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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

JUNE 1961

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

JUNE 1961

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Oak Ridge, Tennessee
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U.S. ATOMIC ENERGY COMMISSION

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

JUNE 1961

This Status and Progress Report summarizes that portion of the Laboratory's work which is unclassified. Some of the topics are included every month, but the majority are reported on a bimonthly schedule.

SPECIAL NUCLEAR MATERIALS PROGRAM

Chemical Plant Criticality Studies. — A series of experiments with up to 19 cylinders of aqueous $UO_2(NO_3)_2$ solution (410 g of U per liter; sp gr = 1.55, 92% U^{235} enrichment) arranged with their centers on triangular and square patterns extended significantly the data describing critical arrays of individually subcritical units. The cylinders were 6 in. in diameter and of variable height up to 50 in. They were contained in aluminum vessels. As examples of the data, 9 cylinders in a 3 × 3 square pattern were critical at a height of 49.8 in. with a surface separation of 3.0 in.; 16 cylinders in a 4 × 4 square pattern were critical at a height of 50.0 in. with a separation of 5.0 in.; 19 cylinders in a triangular pattern were critical at a height of 50.0 in. with a separation of 6.64 in. In a set of similar experiments with individual cylindrical units 8 in. in diameter and 7.5 in. high, enclosed in 1/4-in.-thick Plexiglas containers, arranged in three-dimensional cubic arrays, it has been shown that eight units are critical at a container surface-to-surface spacing of 0.56 in. and that 27 units are critical at a spacing of 2.5 in. The purpose of this study with nearly equilateral volumes of solution, which can be positioned in three dimensions, is to establish a basis for analytical methods of specifying subcritical configurations of fissile materials in storage, transport, etc.

Dissolver Solution Analyses: Plutonium. — Work was continued on the determination of the plutonium content of Pu-Al alloy samples by the coulometric titration procedure mentioned in ORNL-3140. The procedure gives results which agree with those obtained by thenoyltrifluoroacetone extraction and counting techniques on standard synthetic samples, but the coulometric procedure generally gave slightly low results on actual samples and can be remedied by making a reduction at −0.3 v before carrying out the usual procedure.

Plutonium can be quantitatively separated by adsorption on an anion resin from 10 M HNO_3 and elution with 0.1 M HNO_3–0.01 M HF. Coulometric titration of the plutonium in the effluent can then be made after fuming with $HClO_4$ to destroy organic material and remove HF. Precision of the over-all procedure is 0.6% at the 1-mg level.

The use of divalent silver, AgO, as oxidant in the indirect controlled-potential coulometric titration of plutonium was studied. Silver

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ions can then serve as the intermediate reagent. The precision of this procedure is 0.4% at the 5-mg level and 1% at the 0.5-mg level. Consequently, oxidation with AgO gives results comparable with those obtained when the oxidation is made with $HClO_4$.

Work has begun on the separation of plutonium by solvent extraction with tri-n-octylphosphine oxide and on the determination of valence states of plutonium by coulometric titration.

Dissolver Solution Analyses: Uranium. — In ORNL-3140 a method was reported for the determination of uranium in the presence of iron by use of a two-electrode system. Some precision studies have been made by using this technique, with the following results:

Fe Added (mg)	U Added (mg)	U Found (mg)	No. of Titrations	Relative Standard Deviation (%)
None	5.92	5.92	9	0.34
5–12	5.92	5.92	8	0.29
18–50	5.92	5.95	15	0.79

A method is also being developed by which antimony in fluoride salts can be determined by controlled-potential coulometric titration. A supporting electrolyte of 0.5 M tartaric acid–0.8 M HCl is used. Since Sb(III) → Sb proceeds reversibly, the solution is reduced at −0.240 v vs the S.C.E. and reoxidized at −0.080 v vs the S.C.E., with very good agreement between the two values. Some studies are now being made for determining the effect of various concentrations of other acids such as HNO_3 or H_2SO_4 on this system. Further work on this procedure will include studies of possible interferences such as arsenic.

REACTOR DEVELOPMENT PROGRAM

GAS-COOLED REACTOR PROJECT

Oxidation-Resistant Coatings on Graphite. — The oxidation resistance of a siliconized SiC-coated 901S graphite specimen cut from a full-size graphite sleeve for an EGCR fuel element assembly was determined before and after a series of thermal cycles. There was no significant change in the oxidation resistance after 20 thermal cycles from 600°C to room temperature with air cooling. Another sample was quenched in water three times from approximately 600°C, with no significant change in the oxidation resistance. The test was not sufficiently sensitive to detect small changes in the oxidation resistance because of the normal weight loss resulting from oxidation of the uncoated ends; therefore, future tests will be made on completely coated specimens to avoid this complication.

Metallographic measurements were made of the thickness of pyrolytic graphite coatings on similar graphite sleeves. The coatings were much more uniform than the siliconized SiC coatings. Optical measurements on

metallographic sections could be made readily by using polarized light. The coating thicknesses for different specimens varied from about 0.5 mil up to about 5 mils. Calibration curves plotted from these data and eddy-current measurements indicate that the accuracy of the eddy-current technique for the measurement of such coatings is better than ±0.25 mil.

Fabrication of Fueled BeO. — Recent developments in attempts to eliminate microscopic cracking of BeO specimens containing large UO_2 particles indicate two possible causes of the cracking: (1) the release of binder residue during sintering and (2) laminations induced upon release of specimens from the forming die.

Crack-free specimens were prepared by removing the epoxy resin binder by vacuum heat treatment at 600°C prior to sintering and by reducing the angle of taper at the ejection end of the die. These specimens contained 20 vol % UO_2 as 150- to 250-μ particles and had bulk densities of 95% of theoretical. Additional experiments must be conducted, however, before it can be definitely concluded that the cracking can be eliminated in this manner.

Fission-Gas Release from UO_2. — Fission-gas-release tests of neutron-activated commercial UO_2 samples have given release rate parameter (D') values at temperatures between 400 and 800°C that indicate an activation energy of 14.7 kcal/mole. This activation energy is much lower than that reported for UO_2 in the temperature range 800 to 1600°C, namely, 70 to 80 kcal/mole. Anderson *et al.* at Harwell, during thoron emanation studies on UO_2 powder, found three different activation energies for the process: above 1100°C, 81 kcal/mole; between 800 and 1100°C, 38 kcal/mole; and below 800°C, ~20 kcal/mole. It is thought that the value of 14.7 kcal/mole, cited above, is the first confirmation of Anderson's data. Additional tests to validate this low activation energy are planned.

In another test of a UO_2 sample in vacuum at 400°C, the fractional amount of the fission gas present that was released in 70 hr totaled 1.44×10^{-3}. Hydrogen was then admitted to the system, and the Xe^{133} release rate was reduced immediately. This indicated that surface oxidation of the UO_2 sample was responsible to a large extent for the large gas release.

Testing of Dissimilar Metal Welds. — Specimens of 15-in.-OD, 1-in.-wall pipes containing welds of SA-212, grade B, carbon steel to stainless steel and A-387, grade D, chromium-molybdenum steel to stainless steel are being subjected to thermal-cycling tests. Two types of weld metal were used for each dissimilar metal combination: (1) type 347 stainless steel, which is used in general industrial practice, and (2) Inco BP-85, which appears to be a more promising filler metal for EGCR applications. The possibility of an incipient crack was noted in the carbon-steel—to—stainless steel joint welded with type 347 stainless steel after 60 thermal cycles from 1050°F to room temperature (1050°F was selected as the maximum temperature because several authorities thought it would take a very large number of cycles to induce cracking during cycling from 650°F, the expected service temperature, to room temperature). The weld was then cycled an additional 17 times, after which dye-penetrant inspection revealed a definite crack. A 3-1/2-in.-diam plug was therefore machined from the sample and metallographically examined. Cracks were found in the heat-affected zone of the carbon steel.

Dye-penetrant inspection also revealed an incipient crack in the A-387 steel-to-stainless steel joint welded with type 347 stainless steel after 60 cycles from 1050°F. A plug was also machined from this sample and is being examined metallographically. No evidence of cracking has been observed in either of the specimens welded with BP-85 electrodes; cycling of these specimens is continuing.

Evaluation Studies of Coated-Particle Fuel Elements. — Two more neutron-activation tests of pyrolytic-carbon-coated UC_2 fuel particles were run to substantiate the release of Ba^{140} without concurrent release of Xe^{133}. After both tests, Ba^{140} and traces of Ru^{103} were found, but no other gamma activity was detected.

EGCR Experimental Loops. — Draft copies of the preliminary design and hazards summary report on the experimental loops for the EGCR were issued for review by Reactor Division personnel and the ORNL Reactor Experiment Review Committee. Final design criteria were established for the experimental-assembly stringer, the experimental-assembly insertion system, and the cooling system for use during removal of an experimental assembly. Design analyses for the through-tube pressurizer and the loop filling system were completed. Design criteria for cell penetrations were prepared, and the design analysis of the main-stream evaporative gas cooler and associated cooling-system components is in progress. Design analyses were completed for the main-stream pressure-relief valves and the loop purification system, and a title II flowsheet was prepared for the plant and instrument air system.

THERMAL-BREEDER REACTOR PROGRAM

Homogeneous Reactor Program

Homogeneous Reactor Test. — Activities necessary to prepare the HRT for storage (in an assembled state) continued. Five of the six corrosion assemblies desired for analysis and study were recovered from the system. Operations necessary for removal of the sixth assembly are in progress. Securing of instrumentation and controls in a standby state is approximately 70% complete. This work and work on securing of other systems will continue.

HRT Chemical Pilot Plant. — A measurement of the xenon poison level made previously in run 21 was reconfirmed by samples obtained in run 25. Samples of reactor off-gas were isolated in the vapor space above the chemical-plant decay tanks, removed after three days of cooling, and analyzed after a decay period of one month by mass-spectrographic methods for the ratio of the Xe^{136}/Xe^{134} isotopes. At the "normal" operating conditions with 52% power production in the core and at 5 Mw, the poison fraction was 0.009. Samples obtained at 3 Mw following loss of the upper patch, when 70% of the power was produced in the blanket, showed the poison fraction to be slightly higher, namely, 0.010. The longer processing time for iodine removal from the blanket resulted in higher poisoning, even at the lower power.

Thorium Blanket Studies. — Pellets were prepared of ThO_2 made by denitration of thorium nitrate with superheated steam followed by dispersion of the oxide in water to a sol, evaporation of the sol to a gel, and calcination of the gel. When the denitration was to a high N/Th atom ratio, 0.198, and when this ratio was decreased to 0.13 by aging and evaporating with formic acid, yields of > 10-mesh 1200°C-fired fragments were 90 to 98%, but only 48% survived self-grinding in a bed fluidized by water. A sol whose initial N/Th ratio was 0.055, which was adjusted to 0.11 by addition of nitric acid, gave a 48% yield of > 10-mesh 1200°C-fired fragments, but 60% of these survived the 21-hr self-grinding operation. A comparison of slow (in-furnace) and fast (room-temperature) cooldown after 1200°C firing showed no significant difference.

Slurry Circulation Experiments. — A new high-temperature capillary viscometer was fabricated for use with the 200B loop. The test section consists of a 20-in. vertical length of 0.018-in.-ID tubing. The viscometer was calibrated with water at temperatures of 25 to 120°C.

The 200B loop was then charged with a 650°C-fired thoria slurry of an average particle diameter of 1.3 μ. During circulation it is expected to degrade to very small particles. Friction factors in turbulent flow and in laminar flow through the viscometer will be determined.

Engineering Development. — Testing was completed of a 5-in. plastic model of an HRT-size cylindrical core with slotted side entries. Velocities of 5 fps or greater were generated past all surfaces. Based on fluid age measurements, the temperature rise at the hottest point within the fluid volume of a reactor operated with the same flow pattern would be 1.2 times the average rise across the core. The wall temperature in high-flux regions would be about midway between the fluid inlet and outlet temperatures; in low-flux regions the wall temperature would be as high as the fluid outlet temperature. The general design appears to be attractive.

Tests were made for determining the degree of stagnancy within pits simulating a corroded core-tank surface. The test pits were facing downward in a horizontal rectangular channel. Air bubbles were retained most strongly in cylindrical pits with flat bottoms 3/16 in. in diameter by 2 mm deep. Bubbles were not retained in hemispherical pits at velocities greater than 1.5 fps.

Calculations indicate that an accumulation of ZrO_2 on the HRT patch toggle, corresponding to 6 mils of Zircaloy corrosion, would promote boiling on these surfaces. Boiling of the solution to dryness in these crevices could result in melting of the nut.

A magnifying objective lens and three extension tubes for the Omniscope were received from the Lerma Engineering Corporation. Incorporation of these devices into the existing optical system provides an additional 5X magnification for inspection. The unit was tested and found to operate satisfactorily.

A device was designed and fabricated for obtaining ultrasonic thickness measurements of most portions of the HRT core.

MOLTEN-SALT REACTOR PROJECT

MSRE Design. — Reactor-cell design effort was diverted from the usual piping, structure, and support activities so that work could be concentrated

on all cell-penetration design. This was necessary in order to complete these designs in time for inclusion in the lump-sum contract by the July 1 deadline. Work did continue uninterruptedly on power and thermocouple cabling within the cell. These cable layouts are now 90% complete.

Reactor-vessel drawings including the core were approved and signed. Radiator drawings were also finished and approved. Drain-tank drawings including water-cooling design were approved. This will allow the component package comprising the reactor, heat exchanger, radiator, and drain tanks to be sent out for bid on July 1. The design report covering these items was also issued this month.

Engineering drawings composing package A for the lump-sum building modifications were completed. Thus, from an engineering and design standpoint, the bid package for this contract can go out as of July 1.

Process flowsheets and instrument flowsheets are complete for most of the system, and this work continues.

Electrical engineering and design effort was greatly increased during the past month. Major circuit allocation, heater arrangement, auxiliary power programming, and emergency power allocations are being made.

A preliminary design for the track system for the manipulator and stereotelevision vehicle was completed, and final design is in progress.

Design has begun on the jigs and fixtures for assembling and thermal cycling the major components.

Design has begun on the tools for handling the removable section of the sampler-enricher tube.

Component Development. — Construction was started on the loop piping of the full-scale hydraulic model of the core and on the pressure vessel. Bids were received on the internal structure and on the simulated graphite. The choice of aluminum instead of plastic as the material of construction for the simulated graphite was based on the favorable bids.

Operation of the engineering test loop continued with the MSRE coolant salt. An addition of BeO was made to the circulating system after 900 hr to determine the ability of chemical analysis to monitor oxide content. Freeze-valve testing was begun after more than 1200 hr of continuous loop operation at 1100°F.

A sampler-enricher system proposal was issued for comment and approval. The design and development program is based on the operation and containment criteria established by this proposal.

The reactor-vessel heater test has operated satisfactorily for 14 weeks.

Construction of equipment for the fuel-drain-tank cooler test is 85% complete.

Tests were run to determine the thickness of high-temperature insulation required immediately adjacent to the ceramic pipe heater to reduce the temperature to an acceptable level for a less expensive, lower temperature material. A 1-1/2-in. layer of the high-temperature material dropped the temperature from 1400°F at the heater to 1050°F at the inner surface of the 3-1/2-in. layer of standard insulation.

Remote Maintenance. — Uniform heating cycles for the remote-brazing operation were demonstrated by using a 4.2-kc generator and 25-ft-long water-cooled leads to the work coil.

In the maintenance mockups, the supporting steel was erected, the mock pump and motor were mounted, and the secondary piping is being installed.

Conceptual layout drawings for a portable MSRE maintenance facility were completed, and component item detailing was started.

Three prototype yoke-mounted 1/2-in.-pipe block disconnects, fabricated with design variations of integral ring-joint seals, each have now undergone more than 12 assemblies and disassemblies and 30 thermal cycles to 300°F. Seal leakage, with helium, was less than 8×10^{-7} std cc/sec for two units and less than 2×10^{-8} for the third. One of the two commercial Pushomatic-type disconnects purchased from the On Mark Company was received. In early development tests with a set of prototype ring-joint flanges which contained four separate inner 1/2-in. pipe passages sealed with commercial Flexitallic gaskets, the leakage of helium through the ring seal was less than 2×10^{-8} std cc/sec, and the leakage through the inner gasket seals was less than 1×10^{-6}.

MSRE Instrumentation. — Instrumentation requirements are being investigated for the cooling water, building ventilation, and waste disposal systems. Instrument application diagrams for the cooling water and building ventilation systems are in preparation. The necessary taps, connections, and other provisions required for installation of instruments in these systems are being incorporated in the piping drawings.

The requirements for instrument piping and wiring penetrations of containment vessels and building concrete were surveyed, and the necessary penetrations are being incorporated in the building and vessel drawings. Preparation of a proposal for MSRE data-handling equipment is nearing completion. A second conceptual layout of the main control panel, using graphic presentation, is in preparation.

Development of a float-type level transmitter for measurement of liquid level in the fuel- and coolant-salt pump bowls is continuing. Design of the float and vessel arrangement for the prototype assemblies was completed, and these assemblies are being fabricated. Development of the position-sensing differential-transformer assembly is continuing.

Measurements were made of the conductivity of molten salt at various frequencies and applied voltages in order to provide data for use in the design of a single-point conductivity-type level probe. A conceptual design for a probe of this type was evolved, and a prototype probe is being fabricated for testing.

Sample quantities of several types of Inconel-clad and INOR-8-clad mineral-insulated thermocouple wire, including 1/16-in.-OD single conductor and 1/8-in.-OD duplex wire, were received and are being evaluated to determine their suitability for use in the MSRE. Methods of attaching thermocouples to INOR-8 pipes and vessels and of providing the necessary end seals for these couples are being investigated.

Pump Development. — The pump with the molten-salt-lubricated journal bearing has operated continuously for 10,300 hr with $LiF-BeF_2-UF_4$ (62-37-1 mole %) at 1225°F and has been started and stopped 79 times. The drive motor for the Inconel centrifugal pump (PKP type) was repaired, and the possibility of adding ZrF_4 to the fuel in the system drain tank is being investigated to provide barren fuel of a composition close to that of the MSRE fuel.

Additional water tests were performed on the fuel pump to define the effectiveness of the xenon-removal stripper at design operating conditions. Large shaft deflections were noted during water-test operation of the

coolant-pump impeller in the fuel-pump volute; hot proof-testing of the rotary elements for the coolant pumps will be conducted in the fuel-pump hot-test stand using fuel-pump impellers. Fabrication of parts for the water test of the coolant-pump impeller and volute continued.

The founder reported a reduction in the amount of gas and shrinkage defects in a fuel-pump volute cast of modified INOR-8, but a large increase in the number of inclusions was noted. The patterns for the coolant-pump volute and impeller were transferred to another founder for casting with INOR-8 of original specification. Assembly of the hot-test stand for the prototype fuel pump is nearly half completed; the control panels were completed.

Stresses were calculated for several fuel-pump operating conditions. The maximum meridional thermal stress, located in the junction between the spherical shell and cylinder, is 24,000 psi for 10-Mw operation with 5-psig blanket-gas pressure and air cooling of the external wall of the pump tank and is increased by the radial thermal stress of about 2500 psi. The maximum thermal stress in the cylinder proper is 21,000 psi and is located within the pump tank near the position of maximum temperature of 1280°F.

In order to obtain more reliable values of thermal stresses for zero power operation, calculations in which a shallow cone has been substituted for the spherical shell are being made to provide for the meridional thermal gradient which exists in the spherical shell. A check run comparing the shallow cone to the spherical shell gave thermal-stress values 30% higher for the cone. Additional attempts are being made to improve agreement between the two calculational methods.

Procurement and Construction. — Bids for furnishing INOR-8 materials were opened by the AEC Procurement Officer on May 12. Bids for the weld rod, bar, sheet, and plate were acceptable, and contracts for furnishing these materials will be awarded to the successful bidders. Some exceptions were taken to the specifications by the bidders on pipe and tubing, and further study of the bids will be required before purchase contracts are awarded for these materials.

Requests for bids to furnish the completely machined graphite core blocks and additional unmachined blocks were sent to prospective suppliers.

Drawings and specifications for the major reactor components (reactor, heat exchanger, radiator, and drain and storage tanks) are nearing completion. Requests for bids to fabricate these components will go to prospective fabricators early in July.

The cost-plus-fixed-fee contractor has completed the demolition and minor alterations work assigned to him in Building 7503. Drawings and specifications for the first package of major modifications to Building 7503 are completed. Requests for bids to perform this work will go to prospective contractors soon.

Chemistry. — With different cooling rates, different crystalline compounds are obtained by freezing the MSRE fuel ($LiF-BeF_2-ZrF_4-ThF_4-UF_4$; 70-23-5-1-1 mole %). Slowly cooled melts correspond to the equilibrium crystallization path in which $6LiF \cdot BeF_2 \cdot ZrF_4$ forms at 442°C, followed by Li_2BeF_4 at 435°C. However, with cooling rates of 2 or 3°C per minute or faster, the nucleation of $6LiF \cdot BeF_2 \cdot ZrF_4$ frequencly does not occur, and the supercooled melt yields both β-$3LiF \cdot ZrF_4$ and well-formed crystals of

$2LiF \cdot ZrF_4$ as a result of metastable crystallization to phases which are not present in the equilibrium sequence. Temperature-time curves for one example of rapid freezing showed supercooling to 435°C followed by crystallization at 438°C, perhaps of β-$3LiF \cdot ZrF_4$, and then another phase, presumably $2LiF \cdot ZrF_4$, at 431°C after supercooling to 421°C. In all cases the major phase present is Li_2BeF_4, which in the rapidly cooled samples appears as crystallites too small for recognition with petrographic microscopy but which can, however, be identified by x-ray diffraction. In the LiF-ZrF_4 binary system, β-$3LiF \cdot ZrF_4$ has a lower limit of stability at 470°C; thus its appearance in the MSRE fuel is even more surprising.

Metallurgy. — Tests were made for determining the effectiveness of the decomposition products of $NH_4F \cdot HF$ for removal of oxygen contamination from several grades of graphite. Crucibles of grades AGOT and R-0025 graphite were cleaned by exposing them for 20 hr to $NH_4F \cdot HF$ at 500, 600, and 704°C (1300°F), and were then held at 704°C for various times with LiF-BeF_2-UF_4 salt. No evidence of UO_2 was observed in any of the tests. The specimens purged at 704°C contained their salt at temperature for 1000 hr, and the others held their salt for 500 hr. Additional time is being accumulated on these tests. This method is especially attractive if the cleanup can be done at 500°C, since the products of decomposition would be less reactive with the metal components of the reactor.

In-Pile Tests. — The third MSRE capsule irradiation experiment, ORNL-MTR-47-3, completed the second three-week cycle in the MTR during the week of June 12. The temperatures of the graphite-to-salt interfaces during the second cycle were about 1365°F for the capsules with unimpregnated graphite, and were 1425 and 1565°F for the capsules with impregnated graphite. The difference between the temperatures for the two impregnated capsules corresponds to the difference in the local temperatures of the sodium ambient. These temperatures are about 75°F below those of the first cycle, apparently as a result of the plugs being retracted for an unknown reason and then not being fully reinserted.

Preparations are in progress to duplicate the in-pile temperature and thaw-freeze cycles on out-of-pile control sample capsules in induction furnaces.

Reactor Analysis. — Radiation levels above the shield covering the top of the MSRE reactor cell were estimated, based on the new reactor-system layout and a revised estimate of the N^{16} activity in the primary system. The general radiation levels through the solid shield (3.5 ft of barytes concrete and 2.5 ft of ordinary concrete) do not exceed 2.5 millirads/hr except directly over the core, where the dose rate is 30 millirads/hr from gamma rays and 2 millirems/hr from neutrons. If a 1/2-in. gap exists between the ordinary concrete blocks forming the top layer over the reactor, the estimated dose rates are 200 millirads/hr from gammas and 4600 millirems/hr from neutrons.

Two-group, x-y geometry, two-dimensional diffusion theory calculations with the IBM 7090 program Twenty Grand are in progress to obtain flux and power-density distributions in the midplane of the MSRE with several different rod and sample configurations. The presence of the rod channels without rods leads to a flattening of the power distribution, reducing the peak-to-average ratio by about 5%, and a shifting of the location of the peak flux to about 7 in. from the reactor center line.

Estimates were made of the gamma and neutron heating rates in the control tubes. At the reactor midplane the respective rates are 2.5 and 0.1 w/cm^3. Heating calculations were carried out for homogeneous mixtures of core salt and graphite; it is estimated that gamma and neutron heating amounts to 5% of the local fission heating.

Heat Transfer and Physical Properties. — Assembly and filling of a variable-gap device for measuring the thermal conductivity of the MSRE fuel mixture $LiF-BeF_2-ZrF_4-ThF_4-UF_4$ (70-23-5-1-1 mole %) is continuing. The copper-block calorimeters used in the enthalpy determination are being recalibrated by using standard sapphire capsules. An apparatus is being assembled to measure the density of molten salts by use of a bubble-pressure technique.

Fuel Processing. — The complex fluorides of KF, AgF, and SrF_2 with SbF_5 were prepared by reaction of the components in anhydrous hydrogen fluoride. The products were $KSbF_6$ and $AgSbF_6$ for the first two, but the composition of the SrF_2 complex was not determined with certainty. In all cases the complex salts were less soluble in hydrogen fluoride than were the simple metal fluorides. Attempted preparations of an $NaF-MoF_6$ compound in anhydrous hydrogen fluoride resulted in a composition of about $MoF_6 \cdot 5NaF$, perhaps with some HF when the HF solvent was removed by boiling; the solid contained relatively less MoF_6 when the solvent was removed by evacuation at near room temperature. Reaction of LiF, NaF, and KF with UF_6 in anhydrous HF resulted in yellow to orange solids that contained HF as well as UF_6; in general the solids were not stoichiometric, containing less UF_6 than expected. The relative amount of UF_6 in the solids decreased as more vigorous treatment (evacuation and heating) was used to remove the excess HF solvent.

MARITIME REACTORS PROGRAM

ORR Pressurized-Water In-Pile Loop. — The water chemistry of the pressurized-water in-pile loop in the Oak Ridge Research Reactor is being investigated. The objectives of the study are a determination of the behavior of water-borne activity and "crud" and an examination of possible methods for controlling them. The nuclides thus far identified are Mn^{54}, Mn^{56}, Co^{58}, Co^{60}, Fe^{59}, Cr^{51}, Ni^{65}, Mo^{99}, Tc^{99}, Ta^{182}, F^{18}, and Ar^{41}. No attempt has been made to identify nuclides with half-lives less than 1 hr.

Fission products were not detected in any of the samples taken during the period February to April 27, 1961. It was noted, however, that when loop operation was disturbed, such as by temperature cycling, the water activity increased sharply; in fact, during startups, it increased approximately 100-fold. From filtration tests it appears that during normal operation of the loop the bulk of the water-borne activity is in a nonfilterable reactive form and that the increased activity during startup is present mainly in filterable crud, since the nonfilterable activity remained relatively unchanged.

NS "Savannah." — A new set of control-rod drives and an associated reactor control system are being developed for future use in the NS "Savannah" reactor. The Laboratory is providing assistance in simulator

studies, design review, and inspection during fabrication. One proposed feature of the new control system is that all control rods be connected to a programming device which will permit rod movement only in accordance with a pre-established regime. A control-rod positioning program was prepared for the proposed control system when used in conjunction with core I. The order of rod withdrawal selected approximated that specified by the reactor designer for the present control system, but it was adjusted to produce essentially uniform reactivity addition per unit rod withdrawal over the major portion of the entire range of movement. The rate of reactivity addition permitted is adequate to meet all ship maneuvering specifications, provided the expected power reactivity deficit of 1.32% Δk between zero and full power for core I is actually realized.

ARMY PACKAGE POWER REACTORS

Examination of a type 17-4 PH stainless steel rack from the SM-1 control-rod drive system was completed. Nondestructive surface examination by magnetic-particle and fluorescent-dye-penetrant techniques did not reveal any surface imperfections indicative of stress corrosion. Metallographic sections were taken of typical areas of the rack, including the teeth, the threads, and the high-flux end of the rack. None of the sections showed defects in the metal surface. It was concluded that this rack, which had operated in the SM-1 for three years, showed no signs of stress corrosion and was generally in excellent condition.

NUCLEAR TECHNOLOGY AND GENERAL SUPPORT

Fuel Shipment Studies. — Calculated temperature distributions in fuel elements during shipping, if heat could be transferred only by radiation, were reasonably close to the temperatures obtained from experimental measurements with electrically heated mock fuel elements and a simulated shipping carrier, especially at higher heat generation rates. Calculations for a 36-tube bundle and a heat generation rate of 0.0986 w/cm had an average deviation of ~16°C from the measured temperatures; the maximum temperature could generally be predicted more closely. However, there were still noticeable effects of convection, such as nonuniform carrier wall temperatures and unsymmetrical temperatures about the horizontal plane through the center of the bundle.

Release of Fission Products on In-Pile Melting of Reactor Fuels. — During the last ORR shutdown the insertion of the first meltdown experiment in the in-pile fuel element meltdown program was made, and the assembly was found to be satisfactory. Krypton-85 was injected into the system to test the radiation monitor and the charcoal trap. Both operated satisfactorily.

On May 20, while the ORR was operating at 30 Mw, the experiment was inserted into the reactor to a point (5 in. above the fuel) where the temperature of the stainless steel cladding on the fuel specimen was 200°C below the melting point. The experiment remained in that position for 57 hr, building up the fission product concentration in the 3%-enriched UO_2

specimen. The experiment was then fully inserted into the reactor for a period of approximately 10 min and then fully withdrawn. While the meltdown was in progress all instruments and controls reacted as predicted.

Fission product release was observed on the monitor of the inlet to a liquid-nitrogen-cooled charcoal trap at two different times during the insertion. The first was at the time the stainless steel cladding on the fuel specimen melted. At that same instant the Pt vs Pt–10% Rh thermocouple welded to the cladding failed. The second release was observed at the time both W vs W–26% Re thermocouples next to the fuel specimen failed. The latter release was a factor of 10 greater than the first. The liquid-nitrogen-cooled charcoal trap has been removed, and the gases collected on the charcoal are being analyzed.

The experiment was removed from the facility tube and stored in the ORR pool, awaiting hot-cell space. The assembly of the second meltdown experiment has begun.

Basic Reactor Research. – The initiation of a program of experiment and calculation intended to accurately describe scattering processes within the nucleus was previously noted. In the formalism of the optical model being used, the nuclear interaction is replaced by a complex potential well. It has been usual, presumably for the sake of calculational ease, to adopt a complex local potential well, even though such a course requires that the wave-function parameters vary with energy. In the present study, however, an inexpensive, rapid IBM 7090 program has been developed to compute the non-energy-dependent parameters resulting from the adoption of a nonlocal potential well. The present program does not yet include the effect of spin-orbit coupling, and thus is exact only for particles of spin zero, such as alpha particles.

In conjunction with the main program, a "search" program has also been written. This routine, when offered appropriate data, will automatically search for and deliver suitable parameters to fit the data.

A series of computations has been run on a typical midweight nucleus, Fe^{56}, at energies of 4, 7, 14, and 26 Mev. This nucleus and the energies were chosen because some experimental data already exist. Although no comparison with experimental results has yet been made, excellent agreement has been found with results of previous local-potential calculations.

The program is expected to be particularly useful in interpreting results of heavy-ion scattering experiments being carried out elsewhere in the Laboratory. Attempts to utilize the local-potential-well concept in the analysis of such data have not been particularly successful.

Power Reactor Fuel Processing: Mechanical. – The mechanical dejacketing facility for the SRE core 1 fuel was completed and was tested with unirradiated fuel, and operation with irradiated fuel was started. SRE core 1 fuel burned to ~675 Mwd/ton and decayed approximately two years is currently being dejacketed at a rate of 2 to 3 kg/hr.

Five fuel clusters, 350 kg of U, have been processed. The dejacketed slugs were steam-cleaned free of NaK, canned in aluminum, and stored in a shielded facility to await off-site shipment to a chemical processing plant. The interior surfaces of the scraped, emptied jackets were cleaned free of NaK with a plastic "rabbit," and the jackets were rolled and flattened into a coil and disposed of by ground burial along with the spacer wires, end caps, and metallic spiders sawed from each end of a fuel cluster.

The processing rate attained thus far is about 30% of that expected. Tests with unirradiated prototype fuel supplied by Atomics International had indicated a rate of 10 to 20 kg/hr; the lower rate with spent fuel is attributed to embrittlement of the 10-mil-thick tubular stainless steel jackets, which are not appreciably expanded by an internal hydraulic pressure of up to 1700 psig. The uranium fuel slugs were slightly bent, were swollen 10 to 30 mils in diameter, and could not be hydraulically removed from the tubular jackets as expected.

The NaK discharged from each fuel rod is not free-flowing but is heavily oxidized and waxy. This makes it extremely difficult to collect from underneath the Bayol D oil blanket in which it is discharged and to transfer it through lines to the NaK reactor. A preliminary analysis of the NaK shows the presence of plutonium, cesium, and cerium, but no uranium.

Power Reactor Fuel Processing: Solvent Extraction. — The extraction coefficient for niobium from 0.5 M HNO_3 to chemically degraded 30% tributyl phosphate in dodecane was measured as 0.40. Less than 11% of the niobium in the feed was in an unextractable form. The coefficient obtained in organic-to-aqueous stripping experiments was 0.48. The initial concentration of the niobium in the aqueous feed was $\sim 2 \times 10^5$ counts min^{-1} ml^{-1}.

Solvent containing 30% TBP in Amsco, which was degraded by refluxing with 6 M HNO_3, extracted fission products in a manner similar to solvent which becomes degraded in plant operation. However, the synthetically degraded solvent could not be satisfactorily recovered by washing with sodium carbonate, sodium hydroxide, and dilute nitric acid, as can plant-degraded solvent.

Power Reactor Fuel Processing: Modified Zirflex Process. — In continuing studies on dissolution of U-Zr-Sn in 6.5 M NH_4F—0 to 0.6 M NH_4NO_3—0.01 M H_2O_2, no H_2O_2 decomposition was observed when 10% H_2O_2 solution was introduced into the boiling dissolvent through a jacketed water-cooled nozzle. When H_2O_2 was added at a rate of 1 to 2×10^{-5} mole cm^{-2} min^{-1}, the O_2 concentration in the HNO_3-scrubbed, predominantly H_2, off-gas rose, indicating decomposition of the H_2O_2 initially in the dissolvent, and then decreased and remained at ~1% during the period of rapid dissolution. As the dissolution subsided, the O_2 concentration rose slowly and steadily, suggesting that the H_2O_2 addition rate should be controlled by maintaining the O_2 concentration in the off-gas at $\sim(3 \pm 2)$%. The presence of as little as 1% O_2 ensures the maintaining of U(VI) in the dissolver solution; limiting the concentration to 5% O_2 avoids the flammable range.

Unwelded specimens of Haynes alloy No. 21 and welded specimens of type 347 stainless steel exposed to flowing modified Zirflex dissolvent corroded at maximum rates of 0.75 (689 hr) and 6.43 mils/month (500 hr) respectively. Corrosion was maximum at the liquid-vapor interface. Haynes 21 showed no localized attack; the stainless steel suffered extensive edge attack but no selective weld corrosion.

Power Reactor Fuel Processing: Molten-Chloride Process. — Uranium, zirconium, type 304 stainless steel, and niobium dissolved in 20 mole % PCl_5—80 mole % $AlCl_3$ at rates of 100, 8, 4, and 0.01 mg cm^{-2} min^{-1}, respectively, at 250°C and at 14, 2, 1.5, and 0.01 mg cm^{-2} min^{-1}, respectively, at 200°C. This system was investigated because of its low melting

point, which is 190°C when the aluminum chloride content of the melt exceeds 60 mole %.

Power Reactor Fuel Processing: Beryllium- and BeO-Containing Fuel. — The initial dissolution rates of high-fired BeO and BeO–5% UO_2 were measured in boiling sulfuric acid–sodium fluoride, hydrofluoric acid–ammonium fluoride, and nitric acid solutions. The rates of both materials in boiling H_2SO_4 increased from 0.025 to about 3.5 mg cm^{-2} min^{-1} as the acid concentration increased from 6 to 15 M. The data were correlated by the equation log rate = 0.2485 (molarity) − 3.13. In boiling H_2SO_4–0.2 M NaF, the dissolution rate of BeO–5% UO_2 increased from 0.04 to about 3 mg cm^{-2} min^{-1} as the H_2SO_4 concentration was increased from 4 to 15 M: log rate = 0.1688 (molarity) − 2.062. The initial rate of dissolution of BeO–5% UO_2 was < 0.07 mg cm^{-2} min^{-1} in boiling 3.2 to 8 M NH_4F and < 0.02 mg cm^{-2} min^{-1} in boiling 8 to 15.8 M HNO_3.

Power Reactor Fuel Processing: Corrosion Studies. — Nickel, Haynes alloy No. 25, Nichrome V, INOR-8, and Pyroceram 9608 showed maximum corrosion rates of 0.02, 0.02, 0.01, 0.01, and 0 mil/month, respectively, in 188 hr exposure to dry oxygen at 725°C. Unwelded specimens of Nichrome V showed a maximum rate of 0.21 mil/month in 672 hr exposure to boiling 4 M HNO_3; incipient grain-boundary attack was observed in the vapor phase where the rate was maximum. INOR-8 disintegrated in boiling 4 M HNO_3 at a rate of > 295 mils/month.

Carpenter 20 SNb and types 304L and 347 stainless steel were exposed at 50°C for 504 hr to 0.75 M HNO_3–0.6 M Al^{3+}–0.58 M Zr^{4+}–3.93 M F^-; maximum rates for these alloys were 0.16, 0.81, and 0.16 mil/month respectively. After 168 hr exposure to 1.5 M HNO_3–0.6 M Al^{3+}–0.45 M Zr^{4+}–3.04 M F^-, maximum rates were 0.46, 2.12, and 0.36 mil/month respectively. The rate of LCNA in the latter solution was 0.35 mil/month.

In Darex-Purex waste solutions containing 1.82 M stainless steel and 100 ppm Cl^-, welded specimens of type 304L stainless steel were corroded at a maximum rate of 0.75 mil/month in 4082 hr when the solution was 5 M in free HNO_3, as compared with 0.36 mil/month in 6036 hr when the free acid was 1.13 M. In 6036 hr exposure in a solution 2 M in free acid and containing polyethylene chips, the maximum rate was only 0.02 mil/month. The nature of the inhibitor leached from polyethylene is being investigated.

Power Reactor Fuel Processing: Graphite-Containing and Uranium Carbide Fuels. — The standard two-leach 90% HNO_3 process was tested at boiling with two different unirradiated graphite fuel specimens, each containing uranium and thorium, presumably as the dicarbides. With a specimen containing 1.3% uranium and 15% thorium, as uncoated carbide particles dispersed in the graphite matrix, losses were 0.01 and 0.16%, respectively, after two 4-hr leaches. The other specimen contained 9.9% uranium and 33% thorium, as pyrolytic carbon-coated carbide particles. After two 4-hr leaches, uranium and thorium recoveries were only about 6 and 4% respectively.

As the time of digestion with boiling 90% HNO_3 increased from 1 to 48 hr, with specimens containing 1 to 12% uranium, the geometric mean particle size decreased from 300 to 85 μ. Within experimental error, the uranium content of the specimen had no effect on the particle size.

The reaction of uranium monocarbide with water at 90°C yielded virtually the same reaction products as at 80 and 60°C. The average value for four experiments at 90°C was 93.0 ml (STP) of gas per gram of specimen; the gas was 11.6% hydrogen, 85.6% methane, 1.7% ethane, 0.65% propane, 0.28% butanes, 0.081% pentanes, 0.026% hexanes, 0.003% pentanes, and 0.02% of an unidentified material. There was no evidence of a change in reaction products with temperature.

Treatment and Disposal of Radioactive Wastes: High-Activity Waste Calcination. – Simulated Purex sulfate-bearing wastes were incorporated into magnesium and calcium phosphate and borophosphate ceramic glasses with densities of 2.6 to 2.8 g/cc. The volume of solid product per ton of uranium processed varied from 4.8 to 6.9 gal. The leaching rate of a typical magnesium borophosphate glass decreased from 3.2 to 10^{-2} g cm^{-2} day^{-1} at 8 hr exposure to $\sim 4.5 \times 10^{-3}$ at 10 days and 8.4×10^{-5} at 35 days. No detectable ruthenium was volatilized during evaporation-calcination of Purex, Darex, or TBP-25 solutions containing 1.5 M H_3PO_3 to temperatures of 500 to 900°C. When the initial phosphite concentration was 0.1 M, no ruthenium was volatilized until the temperature rose above 150°C. Continuous addition of 0.1 M H_3PO_3 to the feed solution to give a product equivalent to 0.4 M H_3PO_3 in the feed resulted in volatilization of 1.4% of the total ruthenium, as compared with 4.9% when the initial feed was 0.4 M in phosphite with no further addition. No net off-gas was produced in either case.

A full-scale test of the close-coupled pot calcination process, with a continuous 25-liter-capacity still feeding TBP-25 aluminum-bearing waste directly to the 8-in.-diam, 84-in.-long calciner, was completely successful in terms of feed rate, evaporator and pot control, and corrosion. The final-product density was 0.56 g/cc. In a run with standard Purex sulfate-bearing waste, made 1.2 M in sodium and 0.2 M in magnesium to decrease sulfate volatility, only 0.2% of the sulfate volatilized, but the cake melted and pot corrosion was excessive. This was contrary to expectations based on small-scale runs with magnesium additive and large-scale runs with calcium additive.

Treatment and Disposal of Radioactive Wastes: Engineering, Economic, and Hazards Evaluation. – A comprehensive evaluation of the economics and hazards associated with methods of ultimate disposal of highly radioactive liquid and solid wastes was started. A 6 metric ton/day plant is assumed, processing 1500 metric tons/yr of 10,000-Mwd/metric ton uranium and 270 metric tons/yr of 20,000-Mwd/metric ton thorium, equivalent to all the fuel from a 15,000-Mw (electrical) nuclear economy (expected by about 1970). The first results indicate interim storage costs, 0.5 to 30 years, of high-activity liquid wastes to be 2.0×10^{-3} to 9.3×10^{-3} mill/kwhr (electrical) for acidic wastes in stainless steel tanks and 1.5×10^{-3} to 4.7×10^{-3} mill/kwhr (electrical) for neutralized wastes in mild-steel tanks, with optimum combinations of filling time and full time based on present worth considerations.

Capital costs were estimated for a plant building where liquid wastes would be converted to solids by pot calcination, as a function of building size, which varies with different combinations of acid and neutralized wastes and pot diameter, and as a function of shielding wall thickness, which varies with interim liquid storage time before calcination. For

seven different types of calcined solids that might be produced from wastes from the assumed 6 metric ton/day fuel processing plant, for pot diameters from 6 to 24 in. and for interim liquid storage times from 0.5 to 30 years before calcination, the capital costs for pot calcination varied between 1.2×10^{-3} and 2.8×10^{-3} mill/kwhr (electrical). Processing-equipment costs were also estimated, but operating-cost estimates, including the cost of the disposable calciner vessel, are not yet complete.

Treatment and Disposal of Radioactive Wastes: Low-Activity Wastes. — In tests on the scavenging-ion exchange process in a small pilot plant (60 liters/hr) with ORNL low-activity waste, feed clarification was excellent. The effluent contained 3 ppm of turbidity and 8 ppm of dissolved hardness as $CaCO_3$. Decontamination factors were equal to or better than design specifications and confirmed laboratory-scale decontamination factors from strontium and cesium of > 1000, over-all waste volume reductions > 3000, a gross beta-activity decrease to < 10% of the MPC for water, and a strontium and cesium decrease to 1% or less of the MPC's for water for a 168-hr week. The units in sequence are a flash mixer, a flocculator, a sludge-blanket clarifier, an anthracite filter, a polishing filter, and an ion exchange column containing a carboxylic-phenolic resin. Design of a 10-gpm pilot plant is complete, and completion of construction is scheduled for August.

Waste Disposal Research and Engineering: Geochemical Studies. — Sorption of strontium by 0.5 g of vermiculite from 0.1 M $NaNO_3$ solution containing 1.1×10^{-5} M strontium after 24 hr contact was increased from 20% removal by natural vermiculite (pH 6.5) to 45% by vermiculite leached with 1 M NaCl (pH 6.5), to 70% after NaCl-NaOH treatment (pH 9), and to 83% after sodium tetraphenylboron treatment (pH 9).

Sorption of strontium at selected pH conditions showed an increase of 35% in sorptive capacity at pH 9 as compared with that at pH 4.

Addition of potassium salts increased the sorption of cesium by natural vermiculite from 0.5 M $NaNO_3$ solution containing 1.7×10^{-7} M cesium by changing the sorption mechanism from "edge fixation" to "interlayer fixation." Potassium additions to levels of 10^{-4}, 10^{-3}, 10^{-2}, and 10^{-1} M resulted in respective cesium distribution coefficients (K_d) of 15, 9.5, 925, and 44 ml/g. Lattice collapse and interlayer fixation were initiated at 10^{-2} M K^+, although complete collapse did not occur until the potassium concentration was increased to 10^{-1} M. The decrease in K_d at 10^{-1} M potassium is caused by increased competition between potassium and cesium for the interlayer fixation sites.

Waste Disposal Research and Engineering: Disposal in Natural Salt Formations. — Measurements of plastic flow around test cavities in the Carey Salt Company's Hutchinson mine were completed. Strain-gage measurements indicate that total plastic movement in the room containing the heated cavities was greater than would have occurred normally; however, the rate of movement after completion of the tests was approximately equal to that observed prior to the tests.

In the center of the room, the rate of movement prior to startup was 0.0005 in./day; when the power was cut off 400 days later, the rate of

movement was 0.0004 in./day. The total floor-to-ceiling movement for the duration of the heating cycle was 0.5 in., about 0.3 in. more than would have occurred normally. Thus, although the heated cavity produced a temporary increase in rate of movement and consequently a greater net movement, it did not significantly alter the normal changes in room dimensions to be expected as a result of existing overburden pressure.

Waste Disposal Research and Engineering: Disposal of ORNL Radioactive Wastes. – Within burial ground No. 4, 31 to < 1 count min^{-1} ml^{-1} of gross activity has been detected in 8 of 16 observation wells and is found to vary with the sampling period. In several wells the concentration of activity increases as the water table rises, while in others the inverse occurs. The additional water accompanying a rise in water level may cause increased leaching of waste but may also act as a diluent of the waste solution. Interpretation of these data is complicated by the heterogeneity of the waste and the lack of detailed information on burial operations. Increased amounts of Na^+, Cl^-, NO_3^-, and SO_4^{2-} are also present in contaminated wells.

The first month of stream monitoring below the northeast portion of the drainage basin, subject to air-borne contamination and drainage from burial ground No. 3, showed that 7.6 mc of $Sr^{89,90}$, 2.7 mc of rare earths, 0.53 mc of Cs^{137}, and 0.013 mc of $Zr\text{-}Nb^{95}$ were contributed to White Oak Creek.

Waste Disposal Research and Engineering: Deep Well Disposal. – Two ORNL drilling crews, with two crews from the Corps of Engineers, completed 15 test holes in the area of the second fracturing experiment. Partial analysis of the results of this work shows that the geologic structure is more complex than had been anticipated and that folds or faults in the shale have influenced the shape of the grout sheet. It may be necessary to suspend the drilling operations shortly in order to make a detailed study of the work completed as a guide to further drilling. Nothing that has been found is unfavorable to the potential use of fracturing disposal, but the shape of the grout sheet is not that anticipated from earlier work.

A contract has been let for a 3000-ft core hole to determine the possibility of injecting waste into the lower part of the Rome formation, which is not exposed at the surface. Since it now appears that the structure of the beds is important, the need for a seismic survey of the area of the second experiment and also of the proposed site for the operating plant is being investigated.

Waste Disposal Research and Engineering: Process Waste Water and Treatment Plant Studies. – Recent studies have demonstrated that the addition of 125 ppm of PO_4^{3-}, as a supplement to normal lime–soda ash treatment, increases strontium removal from ORNL process waste. A comparison of primary phosphate coagulation with lime–soda ash treatment and phosphate showed that the latter (1) did not require careful pH adjustment, (2) produced a floc of better settling characteristics, and (3) removed as much strontium as the most efficient of primary phosphate treatments. A combination of coagulant aids, 1.0 ppm of Hagan 323 and 2.0 ppm of Hagan 2, greatly improved the settling characteristics of the floc. During a one-week plant test, removals of $Sr^{89,90}$ and Cs^{137} increased from 79 to 87% and from 85 to 97% respectively.

Second-stage treatment of ORNL process waste with sodium-treated vermiculite (grade BO-4), one of the most promising minerals investigated, gave distribution coefficients for strontium and cesium in excess of 5000.

Waste Disposal Research and Engineering: Clinch River Studies. — An estimate has been made of fission product activities (Sr^{90}, Cs^{137}, Ru^{106}, and Co^{60}) in bottom sediments of the Clinch River from Clinch River mile (CRM) 4.7 to CRM 21.6. Eight to ten cores were collected from each of 19 cross sections and were individually analyzed for gross gamma activity. The computed average gamma activity for each cross section compared favorably with "flounder" measurements by the Applied Health Physics Section.

All cores from each cross section were composited and were analyzed for specific nuclides. Except for Ru^{106}, the radiochemical analyses show a maximum specific activity at the mouth of White Oak Creek (CRM 20.8) and another maximum downstream at CRM 11.0. The concentration of Ru^{106} increased from a minimum at CRM 20.8 to a maximum at CRM 8.0.

The specific activity ($\mu c/g$) in each section was multiplied by the density and cross-sectional area of the silt in the section to give the activity in curies per mile. The total number of curies was then obtained by integrating the data from CRM 21.6 to CRM 4.7. Total activity was found to be about 145 curies: 98.0 curies of Cs^{137}, 33.2 curies of Ru^{106}, 11.6 curies of Co^{60}, and 1.83 curies of Sr^{90}.

PHYSICAL RESEARCH PROGRAM

PHYSICS AND MATHEMATICS RESEARCH

High-Energy Physics. — The liquid-helium bubble chamber was exposed at the Lawrence Radiation Laboratory at Berkeley to the highly improved, separated, slow K^- beam. This exposure was done in collaboration with several universities and was the second such experiment. Film from this run is now being scanned for all He-K^- interaction and K^- decays. So far, approximately 4000 interactions and decays have been found in six rolls of film which have been scanned.

Scintillation Spectrometry and Instrument Development. — The angular correlations of three gamma-ray cascades in Xe^{132} have been measured. The data, which were taken every 10° between 90 and 180°, were least-squares fitted to the function $W(\theta) = 1 + A_2P_2(\cos\theta) + A_4P_4(\cos\theta)$. The angular correlation coefficients, which have been corrected for the finite angular resolution of the detectors, are given below:

Cascade E_γ (Mev)	A_2	A_4
0.63-0.673	-0.19 ± 0.07	+0.42 ± 0.10
1.14-0.673	+0.05 ± 0.04	+0.05 ± 0.06
1.32-0.673	+0.31 ± 0.03	+0.03 ± 0.04

The correlation of the 0.63-0.673-Mev gamma-ray cascade is consistent only with the spin assignment of 2 for the 1.30-Mev level and a mixing ratio δ, where $\delta = (Q/D)^{1/2}$, of -5.7 for the 0.63-Mev transition. This predominantly quadrupole character for the transition between the second and first spin 2 levels is consistent with the collective behavior exhibited by even-even nuclei in this region. A spin assignment of 1, 2, 3, or 4 for the level at 1.81 Mev is compatible with the angular correlation of the 1.14-0.673-Mev cascade. The coefficients for the 1.32-0.673-Mev cascade are in best agreement with the theoretical coefficients for the sequence $2(D + Q)2(Q)0$ with $\delta = +0.089$. This small value of δ suggests that the 1.99-Mev level may be due to excitation of the intrinsic structure of the nucleus.

High-Voltage Experimental Program. — The location of a second 2^+ state has been established for five even-even nuclei (Ge^{74}, Ge^{76}, Se^{76}, Se^{78}, and Se^{80}) by means of Coulomb excitation produced by 6-, 7-, and 8-Mev alpha particles. The relatively weak excitation of these states is detected by a coincident measurement of the cascade gamma rays. The B(E2)'s for decay of the second 2^+ state to the ground state by the crossover transition are rather small, being about single-particle value or a little less. For Ge^{74}, Se^{76}, and Se^{78}, the cascade/crossover ratio for the decay of the second 2^+ state is known from radioactive decay measurements. The upper cascade $B(E2,2' \rightarrow 2)$'s exhibit enhancements comparable

with those for the lower cascade B(E2,2 →0)'s. The B(M1,2' →2) values for Ge^{74} and Se^{76} are exceedingly small, being about 10^{-3} times the single-particle estimate. This result is in qualitative agreement with the collective models for vibrational excitations.

Heavy-Particle Physics. – Alpha-particle spectra from nitrogen-induced reactions in Al^{27} were measured from 0 to 165°. The anisotropy of the angular distribution indicates the importance of angular momentum in the statistical theory of nuclear reactions. The angular distribution of ground-state alpha particles in the reaction $Li^6(N^{14},\alpha)O^{16}$ has a pronounced peak in the forward direction. Investigations at backward angles are in progress.

The 86-Inch Cyclotron: Nuclear Physics. – Rolled metallic-foil targets of highly enriched samples of each of the five stable isotopes of zirconium were obtained from the Isotopes Division. These targets and foils of natural yttrium and niobium comprise a set of seven targets being used in a study of the nuclear shell structure near N = 50. It will take several months to complete the study, but the new data already obtained show several features which were not revealed in a previous study with powder targets [Phys. Rev. 118, 1062 (1960)]. The (p,d) spectra show that neutrons 51–56 fill the d5/2 shell, as expected on the basis of the j-j coupling shell model. Neutron pickup from the g9/2 shell can be resolved from pickup from the p1/2 shell, at least in Y^{89} and Zr^{90} and possibly in the other isotopes also. The shift in the Q value for the p1/2 pickup between Y^{89} and Zr^{90} indicates a strong interaction between the p1/2 neutron hole created by the pickup and the p1/2 proton hole in Y^{89}. The (p,d) spectrum from Nb^{93} shows many more poorly resolved states in the neighborhood of the Q value of the g9/2 pickup than are observed in the zirconium and yttrium targets. These states are probably interpretable as different couplings of the g9/2 proton with the g9/2 neutron hole created by the pickup reaction.

The 86-Inch Cyclotron: Applied Physics. – The bombardment time for the production of isotopes for institutions and commercial processors now averages about 150 hr/month. During the past period the following isotopes were produced: Be^7, Na^{22}, Sc^{44m}, V^{48}, Co^{57}, As^{74}, Y^{88}, Pd^{103}, Ce^{137}, Eu^{149}, Tm^{168}, Au^{195}, and Bi^{207}. The demand for high-specific-activity Co^{57} has continued; a total of 2.8 curies of Co^{57} was made for a commercial processor and the Physics Division. A test run for the production of Rb^{84}, of special interest for medical applications, gave a production rate of 3.3 μc/hr, and also ~2.9 μc/hr of Rb^{83}, from proton reactions on natural strontium (SrO_2). Since this yield is inadequate for practical purposes, other modes will be investigated. In an attempt to utilize the available intense neutron radiation for the production of carrier-free Ca^{47}, 10 g of titanium metal was placed back of a magnesium target irradiated for a total of 35 ma-hr; no Ca^{47} was detected from this mode of production. A window-type lithium hydride target for the production of Be^7 was successfully irradiated in a pilot operation. As an alternative to the lithium metal target now used, it should be easier to irradiate and to ship. In a study of the $Se^{77}(p,\alpha)As^{74}$ reaction, the cross section in a thick target was found to be < 240 mb, and the yield was 1.9 mc/ma-hr.

The 86-Inch Cyclotron Operations. – The severity of transient voltages following sparking in the resonator circuit of the cyclotron made it highly impractical to install the crowbar and rf voltage regulator as planned. Subsequently, efforts to improve the existing rf circuits markedly reduced the transient voltages at the oscillator. The machine may now operate for as long as a full 8-hr shift without an interruption of the power supply circuit.

Electronuclear Machines. – Fabrication of the 450-kev electron cyclotron is complete, and the machine is nearly ready for preliminary testing. The Analogue II is an eight-sector, spiral-pole, AVF machine; it will model the magnetic field and beam dynamics of an 850-Mev proton cyclotron under study at ORNL.

The complex air-core magnet system was installed and precisely aligned; it is inside the vacuum chamber. All electrical leads were checked, and satisfactory operation of the 38 power supplies for the main coils and the trimming coils was verified. A precisely regulated 15-v, 530-amp power supply is being prepared for the valley coils, and the vacuum system is being modified to improve the trapping of mercury vapor from the diffusion pump.

The Isochronous Cyclotron. – The master oscillator for the rf system was assembled and is being tested. The four rf-amplifier stages are being assembled in "breadboard" stage for testing. Satisfactory fabrication techniques for the dee and the liner were developed, and the design work was completed; these units are being fabricated. The components for the shorting plane were received; they are being tested and assembled. The main magnet coils were energized to operation level (4400 amp); regulation to better than 1 part in 10^4 was obtained. The 19 AVF magnet power supplies are installed, and the regulators are being fabricated. Installation of the extensive wiring to the control console is continuing. The three pairs of pole tips were precisely aligned on the pole disks, and the two pole-tip assemblies were exactly positioned on the pole bases. The maximum variation of the magnet gap between the faces of the pole tips is 0.0093 in. The magnetometer was calibrated, and the field-measuring equipment was prepared for installation. The valley coils, harmonic coils, and trimming coils were completed and are being potted and vacuum-canned. Installation of these pole-tip windings should be completed and the planned four-month program for magnet testing and calibration should begin in early July.

Stable Isotope Development. – The optimum theoretical shape has been calculated for the pole pieces for the 255° electromagnetic isotope separator described in previous reports. A program was written which will allow the IBM 7090 computer to calculate the field distribution produced by an approximated shim configuration that gives the proper magnetic field. Coordinate information for the pole pieces was transferred to magnetic tape and fed into an automatic template cutter. The template produced from this operation will be used to machine the desired pole pieces. The construction of a source and a receiver for this new separator has been completed. The new unit was tested with magnesium as the feed material and performed satisfactorily.

Special Separations. – A total of 300 Np^{237} detector foils was fabricated and shipped. Based on recent experience, it is now possible to routinely reduce 50-g batches of uranium to the metal.

Decontamination of track 6, the Special Separations Laboratory, and the plutonium condensate room was completed. The manifold and the liner of plutonium calutron tank 610 were removed as one unit and sent to the X-10 burial ground.

Target Preparation. – Experiments have continued with an ion collector operated at high voltage. The most recent approach of this decelerating system to the preparation of accelerator targets involved the adaptation of a mechanical oscillator for rotating the target in an effort to compensate for the inhomogeneous character of the incoming ion beam. This procedure seems to be promising for targets requiring microgram quantities per square centimeter.

Another method for preparing accelerator targets, involving sputtering techniques, has also been investigated. The target is located in the dark space of a Crookes discharge. A thin sheet of material on which the deposition is to be made is placed in the path of an argon discharge at the edge of the dark space. Under the impact of the argon ions from the cathode surface, the desired material is sputtered and deposited on the target. This method has been tested and was found to produce moderately adherent coatings, uniform within 10%.

Equipment is being procured and installed to permit expansion of target fabrication by means of evaporation, rolling, electroplating, and casting.

Evaporation is the most versatile target-making procedure. Five high-vacuum evaporators ranging from bell-jar sizes of 12 to 24 in. and producing pressures of $< 5 \times 10^{-6}$ Torr have been used for making self-supported films of Be, C, Mg, Al, Si, Cu, and Pb, as well as backed targets of LiH, Li, C, SiO_2, CaF_2, Ti, U, Cr, Fe, Al, Ge, As, Y, Zr, Ag, Te, W, Pt, Au, UF_4, NpF_4, and Pm.

Rolling of targets has been accomplished by using a hand mill and a power-driven roll mill, with many targets being rolled to a thickness of less than 1 mil. Targets rolled include Li, Mg, Al, Ca, Fe, Co, Ni, Cu, Zr, Zn, Pd, Ag, Cd, Sn, Pt, Pb, and Ti.

Electroplating techniques have been used to prepare thin self-supporting foils of Co, Ni, Cu, Zn, Cd, and backed targets of Cr, Zn, Ni, Co, and Cd.

Targets of Na, K, Rb, P, Se, Te, and CBr_4 have been cast in stainless steel target holders. Several targets have been prepared with a 30-ton hydraulic press.

CHEMISTRY RESEARCH

Thorium Oxide Studies. – Thoria pellets (P-82) prepared from pressed powders and fired at 1650°C were irradiated at 250°C under D_2O in the LITR to an nvt of 2×10^{20} with little visual damage. The color changed from a glossy tan to a dull gray-black. A small pit was observed in some of the pellets at the rounded corner where the spherical end joins the

cylindrical portion of the pellet, the point of greatest strain. Average weight loss was about 0.04%. Average pellet density under comparable conditions increased from 9.1 g/cc for the nonirradiated pellets to 9.3 g/cc for those irradiated.

Rate data from a series of gas recombination experiments carried out at 250, 265, and 280°C suggest an activation energy of 24 kcal for the palladium-catalyzed recombination. The data were obtained with initial partial pressures of 400 psi of O_2 and 100 psi of D_2, the oxygen being added to the autoclave first. A kinetic expression was assumed that involved a first-power dependence of rate on the deuterium (hydrogen) partial pressure and a 0.5 power dependence on oxygen. Experiments at low O_2/D_2 ratios, at oxygen partial pressure around 200 psi, or in which the D_2 was added first indicate that rates are much more rapid in deuterium-rich systems ($D_2/O_2 \geqq 1$). Hence the activation energy and the kinetic expression assumed above apply only on the oxygen-rich side and with oxygen partial pressures > 300 psi.

Equipment Decontamination. — The average decontamination factor of 13 samples of gas loop piping from Brookhaven in 0.3 M ammonium oxalate—0.1 M ammonium citrate—0.1 M oxalic acid—0.35 M H_2O_2 at 95°C was 210 in 2.5 hr in a modified household dishwasher. Contaminants included irradiated UO_2 and the fission products Sr^{89}, Y^{91}, Zr^{95}, Ru^{106}, Ba^{140}, and Ce^{144}. Operation of the loop with air caused contamination not typical of EGCR operations, such as higher ruthenium residues.

The corrosion behavior of various oxalate-citrate mixtures containing H_2O_2 was extensively studied. At about 0.05 M, peroxide accelerates carbon steel corrosion by a factor of about 10; above 0.15 M, it inhibits corrosion, in the pH range 4 to 5, by an equal factor. Corrosion acceleration and inhibition by H_2O_2 in oxalic acid have been observed previously by British workers in the electroplating industry.

The decontamination factor of type 347 stainless steel (used in a Thorex process cell) from plutonium was between 1000 and 3000 in 30 min at 90°C with acidic fluoride inhibited with 1 M H_2O_2 (0.1 M NaF in either 1 M HNO_3, 0.4 M oxalic acid, or 0.3 M H_2SO_4). The corrosion rate of type 347 stainless steel in the nitric acid mixture was only 0.004 mil/hr at 70°C.

Radiation Chemistry of Organic Moderators. — Samples of purified biphenyl were placed in three pairs of Pyrex tubes, in which they were melted, evacuated, and finally sealed under vacuum preparatory to pyrolysis. The samples were placed in furnaces at regulated temperatures: one pair at 300°C, another pair at 400°C, and the third pair at 500°C. After an exposure period of 48 hr, the set at 500°C had begun to decompose, as evidenced by the straw color. One of these samples was withdrawn at this time, and it crystallized as it cooled to room temperature. The other sample at this temperature became dark brown after 145 hr exposure, becoming a viscous liquid upon cooling to room temperature. The samples at 300 and 400°C have been exposed approximately 330 hr without visible signs of decomposition.

Instrumentation for Analytical Chemistry Research. — A current compensation circuit for the suppression of prior waves is utilized in a new model Q-1988-A polarograph for dc controlled-potential polarography. Tests are being made, particularly at concentrations below 10^{-5} M, of the

technique of graphical correction for residual current, which consists in measuring polarograms relative to a polarogram of the supporting electrolyte, and also of the experimental relationship between corrected wave height and concentration. A study of quantitative derivative polarography with the ORNL model Q-1988 ES polarograph is resulting in procedures for the interpretation and measurement of derivative polarograms. The derivative wave shape for ideally behaving reductions corresponds very closely to the theoretical equation, and good values of n can be obtained from measurement of the peak width. Comparisons are being made of the resolution of overlapping undamped-regular and derivative waves. Both types of overlapping and interfering polarographic waves are being resolved mathematically; proportionality constants are evaluated by a standard addition method. Derivative peak heights are measured at $E_{1/2}$ potentials rather than at potentials where maxima occur in the net derivative waves. Improvements are being made in the circuit design of the ac controlled-potential polarograph, particularly in the polarizing and detector sections. An investigation is being made of harmonic currents in ac polarography, with the goal of comparing the relative effectiveness for concentration readout of phase discrimination and harmonic current measurement. Tests of concentration measurement with the quasi-reference electrode have been made in both dc and ac polarography. In order to perform continuous gamma-absorptiometric measurements of the concentration of heavy elements in flowing streams with monochromatic radiation, an Am^{241} source was used with a rapid-scanning gamma spectrometer having a thallium-activated sodium iodide crystal transducer. Straight-line semilogarithmic plots of the 60-kev count rate vs concentration were obtained for uranium over the concentration range 0 to 320 g/liter, and the count rate is insensitive to flow rate.

Organic Chemistry. – Continued study of the interactions in solution that are related to solvent extraction phenomena included the system n-butyl p-toluene sulfonate, nitric acid, and water. Two significant differences from the corresponding tributyl phosphate system were noted. The equilibrium concentration of nitric acid in the sulfonate is lower than in the phosphate; that is, the sulfonate system shows weaker interactions with nitric acid. Nitric acid is hydrated in the sulfonate phase (0.8 mole of water per mole of nitric acid), whereas it is not hydrated in the phosphate. This suggests that the behavior of water in nitric acid–solvent systems may depend on the strength of the interaction between the solvent and the nitric acid.

Radiation Chemistry. – Yields of H_2, HD, D_2, and CH_3D from the Co^{60} gamma-ray-induced exchange reaction of deuterated silica gel with methane and yields of HD and D_2 from the analogous reaction with hydrogen were measured at room temperature. The CH_3D yields from the methane reaction have a maximum value of 1.6 molecules per 100 ev absorbed by the gel; maximum values for HD and D_2 from the hydrogen reaction are 1.8 and 1.0 respectively. These yields as a function of degassing temperature pass through a maximum near 400°C. The differential yields of deuterated product are increased by continued irradiation. Radiation-induced reaction of the gel with hydrogen gives consistently higher yields of deuterium-containing products than does the reaction with methane. These observations suggest energy transfer to the substrate through a transfer of charge from the gel.

Chemical Physics: Microwave and Radio-Frequency Spectroscopy. – Measurements were completed on the paramagnetic resonance spectra of two species appearing in gamma-irradiated single crystals of KNO_3. Both spectra revealed large N^{14} hyperfine splittings. The parameters of spin Hamiltonians describing the data were determined. One species has parameters close in value to those attributed to NO_3^{2-}. The other species is believed to be NO_2, although the parameters differ significantly from those reported for NO_2 in the lattice of irradiated $NaNO_2$. The traces of the tensors for the spectroscopic splitting factor and for the hyperfine coupling are unchanged in the two lattices. Also, the two extreme principal values for each tensor for the KNO_3 lattice are closer to the trace than are the corresponding values for the $NaNO_2$ lattice. It is therefore concluded that the differences in the parameters are due to very large torsional oscillations of NO_2 in the lattice of KNO_3. Since the traces for corresponding tensors in the two lattices are the same within experimental accuracy, no evidence has been found for differences in the electronic structure of NO_2 in the two lattices.

Chemical Separation of Isotopes. – Installation of the O^{17} cascade was completed. Preoperational testing of the water distillation unit is in progress. Several equipment changes became necessary because of the stringent requirements of this unique system. Satisfactory progress is being made in the shakedown operations, and productive operation is expected to begin soon.

Transuranium Elements. – A solvent extraction process was developed for converting nitrate solutions to chloride solutions for use in transuranium element separations. It is based on selective salt formation by Alamine-336, the order of formation being $ClO_3^- > NO_3^- > Cl^- > HSO_4^- > F^-$. The nitrate concentration of 1 M HNO_3–5 M HCl solution was decreased to < 0.001 M by contact with 30% Alamine-336 in diethyl benzene in a mixer-settler.

Alamine-336 in diethyl benzene was not damaged by irradiation to 25 whr/liter in a Co^{60} gamma source. The solvent irradiated to 100 whr/liter formed stable emulsions when mixed with 11 M LiCl, but degradation products causing this effect were removed by Na_2CO_3 scrubbing and reacidification. Extraction and separation factors were not affected by irradiation. Irradiation of 2-ethylhexylphenylphosphonic acid in diethyl benzene to 100 whr/liter caused no noticeable detrimental physical or chemical effects.

The time required for phase separation, after Alamine-336 in diethyl benzene and 11 M LiCl had been intimately mixed, was decreased a factor of 10 either by adding 100 to 1000 ppm of FX-170 surfactant or by increasing the temperature to 80°C.

In the Alamine-336–11 M LiCl system the order of actinide extraction was verified to be Cf > Bk > Am ≧ Cm. The separation factor between berkelium and californium and between berkelium and curium was ~5. In the 2-ethylhexylphenylphosphonic acid–HCl system the californium-berkelium separation factor was ~5 and the berkelium-curium was ~20; the order of extractability was Cf > Bk > Cm > Am. In the di-2-ethylhexylphosphoric acid–10 M HNO_3 system, Bk(III) was oxidized to Bk(IV) with 0.1 M $KBrO_3$ and extracted. The Bk(IV) distribution coefficient was ~100 and the Bk(III) was ~0.01. The Bk(IV)-Cf(III) separation was at least 10^4 per stage.

Diaphragm sampling pumps with gas as the drive fluid were designed and fabricated. They satisfactorily pumped 10 M LiCl with 13.5-ft suction lift and developed maximum suctions of 23 and 24.5 in. Hg. An electrically driven impact wrench was shown to be suitable for operation of gang disconnects, and a spring-loaded radial gang disconnect showed no damage from ten "makes and breaks," including two assemblies with excessive torques.

METALLURGY AND MATERIALS RESEARCH

Preparation of Pure Single Crystals. – An attempt was made to grow an Li^7F crystal under a vacuum of 2 to 9×10^{-4} mm Hg. The maximum temperature in the nickel crucible was 865°C. Under these conditions the entire Li^7F batch was sublimed to the nearest cool area, approximately 14 in. above the capsule tip. This experiment indicates that, contrary to the literature, a higher pressure must be used to prevent sublimation, at least above the melting point of Li^7F. It indicates also that the purification of several-hundred-gram quantities of LiF by sublimation may be accomplished under easily obtained experimental conditions.

Additional phase equilibrium studies were made in the systems MoO_3-BeO, MoO_3-MgO, and MoO_3-ThO_2 in a survey of possible solvents for the crystallization of oxides. The existence of the compounds $2MoO_3 \cdot ThO_2$ and $MoO_3 \cdot MgO$ was confirmed. Both melt at temperatures > 814°C. A eutectic invariant point exists in the system MoO_3-ThO_2 at 782 ± 4°C, at < 10 mole % ThO_2. It involves MoO_3 and $2MoO_3 \cdot ThO_2$ as the two solid phases.

CONTROLLED THERMONUCLEAR RESEARCH

Arc Research. – Two anodes have been developed which will yield primarily Li^{2+} ions in the arc, as indicated by mass analyzer data. These anodes have been operated continuously up to 4 hr at a time without recharging.

Considerable time has been spent observing the backstreaming of the lithium arc. Mass analyzer data indicate that the backstream contains Li^{2+} ions when there is Li^{2+} in the main arc. Escape of the backstream from the magnetic field was demonstrated by placing a 4-ft extension tank on the end of the solenoid and observing that the backstream hit the far end. Later, a 16-ft extension was placed on the tank, and it was demonstrated that part of the backstream hit the far end. It was also demonstrated that if a floating baffle containing a 1/2-in.-diam hole is placed in the backstream, the portion which strikes the hole goes on through.

Successful helium arc operation has been accomplished in the Gas Arc Facility with a base central-region pressure of 5×10^{-5} mm Hg. Measurements of the partial pressure resulting from inleakage from the ends indicated that about 30% of the total could be thus accounted for. The agreement of this figure with those for deuterium and hydrogen arcs suggests that molecular ion recombination does not play an important role. Molecular ion formation in helium is expected to be negligible.

DCX-1 Facility. – Slow ions escaping the plasma region through the magnetic mirrors were detected with a Faraday cup, whose current output was passed through 14.4- and 28.8-Mc narrow-band-pass amplifiers. Preliminary measurements indicate that the escaping ions are being modulated at the ion cyclotron frequency and also at the various harmonics. Oscilloscope traces of the amplifier output revealed amplitude modulation of both the 14.4- and 28.8-Mc frequencies at 60 cycles, and at 2 and 200 kc. The 60-cycle modulation resulted from ion source oscillations, and the various power supplies have been modified to reduce the 60-cycle ripple. The 2-kc modulation coincides with the commutator ripple of the magnetic field.

A measurement has been made of the variation of containment time with the input current. The containment time decreased by 50% in decreasing the H_2^+ current from 9 ma to 0.2 ma at pressures of 10^{-6} mm Hg; however, for pressures less than 10^{-7} mm there was no detectable change in containment time with H_2^+ current. For H_2^+ currents between 1 and 9 ma, the containment was independent of the current throughout the pressure range 10^{-8} to 10^{-5} mm.

Various modifications are being made in an attempt to reduce the dynamic pressure in the plasma region to 10^{-9} mm Hg. The H_2^+ beam entrance and exit apertures have been relocated so that the entrance aperture is 1/2 in.^{2} and the exit aperture is 1 in.^{2} A steam superheater has been installed to permit baking of the vacuum vessel at 300°C for prolonged periods. Liquid-helium traps are being fabricated and are to be installed in the plasma vacuum region.

The probing of the plasma potential with the lithium beam has been continued, and indications are that the plasma potential is proportional to the input H_2^+, with a value of about 60 v per ma of input H_2^+.

Larger Magnetic Facility. – The DCX-2 facility is now being assembled. The guide tracks for the coils and main vacuum parts are installed, and the main vacuum tank was machined and was mounted on the track. The hydraulic bearings are being tested. The roughing and fore-pumping lines are installed up to track level, and this system is essentially complete and ready for initial testing. One end-pumping manifold subassembly was vacuum-tested and found to be leak-tight at a base pressure of 8×10^{-7} mm Hg. It is ready to be mounted on the track. A tantalum filament wound with niobium and titanium, similar to ones operated by the vacuum-testing group, was tested in the long solenoid facility in a magnetic field of 10 kilogauss. It was structurally stable and continuously evaporated titanium at a satisfactory rate in this field.

The first mirror coil was vacuum-tested and assembled; the coil is now ready to be mounted on the track. The outboard booster coils were tested to a field of 15.9 kilogauss at a power level of ~3.6 Mw in their temporary location near the high-current-injection test area. The coils are being used to provide a nearly uniform field for testing of a full-power, short, experimental snout. This test is now in progress and should yield definitive information on the perturbation of the main field by this snout design. An estimate was made of the effect of a short dipole magnetic field perturbation, aligned along the axis of the main field (which approximates a snout perturbation), on the containment of the trapped particles in the machine. For a 1.2-gauss perturbation on the axis, the

diffusion time for drift to the snout as a result of the perturbation is 32 sec and is inversely proportional to the square of the perturbation field.

Vacuum. – Evaporation of titanium from a filament in a 12-in.-high by 6-in.-diam manifold under a pressure of 0.5 μ He has led to a deposit which pumped H_2 at a rate of > 11,000 liters/sec at a pressure of 5×10^{-7} Torr. This rate corresponds to a sticking fraction of about 0.14, which, although less than has been obtained in large-scale apparatus in this laboratory, is about twice the best value obtained previously in the small-scale test. The optimum helium pressure appears to be about 2.0 μ for both the large and small filament-to-wall distances, which leads to the tentative conclusion that the high flow rates obtained are a function of the deposition process rather than of a gas-phase interaction.

The high sticking factors for hydrogen on films deposited on substrates in the presence of helium at liquid-nitrogen temperatures in the large-scale getter test pump have been verified by additional experiments. A simple, new technique for determining sticking factors was used. The values obtained for hydrogen on the films are consistently near 0.5. Sticking factors for hydrogen measured during the continuous evaporation of titanium at liquid-nitrogen temperatures were observed as high as 0.2. X-ray diffraction studies indicate that the films for both this case and the evaporations in helium are composed of extremely small crystallites.

Work on the use of a standard orifice in calibration of vacuum gages is described in ORNL CF-61-5-109.

BIOLOGY AND MEDICINE PROGRAM

BIOMEDICAL PROBLEMS IN ATOMIC ENERGY OPERATIONS

Radiation Physics and Dosimetry: Optical Emission by Irradiated Silver and Aluminum Foils. – Light emitted by thin foils of silver and aluminum during irradiation by 40- to 115-kev electrons was analyzed with a vacuum ultraviolet spectrometer having an EMI 6256B photomultiplier and a conventional dc current amplifier as the detector. Spectra were obtained between 1700 and 6000 A at 30° from the foil normal for aluminum foils of thicknesses 125, 250, 375, and 500 A and for silver foils of thicknesses 1200, 1600, 2000, and 2400 A. The peak at 3400 A in silver, ascribed to plasma radiation by Brown and Steinmann, was investigated for the foils and energies stated above. For aluminum a continuum was found which increased in intensity as the wavelength decreased. These data are being compared with a generalization of the Frank-Ginsberg transition radiation theory as formulated by Ritchie and Eldridge.

Radiation Physics and Dosimetry: Measurements Over Simulated Plane Sources. – To simulate an infinite plane source, an array of sources was laid out with positions at 100-ft intervals in the form of a square 2000 ft on a side. To facilitate ground measurements, a smaller square array of 100 positions at 10-ft intervals was placed in the center of the large array. Two sets of sources were used in the array. Cobalt-60 and Cs^{137}

sources of 4.5 and 15 mc, respectively, were placed in the large array, with sources one-hundreth of these values in the small array. Measurements 3 ft above the ground indicated 114 to 136 μr/hr for Co^{60} and 122 to 147 μr/hr for Cs^{137}; the spread of readings was due to the variation in the instruments. Spectra were taken from an aircraft at 100-ft intervals above the array by using scintillation counters and a 256-channel scintillation spectrometer. Flights were also made over point sources of Co^{60}, Cs^{137}, and I^{131}.

Radiation Physics and Dosimetry: Dissociative Electron Capture in Water Vapor. — An electron-swarm experiment was conducted to study the process of negative ion formation in water vapor by dissociative electron capture. The capture cross section (due to the formation of H^-) when integrated over energy was 7.7×10^{-18} cm^2-ev, which compares favorably with the electron beam results of Buchel'nikova, who found a value of 6.5×10^{-18} cm^2-ev. The energy at which the process peaks was 6.4 ev, which agrees quite well with the peak energy found by Buchel'nikova, but in general disagrees with other values obtained by mass spectroscopy.

Radiation Physics and Dosimetry: Space Dispersive Properties of Plasma. — The "space dispersion" — that is, the occurrence of the term k in the dielectric constant $\epsilon(\omega,k)$ — can be attributed either to the Doppler effect or to the magnitude of the term ak that may appear in the formulation of the problem ("a" is a characteristic distance such as the Debye length). By use of an approach based on the Doppler effect, the macroscopic parameters of a plasma have been represented in the form of four-dimensional tensors of the fourth order (similar to those introduced by Mandelstam and Tamm).

The phenomenological description of plasma has also been formulated in a three-dimensional space by means of two macroscopic parameters, the electric susceptibility χ_e and the "proper magnetic susceptibility" χ_μ/μ. Expressions for these parameters have been given for the general case of a plasma having an electron velocity distribution f(v) dv and for a few typical specific cases. Both parameters are functions of the frequency and of the wave vector. This formulation shows that a plasma is a magnetically polarizable medium and that the term χ_μ/μ vanishes only if the electron velocity distribution is isotropic. In the current literature the existence of the term χ_μ/μ has not been taken into account, since, by using a "modified representation" of the dielectric constant, the magnetic properties of plasma have not been considered. In the modified representation the dielectric constant ϵ_M is defined by the relationship $k \times B = -(\omega/c)\epsilon_M E$, whereas in the conventional representation the same relationship has the form $k \times B = -(\omega/c)\epsilon E + 4\pi(\chi_\mu/\mu)k \times B$, where $\epsilon = 1 + 4\pi\chi_e$. A general formalism has been developed for deriving the electric and magnetic plasma parameters directly from the Boltzman-Vlasov equations.

Ecology and Marine Studies. — The effect of mixed neutron-gamma radiation upon the soil microflora and its activity was tested in a preliminary experiment. Soil samples were collected from six sites at distances ranging from 70 to 425 m from the air-shielded Dawsonville, Georgia, reactor. Microflora, soil respiration, and percentage moisture were determined in aliquots representing the top 2 cm of soil. The dose received in the top 2 cm was assumed to approximate the corresponding air dose, as

loss of dose through attenuation in the soil will be compensated for by buildup. The accumulated air dose varied from 3 to 330 $\times 10^4$ reps for the period February 1958 to July 1960 and from 3 to 320 $\times 10^3$ reps for the period May 1 to July 1, 1960, for the 425- and 70-m stations respectively. Whereas the data suggest a positive correlation between soil respiration, bacterial and actinomycetes counts, and soil moisture, no direct correlation between dose and any of these factors was found. After eliminating the overriding influence of moisture by plotting the ratio respiration/moisture vs dose, evidence of a negative correlation with dose was obtained. These data suggest that the effect of radiation was indirect. High radiation doses in June 1959 caused the phanerogam vegetation to drop its leaves. This effect resulted in a small quantity of younger, more easily decomposable leaves being contributed to the soil at an earlier than usual period. In the most heavily irradiated areas only a small amount of litter consisting of the most resistant fractions remained at the time of sampling. Consequently, the rate of respiration was lowest in those areas.

TRAINING, EDUCATION, AND INFORMATION PROGRAM

Biology and Medicine Program. — Twenty AEC Fellows arrived from Vanderbilt University on June 7 to begin their summer field training. A trainee from Indonesia, sponsored by the IAEA, arrived on June 8 and will remain with the Health Physics Division until July 14.

ISOTOPE DEVELOPMENT PROGRAM

Recovery of Fission Products and Transuranics from Waste. — In laboratory-scale studies of a head-end double-precipitation step, to be used prior to the ion exchange step in recovering strontium from Purex waste, > 80% of the strontium was recovered. Excess ferric ion was added to the waste solution, and the mixture was diluted with fuming nitric acid to 50 to 55% HNO_3, precipitating > 85% of the sulfate ion in the system. The filtrate from this precipitation was evaporated to the point of nitrate decomposition and treated with fuming nitric acid, to give a precipitate containing about 5% of the iron.

Radioisotope Research and Development. — An Sr^{90} heat source was fabricated and was installed in a thermoelectric generator which will be used by the U.S. Weather Bureau to power a remote weather station. The heat source was prepared from 763 g of $Sr^{90}TiO_3$ powder containing 17,500 curies of Sr^{90}. The compound was synthesized by calcining a blend of $Sr^{90}C_2O_4$ and TiO_2 at 1200°C. The $Sr^{90}TiO_3$ powder was pressed into pellets and then converted into a ceramic form by heating to 1400°C. Calorimetric measurements showed that the heat content of the pellets was 110 w due to Sr^{90}-Y^{90} and 9.5 w from Sr^{89} decay, as of May 12, 1961. The pellets were sealed in a Hastelloy C capsule by remote-welding techniques. The heat source was then sealed in the thermoelectric unit by remote welding.

Preliminary electrical output tests indicated that the unit was performing satisfactorily.

Radioisotope and Stable Isotope Production. — Ion currents equivalent to 2990 g of separated isotopes were collected during the past two months. Isotopic materials collected included Ca, K, Zr, Mg, Sn, Ni, W, and Sm. Separations were performed in the four calutrons in Building 9731 and in 24 of the calutrons associated with the expanded facilities in Building 9204-3.

Chemical recovery and refinement were completed on 28 new inventory lots of isotopes of C, Cd, Cl, Fe, Ga, Ni, Tl, and Yb and on returned samples of Fe, V, and Pb.

A total of 55 conversions was made from inventory forms of stable isotopes to forms more suitable to various requestors. One special target was prepared for the Physics Division from 139 g of highly enriched (99.75%) Pb^{208} by remelting and recasting in a cylinder 1-1/8 in. in diameter and approximately 3/4 in. high. An inventory sample of $Zr^{96}O_2$ was reduced to fine powder, converted to the tetraiodide, and formed into a crystal bar for rolling into a thin foil for accelerator studies.

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