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STATUS AND PROGRESS REPORT

AUGUST 1957

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OAK RIDGE NATIONAL LABORATORY

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August 1957

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

August 1957

This status and progress report summarizes somewhat less than one-half the activities of the Laboratory. A few of the activities are reported every month, but most of them are reported on a bimonthly schedule. Program 4700 is reported separately.

PROGRAM 3000 – WEAPONS

Special Separations

The Low Intensity Isotope Separator was tested successfully with a lanthanum charge. Preparations are under way for plutonium separations in this unit. (AEC Activity 3610)

PROGRAM 4000 – REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test

Repairs to the HRT piping were completed by the reinstalling of all system valves during the first week in August. After air-pressurizing of electrical conduits, refrigeration insulation jackets, and instrument air lines in the cell, the shield tank was flooded with condensate, and the water surface was observed for escaping air bubbles. All leaks were marked for repairs. With the cell flooded, remote maintenance procedures were checked by removing and replacing the fuel circulating pump and a purge pump. The portable refrigeration system was successfully used to freeze plugs in the circulating pump lines 12 ft below the water surface.

Following the remote maintenance period, the cell was drained, and the circulating pumps and pressurizer heaters were turned on to check the water proofing of the electrical connections. All the electrical equipment started without difficulty. The piping was cleaned with hot 3% trisodium phosphate solution, flushed with water, and then treated with hot 5% nitric acid solution. After being flushed again with water, the reactor will be hydrostatically tested to 3000 psi in preparation for extended water and natural uranium runs.

At midmonth a breakthrough test was begun on two of the reactor charcoal beds, involving the injection of a slug of Kr^{85} into each bed. With O_2 as a carrier gas (500 cc/min), it was expected that gas activity would appear in the exit stream in seven to ten days. However, no breakthrough has been observed after 11 days of flow. (AEC Activity 4103.3)

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HRT Chemical Pilot Plant

After completion of the nonradioactive testing program, the HRT chemical plant is being readied for operation with radioactive material. About 30 minor maintenance jobs must be completed prior to closing the cell.

The remote maintenance procedures to be performed ultimately with the cell flooded for shielding are being practiced and perfected. One-third of the 30 pieces of replaceable equipment have been removed and replaced from above the cell. (AEC Activity 4103.1)

Homogeneous Reactor Fuel and Blanket Processing

The adsorption of uranium on ThO_2 from dilute uranyl sulfate solution at 250°C was decreased by a factor of 27 as the calcination temperature of the ThO_2 increased from 650 to 1100°C. Neodymium adsorption on ThO_2 was similar.

Adsorptive properties of oxides with low neutron cross sections are being investigated for possible use of these materials in adsorbing fission and corrosion products. Oxides of aluminum, magnesium, iron, silicon, tin, and zirconium became difficult to dissolve and lost their adsorptive powers when heated in water at 250°C. Bismuth, lead, and calcium oxides remain easily soluble in dilute acid and retained their adsorptive capacity at 250°C. One gram of PbO adsorbed about 600 mg of uranium, 100 mg of neodymium, or 150 mg of cerium. (AEC Activity 4103.1)

Homogeneous Reactor Thorium Blanket Studies – Chemical Development

A slurry of micropulverized 800°C-calcined ThO_2 was irradiated for 2091 hr at full LITR power. All fission products except cesium, corrosion products, protactinium, and U^{233} were with the solid phase, which agrees with previous results in short-term irradiations. The U^{233} content was 0.136% after 37 days of decay.

In out-of-pile studies on the catalytic combination of stoichiometric hydrogen-oxygen mixtures by thorium-uranium oxide slurries (500 g of Th per kilogram of H_2O, 0.5% U) containing 0.05 *m* MoO_3, a slurry of thorium-uranium oxides calcined at 1200°C for 4 hr showed high catalytic activity; that is, >10 moles of H_2 reacted per hour per liter of slurry at 200°C and 500 psi H_2 partial pressure. A slurry of thorium-uranium oxides, calcined at 1000°C for 8 hr, and 0.05 *m* MoO_3 had very low catalytic activity at 280°C even after H_2 treatment. A ThO_2 slurry, 800°C calcination (950 g of Th per kilogram of H_2O), with 0.05 *m* MoO_3 was circulated in a 100A loop for 400 hr at 290°C and showed a very low catalytic activity for stoichiometric H_2-O_2 mixtures in small-bomb out-of-pile tests. The reaction rate, <0.1 mole of H_2 per hour per liter at 280°C and 500 psi H_2 partial pressure, was not appreciably increased by treating with H_2.

Grindability tests on the McBride-Pattison abrasion tester indicated that oxide fired at 1400°C for 64 hr, at 1600°C for 12 hr, and at 1800°C for 2 hr will not be degraded when it is pumped in a loop.

In studies on large-scale preparation of ThO_2, continuous jet precipitation of thorium oxalate gave reproducible mean particle diameters of 0.2 to 1.5 μ, depending on the conditions. A jet precipitator and a continuous rotary filter were installed. This system will produce thorium oxalate of about 1 μ in particle diameter. (AEC Activity 4103.1)

HRP Chemistry – Fuel Studies

Analysis of results obtained with the semimicroapparatus developed for rapid determination of phase-transition temperatures in aqueous salt solutions revealed that undesirably large thermal gradients and positional effects were contributing to a 3 to 5°C temperature uncertainty. Substantial improvement was noted when the aluminum block furnace was replaced by a stirred eutectic fused-salt bath (14% sodium nitrate, 30% lithium nitrate, 56% potassium nitrate). Fused salt baths has been used in earlier studies and were set aside in favor of metal block furnaces because of the spattering hazard as a consequence of the frequent explosive failure of the large-diameter glass tubes used at that time. Subsequent improvement in the technique of tube sealing and the adoption of smaller tubes (1.0 to 1.5 mm ID) have almost completely eliminated tube failure. With the improved apparatus, the two-liquid-phase-transition temperatures have been measured for uranyl sulfate solutions at concentrations from 4.5 to 45 wt % uranyl sulfate and containing 19.25 and 38.75 mole % excess sulfuric acid. The phase-transition temperatures have also been measured for the $CuSO_4$-UO_2SO_4-H_2O system containing 19.25 mole % excess sulfuric acid, based on the total cations, at concentrations of up to 17% $CuSO_4$ and 45% UO_2SO_4 and with $CuSO_4$:UO_2SO_4 weight ratios of from 9:1 to 4:6.

With the use of a semimicroapparatus for phase study, the relationship between the composition of SO_3-H_2O mixtures, fractional filling of quartz tubes, and critical temperature was determined. The critical temperature was found to have a maximal value of 665°C for a composition just less than 0.5 mole fraction of SO_3. (AEC Activity 4103.1)

HRP Analytical Chemistry

In connection with the HRP corrosion testing program, particularly the loop experiments, methods were developed for the separation and determination of cerium, platinum, and gold in solutions of UO_2SO_4. The method for cerium is based on a photometric titration of trivalent cerium, in the presence of pyrophosphate, with potassium permanganate at a wavelength of 525 mμ. By this method, 50 to 100 μg of cerium can be titrated with a coefficient of variation of 6%. Colorimetric methods which are now in use for the determination of gold as the *p*-dimethylaminobenzal-rhodanine complex and of platinum as a complex of stannous chloride were re-examined specifically for the purpose of evaluating the interference of uranium in these procedures. It was found that both methods can be utilized quite satisfactorily for determining either constituent in the presence of as much as 120 mg of uranium.

With regard to the development work on the analysis of slurries of thorium oxide, refinements were made in the procedures which are being used for the determination of aluminum and fluoride. In the method for the determination of aluminum, as the 8-quinolinol complex, a combination of two extraction steps was adapted successfully for the elimination of all interfering substances except titanium. Further applications of the pyrolytic technique for the determination of fluoride revealed that fluoride can be volatilized from thorium oxide more rapidly and at lower temperatures by using WO_3 as the accelerator rather than U_3O_8. By using WO_3 as the accelerator, 100 mg of fluoride can now be completely volatilized in a matter of 20 min or less. (AEC Activity 4103.1)

Slurry Component Development and Slurry Testing

Run 200-A-14 has continued for more than 900 hr at 300°C with no apparent change in the slurry physical properties or the appearance of the particles other than a slight rounding off of the corners. The material being circulated is the regular oxalate-precipitated thorium oxide fired at 800°C which has been refired at 1600°C and ground to an average particle size between 1 and 3 μ. The slurry concentration is about 500 g of Th per kilogram of H_2O and there are no additives other than oxygen. There is no evidence to date of particle growth or sphere formation. (AEC Activity 4103.1)

Slurry Blanket System Development

Run SM-3 was terminated due to mechanical failure of the circulating pump after operating for 948 hr at temperatures up to 200°C with a calculated maximum charge of 500 g of Th per kilogram of H_2O. With the inlet nozzle velocity increased from 10 to about 30 fps (loop flow also increased from 230 to 350 gpm), the slurry appeared to be fully suspended in the blanket with a concentration variation from top to bottom not exceeding about 20%, as judged from measurements of gamma-ray attenuation from a Co^{60} source located at the center of the sphere. The thorium distribution remained essentially unchanged on reducing the loop flow to 300 gpm, but a reduction to 250 gpm apparently increased the thorium concentration in the upper hemisphere. (AEC Activity 4103.1)

Blanket Engineering Research

The vertical tube viscometer framework was erected, and the main parts are being fabricated.

The high-pressure capillary-tube viscometer was partially constructed; completion depends on delivery of the autoclave valves.

Heat transfer measurements were made with a slurry concentration of about 600 g of Th per kilogram of H_2O. From the initial data it is evident that the heat transfer behavior of the slurry corresponds to the transition from laminar to turbulent flow predicted by the Hedstrom correlation.

Drop-out velocities in pipes of 1.0 and 1.9 in. ID were measured in the resuspension loop for a slurry of 140 g of Th per kilogram of H_2O having a yield stress of 0.003 lb/ft^2 and a settling rate of 0.1 cm/sec. Fully suspended flow was observed at velocities of 2.6 fps and higher. As the velocity was reduced, the flow changed to a combination of suspended flow plus a sliding bed, and finally to complete drop-out of solids from the moving liquid into a stagnant bed.

Construction of the 30-gpm vertical loop for studying cake formation was started. (AEC Activity 4103.1)

Core Development

The possibility of utilizing double-walled core tanks with internal cooling to reduce core-tank corrosion and increase lifetime was studied. Core-tank lifetimes were estimated for a range of cooling-fluid temperatures and surface heat transfer conditions. Single core-tank lifetimes were also estimated, and results seem to favor a thicker single tank instead of a double-walled tank for the HRE-3. (AEC Activity 4103.1)

Centrifugal Circulating Equipment

The long-term run on the 400A-1 pump was terminated after 11,361 hr of trouble-free operation at 250°C on 0.04 *m* UO_2SO_4. Corrosion and radial bearing wear were insignificant. Thrust bearing wear of 0.001 in. per 1000 hr of operation was noted. The 300A-1 pump has operated for 2687 hr in the HRT mockup since it was last repaired.

Improvements in the 400A-2 pump shaft seal have lowered the mixing rate between pump and motor cavity to 0.02 liter/hr at a purge of 20 liters/hr. A special shaft seal test rig was constructed to study the effects of speed, eccentricity, and shaft whip on the mixing rate.

Prior to the conducting of heat and material balances on the 4000-gpm Byron-Jackson pump, the pump and loop were operated during several water and TSP rinses.

The 20-cfm blower and loop were modified to permit testing of the hydrostatic-type bearings in the presence of ThO_2 slurries. A sample line was installed to take representative samples of the circulating slurry.

AEC approval of the contract with Reliance Electric for furnishing a 5000-gpm top-maintenance pump was received on August 15. (AEC Activity 4103.1)

Miscellaneous Equipment

A study of the thermal cycle test of the HRT replacement heat exchanger indicates that the shell cycle becomes repetitive after the seventh cycle. The stresses in the unit will not be excessive at any point in the test.

The Crane Company is nearing completion of test sections of titanium-lined steel pipe. The procurement of the titanium heat exchanger from the Pfaudler Company has

been delayed due to the fact that the $\frac{3}{8}$-in. tubes broke when expanded into the tubesheet. New $\frac{1}{2}$-in. tubes were ordered.

An experimental stainless-steel-to-titanium transition joint incorporating an HRT type of leak detector was built and will be thermal-cycle tested. If successful, it will be used on the hot end of an all-titanium letdown heat exchanger for the HRT mockup.

An order was placed for an electrically heated Dowtherm boiler to supply heat to an all-titanium boiling pressurizer for a 400A loop.

Two cast titanium impellers for a Westinghouse 30A pump were received and will be tested in solution and in ThO_2 slurry.

Tests are under way on several material combinations in an effort to find antigalling stainless steel fasteners for pump internal use. (AEC Activity 4103.1)

Heat Removal Equipment

All major decisions on materials, fabrication methods, and inspection of the HRT replacement heat exchanger have been resolved with Babcock & Wilcox Co.

Interest in building small experimental heat exchangers incorporating advanced features has been shown by Combustion Engineering, Griscom-Russell, and Pfaudler, although no firm proposals have been received. Further negotiations are in progress.

The 80-kw heat exchanger which failed in the HRT mockup was sectioned and examined metallographically. The failure was caused as a result of pitting attack on the uranyl sulfate side. All tube joints appeared to be in excellent condition.

The tube-joint tests carried out to date in chloride-containing oxygenated boiling water have not shown any evidence of stress-corrosion cracking. (AEC Activity 4103.1)

Gas Handling Equipment

The HRT recombiners were tested, and their effectiveness was found to be unaffected by HRT operation to date. However, at very low stoichiometric gas rates, efficiencies were only about 99%. This was raised to 100% by the addition of a small wire-mesh recombiner between the condenser and the cold trap. (AEC Activity 4103.1)

Fuel Systems Development

The HRT mockup operated for 620 hr, circulating 0.04 *m* UO_2SO_4 solution. Loop temperature was maintained, with electrical heaters temporarily replacing the 80-kw heat exchanger. The run was terminated because some of the heaters burned out; there was also a suspected leak of uranyl sulfate which could not be definitely confirmed or located. Three dead-end pipes, which were exposed to the high-pressure circulating system for possible oxygen depletion, did not suffer any damage during the run.

A silver-alundum bed, theoretically capable of removing 90% of the iodine going through it, was tested in the mockup. The measured efficiency was 55% ± 20% per pass.

Octagonal- and oval-ring joint gaskets, having the maximum dimensional deviations permitted by ASA tolerances, were thermal-cycled under conditions previously used for HRT-tolerance joints. Leakage results were approximately the same in all the above-mentioned tests. Preliminary torque-load calibrations of the new black-oxide-coated HRT bolts have shown that approximately ten tightenings and loosenings are required before consistent torque-load characteristics are obtained. (AEC Activity 4103.1)

Feed Pump Development

Six diaphragm feed pumps have continued to operate successfully. Current life on these heads is 6675, 5100, 3100, 1900, and 1701 hr, respectively. Two rebuilt purge pump heads, containing 100-mesh protective screens, are ready for testing.

A loop for testing a turbine pump delivering 14 gpm at a 340-psi head is being constructed. Another loop, capable of testing six feed pumps simultaneously, was constructed, and initial operation will be the testing of two boiler feed pumps.

Check-valve tests in water and in uranyl sulfate solution demonstrated that the following materials are promising: Star J vs 17-4 PH, Al_2O_3 vs itself, Kennametal K501 vs itself, Rexalloy vs Stellite 1, Haynes 25 vs Carpenter 20, and Star J vs type 347 stainless steel.

Fatigue tests of type 347 stainless steel sheet in air, water, and uranyl sulfate solution demonstrated that corrosion fatigue reduces the endurance of cold-rolled material when it is tested in uranyl sulfate, whereas annealed material is relatively unaffected. (AEC Activity 4103.1)

PACKAGE REACTOR DEVELOPMENT

Army Package Power Reactor (APPR-1)

The Laboratory continued to furnish technical support to the Army Reactors Branch (AEC) on the 10-Mw pressurized-water reactor being tested at Fort Belvoir, Virginia, by Alco Products, Inc. The 700-hr performance test was concluded on July 2 with only 8 hr of outage; performance exceeded expectations. A six-month training and endurance testing program is now under way.

Results of metallurgical studies on incorporation of Eu_2O_3 into the absorber plates of the control-rod assembly indicate that iron, nickel, or silicon-free elemental stainless steel powder can serve as suitable matrix materials. Powder compacts containing approximately 30 wt % Eu_2O_3 dispersed in either plain or modified type 304 stainless steel showed a pronounced volume increase when sintered above 2000°F. This anomalous behavior was traced by screening tests to a solid-state reaction between two minor constituents: silicon and sulfur.

In a preliminary test, the feasibility of including a small absorber section in the control-rod fuel plate to serve as a flux suppressor was demonstrated. A well-defined

poison section was achieved, containing 17 wt % Lindsay oxide mix in stainless steel. Cladding tests indicated excellent bonding between fuel and absorber sections as well as between cladding and matrix material.

Two enriched B^{10} absorber sections and one plain stainless steel section were fabricated and forwarded to Alco Products, Inc., for calibration in the critical facility at Schenectady. The B^{10} absorber sections contain 8.5 and 33.8 g of B^{10}; the absorber sections now operating in APPR-1 contain 56.4 g.

In the APPR-1 radiation damage program, 18 absorber samples are now in-pile at the MTR. Irradiation times are designed to provide data covering a range of burnup from 5 to 30%. Postirradiation examination and analysis of previously irradiated fuel samples continued. (AEC Activity 4601.1)

Gas-Cooled-Reactor Development

Design and component procurement continued for the gas-cooled, materials testing facility which will be installed in the Oak Ridge Research Reactor. The arrangement whereby design assistance was being furnished by Catalytic Construction Company, under a subcontract, was terminated on July 1. The design is being reviewed and will be completed by the Laboratory.

Thermal stress calculations in the primary system piping are being rechecked with an existing Oracle program. The mechanisms being developed for changing samples remotely and for retraction of samples from the neutron flux region look promising. Procurement of all major components to be furnished by outside vendors is under way. Orders were placed for the blowers, cooler, and hot-gas filter. Invitations to bid were sent out for the economizer and the preheater. A nuclear mockup of the in-pile section is being fabricated to permit flux and reactivity measurements during ORR preoperational tests. Loop flow and heat transfer characteristics were simulated on the Laboratory Reactor Controls Computer to permit study of transient conditions. (AEC Activity 4603.1)

Maritime Ship Reactor (MSR)

Arrangements are being made for the Laboratory to provide technical support for the Maritime Reactors Branch (AEC) projects and development programs. This effort will be centered in the Laboratory's Package Power Reactor Group and will initially consist in assistance in technical review and development planning associated with the first nuclear merchant ship, scheduled for operation in 1960. This ship will be powered by an 80-Mw, slightly enriched, pressurized-water reactor. George G. Sharp, Inc., of New York is designing the ship and Babcock & Wilcox Co. will furnish the reactor and propulsion equipment. (AEC Activity 4603.1)

GENERAL REACTOR RESEARCH

Fuel Element Development

The objective of the present program has been to develop a satisfactory fuel material for aluminum plate-type elements, which contains uranium with a 20% enrichment of the U^{235} isotope. The 20% enrichment limitation presents fabrication difficulties because of the higher concentration of uranium required. Investigations are currently being conducted on 48 wt % U–Al alloys and dispersion-type fuels containing uranium oxides and uranium carbides, respectively.

The highly concentrated 48 wt % U–Al alloy can be prepared successfully by using conventional air-inductance melting and casting procedures in graphite crucibles and molds. The high strength and brittle nature of the alloy at 550°C make fabrication difficult. These properties are especially reflected during plate fabrication in which deformation at the fuel core ends results in serious localized thinning of the clad. With type 1100 aluminum consistent failures have been observed. The use of high-strength aluminum alloys such as types 5050, 5154, and 6061 tends to minimize the defect encountered, resulting in a minimum of 3 mils of localized clad thickness in a nominal 17-mil-thick-clad plate. The 48 wt % U–Al alloy was irradiated in a fuel element in the MTR to an estimated 25% burnup of U^{235} atoms present, with no apparent dimensional changes of the fuel element.

Compatibility studies of 55 wt % UO_2 and U_3O_8 dispersions in fuel-size aluminum plates, heat-treated at 600°C, have revealed that $UO_3 \cdot H_2O$ reduced to UO_2 in a helium atmosphere instead of in hydrogen, as well as fused UO_2, reacts with aluminum at 600°C. After a 24-hr heat treatment the composite fuel plates have shown a volume increase greater than 20%. In contrast, the U_3O_8 dispersion in aluminum showed no change in this time interval. However, x-ray diffraction examination revealed that approximately 10% of the U_3O_8 had been converted to UO_2.

Similar compatibility studies of dispersions containing UC_2 have not revealed any significant reaction with aluminum after 16 hr at 600°C. (AEC Activity 4203)

Waste Disposal Research and Engineering – Disposal of High-Level Radioactive Wastes by Sintering

Pilot Pit No. 2, a large-scale test of the sintering method for fixation of high-level waste, was placed in operation on August 14. It is designed to produce a sintered cake 6 ft in diameter by 2 ft thick, utilizing an electrical immersion heater to simulate the heat of radioactive decay in reactor fuel processing waste. Approximately 100 millicuries of mixed fission products was added as tracer. The initial power input was 12.5 kw, corresponding to waste from the MTR at 21 days out of the reactor. The rate of heat application is being reduced each day to simulate self-heating along the natural decay curve. (AEC Activity 4305)

Waste Disposal Research and Engineering – Disposal of High-Level Radioactive Wastes into Geologic Structures

Investigations into the problems of waste disposal in salt are largely in the planning stage, although some laboratory work on chemical compatibility has started. Inquiries directed to the state geologists of Michigan, New York, and Kansas, three states having extensive and important salt deposits, indicate their willingness to provide information and assistance in this study.

The start of the investigation of disposal into deep wells awaits a proposed organizational meeting of the American Petroleum Institute, the U.S. Geological Survey, and the Laboratory. The API has appointed the man who will direct their efforts, and they are now in a position to start work. The Geological Survey is preparing a report on the general suitability of the principal physiographic subdivisions of the U.S. for waste disposal, including deep wells. It is clear that the first requirement is for a definition and description of the waste types and of the solutions resulting from preliminary waste treatment which might be suitable for deep-well disposal, so that preliminary laboratory determinations of viscosity, chemical compatibility with various earth formations, and ion exchange properties can be started. It also seems probable that the best site for a large-scale field experiment will be one of the enclosed desert valleys of Nevada. A survey of maps of the region has been started to get some idea of the possible choices. (AEC Activity 4305)

Waste Disposal Research and Engineering – Dispersal of Radionuclides in the Environment

To determine the effectiveness of the White Oak Creek–Clinch River system in diluting and dispersing the wastes from the Oak Ridge National Laboratory, tracer-level tests were run on July 4 to 7 and on July 9 to 13. The Tennessee Valley Authority was conducting reaeration studies in the Clinch River during this period and maintained a steady flow in the river of 3000 ft^3/sec for the first test and 6000 ft^3/sec for the second test. Five curies of I^{131} was injected into White Oak Creek at its confluence with the Clinch River for each test. Samples were taken continuously during the course of the test at Clinch River mile 19.6, 17.5, 15.5, and 13.1. Scintillation counters were used to measure the concentration of radioiodine flowing past the sampling stations. Through a cooperative arrangement with the U.S. Geological Survey, the flow through this reach of the river was measured during the test. The velocity and temperature profiles at the sampling stations were also determined by the U.S. Geological Survey.

Downstream samples were collected at Centers Ferry, Clinch River mile 4.4, and at the Kingston Steam Plant, Emory River intake.

These data are being tabulated for analysis. (AEC Activity 4305)

PROGRAM 5000 – PHYSICAL RESEARCH

ISOTOPE PRODUCTION

Radioisotope Production

The use of CCl_4 as the carrier solvent in the initial operations of the Short-Lived Fission Products unit resulted in a high free chloride content in the mixed-fission-product solution after the extraction of the uranium. Carbon tetrachloride was used because of its high density and low flammability.

Radioisotope Development

Approximately 400 curies of Xe^{133} released from dissolved irradiated uranium was recovered in an experimental production run.

Phase II equipment installation is 21% complete at the Fission Product Pilot Plant. Phase IV design drawings are scheduled for completion by September 30.

Six millicuries of Tc^{95} was recovered from a molybdenum cyclotron target by using a copper-carrier technique for use in tracer experiments on Fission Product Pilot Plant flowsheets.

Preliminary results of tracer-scale experiments on ruthenium precipitation indicate greater than 99% efficiency when ruthenium is coprecipitated with iron from a Purex solution containing 0.06 *M* hydrazine.

A coprecipitated $Sr^{90}SO_4$-$BaSO_4$ mixture was prepared for ORINS to determine the feasibility of producing a beta-activated low-energy gamma-ray source suitable for radiation treatment in which limited penetration of tissue is required. The 177-mg pellet containing 1.5 curies of Sr^{90} was enclosed in a stainless steel capsule. The radiation reading through the 20-mil window seven days after the precipitation of the sulfate was approximately 6 r/hr at 18 in.

A 0.4-mg sample of elemental iodine (51.3% I^{129}) was irradiated for seven days in a flux of 8.5×10^{11} neutrons$\cdot$cm$^{-2}\cdot$sec^{-1} in order to produce 4.25 mc of 12.6-hr I^{130}. The experiment gave yield data and permitted development of routine analytical procedures. (AEC Activity 5100)

Stable Isotope Separation

The processing of titanium in order to separate isotope masses 46, 47, 48, 49, and 50 was completed early in August. Ions were received during 5422 calutron hours. Total collection of enriched material is estimated to be 245 g.

The separation of chromium (masses 50, 52, 53, and 54) in the alpha channels is nearing completion. The amount collected to date is estimated to be 450 g.

Carbon dioxide is being used as charge feed for the beta calutrons in the separation of carbon isotopes. The ultimate goal of this process is the procurement of a 1.5-g sample of C^{13} having a purity of approximately 90%.

New lots of Zn^{64} (two samples), Zn^{66}, Zn^{67}, Zn^{68}, Zn^{70}, Cl^{37}, Dy^{160} (two samples), B^{10} (three samples), and B^{11} (two samples), and combination lots of Fe^{54} (two samples), Fe^{57}, and Fe^{58} have been added to the inventory. Chemical processing has been completed on new lots of Re^{185}, Re^{187}, Dy^{160}, Dy^{164}, and Dy^{156}; and these will be available as soon as mass spectrometric analyses are completed.

Conversions of inventory forms were made as follows: Li^6 metal to $Li_2^6CO_3$, Li^6 metal to $Li_2^6SO_4$ (two samples), elemental B^{10} to $H_3^{10}BO_3$ (three samples), five isotopes of tin from SnO_2 to metal, and $Ni^{61}O$ to Ni^{61} metal. Cyclotron targets were prepared as follows: normal calcium metal (three), normal magnesium metal (two), and Cr^{54} metal. Special thin metallic targets were fabricated from $Mg^{25}O$ (two), $Mg^{24}O$, Li^6 metal, Li^7 metal, $Pb^{208}O$, $Zn^{64}O$, and $Zn^{68}O$. An unusually large target was prepared by encapsulating approximately 4500 g of 97.75% Li^7 metal in a stainless steel container.

Stable Isotope Development

The new version of the high-temperature (800 to 1000°C) ion source has been subjected to a series of dry runs in order to check temperature-heater power relationship. One successful run with $LaCl_3$ charge has been completed, and the source is being prepared for use in erbium separation.

Filament life in titanium separation was increased by operating the filament at a slightly increased temperature over that normally assumed to be adequate. This technique permitted the use of a low (60 to 80 v) arc voltage and consequently resulted in retarded filament wear by the bombarding ions.

Vapor flow of $TiCl_4$ used as a charge feed in titanium isotope separation was stabilized by the use of a low-pressure leak valve with a 45-deg-taper needle seating against a 90-deg brass seat. Previous valves used had a conventional 5-deg-taper needle and seat, the seating surface being some $\frac{3}{4}$ in. in length. Whereas $TiCl_4$ vapor liquefied in this type of valve, it passed freely at controlled rate through the valve now in use.

The possibility of using a thermally controlled leak valve to regulate vapor flow of gases into the calutron arc region was investigated. The valve tested did not pass sufficient volume at the required pressure differential nor did it respond as rapidly as was desired.

A receiver, fabricated primarily of deoxidized copper, has been designed for the collection of C^{13}.

Two receivers for use in the initial separation of erbium isotopes have been assembled. All isotopes are to be collected in graphite pockets that have been purified in a carbon tube furnace designed specifically for this type of collector pocket.

A beta-type ion source which utilizes two independent filaments has been run successfully, essentially doubling the filament life achieved during the run cycle in the normal type of source. Operating technique calls for the filament in the normal position

to be used until it fails. At this time, a shutter located in the arc chamber and used to prevent this second filament from ion bombardment is opened, and the second filament is operated during its useful life. This source is adaptable to use with charge materials which do not form metal-like growths within the arc chamber. The source currently is being used in carbon isotope separation.

The design of a 180-deg inhomogeneous field mass spectrometer has been completed, and shop work is in progress. Further work on this project will be the responsibility of another group.

Targets of isotopic magnesium have been prepared from MgO by a new technique. Magnesium oxide is intimately mixed with an excess of aluminum powder and pelleted at $7\frac{1}{2}$ tons/in.^{2}. The pellet is broken up, placed in an Inconel boat, and heated to 950 to 1000°C in a vacuum chamber. Magnesium metal is deposited in thin sheets on suitable targets with as little as 0.05% Al as an impurity.

The chemical development work on osmium has been terminated for the present, since $OsCl_4$ was found to sublime satisfactorily from hot graphite. Osmium(IV) chloride is expected to be used as the charge material in a forthcoming osmium collection. (AEC Activity 5100)

PHYSICS

High Voltage Program

A phase-shift analysis on 12 neutron elastic-scattering angular distributions on C^{12} from E_n = 1.45 to 4.10 Mev has been completed. Phase shifts up to $d_{5/2}$ were used. The $s_{1/2}$, $p_{1/2}$, and $p_{3/2}$ phase shifts all have negative sign. Two $d_{3/2}$ resonances occur at 2.95 and 3.67 Mev, with widths of 90 kev and 1.69 Mev, respectively. A $d_{5/2}$ resonance occurs at 2.076 Mev with a width of 7 kev. The *s*-wave potential scattering phase shift vs neutron energy curve thus obtained is in very good agreement with that predicted from a phenomenological nuclear potential [*Bull. Am. Phys. Soc.* **2**, 286 (1957)].

The coulomb excitation of Pt^{195} has been studied by using both protons and alpha particles. Excited states at 100, 130, 210, and 240 kev have been established from variation in yields and from coincidence measurements. An angular distribution of the 240-kev gamma rays shows that the state at 240 kev is $\frac{5}{2}^+$.

The 2^+ vibrational state in W^{186} has been identified, and its yield was determined as a function of proton energy.

The second 2^+ state in Os^{188}, Os^{190}, and Os^{192} has been determined by gamma-gamma coincidence studies on a target of normal osmium bombarded by 4- to 5-Mev protons.

Recent (p,n) cross-section measurements both at ORNL [*Bull. Am. Phys. Soc.* **2**, 177 (1957)] and at Argonne National Laboratory [*Bull. Am. Phys. Soc.* **2**, 177 (1957)] reach a value at least twice as great as that predicted by a black-nucleus model between masses 65 and 85. By approximating the coulomb potential inside the nucleus by a constant,

$\frac{4}{3}$ the height of the barrier, proton strength functions have been calculated (with the aid of an Oracle code by Dresner) for a complex square well of radius $1.45A^{1/3}$ fermis. Peaks in the strength functions for s- and d-wave protons can reproduce the observed position, that is, mass number, of the peak in the (p,n) cross sections if the depth of the specifically nuclear well is taken as 46 Mev. This is 4 Mev greater than the depth used by Feshbach, Porter, and Weisskopf [*Phys. Rev.* **96**, 448 (1954)] in their analysis of neutron cross sections. (AEC Activity 5220)

Atomic Beam Spectroscopy

The atomic beam magnetic resonance technique has been used to measure the nuclear spin of 25-min I^{128}. A value of 1 was obtained, thus confirming the prediction of Benczer, Farrelly, Koertz, and Wu [*Phys. Rev.* **101**, 1027 (1956)]. The degree of molecular dissociation was enhanced by superheating of the iodine vapor, and detection was accomplished by deposition, with subsequent counting with a scintillation counter. The radiofrequency spectrum was observed in the stray field (about 2.5 gauss) of the deflecting magnets. The equipment was calibrated by means of a beam of potassium atoms. (AEC Activity 5220)

The 86-Inch Cyclotron – Nuclear Physics

Anomalous inelastic proton scattering in heavy elements was studied as a function of incident proton energy from 23 to 12 Mev. In general, the peak remains at about $Q \cong -2.5$ Mev, and the cross section remains about constant. In the zinc isotopes, however, there is a definite shift in the $-Q$ value by about 0.6 Mev as the energy is lowered through the range. The $-Q$ value is about 0.2 Mev smaller in Zn^{68} than in Zn^{64}; the cross section is about the same. The anomalous (p,p') group in CsI (Z = 53 and 55) was studied; its cross section is about $\frac{2}{3}$ as large as in elements Z = 40 to 52.

The magnetic analyzing system was put into operation after a period of experimental difficulties; the resolution is about 100 kv, being limited by the energy distribution in the incident proton beam. The (p,p') reaction in silver was studied with this resolution. The lower energy member of the anomalous doublet is slightly too wide to be explained by a single energy level; the higher energy member is very broad. Three lower energy peaks were also observed. (AEC Activity 5220)

The 86-Inch Cyclotron – Applied Physics

The isotopes Mn^{54}, As^{74}, Y^{88}, and Bi^{205} were produced in service irradiations for outside customers. The Mn^{54} was made from a chromium target enriched to 80% Cr^{54}. The isotopes Y^{88} and Tc^{95m} were produced for other ORNL divisions. Bombardments were made in the external beam in order to determine the excitation functions of $Ni^{58}(p,\alpha)Co^{55}$ and $Ni^{58}(p,2\alpha)Mn^{51}$. (AEC Activity 5220)

Heavy-Particle Physics

Uranium metal targets and U-Mo alloy targets were bombarded with 28-Mev nitrogen ions in a search for coulomb excitation fission. Preliminary results indicate that the cross section for this process is smaller than 10^{-29} cm^2. Experiments are continuing on the angular distributions of light reaction products from the nitrogen bombardment of aluminum. (AEC Activity 5220)

Spectroscopy Research Laboratory

The Zeeman patterns of 114 lines of the spectrum of singly ionized plutonium were measured and analyzed. Many of these patterns had been observed previously on plates taken in another wavelength setting of the Echelle-Littrow spectrograph. The agreement between the g factors from the two sets of data was within the probable error of the determinations. Most of the patterns which were not previously observed involved levels of moderately high J value, for example, $7/2$, $9/2$, and $11/2$, and may confirm the existence and fix the relative position of additional low levels of the $^{6,8}F$ terms from $5f^6 7s$ and of levels arising from $5f^6 6d$. (AEC Activity 5230)

Electronuclear Machines

Cyclotron Analogue II is being designed as an electron model of the proposed 900-Mev azimuthally varying field (AVF) proton cyclotron. Design studies indicate the feasibility of using one-turn sector coils to produce the azimuthal field variations. This will greatly simplify fabrication problems. Theoretical studies of beam deflection have not yet indicated whether the optimum number of sectors would be 8 or 12. A sector coil design which can be used in either configuration is being sought so that fabrication can proceed.

Experimental studies of axial focusing problems in the central region of the cyclotron are being made in the ORNL 44-Inch Cyclotron. Grid-type structures are placed in the electric accelerating gaps in such an arrangement as to provide strong electric focusing forces. This system, usually referred to as "programing of turns," appears to be adequate in providing necessary axial focusing out to a radius where magnetic focusing can be made as strong as needed. Preliminary results give proton currents of 8.5 ma after six turns in a 3-in. gap. This performance closely approximates the specifications for the proposed 900-Mev fixed-frequency cyclotron.

Studies of problems involved in the design and fabrication of high-flux AVF magnets were initiated. Five sets of AVF shims were tested in a model magnet; convergence of the field shape toward the desired configuration has been gratifyingly rapid. (AEC Activity 5240)

Mass Spectrometry and Related Techniques

Experimental studies of ion-molecule collision phenomena have been continued. Fragments produced by collision reactions of 5.1-kev positive and negative formic acid ions are shown below:

Absolute Cross Sections for Collision Processes

Reaction*	Cross Section (cm^2)
$HCOOH^+ + Kr \rightarrow O^- + (Kr) + (HCOH)$	1×10^{-19}
$HCOOH^+ + Kr \rightarrow OH^- + (Kr) + (HCO)$	0.6×10^{-19}
$HCOOH^+ + Kr \rightarrow HCOO^- + (Kr) + (H)$	0.1×10^{-19}
$HCOO^- + He \rightarrow HCO^+ + (He) + (O)$	3×10^{-18}
$HCOO^- + He \rightarrow CO^+ + (He) + (OH)$	1×10^{-18}
$HCOO^- + He \rightarrow COO^+ + (He) + (H)$	1×10^{-18}
$HCOO^- + He \rightarrow HCOO^+ + (He)$	0.4×10^{-18}

*It is not known whether the species indicated by parentheses are ions, free radicals, or neutrals.

These data indicate that both positive and negative ion fragments are produced by ion-molecule collision of either positive or negative ions. (AEC Activity 5250)

CHEMISTRY

Raw Materials Chemistry

In further studies of the amine extraction (Amex) process for uranium from sulfuric acid ore leach liquors, it has been found that addition of alcohol to the kerosene diluent greatly improves the selectivity of di(tridecyl)amine for uranium over iron(III). The di(tridecyl)amine had previously shown advantages over several other amine extractants in regard to phase separation, aqueous solubility, and organic solubility but had the disadvantage of lower selectivity with respect to iron(III). The better selectivity now available through alcohol addition makes this amine a good possibility for process application.

Of a number of tertiary amines tested, including tri-*n*-octyl, tri-iso-octyl, mixed tertiary (*n*-octyl and *n*-decyl), trilauryl, and tris(tridecyl), trilauryl amine demonstrated the best compatibility with uranium liquors containing molybdenum. Each of the other amines showed some precipitation of a polymolybdic acid-amine complex from the solvent when it was stripped with sodium chloride solutions. Certain secondary amines, including S-24, 9D-178, and di(tridecyl), have also demonstrated good compatibility with molybdenum liquors.

Di(2-ethylhexyl) phosphoric acid (D2EHPA) has been reacted with phosphorus pentoxide in order to produce a reagent mixture that can be used in kerosene to extract uranium from commercial (30% P_2O_5) phosphoric acid. The uranium extraction power of the reagent mixture is more than 1000 times greater than the uranium extraction power of the untreated D2EHPA. Similar to the Dapex process, sodium carbonate stripping can be used if the kerosene diluent is modified with TBP. The reagent has shown fairly good stability during recycle and can be at least partially regenerated after use by reaction with additional phosphorus pentoxide.

In the usual process for solvent extraction of vanadium from sulfate leach liquors with amines, the vanadium must be in the pentavalent state and the acidic liquors must be neutralized to pH 2. Recent studies have shown that vanadium(III) can be extracted with primary amines at relatively low pH levels. With 0.1 *M* Primene JM-T in kerosene, the extraction coefficients for vanadium(III) from 0.7 *M* sulfate solution are 3.5 and 2 at pH 1.2 and 0.7, respectively.

A pump-mixer-settler system with external reflux at each end was developed; it is suitable for separation of rare earths by liquid-liquid extraction at high concentrations. A 17-stage system gave a separation factor for Yb/Y of 630 (1.46 per stage) in TBP extraction from 14 *N* nitric acid nearly saturated with an yttrium-earth nitrate mixture. An 80-stage system has been constructed and placed in operation. (AEC Activity 5310)

High-Temperature and Structural Chemistry

Equilibration-and-sampling tests and cooling curves yielded a phase diagram for the LiF-Li system that, by its shape, represents a logical extension of the series CsF-Cs, KF-K, and NaF-Na. By extrapolation, its consolute temperature is estimated to be near 1350°C. The monotectic compositions, at approximately 841°C, that is, 2 deg below the melting point of LiF, are approximately 1 and 97 mole % Li in the salt-rich and metal-rich phases, respectively.

In the study of the electrical conductivity of four examples of alkali-metal solutions in their molten halides, namely, Na in NaCl and in NaBr, and K in KCl and in KBr, the following results were obtained: (1) The specific conductivity of the solution increases monotonically with the metal concentration. (2) The temperature coefficient of the metal contribution to the conductance is positive. (3) The equivalent conductance of sodium metal measured far below the consolute temperature of the two sodium systems goes through a minimum in the concentration range between 6 and 10 mole % Na, depending on the nature of the anion and the temperature; the potassium systems measured above their consolute temperatures exhibit no minimum. This is interpreted as conforming with the phase diagrams and indicates that at the temperatures of the measurements, Na atoms associate in the solution, perhaps to form Na_2 molecules, while K atoms do so to a much less degree.

The transformation of calcite to aragonite by grinding was found to be suppressed by the incorporation of magnesium, probably as carbonate, into the calcium carbonate crystal lattice. Manganese failed to give the same effect. (AEC Activity 5330)

Radio-Organic Chemistry

Mass spectrometric cracking patterns produced with 50-ev electrons in deuteroformic acids revealed the following:

1. The positive ion at mass 45 (CHO_2^+) results from loss of hydrogen at both possible positions to about an equal extent.

2. The positive ions at masses 13 (CH^+) and 29 (CHO^+) are formed by reactions involving loss of hydrogen from both possible positions in formic acid. However, in both cases most of the hydrogen lost comes from the oxygen attachment.

3. A negative ion at mass 45 (CHO_2^-) is formed by loss of hydrogen, exclusively from the oxygen attachment.

4. The formic acid dimer present yields a negative ion at mass 91 by loss of hydrogen, exclusively from the oxygen attachment, to form ($HCOOH{\cdot}HCOO^-$). (AEC Activity 5330)

Radiation Chemistry

The 100-ev yields of the intermediates D, OD, D_2, and D_2O_2 in the gamma-ray decomposition of D_2O (0.4 *M* sulfuric acid solution) were evaluated as $G_D = 3.99$, $G_{OD} = 3.14$, $G_{D_2} = 0.38$, $G_{D_2O_2} = 0.81$, and $G_{-D_2O} = 4.75$. The corresponding values for H_2O are $G_H = 3.68$, $G_{OH} = 2.96$, $G_{H_2} = 0.45$, $G_{H_2O_2} = 0.81$, and $G_{-H_2O} = 4.58$. These values are based on the measured initial yields for the oxidation of Fe^{++} in the presence of O_2, $G(Fe^{+++}) = 16.72$, the formation of D_2O_2 in oxygenated acid solution, $G(D_2O_2) = 1.24$, and the formation of D_2 in degassed solution containing Br^-, $G(D_2) = 0.38$. The corresponding values for solutions in H_2O are $G(Fe^{+++}) = 15.6$, $G(H_2O_2) = 1.17$, and $G(H_2) = 0.45$.

The yield of H_2 in the gamma-ray decomposition of $NaNO_3$ solution depends on the nitrate concentration and can be expressed by the equation,

$$G(H_2) = 0.45 - 0.40(NO_3^-)^{1/3} .$$

The decrease in H_2 yield with increased NO_3^- concentration results from scavenging of the precursors (H atoms) of H_2 in the tracks of the ionizing particles. In general, solutes that react with H atoms decrease the yield of H_2, and solutes that react with OH radicals decrease the yield of H_2O_2. The dependence on the cube root of the solute concentration has been found to hold for a number of solutes. (AEC Activity 5330)

Chemistry of Fused Salts

Ion self-diffusion coefficients of molten $AgNO_3$ were measured between 230 and 290°C with the use of Ag^{110} and N^{15} as tracers. For the silver ion, the values of A and ΔH

in the rate equation $D = Ae^{-\Delta H/RT}$ are 0.49×10^{-3} and 3.7 kcal, respectively. The latter value is lower than values found in $NaNO_3$, KNO_3, and $CsNO_3$, which were between 5 and 6 kcal. The extrapolated value of D for Ag^+ at 350°C is approximately equal to that for Na^+ in $NaNO_3$ and, therefore, is considerably higher than values for K^+ and Cs^+ in their respective nitrates. Tentative results for NO_3^- in $AgNO_3$ indicate that the ratio of the self-diffusion coefficients of the cation to the anion is approximately the same as in $NaNO_3$ and, again, is considerably higher than in KNO_3 and $CsNO_3$. (AEC Activity 5330)

Molten Salt Thermodynamics

As part of a continuing study of activities in molten salts, theoretical and experimental work is being carried out on reciprocal systems such as K^+, Ag^+, NO_3^-, and Cl^-. The theoretical treatment of Flood and co-workers, which assumes random mixing of ions of a given sign and takes into account the attraction between nearest neighbors, was modified in two ways. A simplified development was found, and a generalization to include the effect of longer-range-than-nearest-neighbor interactions is proposed.

Experiments on the reaction between $AgNO_3$ and KCl in KNO_3, by means of emf measurements of the relative activity of $AgNO_3$, and also by a visual determination of the solubility of AgCl, led to a heat of solution of 20.1 kcal/mole for AgCl. This agrees with the value of 19.5 kcal/mole predicted by theory. However, the $AgNO_3$ exhibits more pronounced negative deviations from ideality than were predicted. This is interpreted as evidence of nonrandom mixing and indicates the need for further refinement of the theory to accommodate the existence of preferred neighbors. (AEC Activity 5330)

Analytical Chemistry Research

A radioactivation method for the determination of oxygen in lithium has been subjected to test, and it was found that the procedure is sufficiently sensitive and reproducible for this purpose. The method involves the irradiation of a sample in the ORNL Graphite Reactor to produce F^{18}, $t_{1/2}$ = 112 min, by the nuclear reaction $Li^6(n,\alpha)H^3$ and $O^{16}(H^3,n)F^{18}$. The F^{18} is separated, and its activity is compared with that of a comparator sample that had been treated similarly. From this comparison, the concentration of oxygen in the unknown sample can be estimated. The results of a series of analyses revealed that reproducible data with a sensitivity of the order of 10 ppm can be obtained. A similar technique can be used to determine oxygen in other metals or alloys.

In a continuation of the experiments on the separation of the metal elements by extraction with a mixture of tri-*n*-octylphosphine oxide (TOPO) and cyclohexane, it has been established that titanium can be extracted completely from 7 *M* aqueous sulfate solutions, while on the other hand negligible extraction takes place from 1 *M* H_2SO_4. The principal species in the organic phase was found to be $TiOSO_4 \cdot 2TOPO$. Tests also revealed that niobium can be extracted readily from hydrochloric acid, moderately well

from sulfuric acid, and essentially not at all from nitric or perchloric acids. The extraction coefficient of niobium from 4 *M* HCl is about 200, while from 6 *M* HNO_3 the coefficient is about 0.02. The pronounced effect of HCl concentration on the extractibility of niobium is evidenced by the fact that from 3 *M* and 5 *M* HCl the extraction coefficient is only 20.

METALLURGY

Ceramics Research

Waste Disposal. – Investigations on the retention of fission products (without prior separation) in fired ceramic bodies by utilizing naturally occurring materials such as ball clays, bentonites, phosphate slimes, shales, and attapulgites have been carried out. Efforts have been made to decrease the amount of clay necessary to completely retain the activity in 250 ml of Hope solution, when tagged to 20,000 to 40,000 counts/min/ml, by use of a small colloid mill. With better dispersion, a given amount of clay should retain increased amounts of activity.

Several mixtures of clay and Hope solution have been made and tagged to a count of roughly 200,000 counts/min/ml. Because of the excellent results with attapulgite clays in the low-activity ranges, they were used in the high-activity mixes. Results from these mixes show that an increase in firing temperature was necessary to retain the activity. This may be circumvented by addition of fluxes or by better dispersion of the clay.

A nitrogen gas adsorption system has been built and is in the process of being calibrated. It will be used in surface-area determinations in an effort to correlate retention of activity and surface area on the clays used in the past year.

Bulk density tests and per cent porosity measurements by a benzene suspended-weight–wet-weight method were made on 17 different sinters of the Purex-clay mixes. The results were used, together with measured slurry densities and weight loss determinations, to obtain the volume reduction (from volume of slurry to volume of sinter) exhibited by different mixes at several sintering temperatures. The density values for this reduction ranged from 2.5 to 12.5. Per cent porosities ranged from 79 to 26. The volume reduction ratio is of great importance in considerations for waste disposal pits.

Silica-glass-dish tests were run parallel to leach tests for sinter mixes by using 100- and 50-g proportions of high-volatile-matter attapulgite clay and a 50-g proportion of ball clay in a 250-ml Purex waste solution, tagged to 6715 counts/min/ml with mixed fission products. The results of these tests corroborate indications in earlier tests that volatilization of some radioactive material or some change in the surface of the sinter occurs between 300 and 500°C. The leach tests show complete retention of mixed fission products at the 7000-count/min/ml level by the sinters tested.

Fuel Element Development. – Several new techniques are being tried for putting cores of UO_2 in the Si-SiC fuel plates. The problem remains the same – that is, putting in

larger amounts of fuel and, at the same time, trying to avoid the reaction between Si and UO_2. The new techniques are based on core additions which will absorb heat in reacting or fusing, or which will shield the core from the exothermic heat of the Si-C reaction. Several heat-treating experiments have been performed which indicate that it is possible to increase the β-SiC content of Si-SiC pieces from 75% to approximately 98%. This has opened up the possibility of making a dense SiC fuel element. (AEC Activity 5420)

Fundamental Physicometallurgical Research

Development of fiber textures as a function of the amount of deformation was studied in a series of aluminum rods swaged to 40, 60, 70, 80, 90, 95, and 99% reductions in area from a cast ingot. The <001> texture of the casting decreased with increasing reductions up to 70%. Recrystallization occurred at room temperature for reductions of 70 to 90%, which caused the relative amount of <001> texture to increase from approximately 30 to 65%. For reductions greater than 90%, the amount of <001> again decreased with increasing deformation. The deformed grains appeared to rotate first toward <112>, then toward <111>. For reductions greater than 95%, the minor component near <112> of lower reductions was entirely absent.

In the fundamental studies of zirconium and its alloys, recent experiments in the liquid-helium temperature range have shown that the lattice contribution to the specific heat of alpha zirconium is given by $1.944 \times 10^9 (T/294)^3$ ergs/mole/deg and that the electronic contribution is given by $2.87 \times 10^4 T$ ergs/mole/deg. For a zirconium–8% indium alloy the electronic term is increased and the Debye temperature is decreased. The increase in the electronic term corresponds to an 8% increase in the density of states, agreeing with the observed expansion of the axial ratio with electron additions and with increasing temperature. The change in the Debye temperature is considerably smaller than that predicted by the Kopp rule. (AEC Activity 5420)

PROGRAM 6000 – BIOLOGY AND MEDICINE

BIOPHYSICS

Radiation Dosimetry Programs

Measurement of Stopping Power at Low Energies. – A knowledge of the stopping power of matter for low-energy electrons is essential to the setting of maximum permissible limits of exposure to beta rays and to the evaluation of the secondary electron flux produced in media subjected to radiation bombardment. Preliminary experiments indicate that the stopping power of matter may be measured for very-low-energy particles. For electrons the only precise data presently available at low energy concern the energy loss of 148-kev electrons in aluminum. There apparently is no experimental information for lower

energies where the Bethe formula predicts a great increase in stopping power. In particular, the shell corrections which are known to apply to heavy-particle slowing down will be expected to modify the Bethe formula considerably at low energies.

The present experiment as conceived avoids the problem which has so far limited stopping-power measurements to higher energies, namely, the absorption and scattering in the window which separates the vacuum of the accelerator and the detector (ion chamber or counter). It now appears possible to use the heat radiated from the foil as an index of the energy absorbed. Calibration of the radiation detector is accomplished by heating the foil with an electric current running from edge to edge. The stopping power may be calculated from the watts of electric power required to cause the same detector response as that found with beam heating.

A blackened Thermistor in a Wheatstone bridge circuit, when used as a radiation detector, gave a sensitivity of 6 cm of galvanometer deflection per milliwatt of foil power. For comparison, a 10-kev electron beam of 1 microampere strength which lost 10% of its energy in the foil produced 1 milliwatt of heating and hence 6 cm of deflection.

Validity of the Bohr-Lamb Criterion. – The Bohr-Lamb criterion [*Phys. Rev.* **58**, 654 (1940); *Phys. Rev.* **58**, 696 (1940)] is based on an assumption that an ion passing through matter is stripped of all its orbital electrons that have velocity smaller than the translational velocity of the ion. This criterion is not based on any rigorous theoretical arguments, and its order of accuracy has never been determined, partly because it was correlated with statistical atomic models which represent merely a rough approximation.

In this investigation an effort was made to establish the possible accuracy of the Bohr-Lamb criterion by using, instead of a statistical model, very reliable data obtained by Lisitzin [*Soc. Sci. Fennica Commentationes Phy. Math.* **10**, No. 4 (1938)] on ionization potentials of various ions. The Lisitzin data are based on a study of various sequences of isoelectronic systems and provide values for electronic orbital velocities that are of relatively high order of accuracy. These values have been used in order to correlate the Bohr-Lamb criterion with experimental data. The results show that the Bohr-Lamb criterion is only applicable to fission fragments and not to lighter ions. In order to remedy this situation the procedure followed was that suggested by Knipp and Teller [*Phys. Rev.* **59**, 659 (1941)], and two empirical parameters, γ_L and α_L, were introduced; they are defined as follows:

$$\gamma_L = \frac{v_L}{V} ,$$

$$\alpha_L = \frac{Z_L^*}{Z_{av}^*} ,$$

where V and Z_{av}^* represent the velocity and the average charge of a moving ion; v_L is the velocity of the most loosely bound electron having velocity $v_L = V$. [The values v_L and Z_L (Bohr-Lamb) have been determined from graphs based on the computations of Lisitzin.]

The numerical values of γ_L and α_L corresponding to all available measurements of ions of various velocities were determined. The results fail to show any regularity in the behavior of these parameters as a function of the ionic species, the ionic velocity, or the surrounding medium. A survey of the literature covering the last 16 years failed to suggest a definite opinion regarding the accuracy of the Bohr-Lamb criterion. This may be due to the paucity of experimental data or to the lack of uniformity in the quality of various measurements made on ionic charges and velocity. (AEC Activity 6140)

Internal-Dose Studies

An analytical procedure has been developed for the determination of uranium alpha activity in urine. This new technique is based on the use of an anion exchange resin column to remove the uranyl chloride complex from the urine solution. The urine can be processed directly, thereby eliminating the oxidation of the organic material of the sample. The eluted uranium can be transferred directly to a stainless steel planchet for counting. Average recovery is about 90%.

The gamma-ray spectra of several nuclides have been investigated to ascertain the practicability of administration to mice of mixtures of radionuclides for information upon which to base the computation of maximum permissible concentration values. It was found that binary mixtures of Co^{60} plus Cs^{137} and of Sb^{124} plus Ce^{144} can be assayed with 5% accuracy. A pilot study of the distribution of Sb^{124} and Ce^{144} showed that, following a single oral dose of these isotopes, the skeleton contained 56.6% of the total body burden of Sb^{124} and 9.7% of the Ce^{144} body burden 13 days after the administration of the isotopes. At the same time interval the liver was found to contain 23.4% of Sb^{124} and 59.6% of Ce^{144} in terms of the total body burden. Twenty days after administration, the retention of Ce^{144} in the skeleton and the liver was approximately equal, 39.6% vs 36.2% of the total body burden. (AEC Activity 6440)

Ecological Studies

The July leaf and twig samples from the monitor trees 500 ft from the radioactive waste pits had a significant increase in the concentration of Ru^{106}, compared with the June samples. This is attributed to the decrease in precipitation in the June-July period, which would result in increased evaporation and concurrent transpiration, thereby moving more fission product from the root region to the tree tops.

Further analyses were completed for Sr^{90}, Cs^{137}, and Co^{60}. In 48 samples selected at random from a plot 50 by 50 ft in the upper part of White Oak Lake bed, the following concentrations were obtained: total Cs^{137}, 1.47 $\pm$ 0.067 microcuries per 100 g of soil; total Co^{60}, 0.36 $\pm$ 0.018 microcurie per 100 g of soil; and 1 *M* ammonium acetate extracts for Sr^{90}, 0.031 $\pm$ 0.009 microcurie per 100 g of soil.

Comparison of 1956 and 1957 populations of insects on vegetation in White Oak Lake bed shows some changes in species composition, but the estimates of biomass for those

years are similar. The changes in the lake bed vegetation probably account for changes in insect species. An increase in the diversity of the Acarina (mites) in White Oak Lake bed soils occurred during this period. Probably this increase is related to the accumulation of litter and to the more varied flora present this year.

Seven species of algae, typical of the Clinch River and its tributaries, were tested for their ability to concentrate Cs^{137}. Considerable variation occurred between species. Concentration factors ranged from 52 to 1530. (AEC Activity 6440)

Waste Disposal Research – Soil Disposal of Intermediate-Level Radioactive Wastes

Chemical Waste Disposal Pits. – Five and a half million gallons of liquid waste were transferred to the pits through December 1956. These wastes, at the time of discharge, contained about 58,000 curies of Cs^{137} and 15,000 curies of Ru^{106}. Approximately 110 tons of Na and 140 tons of NO_3, the principal inert constituents, were released to pit 3, and about 54 tons of Na and 80 tons of NO_3 were released to pit 4.

The liquid budget for 1956 indicates that pit 3 gained as much liquid from rainfall as it lost through evaporation and seepage. From the standpoint of liquid disposal only, the three-pit system would have operated as efficiently without this pit. The pit was of some value, nevertheless, since 370,000 gal of waste seeped out of the pit, carrying with it appreciable quantities of radioactive constituents for adsorption on the surrounding soil. As a consequence, the utilization of the adsorptive capacity of the soil around the other two pits was reduced. The quantity of radioactive constituents which overflowed into pit 2 from pit 3 was reduced by coprecipitation, dilution with rain water, and decay. During this period, pit 2 had a net loss (evaporation plus seepage minus rainfall) of about one million gallons. The liquid stage in pit 4 was observed to fall at a near constant rate of 0.21 ft per day, due in large measure to seepage. As an example, between the stages of 7 and 8 ft, this rate of fall is equivalent to 20,000 gal per day.

The rates of flow in the streams receiving radioactive contaminants from the pits were measured continuously, and periodic samples were collected and analyzed to determine the total transport of the waste constituents. The quantity of activity entering a stream over a period of time was uniform, but the concentration changed rapidly during wet weather and increased the flow in the stream. Cesium-137 reached the streams in quantities too minute to be detected by gamma-ray spectrometry and radiochemical analysis, but it was detected in the leaf litter of the immediate environs. The quantities of Ru^{106} and NO_3 reaching the streams and discharged from White Oak Creek were diluted in the Clinch River to concentration values less than the recommended values for lifetime drinking-water use. (AEC Activity 6440)

Mathematics and Computations for Health Physics

A preliminary analysis of air-monitoring data collected from the waste pit area, the ORNL area, and the off-site area has been completed. By using gum-paper-ash measurements of activity in counts per minute for January through April 1957, the following conclusions were reached:

1. Several data-collecting stations in the pit area may be eliminated.
2. The stations in the off-site area collect consistent information.
3. The stations in the ORNL area reflect varying amounts of activity with differences which can be demonstrated to be statistically significant.
4. No statistically significant association may be demonstrated between the level of waste in pit 4 in the pit area and the activity measured by the collecting stations surrounding pit 4.

Additional data for approximately one month will be gathered from which a final analysis will be performed. (AEC Activity 6440)

PROGRAM 8000 – WORK FOR OTHERS

ASEE-AEC Nuclear Energy Institute

The Nuclear Energy Institute extended from July 1 to August 23, 1957. The course was taught by R. A. Charpie and was attended by 20 members of university faculties. (AEC Activity 8736.3)

Professional Health Physics Training Program

The 26 AEC Fellows in Radiological Physics and one Air Force officer have completed three months of training in Applied Health Physics, while two Air Force officers completed six months of training.

Of the ten Fellows who received six-month extensions of their fellowship to complete the requirements for the M.S. degree, three are remaining at ORNL to do their research. Seven of the Fellows have accepted full-time jobs in Health Physics, while three are entering military service with the U.S. Public Health Service. The remaining six are taking part-time jobs to enable them to complete their master's degrees. (AEC Activity 8780)

MISCELLANEOUS REPORTS

OPEN LITERATURE PUBLICATIONS

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Hochanadel, C. J., and T. W. Davis, "Radiolysis of Solid Nitrates," *J. Chem. Phys.* **27**, 333 (1957).

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Rose, M. E., *Elementary Theory of Angular Momentum*, Wiley, New York, 1957.

Shapira, R., D. G. Doherty, and W. T. Burnett, Jr., "Chemical Protection Against Ionizing Radiation. III. Mercaptoalkylguanidines and Related Isothiuronium Compounds with Protective Activity," *Radiation Research* **7**(1), 22 (1957).

Stoughton, R. W., and J. Halperin, "On the Effective Capture Cross Section of Pu^{240} for Reactor Neutrons," *Nuclear Sci. and Eng.* **2**, 481 (1957).

Sworski, T. J., "Photoreduction of Ceric Ion in Sulfuric Acid Solutions. Effect of Thallous Ion," *J. Am. Chem. Soc.* **79**, 3655 (1957).

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Wilkinson, M. K., N. S. Gingrick, and C. G. Shull, "The Magnetic Structure of Mn_2Sb," *Phys. and Chem. Solids* **2**, 289 (1957).

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Wilks, J., Clarendon University, Oxford, England

Yokoo, Y., Kyoto University, Kyoto, Japan

RADIOISOTOPE SALES AND COSTS

Type of Transaction	July 1957	FY 1958 to Date
Domestic sales	$228,764	$228,764
Foreign sales	3,424	3,424
Project-transfer	3,504	3,504
Project-cash sales	8,578	8,578
Technical cooperation program credits	0	0
Plant credits	3,740	3,740
AEC credits	10,991	10,991
Total radioisotope income	$259,001	$259,001
Total radioisotope costs	$138,776	$138,776
Total radioisotope shipments	1,203	1,203
Helium		
Income	$ 3,316	$ 3,316
Costs	$ 2,230	$ 2,280
Shipments	3	3

GROSS OPERATING COSTS

	July 1957	FY 1958 to Date
Programmatic operating cost – net	$3,879,119	$3,879,119
Equipment	208,252	208,252
Construction	82,961	82,961
Work for others – transfers	369,891	369,891
Inventory changes	139,152	139,152
Reimbursable work for others	38,142	38,142
Deferred charges	(101,273)	(101,273)
Adjustments to cost of prior years	(90,429)	(90,429)
Total laboratory cost – net	$4,525,815	$4,525,815
Estimated cost for August	$4,500,000	
Estimated cost through August	$9,025,815	

Credit ( )

[redacted]

PERSONNEL SUMMARY

	Number of Employees, August 1957	New Employees, August	Terminations, August
Administration	64	1	1
Operations*	135	2	1
Engineering, shops, and mechanical	880	2	6
Laboratory and research	2303	24	86
Protection	118	1	0
Service	407	9	7
Total	3907**	39	101

*Includes Electrical Distribution and Steam Plant as well as the Operations Division.
**Includes 950 Laboratory employees in the Y-12 Area.

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Reports in this series issued during the past year:

August 1956	ORNL-2166
September 1956	ORNL-2185
October 1956	ORNL-2205
November 1956	ORNL-2232
December 1956	ORNL-2248
January 1957	ORNL-2261
February 1957	ORNL-2281
March 1957	ORNL-2299
April 1957	ORNL-2316
May 1957	ORNL-2342
June 1957	ORNL-2355
July 1957	ORNL-2370

Approved by Alvin M. Weinberg, Director

[redacted]