laboratory, Building No. 3504	\$112,000
Addition to LITR, Building No. 3005	16,000
Bulk Treatment Storage Pit near Building No. 3019	37,000
Offices in Wing 1, Building No. 4500	54,000
Alterations to Health Physics Laboratory, Building No. 2001	76,000
Engineering Inspection Facility, Building No. 7002	15,000
Loop Facility, Building No. 4501	71,000
X-ray and Dark Room Facility, Building No. 4501	21,000
High Pressure Test Facility, Building No. 4501	67,000
Alterations to Reactor School, Building No. 2069	17,000
Pilot Pit for Health Physics	12,000

## VISITORS

### Chemistry Advisory Committee:

Dodson, R. W.  
Emmett, P. H.  
Eyring, Henry  
Larson, C. E.  
Schomaker, V.  
Seaborg, G. T.

### Chemical Technology Advisory Committee:

Benedict, Manson  
Katz, D. L.  
Larson, C. E.  
Seaborg, G. T.  
Squires, Lombard

### Health Physics Advisory Committee:

Allison, S. K.  
Hamilton, J. G.  
Langham, W. H.  
Wolman, Abel

Leidheiser, Henry, member Metallurgy Advisory Committee

### FOREIGN VISITORS:

Bacq, Z. M., University of Liege, Belgium  
Carlbom, L., AEC, Sweden  
Cockcroft, Sir John, Director of Atomic Energy of Great Britain  
Cottrell, A. H., United Kingdom Atomic Energy Authority  
Cummins, W. S., U.K.A.E.A., Harwell, England  
DaSilvo, M. P., Brazilian Government  
DeFoy, R., Atomic Energy Facilities of Belgium  
Dubbeldam, P., M.I.T. (Citizen of The Netherlands)  
Elthan, B. E., U.K.A.E.A., Risley, England  
Gatti, E., CISE, Italy  
Geisel, B., Brazil  
Gibrat, R. P., Paris, France  
Girard, A., Secheron Works Co., Switzerland  
Griffiths, D. R., Electric Trust of South Australia  
Gross, B., Nat'l. Inst. of Technology (Citizen of Brazil)  
Henningsen, E. J., Nat'l. Health Service of Denmark  
Hurley, F. I., U.K.A.E.A., Capenhurst, England  
Hurst, R., U.K.A.E.A., Harwell, England  
Junkerman, W., Babcock and Wilcox of Germany  
Leibfried, G., Univ. of Gottingen, Germany  
Lescop, R. H., Government of France  
Lindner, L., Inst. Voor Kernphysick, Onderzoek Ooster-Ringdejk  
Lucke, K., Brown University (Citizen of Germany)

VISITORS (Continued)

Maffei, F. J., AEC of Brazil  
Molinari-Cairoli, C., Army of Brazil  
Mott, N. F., Cavendish Laboratory, Cambridge, England  
Newby, D., U.K.A.E.A., Harwell, England  
Psarofaghis, G., Secheron Works Co., Switzerland  
Seegar, A. K., Max-Planck Institute, Germany  
Short, G. H., National Physical Laboratory, Great Britain  
Sievert, R., Inst. of Radio Physics, Stockholm, Sweden  
Sips, R., Union Chimique Belge, Belgium  
Telles-Gardy, P. A., Navy of Brazil  
Vanden Bosch, J., Atomic Energy Facilities of Belgium  
Vickery, R. C., Horizons, Inc. (British Citizen)  
Ward, A., M.I.T. (Citizen of Britain)  
Weiss, E. L., Technische Hochschule, Munich, Germany

RADIOISOTOPE SALES AND COSTS

<u>Type of Transaction</u>	<u>September 1956</u>	<u>FY 1957 to Date</u>
Domestic Sales	\$ 92,919	\$314,230
Foreign Sales	41,036	47,207
Project-Transfer	831	3,768
Project-Cash Sales	3,526	11,029
Technical Co-Operation Program Credits	2,450	2,470
Plant Credits	2,833	12,286
AEC Credits	<u>11,136</u>	<u>40,960</u>
 Total Radioisotope Income	 \$154,731	 \$431,950
 Total Radioisotope Costs	 \$169,225	 \$354,952
 Total Radioisotope Shipments	 993	 3,201
 Helium		
Income	\$ 3,120	\$5,420
Costs	164	2,462
Shipments	2	10

GROSS OPERATING COSTS

	<u>Cost for September</u>	<u>FY 1957 Cost to Date</u>
Programmatic Operating Cost - Net	\$4,783,318	\$12,616,475
Equipment	205,248	668,473
Construction	93,515	473,841
Work For Others - Transfers	20,877	232,621
Inventory Changes	(26,448)	(101,088)
Reimbursable Work for Others	85,076	178,949
Deferred Charges	<u>(23,021)</u>	<u>(383,219)</u>
 Total Laboratory Cost - Net	 \$5,138,565	 \$13,686,052
 Estimated Cost for Next Month	 <u>\$4,900,000</u>	 <u>\$18,586,052</u>

( ) Credit

PERSONNEL SUMMARY

	<u>Number of Employees October, 1956</u>	<u>New Hires October</u>	<u>Terminations October</u>
Administration	71	2	0
Operations*	127	1	1
Engineering, Shops, and Mechanical	837	13	8
Laboratory and Research	2155	36	8
Protection	127	0	0
Service	<u>387</u>	<u>9</u>	<u>2</u>
	3704	61	19

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

A total of 934 Laboratory personnel are located in the Y-12 Area.

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Reports in this series issued during the past year:

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April 1956	ORNL-2082
May 1956	ORNL-2109
June 1956	ORNL-2123
July 1956	ORNL-2144
August 1956	ORNL-2166
September 1956	ORNL-2185

Edited by F. T. Howard

Approved by Alvin M. Weinberg, Director