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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

July, 1957

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

PROGRAM 2000 - SPECIAL NUCLEAR MATERIALS

Waste Metal Recovery - Recovery of plutonium from Chalk River solutions, oxide, and scrap was started. About 1.8 kg of plutonium has been recovered and purified by ion exchange from the nitrate solutions. Two batches of PuO_2 were dissolved successfully in 10 M HNO_3 containing 0.01 M HF; the dissolution rate was slow, requiring 72 to 96 hr for completion. (AEC Activity 2350)

Excer Process - In the Excer process, uranium in an ore concentrate is converted by ion exchange to a form suitable for reduction, is reduced, and is precipitated as $UF_4 \cdot 3/4H_2O$. The Ionics, Inc., 9- by 10-in. membrane electrolytic reduction cell has operated a total of 700 hr without damage to the components. In iron-reduction cell experiments, reduced uranium was separated from iron by a factor of 5 by means of an anion exchange resin.

Hydrated UF_4 precipitated from a reduced uranium solution filtered readily when the supernatant was separated immediately to prevent cooling and formation of fluffy $UF_4 \cdot 2.5H_2O$.

In a single two-stage run in the fluidized-bed dehydrator, specification grade product, less than 0.2% H_2O, was produced at a rate of 2 lb/hr. (AEC Activity 2702)

Fluorox Process - In the Fluorox process, UF_6 is prepared by oxidation of UF_4 with dry air or oxygen. Temperatures of 750 to 850°C were reached in the fluidized-bed oxidation reactor by burning carbon monoxide--oxygen mixtures internally in a fluidized bed of 40- by 100-mesh sand as a supplement to electrical wall heating.

Thermochemical calculations indicated a high probability of reaction between UF_6 and CO at temperatures of 298 to 1300°K. Formation of UF_5 by a similar reaction is thermodynamically favorable in this temperature range. (AEC Activity 2702)

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Metallex Process - In the Metallex process, anhydrous $ThCl_4$ is reduced to $ThHg_3$ by sodium amalgam, and the $ThHg_3$ is converted to massive thorium by vacuum distillation of the mercury. The average reduction efficiency in five reduction-washing runs in the continuous facility (2.6 lb of thorium per hour) was 76%. Amalgamated nickel decanters were used to purify the amalgams.

In laboratory studies the density of the sintered metal was increased 12% and the ThO_2 content metal was decreased by a factor of 2, by rewashing the amalgam with 1 N HCl in water, 1% sodium versenate, or saturated pyridine. (AEC Activity 2704)

PROGRAM 4000 - REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test - The replacement of flanges and leak-detector lines in the HRT was completed, and the reactor piping was flushed with water in preparation for resealing the system. An inspection of the low-pressure valves, which were removed during the flange replacement, revealed widespread surface pits in the stainless steel disks to which the bellows are attached; new material was obtained from the manufacturer, and all the original disks and bellows assemblies were replaced.

The demineralized-cooling-water loop was completed and flushed, and a successful 100-psi pressure test was made on the check valves which prevent backflow of coolant from the shield. Further preparations for the resumption of testing included an ultrasonic measurement of the core-wall thickness, and repair and installation of the shield divider gate for the forthcoming remote-maintenance experiments.

Following recent confirmation that galvanized or cadmium-plated bolts deteriorate at reactor temperatures, due to diffusion of the coating material into the bolts, a new set of bolting material was ordered for the HRT flanges. The shipment has been delayed because of production difficulties, however, which may delay reassembly of the reactor piping. (AEC Activity 4103.3)

HRT Chemical Pilot Plant - Testing of the HRT chemical plant was concluded with two additional solids dissolutions of simulated corrosion products and an integral test of the complete low-pressure-system operating cycle. Results from the solids dissolution tests showed greater than 99.5% dissolution. Performance of all components was judged satisfactory. (AEC Activity 4103.1)

Mathematics and Computation--Homogeneous Reactor Development - Oracle codes were written for determining the nuclear characteristics of two-region, time-dependent, thorium-breeder reactors, and for evaluating the zero- and first-order Bessel functions of the second kind. Two output routines were prepared to facilitate the obtaining of results from the two-group, N-region Oracle calculation. (AEC Activity 4103.1)

Reactor Analysis - Nuclear characteristics of HRE-3 type spherical reactors were evaluated. A breeding ratio between 1.04 and 1.08 appears possible for a 9-ft-dia reactor having a 5-ft-dia core and a blanket thorium concentration between 500 and 1000 g/liter. The ratio would be lower by about 0.03 if xenon were not removed. If the heat exchanger surface corroded to a depth of 0.001 in. and the soluble corrosion products were distributed uniformly throughout the fuel solution, the associated decrease in breeding ratio would be about 0.06 for a reactor with a 5-ft-dia core.

Two-group, two-region calculations for some cylindrical and spherical thorium breeder reactors were performed. For a given core volume, the breeding ratios were nearly the same for these two geometries. Maximum wall power densities were always higher for the cylindrical reactors.

The breeding ratios for several spherical, thorium breeder reactors were evaluated on the basis of a multigroup model, and the results were compared with those of two-group calculations. The two-group method gave breeding ratios about 5% higher than did the multigroup method. This difference was due primarily to the values for η^{23} in the resonance region; resonance absorptions in fuel were not considered in the two-group model. (AEC Activity 4103.1)

Homogeneous Reactor Instrumentation - The necessary engineering work was completed in order to provide a means of control-panel actuation for the bleeding of accumulated gas from the HRT feed pumps by means of valves, to permit remote speed control of the fuel heat exchanger feed-water pump, to provide for the increased instrumentation necessitated by the increase in capacity of the refrigeration system, to control the pumps used for feed-water treatment, to instrument the flow-measuring-type leak-detecting system, and to revise the condensate control system so that purge water could be drawn from the condensate tanks.

A pressure transmitter suitable for direct connection to 650°F reactor process lines was tested and found to be accurate to within 2% and to have a natural frequency of 375 cycles/sec. This high-frequency response performance will be advantageous in reactor kinetics studies for determining the effectiveness of the pressurizer in damping reactivity excursions. (AEC Activity 4103.1)

HRP Design - An iodine removal bed, employing silvered-alundum Raschig rings, was designed for addition to the HRT fuel recombiner in order to minimize iodine poisoning of the platinum catalyst in the recombiner.

An independent leak-detector system was designed to serve the fuel inlet and outlet flanges on the HRT reactor vessel, the mean heat exchanger head flanges, and the circulating-pump flanges. This system permits purging of the leak-detector lines to those flanges which are not to be replaced during the current HRT flange replacement program and provides the opportunity of sampling the leak-detection fluid for the presence of chloride contaminants. A sensitive indicating system, incorporating a capillary-tube flowmeter, was designed to supplement the indicating facilities in all the leak-detection systems.

Basic design criteria and conceptual drawings were completed of remote maintenance and transport facilities for the removal and replacement of the fuel and blanket corrosion specimen holders and the pressure-balancing-system rupture-disk assembly in the HRT.

The fuel and blanket feed-pump discharge piping of the HRT was redesigned to permit venting of the fuel injection pumps should they become gas-bound.

Preliminary flowsheets and design data were prepared for HRE-3, a 60-Mw thorium breeder reactor. (AEC Activity 4103.1)

HRP Metallurgy - Zirconium-niobium alloys have shown promise of having a resistance to in-pile corrosion by uranyl sulfate solutions superior to that of Zircaloy-2. The difficulty with these alloys is a hardening and embrittling which occurs during aging at temperatures as low as 350°C. X-ray diffraction studies were made, and the hardening phase was shown to be a niobium-rich phase. The hardening probably results from lattice strain as a result of shrinkage during formation of the new phase. The addition of 2% molybdenum to these alloys slows down the hardening reaction, while a 5% addition suppresses it, at all temperatures, for at least two weeks.

No change in tensile properties of Zircaloy-2 as a result of either radiation damage or hydrogen pickup was found in samples irradiated for 1672 hr (or 3765 Mwhr) in uranyl sulfate in in-pile loop L-2-10. (AEC Activity 4103.1)

Laboratory Corrosion Studies - Stress-corrosion cracking has been observed in type 347 stainless steel at temperatures from 200 to 300°C in distilled water at pH levels of 2.8, 6.5, and 10.5 with chloride concentrations of 25, 50, and 100 ppm and dissolved oxygen concentrations of approximately 10 and 1200 ppm. The time required for cracking to occur varied between 100 and 700 hr.

Pertechnetate concentrations of 100 ppm and less in oxygenated distilled water of pH 2.8 and 6.5 at 300°C and containing 100 ppm chloride were ineffective for preventing stress-corrosion cracking in type 347 stainless steel. With an initial pertechnetate concentration of 310 ppm, however, cracking was prevented for 1500 hr, the duration of the test. Some loss in pertechnetate concentration was experienced.

Types 202, 414, and 431 stainless steel were tested in boiling 5% HNO_3, in oxygenated HRT core solution at boiling temperature and at 200 and 300°C, and in boiling 1.33 m UO_2SO_4 solutions. With the exception of type 202 stainless steel, none of the alloys exhibited favorable corrosion resistance. The corrosion resistance of the type 202 alloy was comparable with that of type 347 stainless steel in all environments. (AEC Activity 4103.1)

Dynamic Solution Loop Corrosion Tests - A fourth test of the mockup of the Zircaloy-2--stainless steel transition and expansion joint as used in the HRT reactor vessel was completed. The test lasted 1201 hr, 143 hr on water and 1058 hr on fuel solution (0.04 m UO_2SO_4, 0.02 m H_2SO_4, 0.005 m $CuSO_4$). Fifty thermal cycles were made, one per day between 300 and 100°C, but no mechanical deflections of the bellows were made. Steady-state operation was at 300°C. No leakage of fuel solution through the bellows or past the transition joint was detected. The pitting attack, observed previously on the bellows at the edge of the reinforcing rings, stopped in the absence of mechanical deflection. The bellows and transition joint have remained sound and leak-tight for a total of 4118 hr, during which time the bellows and joint were exposed to fuel solution for 3617 hr, subjected to 166 thermal cycles, and mechanically deflected 148 times.

The series of long-term runs at 200, 250, and 300°C with a solution of the composition proposed for use in the HRT was concluded. The tests had continued for roughly 20,000 hr at each temperature. It was shown that once the oxide film formed on the pins in the first test, insignificant corrosion occurred during subsequent exposures. Stainless steel and titanium stress specimens exposed during about the last 13,000 hr of these tests gave no evidence of stress-corrosion cracking. (AEC Activity 4103.1)

Small-Scale Dynamic Slurry Corrosion Tests - In toroid tests at 250°C and 26 fps, with oxygen added, circulation of thoria slurries resulted in increased rates of corrosion of type 347 stainless steel and titanium when sodium metasilicate had been added. At pH 12, titanium and carbon-steel pins were consumed.

A test of 1026 hr duration in toroids at 250°C and 26 fps indicated a general decrease in corrosion rate by oxygenated circulating slurries with extended time, for type 347 stainless steel, SA-212-B steel, Zircaloy-2, and titanium. The slurry, previously circulated in loop runs, was not further degraded during the test.

Special preparations of thoria spheres and of recalcined thorium-uranium oxide were circulated as slurries at 250°C and 26 fps in toroids. The larger spheres (~ 85 μ) characterizing one batch were degraded. Corrosion rates in all cases were low. (AEC Activity 4103.1)

Dynamic Slurry Loop Corrosion Tests - Slurry prepared from thoria calcined at 1600°C was circulated for 250 hr at 300°C with an oxygen atmosphere in a 100A pump loop at an average concentration of 408 g of thorium per kilogram of water. The thoria, of mean particle diameter 1.3 μ, was not degraded. Corrosion of specimens and loop components was low.

Slurry prepared from 800°C-calcined thoria, micropulverized (two passes) to a mean particle diameter of 1 μ, was circulated for 300 hr at 300°C with an oxygen atmosphere in a 100A pump loop at an average concentration of 591 g of thorium per kilogram of water. Further degradation of the slurry was slow, but resulted in a final particle size of 0.5 μ. Although specimen corrosion rates were normal, loop corrosion, much of which represented attack on pump parts, occurred at high rates during the first part of the run.

Two loop runs were made at 300°C with oxygenated slurry prepared from thoria calcined at 650°C. In both runs soft slurry plugs formed in low-velocity sections of the loop system when the loop charge concentration reached 700 to 800 g of thorium per kilogram of water. The tests were stopped after 13 hr and 196 hr, respectively. Corrosion rates (in mils per year) were at normal levels: for the loop, 4; at 20 fps, type 347 stainless steel, 2 to 3; SA-212-B carbon steel, 13 to 22; and Zircaloy-2, 1.

Circulation of slurry, prepared from thoria calcined at 550°C, for 579 hr at 300°C, with an oxygen atmosphere at an average circulating concentration of 404 g of thorium per kilogram of water, gave satisfactory operation and resulted in moderate corrosion rates with negligible attack on pump parts. (AEC Activity 4103.1)

In-Pile Solution Corrosion Loops--LITR - Irradiation of the first all-titanium in-pile loop, L-2-14, was completed. This was the third loop experiment in the HB-2 beam hole. The total circulation time with enriched fuel solution was 663 hr. The energy output of the LITR during the inserted time was 1530 Mwhr. The loop contained a solution of 0.17 m UO_2SO_4, 0.4 m H_2SO_4, and 0.15 m $CuSO_4$. The main-stream operating temperature was 280°C. The over-all titanium corrosion rate, based on oxygen consumption, was 2.7 mils/year.

Irradiation of stainless steel loop L-2-17, the fourth loop experiment in the HB-2 beam hole, was also completed. The total circulation time with enriched solution was 1147 hr. The energy output of the LITR during the inserted time was 2625 Mwhr. The loop was charged with a solution of 0.04 m UO_2SO_4, 0.025 m H_2SO_4, and 0.005 m $CuSO_4$. The operating temperatures were 300°C in the main stream and 315°C in the pressurizer. No evidence of solution instability was observed at these conditions. The over-all stainless steel corrosion rate was 0.8 mil/year based on oxygen consumption and 0.6 mil/year based on nickel in solution. (AEC Activity 4103.1)

In-Pile Solution Corrosion Loops--ORR - The design of auxiliary equipment for the ORR loop package was essentially completed; fabrication of the beam-hole liner and loop-package container will commence soon. (AEC Activity 4103.1)

Adsorption and Radiation Studies - An experimental program has been undertaken to obtain data for prediction of the effectiveness of the charcoal adsorption beds in the holdup of fission gases from the Homogeneous Reactor Test. A tracer technique using pulses of radiokrypton in experimental charcoal adsorption beds was applied to an investigation of factors which influence the holdup

of fission gases by adsorption beds. An analytical expression was developed, based on a theoretical plate model, which is used to evaluate experimental data. Tests were run to determine the effects of charcoal temperature, adsorbed moisture, quality of packing of the charcoal in the bed, and to compare the holdup of xenon with that of krypton. Experimental and theoretical work is being continued on these and other factors. (AEC Activity 4103.1)

GENERAL REACTOR RESEARCH

Basic Reactor Research - A computation of the critical size of bare hydrogenous reactors by use of the Fourier transform of the thermal-neutron flux distribution as the nonleakage probability involves an estimate of the infinite medium multiplication factor. A calculation of this factor for various concentrations of U^{235} is being carried out. An estimate of the fission integral by use of the Breit-Wigner formula and BNL-325 parameters in the region where they are known and a numerical integration of the BNL cross section curve above that region were made which agree well with experiment. The principal uncertainty at present is the neutron energy spectrum in the epithermal region.

A theoretical analysis of the radiative capture and inelastic scattering cross sections in U^{238} was started. The analysis includes careful account of the fluctuations in the neutron widths. The data at 25, 150, and 500 kev indicate that the S-, p-, and d-wave strength functions are all roughly equal to the value found for S-waves from low-energy neutron-scattering experiments.

The investigation to determine the energy spectrum of prompt gamma rays resulting from the thermal fission of U^{235} was reactivated. For this experiment, thermal neutrons from a thermal column adjacent to the Bulk Shielding Facility reactor are allowed to impinge upon a spiral fission chamber used as the source. This source is then viewed by the collimator of a multiple scintillation crystal gamma-ray spectrometer. Preliminary tests are being performed to determine the best methods for reducing the prompt neutron background and to determine the minimum reactor power that can be used. (AEC Activity 4202)

Metallurgical Materials and Processing - The result of contacting zirconium with solid magnesium metal or vapor is embrittlement of the zirconium due to magnesium penetration of the grain boundaries. The practical significance of this observation is that the zirconium cladding on fuel elements may become susceptible to mechanical removal as a result of embrittlement, or that chemical leaching of the grain boundary material may lead to disintegration. Two to three hours at 625°C is sufficient time to completely penetrate 30 mils of zirconium. Two specimens of this material, heat treated at 350 and 500°C to promote microstructural changes, were resistant to nitric acid; however, the embrittled zirconium cladding on a uranium rod was 90% removed by mechanical working in a rotary tube and rod straightener.

Liquation of uranium oxide--stainless steel fuel-element samples in order to afford an opportunity for gravity concentration of uranium oxide in the bottom portion of the melt has been examined. Increasing the carbon content

to about 5% in type 347 stainless steel--uranium oxide fuel-element samples resulted in partial melting at 1200°C, but segregation of uranium oxide particles did not occur because of the large number of interlocking carbides present at this temperature. (AEC Activity 4203)

Power Reactor Fuel Processing: Darex Process - In the Darex process, stainless-steel—containing fuel elements are dissolved in aqua regia, and the chloride is stripped from the dissolver solution prior to solvent extraction of the uranium. Solvent extraction feed, 3 N in nitric acid and containing 40 g of stainless steel per liter, was successfully prepared by boiling off azeotropic nitric acid from stripped dissolver product until the solution contained 140 g of stainless steel per liter and was 9 M HNO_3 and then diluting with two volumes of water. The azeotropic nitric acid vapors were suitable for return to the stripper. The dissolution rate of sintered UO_2 in aqua regia was twice that of stainless steel, so that the Darex process could probably be used for stainless-steel-clad UO_2 fuel. Haynes-21 appeared to be suitable for construction of a dissolver, although not so desirable as titanium. (AEC Activity 4301)

Power Reactor Fuel Processing: Zircex Process - In the Zircex process, zirconium—containing fuel elements are hydrochlorinated to form volatile $ZrCl_4$, and uranium is recovered from the solid residue. Hydrochlorination of Zircaloy-2-clad UO_2 appears feasible as a result of an experiment in which hydrochlorination of a PWR fuel element resulted in loss of only 0.0014% of the uranium to the sublimate and 0.0077% to the nitric-acid-insoluble residue. The relation between the hydrochlorination rate of Zircaloy-2 and the HCl partial pressure at 475°C was shown to be $r = 1.43P^{0.5}$.

A U-Zr-Nb alloy containing 93.5% U was hydrochlorinated, with a total uranium loss of 0.114%.

Corrosion tests under actual process conditions indicated that type 300 series stainless steel may be suitable for construction material in a gas-phase hydrochlorination process and that nickel or Hastelloy-B may be suitable for a liquid-phase process. For a combined hydrochlorinator-dissolver, the high-cobalt alloys Haynes-25 and S-816 appeared to be suitable. (AEC Activity 4301)

Power Reactor Fuel Processing: Alternate Aqueous Dissolution Studies - Other aqueous reagents are being investigated for fuel elements that are not soluble in nitric acid. Hot 6 M H_2SO_4 removed the stainless steel from a Yankee Atomic Power fuel element at the feasible rate of 4 to 6 $mg/cm^2 \cdot min$, with less than 0.01% loss of uranium from the UO_2 core. Volume reduction of the decladding solution in order to precipitate the salts and permit recycle of the acid was unsuccessful. Precipitation of the waste with calcium hydroxide produced an equal-volume cake that resisted leaching.

In a 2.5-hr reflux, about 0.1% and 0.01% of the uranium was dissolved from U--10% Mo and U--10% Nb alloys, respectively, by 6 M H_2SO_4. Nearly 1% of the uranium dissolved when uranium metal was refluxed.

Uranium was extracted from the residue from the sulfuric acid dissolution of the stainless steel component of APPR fuel elements by aqua regia with about 1% loss.

Zircaloy-2-clad UO_2 cores were completely stripped by 2 to 15 M HF. Uranium losses were from 0.19 to 0.05%, being highest in the lowest acid concentration. Carpenter 20 stainless steel, a possible material of construction, was satisfactorily resistant to dissolution of zirconium with 8 M HF, followed by dissolution of uranium in boiling 4 N HNO_3.

A stainless steel dissolver using acid recycle with external heat exchanger and filter was operated continuously with 96% current efficiency in the electrolytic dissolution of stainless steel. Commercial zirconium dissolved in 3 M HCl with and without HF and H_2O_2 with current efficiencies of 111 to 207%. Scouting experiments with 3 to 6 M H_2SO_4 as the electrolyte for zirconium dissolution were not encouraging. (AEC Activity 4301)

Power Reactor Fuel Processing: Ion Exchange Treatments - Uranium was selectively sorbed by an anion exchange resin from a chloride-fluoride-zirconium solution. From a fluoride-zirconium solution containing no chloride, zirconium was readily precipitated with alkali, leaving the uranium in solution for further ion exchange processing. (AEC Activity 4301)

Power Reactor Fuel Processing: Mechanical Processing - The Mackintosh-Hemphill derodding machine successfully removed the aluminum jackets from Hanford W slugs. Longitudinal scoring to a depth of half the thickness of stainless steel or zirconium tubing was not sufficient to allow removal of the cladding by pressure rollers. (AEC Activity 4301)

Power Reactor Fuel Processing: Solvent Extraction - Laboratory tests indicated that the recently proposed MTR-type uranium-aluminum fuel elements, with a 3% silicon core, will require a dehydration step to minimize emulsification during solvent extraction recovery of the uranium. (AEC Activity 4301)

Fused Salt--Fluoride Volatility Processing - In the fused salt--fluoride volatility process a uranium fuel element is dissolved in HF in a fused fluoride medium, and the UF_4 formed is fluorinated to volatile UF_6 which is absorbed in NaF traps. In another flowsheet run in the volatility-absorption portion of the Pilot Plant, only 5 ppm of uranium remained in the fused salt after fluorination. Of the uranium losses, 3.3% was recoverable (absorbed in the chemical traps) and 0.06% was nonrecoverable.

In further laboratory studies, the chief activity transfer in the fluorination step was during UF_6 volatilization, which confirms preliminary studies. Both the volatile fission-product fluorides and the rare-earth fluorides, which are relatively nonvolatile, were transferred during this step. Both CaF_2 at 100°C and NaF at 400°C were good absorbents for volatile and particulate impurities in the product gas stream. The use of alundum resulted in a large uranium loss. (AEC Activity 4302)

Waste Treatment and Disposal - In the electrolytic treatment of ORNL radioactive wastes to destroy nitrate and to plate out the ruthenium, about 18 kwhr was required per pound of nitrate, and about 90% of the ruthenium was plated on the cathode. (AEC Activity 4305)

Long-Range Planning Studies - Fuel exposures in heterogeneous thorium breeder reactors, moderated by D_2O, have been calculated for continuous-irradiation-type fuel cycles. The fuel elements were considered to move through the reactor at a constant rate and to be exposed to a spatially dependent neutron flux. Fuel exposure at the point of discharge was calculated as a function of reactor size. For the case of an average breeding ratio equal to 1, preliminary results show the exposure to be about 20% smaller than that obtained when the neutron flux was uniform and the fission products were built up uniformly and remained uniformly distributed during the period of exposure.

Results pertaining to the safety of the ORNL Graphite Reactor, assuming that the reactor contains highly enriched annular-type cylindrical fuel elements, indicate that for a given Δk_e, the most important parameter is the time lag between the scram signal and the time the control rod has moved to a position 4 ft within the reactor. For a 200-msec time lag, it appears that a 3% Δk_e is permissible. (AEC Activity 4510)

PROGRAM 5000 - PHYSICAL RESEARCH

Reactor Operations - Because of the high rate of fuel failures at the Graphite Reactor, the spare fuel is being used at a rate which would exhaust the supply within a year. Some Savannah River slugs have been ordered for use in radioiodine production in order to conserve the present supply, and the reloading of the Graphite Reactor with enriched fuel is being expedited.

Two radiation incidents from experiments caused evacuation of the LITR for short periods during July. On July 9, during shutdown operations, some lead shot were inadvertently spilled into the reactor tank. Two additional days of shutdown were required to remove shot from the core. Other operations were uneventful.

The Oak Ridge Research Reactor (ORR) - The reactor building, shielding, and cooling system were accepted from the contractor by the AEC and ORNL on July 15, 1957. Several items of equipment remain to be completed, and work by the contractor continues on these items.

The cooling systems have been cleaned and flushed with demineralized water. Pumps, valves, and other equipment have been operated in an attempt to determine if any modifications are necessary during the reactor installation phase. Temporary piping and flanges are now being removed to allow necessary mechanical work prior to installation of the reactor mechanical drive components.

The reactor control cubicles have been moved into the building; electrical and instrument work related to reactor control has been started.

The reactor tank has been hydrostatically tested by the vendor in Boston. Several repairs were found to be necessary, and this work is now being done.

Disassembly of the mechanical rod drive test is nearly complete, and the components are being moved to the ORR building.

PHYSICS

Neutron Velocity Selector - Transmission measurements of a sample of fission-product samarium (containing 3 mg Sm^{151}) were analyzed to give parameters of the resonances in Sm^{151} up to 10 ev. Transmission measurements were made from 0.1 to 50 ev with two small samples of 2.5-year Pm^{147} prepared by the Chemistry Division. In order that these small samples (6.8 and 27 mg) could be used, the neutron beam was collimated to a cross sectional area of only 1 mm^2. The new high-intensity spectrometer for partial cross section measurements at the LITR was completed and is being installed at the LITR. (AEC Activity 5220)

Recoil Spectrometry - The 5.3-day activity in Xe^{133} consists in β^- emission followed in about half the cases by internal conversion of an 80-kev gamma ray. This balance between pure beta emission and beta emission followed by internal conversion makes Xe^{133} particularly attractive as a subject for charge spectrometry because the spectrum should show a combination of the distribution arising from pure beta emission with that arising from internal conversion; that is, it should show a dip followed by a peak.

The results of a survey do indeed show this behavior. The distribution of the product ions is as follows:

Charge	Per cent of decays	Charge	Per cent of decays
1	36.1	12	3.1
2	4.0	13	1.68
3	2.3	14	1.06
4	2.1	15	0.64
5	3.0	16	0.33
6	3.9	17	0.14
7	5.8	18	0.048
8	9.2	19	0.019
9	11.7	20	0.012
10	8.9	21	0.048
11	5.7	22	0.024

It will be noted that the most probable charge in the internal conversion part of the distribution occurs at charge 9. This is in agreement with earlier work with Xe^{131} which showed the peak at charge 8, because in Xe^{133} there is a beta-particle emission which is absent in Xe^{131}, and this gives all ions one more unit of charge. (AEC Activity 5220)

Neutron Diffraction - A single-crystal neutron diffraction study was made of the magnetic properties of $MnBr_2$. Antiferromagnetic ordering of the Mn^{++} ion spin moments develops in this compound at the very low temperature of 2.16°K. It was thus necessary to develop a single-crystal goniometer device that would operate in a cryostat with helium maintained at low pressures to attain temperatures down to about 1.3°K. The apparatus also included a magnet so that diffraction measurements could be made on the crystal at low temperature in magnetic fields of up to about 15 kilogauss.

A rather complicated antiferromagnetic structure was observed in this hexagonal-type compound, which in the absence of a magnetic field showed threefold symmetry about the c axis of the crystal. Application of a magnetic field along a given direction in the hexagonal layers destroyed the threefold symmetry and produced a single antiferromagnetic domain along one of the hexagonal axes. These domains could be rotated by the field to any one of three hexagonal axes. The fact that the domains were observed to be stable along only three of the six hexagonal axes could be used to develop arguments relating to the role of the bromine ions in the indirect coupling mechanism involved between the spins of the magnetically active manganese ions. Other effects, such as the depression of the ordering temperature with the application of a field, were also observed. Such effects can be observed only in antiferromagnetics with very low transition temperatures. (AEC Activity 5220)

CHEMISTRY

Chemical Engineering Research - The performance of 0.25- to 3.75-in.-dia hydroclones in separating water from kerosene was relatively independent of size. (AEC Activity 5310)

Extraction Reagent Performance - The addition of benzene or xylene to TBP-Amsco decreased the radiation degradation of the solvent, as evidenced by a decrease in the amount of acids formed and by gas chromatographic analysis. However, these additives are not practical because of chemical side effects. (AEC Activity 5310)

Chemistry of Corrosion - According to the Evans-Hoar theory, the chromate ion is an inhibitor because of its ability to precipitate, in situ, any ferrous ions emerging from defects in the protective film. Their experiment on the precipitating action of chromate ions was repeated with the pertechnetate ion in the absence of air. No precipitate was obtained, in accordance with expectations based on the fact that the pertechnetate ion has no buffer action, so that the acidity is not reduced to the point at which the reaction becomes thermodynamically possible. Even the small precipitate formed after exposure to air for five days had a beta activity which showed that an insignificant amount of pertechnetate was reduced in its production. (AEC Activity 5330)

Ion Exchange Studies - Distribution coefficients for the partition of tracer quantities of iron(III) between a sulfonium anion exchanger, Stamex S-44, and various concentrations of hydrochloric acid solutions were measured. The values obtained are virtually the same as those reported in the literature for Dowex 1, a quaternary amine anion exchanger. This striking similarity suggests that this absorption is more a function of the nature of the complex ion in solution than of the structure of the exchange resin.

The ammonium-sodium cation exchange equilibrium was studied as a function of exchanger capacity of a series of variable-capacity resins previously described. It was again found that the selectivity for the preferred ion increased with decreasing capacity. This result explains, at least in part, the positive deviations obtained in the thermodynamic calculations of cation and anion exchange selectivities, since these deviations are largest for the more highly cross-linked (and lowest capacity) exchangers. (AEC Activity 5330)

Chemistry of Technetium - The ultraviolet and visible spectra of $ReCl_3$ and $ReBr_3$ in aqueous solutions were observed. The $ReCl_3$ dissolved in 12 M HCl has absorption maximums at 7775, 5200, and 3140 Å, with molar extinction coefficients of 160, 630, and 4180, respectively. The $ReBr_3$ dissolved in 8 M HBr has absorption peaks at 7650, 5300, 4510, 3890, and 3350 Å, with approximate molar extinction coefficients of 205, 720, 1790, 3000, and 3400, respectively.

The visible spectra of $ReCl_3$ and $ReBr_3$ were also observed in acetone. The $ReCl_3$ has two absorption maximums at 7525 and 5100 Å with molar extinction coefficients of 220 and 660, respectively. The $ReBr_3$ has two absorption maximums at 7500 and 4590 Å with molar extinction coefficients of 250 and 1900, respectively.

The $ReCl_3$ is not stable in water, 1 M $HClO_4$, and 2 M H_2SO_4; however, the solutions are stable for sufficient time to obtain absorption maximums. In each case two maximums were observed as follows: 7600 and 5075 Å for water, 7570 and 5070 Å for 1 M $HClO_4$, and 7550 and 5050 Å for 2 M H_2SO_4.

Twin absorption peaks recently observed elsewhere at 2050 and 2020 Å for ReO_4^- were confirmed. Comparison of the spectra of ReO_4^-, TcO_4^-, and MnO_4^- suggested that MnO_4^- might have an absorption maximum above 8000 Å. The spectrum of $KMnO_4$ in water was observed to 13,600 Å, but no additional absorption maximums were found.

Measurements of the spectra of K_2MnO_4 dissolved in 8 M KOH and of Na_3MnO_4 dissolved in 12 M NaOH confirm those reported elsewhere. The K_2MnO_4 has maximums at 6050, 4360, 3525, and 2990 Å; and the Na_3MnO_4 has maximums at 7550, 6750, and 3250 Å. (AEC Activity 5330)

Characterization of Short-Lived Fission Products - Scintillation spectrometer measurements of the radiations of 16-sec Tc^{100} disclosed gamma-ray energies of 0.542 ± 0.005, 0.600 ± 0.007, 1.18, and 1.55 Mev. Beta-gamma and gamma-gamma coincidence spectrometry will be used to establish the positions of these gamma rays in the decay scheme.

The energy of the most prominent gamma ray of 86-sec I^{136} was measured simultaneously with a Y^{88} sample; the energy thus obtained was 1.32 ± 0.01 Mev. A beta ray of 5.7 ± 0.1 Mev was in coincidence with the 1.32-Mev gamma ray, and the beta-ray transition to the ground state of Xe^{136} was measured as 7.1 ± 0.1 Mev. (AEC Activity 5330)

High-Temperature Aqueous Solution Chemistry - Studies of the homogeneous catalysis of the hydrogen-oxygen reaction in aqueous solutions at elevated temperatures were continued with emphasis on comparison of environmental effects at 200°C with those previously observed at 175°C. At both temperatures the apparent hydrogen solubility was directly proportional to the square root of the copper concentration, and the catalytic activity of the solution was directly proportional to the copper concentration. The influence of the sulfuric acid concentration, over the range 0.01 to 0.20 M, on the apparent solubility was much less at 200 than at 175°C, but the point of maximum solubility was about the same (0.04 to 0.05 M acid). At 200°C the catalytic activity was inversely related to the acidity over the whole range, whereas at 175°C the inverse relationship was evident only below 0.04 M acidity.

Experimental determination of the densities of D_2O liquid and vapor at nine temperatures between 200 and 375°C provided confirmation and extension of data in the literature and forms a basis for improved calculations of vapor-liquid volume ratios for use in studying the kinetics of the deuterium-oxygen reaction in heavy-water systems. (AEC Activity 5330)

Chemical Separation of Isotopes - An investigation of systems for enriching the isotopes of sulfur was initiated. Several organic addition compounds of SO_2 were studied. No sulfur isotopic fractionation was observed in a single-stage equilibration between SO_2 gas and SO_2 dissolved in ethylene sulfite or dimethyl aniline. The isotopic fractionation between SO_2 gas and the SO_2 addition compounds of dimethyl aniline and pyridine was measured in an experiment in which a 30-bubble plate column was used. The liquid phases contained an SO_2/amine ratio of about 1.5. Assuming a column efficiency of 50%, the

effective α was approximately 1.001 with S^{32} enriching in the gas phase. An α of <1.001 with S^{32} again enriching in the gas phase was estimated from data obtained from the distillation of an ethylene oxide--SO_2 addition compound which distilled at atmospheric pressure and 17°C. (AEC Activity 5340)

METALLURGY

High-Temperature Reactions of Metals and Ceramics - Studies are being made of the densities of fused-salt mixtures over wide temperature ranges. This research is intimately related to previously reported studies on the absorption spectra of fused salts. In the latter work precise density values are needed in calculating molar absorbency indices from absorption measurements.

The densities are determined from the difference in weight of a platinum bob weighed first in air and then immersed in the fused salts. In making these measurements, considerable attention is given to maintaining the melts in a contamination-free condition.

The apparatus has been tested by using salts of known density, namely, sodium nitrate and potassium nitrate. Density values obtained have a maximum deviation from the literature values of less than 0.5%. The following table is illustrative of the information obtained to date. The values given have not been mathematically averaged.

Material	Temp (°C)	Density (g/cc)	Temp (°C)	Density (g/cc)	Temp (°C)	Density (g/cc)	Range (°C)
Pure $NaNo_3$	335.4	1.8961	373.9	1.8684	422.3	1.8340	325-450
Pure KNO_3	346.4	1.8568	394.1	1.8226	453.1	1.7771	345-505
10% KCl--KNO_3	349.3	1.8472	416.2	1.7971	515.5	1.7264	345-540
20% KCl--KNO_3	428.6	1.7868	533.8	1.7109	581.6	1.6767	430-580

(AEC Activity 5420)

OTHER PHYSICAL RESEARCH PROJECTS

Oracle - A new input-output system was installed which is superior to the old system in versatility, reliability, and speed. This was accomplished by replacing some of the old equipment, by adding some new devices, and by the addition of circuitry which permits the Oracle to accept alphameric characters and which also allows more complete checking.

The console was completely redesigned. Additional indicator lights were added and all lights regrouped to facilitate visual monitoring of the Oracle. The numerous toggle switches used in the old console to manually insert instructions and data (on a binary bit-by-bit basis) were replaced with a compact keyboard. The keyboard, consisting of a control-key panel and an information-key panel, reduces by a factor of 4 the number of operator manipulations

required to perform a specific operation. A console typewriter acts as a keyboard monitor by printing a character or symbol which is associated with each key each time that key is depressed. When used in this function the console typewriter produces a record of all information and instructions inserted into the Oracle by the operator.

While automatic input is still performed by a 200-character-per-second Ferranti photoelectric reader, new output equipment was added. The old 20-character-per-second paper-tape punch was replaced with a 60-character-per-second unit, and high-speed output is now possible by means of a magnetic-tape recorder which operates at a speed of approximately 900 characters per second. In addition, the console typewriter can be used as an output device for small quantities of data. The curve plotter is the same as in the previous system with the exception of a few minor alterations. A cathode-ray tube designed for this specific function replaces the old, smaller tube, and a camera with greater film capacity is now used. Curve-plotter monitoring is accomplished by paralleling the display tube with a Hughes Memotron which has been installed in the console.

New off-line equipment was added to complement the new input-output system. Paper-tape preparation units operating in either the hexadecimal or alphameric mode provide facilities for preparing, verifying, and reproducing tapes for Oracle input. Output from the Oracle can be printed up on typewriters from either the paper-tape or magnetic-tape media.

PROGRAM 6000 - BIOLOGY AND MEDICINE

BIOLOGY

Cytology and Genetics--Insects - The frequency of genetic effects induced by x rays in mature sperm of *Drosophila* which have been held for 24 hr after irradiation is significantly lower than that observed when the males are mated immediately after exposure. Since this difference could arise by restitution of some of the chromosome breaks initially induced by irradiation, fractionated dose experiments were designed to test for possible chromosome restitution within the first 24 hr after irradiation.

Preliminary results of these experiments show that the percentage of translocations induced by 4000-r x rays given in two 2000-r exposures separated by 18 hr is lower (10.2%) than that of similar exposures 6 hr apart (12.0%). Although these percentages are not significantly different, it is of interest that the expected percentage for the former fractionated series, on the basis that some chromosome restitution occurs, is 10.3 and for the latter, 13.0. If chromosome restitution does occur, then this process must occur at some time between 6 and 18 hr after irradiation. (AEC Activity 6130)

Pathology and Physiology - Attempts to promote the survival of irradiated F_1 hybrid mice by the injection of parent spleen tissue have disclosed a heretofore unrecognized lethal reaction caused by implantation of foreign spleen cells. This effect is believed to result from the production, by the graft, of antibodies which act against the tissues of the recipient. Study of this reaction offers promise of providing insight into the successful management of transplantation reactions in general and also of furnishing a new approach to the experimental treatment of cancer. (AEC Activity 6130)

Cell Physiology - Characterization of rat serum proteins was continued. The sedimentation constants of serum albumin and gamma globulin were found to be 4.75 and 6.94 at zero concentration in water at 20°C. Basic proteins from chicken erythrocytes were characterized electrophoretically, and partial separation was achieved by ultracentrifugation through starch. The formation of granules and vesicles by clear solutions of rat liver proteins was studied under controlled conditions. Peptides extracted from microsomes by methods devised in this laboratory were studied chromatographically and found to give the same bands under several conditions of extraction. (AEC Activity 6130)

Biophysics - Work was continued on the variation of free radicals in bacteria which occur when the bacteria are treated with S,2-aminoethylisothiuronium (AET), ionizing radiation, and AET plus radiation. The observed amount of free radical and the shape of the paramagnetic resonance curve were found to change after the addition of the protective compound. The basic changes in the free radicals are still obscure. Instrumental modifications to improve the sensitivity of the paramagnetic resonance spectrometer are in progress.

Further refinement in the dosimetry for the 14-Mev neutrons produced by the Cockcroft-Walton accelerator was achieved by precise inverse-square measurements with a polystyrene-acetylene ion chamber and by statistical analysis. The ratio of dose caused by neutron interactions at the room walls, floor, and ceiling to dose emitted from, or very near, the target was found to be less than 10% of the total dose at 15 cm from the target and even less than this nearer the target.

The Cockcroft-Walton accelerator was employed in cooperation with various investigators from other groups in the Biology Division for studies on recovery times from acute radiation injury in mice, protection against 30-day lethality in mice after oral administration of AET and APT (S,γ-aminopropylisothiuronium·Br·HBr), genetic effects in *Drosophila virilis* (both 3- and 14-Mev neutrons), and radiation damage to spermatogonia in mice (3-Mev neutrons).

Most of the Victoreen ion chambers used in x-ray irradiation experiments in the Biology Division were recalibrated vs the standard chambers of the Biology Division. The latest correction factors obtained, none of which differed by as much as 3% from previous values, were issued to the respective users of the chambers.

A study intended to answer the question of what intermediate value of linear energy transfer (LET) gives the proper single number characterization of an LET spectrum for description of a biological experiment, assumed to be independent of dose rate, reveals that the proper LET number depends on the shapes of the dose response curves and on the shape of the relative biological effectiveness (RBE) vs LET curve for the observed effect. For linear dose response curves and linear RBE vs LET curves, the "energy average LET" is the proper number. For linear dose response curves and RBE = A + B/(LET), where A and B are constants, the "track average LET" is the proper number. The second mathematical model with negative values of B more nearly agrees with the recessive lethality observed in Drosophila and with the various chromosome aberration frequencies observed in Tradescantia than does the first model. Other mathematical models including quadratic and exponential dose response curves are being investigated. (AEC Activity 6130)

Mammalian Recovery - Lethally irradiated mice receiving massive and multiple injections of homologous or heterologous bone marrow showed the same delayed death pattern as the controls that received standard doses of homologous and heterologous bone marrow. Mice that were exposed to 200 r per day for five days and then given homologous or heterologous bone marrow showed increased mortality over the x-ray controls, indicating a killing effect of foreign bone marrow under these circumstances.

Erythrocyte life-span studies, in which Cr^{51} was used, indicate that the survival time of erythrocytes from irradiated mice given rat bone marrow is shorter than the survival time of normal rat erythrocytes. (AEC Activity 6230)

PROGRAM 8000 - WORK FOR OTHERS

Oak Ridge School of Reactor Technology - The Committee on Admissions to the Oak Ridge School of Reactor Technology met on June 21, 1957, to consider applicants for the second session of the ORSORT-University Cooperative Program. Forty-eight were accepted and assigned to the six participating universities, in which classes will begin about September 1, 1957. Nine applicants were accepted for direct entry into the ORSORT phase (beginning September 9, 1957) of the first session of the program. (AEC Activity 8712)

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VISITORS

FOREIGN VISITORS:

Akazawa, M., House of Representatives, Japan
Akita, D., Parliamentary Vice Minister, Japan
Becker, G. W., University of Marburg, Germany
Chak, A. M., Kansas State College (Citizen of India)
D'Eye, R. W. M., AERE, Harwell, England
Flamme, Edouard Maurice, S.E.E.N., Brussels, Belgium
Isawa, H., Secretary to K. Saito of Japan
Jolles, P. R., Int'l. Atomic Energy Agency (Citizen of Switzerland)
Kanno, W., House of Representatives, Japan
Kawabata, T., Ministry of Welfare, Japan (Univ. of Washington)
Kosaka, Z., House of Representatives, Japan
Kotzenberg, A., Department of Commerce, Union of South Africa
Kroll, Theodore G., Societe Generale Metallurgizue de Hoboken, Belgium
Louckx, P., Nuclear Development Associates (Citizen of Belgium)
Luppens, J. Rene, Societe Generale Metallurgizue de Hoboken, Belgium
Magari, T., Japanese Embassy
Martin, Frederick S., United Kingdom A.E.A., Harwell, England
Matsui, S., International Cooperative Bureau, Japan
Mercer, Edward R., United Kingdom A.E.A., Berkshire, England
Pang, T. S., University of Taiwan, Formosa
Perio, P., French AEC
Preston, J., Allegheny Ludlum Steel, Albany, New York (Citizen of Great Britain)
Rosenberg, H. M., University of Illinois (Citizen of Great Britain)
Rudstam, S. G., University of Uppsala, Sala, Sweden
Saito, K., Member of Diet, Tokyo, Japan
Sasaki, Y., Atomic Energy Bureau, Japan
Simon, G. F. Technische U., Berlin, Germany
Skjoldebrand, Robert H. A., Ab Atomenergi (Washington, D. C.)
Tanaka, Y., Japanese Embassy
Taniguchi, K., Mitsubishi Co., Nagasaki City, Japan
Uda, K., Japanese Atomic Energy Commission
Wagener, J. S., Kemet Co., Division of UCC (Citizen of Germany)
Wakabayashi, Ryoichi, Tokyo Shibarza Electric Co., Yokahama, Japan
Wang, S. Lung, Kansas State College (Citizen of China)
Yoshikawa, H., Mitsubishi Co., Tokyo, Japan

[redacted]

RADIOISOTOPE SALES AND COSTS

Type of Transaction	June 1957	FY 1957 to Date
Domestic Sales	$141,479	$1,893,902
Foreign Sales	18,193	180,984
Project-Transfer	1,054	14,585
Project-Cash Sales	73,632	136,812
Technical Co-operation Program Credits	0	3,395
Plant Credits	92,303	127,378
AEC Credits	16,552	207,849
Total Radioisotope Income	$343,213	$2,564,905
Total Radioisotope Costs	$130,710	$1,524,194
Total Radioisotope Shipments	1,187	13,754
Helium		
Income	$4,025	$47,387
Costs	3,722	9,980
Shipments	4	39

GROSS OPERATING COSTS

	Cost for June	FY 1957 Cost to Date
Programmic Operating Cost - Net	$4,199,418	$51,307,364
Equipment	482,005	2,864,938
Construction	152,721	1,951,196
Work for Others - Transfers	1,047,366	1,630,235
Inventory Changes	2,519,736	2,349,768
Reimbursable Work for Others	125,257	892,741
Deferred Charges	70,778	(157,123)
Adjustments to Cost of Prior Years	(1,603,933)	(1,603,933)
Total Laboratory Cost - Net	$6,993,348	$59,235,186
Estimated Cost for July	$4,600,000	$4,600,000

Credit ()

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PERSONNEL SUMMARY

	Number of Employees July, 1957	New Hires July	Terminations July
Administration	70	0	0
Operations*	134	1	1
Engineering, Shops, and Mechanical	881	13	5
Laboratory and Research	2360	33	19
Protection	117	1	0
Service	407	7	8
	3969	55	33

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

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

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Reports in this series issued during the past year:

July 1956	ORNL-2144
August 1956	ORNL-2166
September 1956	ORNL-2185
October 1956	ORNL-2205
November 1956	ORNL-2232
December 1956	ORNL-2248
January 1957	ORNL-2261
February 1957	ORNL-2281
March 1957	ORNL-2299
April 1957	ORNL-2316
May 1957	ORNL-2342
June 1957	ORNL-2355

Edited by R. B. Parker and P. B. Dunaway

Approved by Alvin M. Weinberg, Director

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