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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

SEPTEMBER 1958

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September 1958

DATE ISSUED

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

TABLE OF CONTENTS

	Page
PROGRAM 4000 — REACTOR DEVELOPMENT	4
HOMOGENEOUS REACTOR PROJECT	4
Homogeneous Reactor Test	4
HRT Chemical Pilot Plant	4
Fuel Processing	5
Gaseous Fission Product Disposal	5
Blanket Processing	5
Mathematics and Computation: Homogeneous Reactor Development	6
Reactor Analysis	6
Homogeneous Reactor Instrumentation	6
HRP Design	7
HRP Metallurgy	7
Laboratory Corrosion Studies	8
Dynamic Solution Loop Corrosion Tests	8
Dynamic Slurry Loop Corrosion Tests	9
In-Pile Solution Corrosion Loops: LITR	9
In-Pile Solution Corrosion Loop: ORR	9
In-Pile Autoclave Slurry Corrosion Studies	9
Supporting Radiation Corrosion Studies	10
CIVILIAN-POWER ADVANCED GAS-COOLED REACTOR	10
Gas-Cooled Reactor: Design	10
Gas-Cooled Reactor: Experimental Engineering	11
Gas-Cooled Reactor: Radiation Effects	11
Gas-Cooled Reactor: Metallurgy	12
GENERAL REACTOR RESEARCH	13
Basic Reactor Research	13
Radiation Detector Development	14
Liquid Metals Research	14
Fuel Element Catastrophe Studies	14
Reactor Safety Studies	14
Power Reactor Fuel Reprocessing: Zircex Process	15
Power Reactor Fuel Reprocessing: Solvent Extraction	15
Power Reactor Fuel Reprocessing: Alternate Aqueous Processes	15
Power Reactor Fuel Reprocessing: Darex Process	16
Fused Salt—Fluoride Volatility Processing	17
Waste Treatment: Darex Waste	17
Waste Treatment: Ion Exchange Methods	18
Long-Range Planning Studies	18
PROGRAM 5000 — PHYSICAL RESEARCH	19
Reactor Operations	19
Laboratory Facilities	19

TABLE OF CONTENTS (Continued)

	Page
PHYSICS	19
High-Voltage Experimental Program	19
Neutron Diffraction	20
CHEMISTRY	20
Extraction Reagent Performance: Radiation Damage	20
Feed Materials Processing: Hermex Process	20
Ion Exchange Technology	21
High-Level Nuclear Chemistry	21
Chemistry of Corrosion	21
Chemistry of Technetium	21
Chemical Separation of Isotopes	22
METALLURGY	22
High-Temperature Reactions of Metals and Ceramics	22
PROGRAM 6000 — BIOLOGY AND MEDICINE	23
BIOLOGY	23
Cytology and Genetics: Insects	23
Pathology and Physiology	23
Biochemistry: Nucleoproteins, Amino Acids, and Enzymes	23
Plant Physiology and Photosynthesis	24
Biophysics: Electron Spin Resonance Studies	24
Biophysics: Silver-Activated Phosphate Glass	24
Biophysics: Deviation from Inverse-Square Law	25
Biophysics: Point Source Alpha and Proton Irradiation Facilities	25
Microbial Protection and Recovery	25
Mammalian Recovery	26
Radiation Immunology	26
PROGRAM 8000 — WORK FOR OTHERS	27
Oak Ridge School of Reactor Technology	27
MISCELLANEOUS REPORTS	28
Open Literature Publications	28
Visitors	30

OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

September 1958

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.

PROGRAM 4000 — REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test. — On September 12, run 17 was completed as scheduled after amassing a total of 1074 hr of continuous operation completely free of mechanical difficulties. Thermal power generation for the run was 2526 Mwhr, mostly at 3.5 and 1.8 Mw.

As mentioned in the August progress report, run 17 was characterized by unexplained changes in the uranium inventory and by occasional excursions of power. Although the power excursions were usually less than 1 Mw in magnitude, an excursion of about 20 Mw was experienced while operating at 3.5 Mw on August 30. The same power rise would have resulted from a linear rate of reactivity addition of about 0.7%/sec for 3 sec. Subsequently the power was reduced, and a systematic study of the effects of power and temperature was pursued until the termination of the run. Preliminary indications are that any temperature effect is small compared with that caused by power.

After shutdown the reactor was rinsed with condensate, and the core and blanket access flanges were opened. A periscope was used for viewing the interior of the core vessel. The inner surface of the upper hemisphere appeared as it had before power operations were started, although ultrasonic measurements indicated the loss of about 40 mils of Zircaloy. The top diffuser screen was attacked, and at several locations small portions of web had corroded away. Several corrosion specimens were found lying on the top screen. When the corrosion sample holder (which had already been moved to the hot storage pool) was examined, it was seen that 22 of the 48 specimens had become detached from the holder.

A new viewing device was installed in the blanket region. The hole which developed in the core vessel on April 4 was clearly visible. It is pear-shaped and is approximately 1 in. long and ½ in. wide. The hole is located in the region of transition between the 30- and 90-deg cones, which coincides with the elevation previously determined by filling the vessel with heavy water. (AEC Activity 4103.3)

HRT Chemical Pilot Plant. — Removal rates for corrosion-product solids increased markedly during the initial portion of reactor run 17, owing largely to an increase in zirconium oxide removal. In addition, significant quantities of uranium were

concentrated in the underflow receiver for the first time. During the initial 290-hr run, 530 g of corrosion-product solids, analyzed as 47% Zr, 23% Fe, and 4% Cr, was removed. Only 150 g, of essentially identical composition, was removed in the subsequent 438-hr run. The mass of uranium collected, apparently as a solid phase, totaled 92 g in the first run and 132 g in the second.

During the final days of run 17, the off-gas flow from the reactor was routed through the charcoal bed in which a fire occurred at the beginning of the run. No additional activity was released, and temperatures in the bed were normal, indicating that damage was minor.

The initial reactor fuel charge, which had been stored in the cell since run 13, was transferred to the waste evaporator, where 375 lb of the approximately 395 lb of D_2O associated with the fuel was recovered by evaporation. (AEC Activity 4103.1)

Fuel Processing. — Experiments with simulated HRT fuel solutions at 270°C showed that exchange of elemental iodine between liquid and corrosion-product solids is easily reversible. In tests in which traced iodine had been adsorbed on such solids, equilibrium with iodine in the liquid phase was attained within 5 min. The apparent aging of iodine in the HRT, as evidenced by I^{133}/I^{131} ratios in high-pressure fuel samples, may be accounted for by assuming that ten times more iodine is adsorbed on solids in the HRT than is circulating in solution and that exchange of iodine between the two phases accounts for the apparent age of the iodine in the HRT fuel samples. At 250°C, distribution of iodine between elemental and iodate valence states in simulated HRT fuel solution is not greatly affected by Co^{60} radiation at an intensity of 23 w/liter, but evidence has been found which indicates that the stability of the elemental form is slightly enhanced. (AEC Activity 4103.1)

Gaseous Fission Product Disposal. — The effect of CO_2 in O_2 sweep gas on the adsorption of fission gas (Kr^{85}) by activated charcoal has been investigated, and it was found that the dynamic adsorption coefficient (k) was reduced by 33 and 57% by adding 10 and 50% CO_2, respectively, to the O_2 sweep gas. Pure CO_2 sweep gas reduced the value of k by 70%. This impairment of efficiency possibly explains the rare-gas activity breakthrough observed during the startup for the last power run of the HRT. The gaseous products resulting from the combustion of charcoal in oxygen are being determined. Results from one typical experiment indicated CO (67%), CO_2 (25%), O_2 (1%), and inert gases (7%). A possible cause of the high temperatures noted in the charcoal beds is thought to be the recombination of D_2 and O_2 on the charcoal surface. (AEC Activity 4103.1)

Blanket Processing. — Several torch-feed assemblies were tested, and a design was developed which operates smoothly for the flame denitration of thorium-uranium nitrate solutions in an O_2-C_2H_2 flame. Mixed oxide of 1.5-μ mean diameter, 85 wt % below 5 μ and 5.8 m^2/g surface area, was produced by this method and was classified for removal of over 5-μ material and submitted for toroid testing.

Fluidized-bed equipment installed for direct denitration of $Th(NO_3)_4$ solutions operated well with an initial ThO_2 charge with sprayed H_2O as the feed stream. Feed-system modifications were necessary to permit successful feeding of $Th(NO_3)_4$ solutions.(AEC Activity 4103.1)

Mathematics and Computation: Homogeneous Reactor Development. — A machine program for the IBM-704 was written which calculates the reactivity associated with specified reactor-power behavior. A harmonics calculation for determining the nuclear characteristics of small D_2O-moderated reactors was programed; two regions are considered, and fuel can be present in both regions. An Oracle routine was written which permits utilization of an existing least-squares subroutine for fitting a specified functional relation to a number of experimental points. A machine program was written for calculating the thermal-flux disadvantage factor associated with a lattice of absorbing rods placed in a fuel mixture. (AEC Activity 4103.1)

Reactor Analysis. — Nuclear calculations were performed for the HRT on the assumption that the ratio of blanket to core fuel concentration was 0.40. By means of a two-group, two-dimensional model (CURE program), the effect of the core corrosion sample holder on the thermal-neutron flux distribution was investigated. With the holder the maximum flux occurred 10 cm from the center of the core. Based on CURE calculations, it was found that a given amount of U^{235} deposited on the top screens of the HRT is approximately equal in importance to the same amount uniformly distributed throughout the high-pressure system. Also, the concentration coefficient of temperature was obtained as a function of temperature. At 280°C (core and blanket) the relative change in core critical concentration was found to be 0.0034 per degree centigrade change in core temperature.

The HRT presently operates with the blanket pressurizer completely filled with water. Under this condition it appears permissible to operate with blanket fuel concentrations up to about 0.6 the core fuel concentration insofar as reactor safety is concerned.

The rate of reactivity addition required to cause a specified pressure rise in the present HRT was calculated as a function of initial reactor power. With the reactor initially at 1 Mw, a rate of reactivity addition of 4% Δk_e/sec would result in a maximum pressure rise of about 1000 psi. Movement of about 50 g of U^{235} from the top screen to the center of the core would add 1% Δk_e to the reactor.

During HRT run 17, a number of power pips were observed. The frequency of these pips appears to increase with increasing power level above a power of about 2 Mw; below this power level no pips were observed. At a given power level there appears to be no correlation between the relative power rise during a pip and the time interval between pips. (AEC Activity 4103.1)

Homogeneous Reactor Instrumentation. — As an aid in determining the cause of the periodic power surges observed in the operation of the HRT, the instrumentation system was revised slightly so that high-speed recording devices could be connected to the measurement channels for neutron level, period, pressure, pressurizer level, and temperature of core corrosion sample.

The 2-in.-dia television camera with a separate preamplifier was successfully tested on the remotely actuated mechanism developed for use in viewing the HRT core vessel. To provide camera position indication to the operator of the manipulator controls, the angle of rotation of each of the three arm-positioning hydraulic cylinders is transmitted to the control console by a miniature linear slide-wire.

A control-valve actuating system utilizing 500-psi water as the working fluid was cycled 86,715 times before the 10-in.-dia power cylinder failed by cracking around the circumference of the cylinder. The water-operated actuators for large valves require smaller-sized cylinders than those operated on compressed air, and the water is more resistant to radiation damage than the oils in conventional hydraulic systems.

A recently completed series of tests of the temperature control system for the HRP in-pile loop being developed for the ORR indicated that satisfactory automatic control of the loop temperature can be effected in the event of a reactor scram or setback. The tests were conducted on the engineering test mockup, with radiation-induced heating effects being simulated by resistance heating elements. (AEC Activity 4103.1)

HRP Design. — A replaceable-core concept of the HRT pressure vessel was prepared for use in obtaining comparative cost estimates.

The thermal stress in the existing HRT vessel at 5 Mw reactor power was estimated from temperature data to be 6800 psi.

A tube to permit removal of solution from the high-flux area of the HRT core during operation was designed.

The design of a thimble to obtain information on fast-neutron fluxes at the pressure-vessel wall was completed.

Studies on the HRE-4 slurry reactor, including flowsheets, component and equipment layouts, and preparation of the design report, are continuing. The system utilizes a straight-through 4.5-ft-dia core vessel, a 600-gpm circulating pump, an inverted-L-type heat exchanger, and a dump tank which also serves as the pressurizer (AEC Activity 4103.1)

HRP Metallurgy. — A high degree of preferred orientation and mechanical anisotropy are found in Zircaloy-2 that has been formed by conventional fabrication processes. Restricted transformation relationships between the alpha and beta phases prevent randomizing by the use of simple heat treatments such as are effective with steels. The effects of various fabrication practices are evident in impact tests and in preferred-orientation studies, but they are not shown by variations in yield strengths, tensile strengths, or elongation as measured in tensile tests. In the latter tests the only indication of fabrication effects is the shape of the fractured specimen. Whenever flow has occurred the fractured tensile specimen shows an elliptical cross section with the major axis of the ellipse always within 3 deg of the normal to the plate. A study of the cross sections from the fracture to the shoulder has been shown to be a method of

separating the fabrication variables. These studies have been confirmed by subsize Izod and full-size Charpy impact tests. Variations in elliptical eccentricity ($\sqrt{a^2 - b^2}/a$) from 0.25 to 0.76 were found for specimens whose conventional mechanical properties were within the experimental error. Of the wide variety of fabrication variables studied to date (all of which, however, used straight rolling), the presently recommended HRP fabrication schedule appears to provide the most nearly isotropic plate obtainable by the use of accepted commercial practices. (AEC Activity 4103.1)

Laboratory Corrosion Studies. — An age-hardenable casting alloy, CD-4MCu (25–27% Cr, 4.75–6.00% Ni, 0.04% C max, 1.75–2.25% Mo, 2.75–3.25% Cu, bal Fe), was corrosion-tested in boiling 5% HNO_3, in simulated fuel solution (0.04 m UO_2SO_4, 0.02 m H_2SO_4, 0.005 m $CuSO_4$) in the presence and absence of chloride ions, and in chloride-containing water. In the fuel solution at 100 and 300°C and in the nitric acid solution, corrosion rates were less than 1 mil/year. In addition, no cracks were found in stressed specimens exposed to the boiling fuel solution containing 50 ppm chloride ions or in water containing 100 ppm chloride ions and oxygen at 300°C. A CD-4MCu bolt was stressed to approximately 45,000 psi with a nut and ferrule arrangement and tested in the fuel solution at 300° for 500 hr. At periodic intervals the stress on the bolt was released, and at no time was galling encountered; similarly, no cracking or accelerated corrosion was observed. In view of the very favorable corrosion resistance and mechanical properties of this alloy, its use should be considered wherever a cast material is desirable in the construction of aqueous homogeneous reactors. (AEC Activity 4103.1)

Dynamic Solution Loop Corrosion Tests. — In order to investigate the stability of dilute uranyl sulfate solutions, a titanium loop was fitted with an electrically heated 3/8-in.-OD Zircaloy-2 bypass. A solution of the same composition as that in the core region of the HRT at low power in run 17 (0.025 m UO_2SO_4 + 0.015 m D_2SO_4 + 0.011 m $CuSO_4$ + 0.0036 m $NiSO_4$ in D_2O) was passed at 0.3 fps through the bypass and heated to maintain an outlet temperature of 320°C, with the solution circulating in the main loop at 280°C. Uranium, copper, and nickel gradually disappeared from the solution in the main loop, presumably as a heavy second liquid phase adhering to the walls of the heated bypass.

The experiment was repeated with the bypass solution outlet temperature at 310 and 300°C, and a loss of uranium, copper, and nickel from the main solution occurred in each case.

The loss of uranium and copper was not completely analogous to that observed in the HRT at high power during run 17. The ratio of acid to uranium increased, but no net increase in the total amount of acid occurred. Sulfate ions were lost mole for mole with uranium, copper, and nickel.

The calculated wall temperature of the Zircaloy-2 section was above or near the second-liquid-phase temperature of the solution (334°C as observed in a quartz tube) in every instance. However, errors in the thermocouple measurements and uncertainties in the calculations prevented a definite knowledge of the wall temperature. Accordingly, it is not known whether boiling occurred at the wall. (AEC Activity 4103.1)

Dynamic Slurry Loop Corrosion Tests. — The first phase of a slurry loop test to evaluate the thoria prepared for possible use in the first ORNL-PAR (Westinghouse) in-pile loop experiment in the ORR was completed. This period consisted of 382 hr of circulation at 280°C of a slurry of the 1600°C-calcined, 2.4-μ-av-dia thoria (450 g Th per kg of D_2O). The general attack rate of the austenitic stainless steel system was 1 mil/year. No attack was noted on the circulating pump fabricated of titanium. During the first 190 hr the slurry pH was 5.4. The corrosion rate of the system was not affected by the addition of 0.008 m MoO_3, a proposed recombination catalyst, after 190 hr of operation. Slurry pH after this addition was 2.4. Handling properties of the above slurry were quite satisfactory. Examination of mixtures containing fourfold greater concentrations of molybdenum oxide indicated the formation of dense sediments at room temperature with such proportions. (AEC Activity 4103.1)

In-Pile Solution Corrosion Loops; LITR. — In-pile loop L-2-22, which is constructed of type 347 stainless steel and contains various zirconium, titanium, and stainless steel alloy corrosion specimens, has been operating satisfactorily in the LITR HB-2 facility for approximately 1400 hr, with an over-all corrosion rate of 0.5 mil/year based on oxygen consumption. The experiment utilizes a 0.04 m UO_2SO_4 solution in D_2O along with the following additives: 0.0025 m $CuSO_4$, 0.10 m D_2SO_4, and 0.20 m Li_2SO_4.

Solution analyses and radiolytic-gas pressure measurements show that the copper concentration has gradually decreased to about half its original value. Analyses also indicate that the uranium concentration has decreased approximately 10% during the operation. (AEC Activity 4103.1)

In-Pile Solution Corrosion Loop: ORR. — Flux measurements, by means of cobalt monitors, were made in the HN-1 beam hole of the ORR, in which an aluminum mockup of the core and loop jacket with stainless steel liner was installed. Values ranged from 6×10^{13} neutrons·cm^{-2}·sec^{-1} at a point 2 in. from the lattice to 1.4×10^{13} at 6 in. from the lattice, with the reactor set at lattice pattern No. 4. It is estimated that the maximum thermal flux in an ORR loop, with the reactor at 20 Mw, will exceed that in the LITR HB-2 loop facility by a factor of 3 to 4. The estimated average flux in the ORR loop is only a factor of 2 to 3 greater than that in HB-2.

A duplicate of the proposed first in-pile ORR loop has been operating satisfactorily at Y-12 for more than 300 hr. Construction of the first in-pile loop is scheduled for completion in four to six weeks. (AEC Activity 4103.1)

In-Pile Autoclave Slurry Corrosion Studies. — An over-all corrosion rate of 2 mils/year at an average fission energy of 1.2 w/ml and a maximum fission energy of 6 w/ml was observed for a Zircaloy-2 autoclave containing thoria-urania slurry in D_2O and a deuterium atmosphere at 280°C. This rate was based on time at high temperature after pretreatment. The slurry, with a concentration of 980 g of Th per kg of D_2O, contained 0.04 m MoO_3 added as a recombination catalyst. The thoria contained 5% coprecipitated enriched uranium based on thorium. The autoclave was operated at elevated temperature for 144 hr prior to any irradiation and for 169 hr at temperature in hole HB-6 of the LITR. After 22 hr of smooth operation at 6 w/ml,

a number of sharp pressure surges and subsequent drops were experienced, requiring the autoclave to be moved to a retracted position. The pressure effects appear to have been due to an increased rate of gas production by the slurry. During the early smooth inserted operation, values of G_{D_2} of 0.016 and 0.005 molecule of D_2 per 100 ev were observed; after this time, five observations ranged from 0.10 to 0.16. No abrupt changes in catalyst activity were associated with the onset of the pressure surges; however, the values (averaging 0.1 mole of D_2 per liter per hour per 100 psi radiolytic D_2) became more irregular as the run continued. (AEC Activity 4103.1)

Supporting Radiation Corrosion Studies. — Several series of batch adsorption experiments were carried out to study the adsorption of uranium from UO_2SO_4 solution on hydrous zirconium oxide at elevated temperatures. Exposures were made in ampoules of pyrex heated to the desired temperature and then cooled to room temperature before the oxide and the solution were separated for analysis. The hydrous oxide was prepared from zirconium sulfate and air-dried at 100°C. A measurement of the surface area of the as-prepared material showed 220 m^2/g. Adsorption temperatures of 250, 150, 100, and 25°C were employed. In general, the adsorption of uranium per gram of oxide increased with increasing temperature to 150°C. However, the adsorption per gram of oxide at 250°C was less than at 100°C. The following values for adsorption from an 0.08 m UO_2SO_4 solution containing 0.02 m excess H_2SO_4 are illustrative:

°C	mg of U per g of oxide
25	20
100	59
150	71
250	51

There is evidence that the decrease in adsorption in going from 150 to 250°C is associated with a decrease in the surface area of the hydrous oxide during the high-temperature exposure. (AEC Activity 4103.1)

CIVILIAN-POWER ADVANCED GAS-COOLED REACTOR

Gas-Cooled Reactor: Design. — Steps were taken to inaugurate a program of review of the Kaiser-ACF design work on the GCR. A series of conferences was held with ACF to acquaint the ORNL group with the present status of the design. Design meetings were attended and some analyses of designs were initiated.

A theoretical study of the process of diffusion of fission products from solid fuel bodies was initiated. Such fundamental information is needed in (1) deriving diffusion coefficients from test data, (2) applying diffusion coefficients to predict fission product escape from a fuel element, and (3) evaluating plans for fuel element testing.

Calculations on the diffusion rates of fission product gases through graphite capsule walls have been completed and are being checked. These will provide a good basis for appraising the hazards problems of GCR's designed to operate with the gas stream contaminated.

Since any fuel element exposed to the dynamic pressure of a flowing coolant stream will be subject to a self-excited flutter, a few general fuel element shapes are being studied in an effort to determine when flutter is likely to occur. The case of a single, suspended capsule was analyzed first. As might be intuitively suspected, flutter will occur above some critical value of the fluid dynamic pressure which is below the pressure required to blow the fuel elements sideways. It appears that if the dynamic pressure is further increased certain fuel element configurations will again become stable. The implication is that fuel element flutter can occur between certain upper and lower limits of dynamic pressure and that trouble can occur in trying to either uprate or derate a reactor which may be operating satisfactorily at its design point. A careful test program on this subject is indicated. (AEC Activity 4110)

Gas-Cooled Reactor: Experimental Engineering. — Developmental studies are under way on two types of compressors for the gas-cooled test loop to be operated in the ORR. Development proposals received from five vendors in accordance with specifications issued previously for 10,000-hr-life compressors are being evaluated. It appears, however, that the development of the gas bearings required to assure a life of 10,000 hr without maintenance or servicing will take a long time. Therefore compressors with grease-lubricated ball bearings are being developed for the initial ORR tests that can be expected to operate for a period of 2000 to 3000 hr without maintenance. Equipment is being designed and procured for performance testing of bearings and compressors.

Out-of-pile exposures of fuel capsule and reactor structural materials plus various grades and types of treated and untreated graphite in controlled gaseous environments were continued. Static gas pot tests 6 and 7 are under way. Equipment is available for low-pressure natural-convection tests, and equipment is being procured and assembled for both thermal-convection and forced-convection high-pressure loops. The specimens exposed in these out-of-pile tests are examined metallurgically (see section entitled "Gas-Cooled Reactor: Metallurgy").

The fuel capsule irradiation program was outlined, and design work is under way on irradiation facilities, equipment, and prototype capsules. Three major categories of experiments were delineated that will involve the irradiation of prototype fuel capsules (0.705 in. OD x 6 in. long) in the ORR and the ETR, reduced prototype fuel capsules (0.500 in. OD x 6 in. long) in the GETR (General Electric at Vallecitos), and miniature prototype fuel capsules (0.156 in. OD x 2 in. long) in the LITR. The LITR irradiations are well under way (see the following topic); a third capsule was prepared for insertion. (AEC Activity 4110)

Gas-Cooled Reactor: Radiation Effects. — The second miniature prototype fuel capsule is now being irradiated in the LITR. It was inserted on June 24, 1958, and was removed on September 30, making a total of approximately 2000 hr of irradiation

at full power in a flux of approximately 2×10^{13} neutrons·cm^{-2}.sec^{-1}. The inner temperature is being maintained at 1770°F and the shell temperature at 1130°F. The hot-cell apparatus was prepared for taking fission gas samples.

The cask for withdrawing irradiated samples from the ORR was fabricated, and most of the required instrument components were received. The spectrometer assembly was checked with three known isotopes and found to be satisfactory.

The positioning device for an instantaneous fission-gas analysis experiment in the ORR was completed and assembled. Design work is under way on the sample capsule, facility tube, header boxes, and associated equipment for the experiment.

Oxidation and erosion tests were performed on SiC-Si—coated high-density graphite supplied by the Minnesota Mining and Manufacturing Company. One test consisted of a near-sonic blast of process air from a needle jet directed upon a small area of a 3/4-in.-dia, 3/4-in.-long specimen. After 1000 hr at 1000°C, there was no evidence of damage due to erosion and only a 0.1% weight gain that may have been due either to oxidation of the silicon or to impurities in the air stream.

A second test was then made by using hotter specimens with air at a lower velocity and a higher mass flow. Three samples were used that were each 1 in. long and 1/4 in. in diameter. The air flow was 1 scfm and the velocity was 180 mph; the temperature of the specimens was 1100°C. After 30 hr, one of the samples began to lose weight. This was an indication of a pinhole in the SiC-Si cladding. The weight loss accelerated with time, and after 400 hr the sample was only a hollow shell of SiC-Si. The shell still had the same appearance and there was no pinhole visible, even though all the graphite had oxidized and left the specimen as CO_2. The other two samples showed no weight or appearance change. The test was terminated after nearly 700 hr. The two remaining samples, along with two similar untested specimens, were then placed in the isotope stringer of the ORR, where they are currently being irradiated. (AEC Activity 4110)

Gas-Cooled Reactor: Metallurgy. — The reactions of type 304 stainless steel with low-pressure CO_2 in argon as a carrier gas were studied in two 100-hr runs at 1500°F; the gas mixtures contained 0.63 and 0.1% CO_2, respectively. In both tests, a thin, adherent magnetic oxide film was formed on the steel. The weight changes in the samples were 0.117 and 0.109 mg/cm^2, respectively. No decarburization was detected.

A creep-buckling specimen of type 304 stainless steel capsule material without inserts, which was being tested at 1300°F and an external pressure of 300 psi, collapsed completely after 2200 hr. Additional specimens with inserts to simulate fuel pellets are being tested. Results from one creep-buckling test of capsule material (with inserts) at 1400°F with a 1600°F hot streak showed that collapse occurred in 500 hr at 300 psi. A diametral clearance of 0.010 in. had been provided between the inserts and the capsule wall; wrinkling occurred in the hot-streak portion.

Tube-burst tests of capsules were initiated. One specimen tested at 1500°F with a 400-psi internal pressure ruptured in 54 hr. Examination revealed the rupture to be in the weld zone of the end closure. End plugs of several designs are being prepared, and the optimum welding conditions will be determined. Specimens with these end plugs will, in turn, be evaluated by similar tests.

A preheating apparatus for use in the welding of beryllium sheet was completed. Two automatic fusion welds were made under restraint at 400°C without cracking. All room-temperature welds of this type had previously shown complete cracking in both the weld metal and the fusion zone.

The results of tensile tests on samples of types 304, 310, 316, and 410 stainless steel that were hung in the helium atmosphere above TSF graphite in static pot tests 3 and 4 were received and were compared with the results of tensile tests on as-rolled specimens. In test 3 the specimens were held at 500°F for 100 hr, and in test 4 the specimens were held at 1400°F for 900 hr. The stainless steel samples from both tests showed decreases of 10 to 20% in the room-temperature tensile strength and 50 to 70% in room-temperature 0.2%-offset yield strength, as compared with as-rolled specimens. In addition, the ductility increased by about 50%. Comparative tensile tests at 1400°F were less conclusive than the room-temperature tests. However, the tensile strengths of all specimens compared favorably with the accepted values for commercial alloys in the annealed condition, both at room temperature and at 1400°F.

The results of tensile tests on similar stainless steel specimens from natural-convection test No. 3, in which TSF graphite and helium were used and the maximum test temperature was 1400°F, were much the same as the results of the static pot tests. The results from test No. 4, however, in which the specimens were exposed to CO_2 at 1000°F, showed that some hardening of the steel specimens had occurred. These specimens exhibited 5 to 10% lower ductility accompanied by slight increases in tensile strength. (AEC Activity 4110)

GENERAL REACTOR RESEARCH

Basic Reactor Research. — The distribution of fission neutrons in water is being measured at the thermal column of the ORNL Graphite Reactor in an effort to resolve the well-known age discrepancy. Emphasis is being placed on an investigation of the distribution of neutrons near the source and on various effects which may have biased the results of previous experiments.

The mutual self-shielding correction (Dancoff correction) to the resonance integral in a random pebble bed reactor has been calculated.

A simple statistical model which accounts for the general features of the distribution of the spacings of nuclear resonance levels has been suggested; it involves no special assumptions other than that of Porter and Thomas (Phys. Rev. 104, 483, 1956). (AEC Activity 4202)

Radiation Detector Development. — A method of using a signal from one of the photomultiplier tubes mounted on the 9-3/8-in.-dia total absorption NaI(Tl) crystal to trigger the input of the multiple-channel analyzer is being employed to improve the effective resolution of the crystal. With such a scheme it is possible to resolve the multiple peaks that may compose the observed photopeak when the input is not gated. (AEC Activity 4202)

Liquid Metals Research. — Four types of studies were initiated to gain a better understanding of the basic mechanisms of mass transfer in systems which utilize liquid metals as coolants. These include the theoretical analysis of existing engineering-type data, the design of seesaw tests that are amenable to analysis, the development of a thermal convection loop from which mass transfer coefficients are extractable, and the measurement of diffusion coefficients of metallic solutes in liquid-metal media.

The following results have been obtained to date. Equations were derived which relate the distribution of corrosion attack or cold-zone deposits with the rate-controlling step in a system exhibiting thermal-gradient mass transfer. These equations enable the determination of the rate-controlling step from measured temperature-attack distributions. A correlation was found between the sizes and shapes of crystals deposited in mass transfer systems and the hydrodynamic stresses encountered. The analysis showed that large dendritic crystals would be expected if viscous flow occurs and that small equiaxed crystals would obtain under highly turbulent flow conditions. These predictions were corroborated by corrosion data. An analysis of the seesaw test showed that mass transfer coefficients could be extracted from this test under the proper conditions. A seesaw test rig for the measurement of mass transfer coefficients in liquid mercury was designed and constructed. (AEC Activity 4203)

Fuel Element Catastrophe Studies. — Aluminum alloy (MTR) fuel plate was compared with Geneva-type (UO_2-Al) plate for release of rare gases and iodine at 850°C. When melted in air and kept molten for 5 min, the alloy plate released 15% of the rare gases, as compared with 5% for the Geneva-type oxide-based fuel plate. About 0.01% of the iodine was released from the Geneva-type plate, as compared with about 2 to 3% from the alloy.

The release of fission cesium from punchings from APPR fuel plate with 25% burnup of U^{235} has been observed as a function of the rate of heating. When the time required for heating to the melting point was increased from 6 sec up to 42 sec, the release of Cs^{137} increased at a uniform rate from 16 to 72%. These numbers exceed those determined for cesium at negligible burnup by factors of 3 or more. (AEC Activity 4252)

Reactor Safety Studies. — In preparation for studying the effect of voids in the reflectors of pool-type reactors by means of the Pool Critical Assembly (PCA), final adjustments and changes on the aluminum tank were made, and the operation of the tank after it was placed in the BSF pool was checked. In an attempt to determine the proper fuel element loading to be used for the experiments, it was found that a 4 x 9 loading (140-g elements) would contain more

than 2-1/2% excess reactivity, which is more than the maximum allowed; therefore a 4 x 7 loading with an additional half element in the fifth row will be used for the initial void experiments.

The fabrication of a prototype control-rod drive for the stainless-steel—clad Bulk Shielding Reactor II (BSR-II) is 90% complete. The control-rod design has been modified to provide for the rapid insertion of fuel as required for transient tests, and the design of a preliminary grid plate adapter for mounting the BSR-II in SPERT-I has been sent to NRTS, Idaho Falls, for approval. The design of a single-channel control system for the BSR-II is 50% complete. (AEC Activity 4252)

Power Reactor Fuel Reprocessing: Zircex Process. — Data from a single run indicate that CO_2 as an impurity in anhydrous gaseous HCl produces a slightly higher uranium loss to the HNO_3-insoluble residue than does an equivalent amount of O_2 in the HCl. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Solvent Extraction. — Uranium and plutonium recoveries greater than 99.98% were obtained in the laboratory on a batch countercurrent test of a Hanford Darex-Redox flowsheet.

In tests of solvent recovery by the dry lime method, a solution of 50% tributyl phosphate in Amsco irradiated to 20 whr/liter was successfully recovered by treatment with lime. Higher irradiations required more extensive treatment. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Alternate Aqueous Processes. — Studies of the Zirflex process, in which PWR blanket rods (UO_2 clad with zirconium) are declad with NH_4F and the UO_2 is then dissolved in HNO_3, are continuing. Unirradiated PWR blanket rods which had been autoclaved for 30 days at 300°C and 2000 psi (1200 psi of steam and 800 psi of O_2) were readily declad with boiling 6 M NH_4F—0.75 M NH_4NO_3 in 3 to 6 hr. The maximum uranium loss to the decladding solution was 0.04% regardless of dissolution time, while the maximum total uranium loss under simulated flowsheet conditions (decladding and UO_2 dissolution) was 0.11%. A settling method was developed for separating and collecting the solids obtained during dejacketing studies of the prototype PWR blanket elements.

The Zirflex process is also being studied for the EBWR fuel (U-Zr-Nb alloy clad with zirconium). The average dissolution rate of thin plate fuel in boiling 6 M NH_4F is about 2.5 $mg \cdot min^{-1} \cdot cm^{-2}$. Over 20 hr is required for complete dissolution of the plates. Tests were also run to compare the Niflex (FAN) process with Zirflex for application to EBWR fuel. It was determined that autoclaved Zircaloy-2 specimens dissolved more slowly in FAN solutions than in 6 M NH_4F. If the decladding of EBWR fuel requires 2 hr in 6 M NH_4F, about 20 and 40 hr will be required with 12 M HNO_3—1.0 M HF—1.0 M $Al(NO_3)_3$ and 12 M HNO_3—0.1 M HF—0.1 M $Al(NO_3)_3$ FAN solutions, respectively.

The Sulfex process studies, in which stainless-steel-clad UO_2 (Yankee) and ThO_2-UO_2 (Consolidated Edison) fuel elements are initially declad with H_2SO_4, are being continued. In the experiments with Yankee fuels, less than 10 ppm of

sulfate was found in the Purex-type feed prepared by dissolving water-washed UO_2 pellets in nitric acid after a Sulfex dejacketing step. In the tests with Consolidated Edison fuels, the presence of 5 g/liter of stainless steel corrosion products in the initial H_2SO_4 dissolver solution resulted in a 200- to 1000-fold reduction of the initial rate of dissolution of type 304L stainless steel from about 5 to 0.012 $mg \cdot min^{-1} \cdot cm^{-2}$ in 4 M H_2SO_4 and from about 12 to 0.017 $mg \cdot min^{-1} \cdot cm^{-2}$ in 6 M H_2SO_4.

Only about 2% of the boron added to synthetic Consolidated Edison dissolver solution was lost during boildown for adjustment of feed.

Because the Foreign Research Reactor U-Al fuels contain considerable (2%) silica, special feed preparation studies were made. Gravity filtration of gelatin-treated Foreign Reactor dissolver product, containing 1 g/liter of filter aid, through a precoated 30-mesh sand filter produced a satisfactory solvent extraction feed. A flowsheet for the first cycle of solvent extraction was adequately demonstrated with feed prepared from an unirradiated prototype fuel element and containing plutonium tracer. (AEC Activity 4301)

Power Reactor Fuel Reprocessing: Darex Process. — A 13-1/2-hr Darex run with a dissolved prototype APPR fuel element as feed was made in the continuous loop. Steady-state operation was not achieved because the insoluble silica (2%) in the fuel interrupted operation of the stripper three times during the run. The heavy siliceous coat found inside the stripper upon termination of this test was easily removed with hot 2 M NaOH. The slab dissolver used in the above run has been replaced by a 4-1/2-in.-dia dissolver sufficiently tall to contain a 22-in.-long APPR element. In a 5-1/2-hr shakedown run with the new dissolver, the rate of dissolution of fuel was 6.5 g/min at an aqua regia flow rate of 100 ml/min. Only mild foaming occurred above the 3-1/2-in. depth of liquid in the dissolver.

A 2 N NaOH solution is a satisfactory scrubber for the off-gas from the batch Darex process if enough nitrite or sulfite is present to reduce hypochlorite to chloride.

In batch Darex tests, the volume of off-gas from the dissolution is about 275 liters per kilogram of fuel; if air is excluded from the dissolver, the off-gas is essentially all NO. Feed adjustment tank solutions containing 1 M HNO_3 and more than about 200 g of stainless steel per liter are unstable at room temperature.

Experiments on the use of anhydrous NO_2 for stripping the chloride from Darex solutions at room temperature were made. The structure of nitrosyl chloride indicates that it may be formed by several different mechanisms such as the coupling of free radicals and the combination of ions. The ionic mechanism permits removal of the chloride from a nitrate solution as volatile nitrosyl chloride at a low temperature. (AEC Activity 4301)

Fused Salt–Fluoride Volatility Processing. – The material balance for the nine runs for the recovery of fuel from critical experiments is as follows:

	Uranium Content (g)	
Feed		72,331
UF_6 product	71,761*	
Waste salt	9	
On NaF	524	
Water wash	320	
Total recovery		72,614

*99.21% of feed.

The 524 g recovered on sodium fluoride includes all retention on the sodium fluoride bed, both from routine operation and from purging at the conclusion of the series of runs. The 320 g was the amount adhering to the walls of the piping and vessels. Both these quantities are recoverable by aqueous processing at Y-12.

Three of the runs were spiked with irradiated salt from loop experiments. The activity of the feed salt is given below for the run in which the amount of activity was the greatest. There were no detectable fission products in the product from any of the spiked runs, and the gross beta and gross gamma activities were no greater than would be expected from the uranium itself.

	Counts/min/mg
Gross gamma	9.26×10^4
Gross beta	4.14×10^5
Cs gamma	6.75×10^4
Nb gamma	2.00×10^4
Zr gamma	1.10×10^4
Total rare-earth beta	3.41×10^5

Three of the runs were spiked with plutonium in increasing amounts; 98% of the Pu remained with the waste salt. In the run with the most Pu, almost 10 g, the product contained only 3.4 ppb. Since the feed salt contained several times the concentration of plutonium expected from high-enrichment fuel irradiated to 25% burnup and the product was still satisfactory, no difficulty with contamination of the product by plutonium is anticipated in the future. (AEC Activity 4302)

Waste Treatment: Darex Waste. – In laboratory studies of the destruction of nitrate ion in simulated concentrated acid wastes from power reactor fuel reprocessing plants, 2 to 2.5 moles of nitrate was destroyed per mole of formaldehyde

used in continuous runs in which the off-gases were contacted with the incoming acid waste. In comparison, 1.5 moles of nitrate was destroyed per mole of formaldehyde in previous batch runs in which the nitric oxide in the off-gases was not given a chance to react with the incoming nitric acid. Nitric acid in the simulated waste solutions appears to be more reactive toward formaldehyde than the same concentration of pure nitric acid. (AEC Activity 4352)

Waste Treatment: Ion Exchange Methods. — In scouting studies of waste treatment by ion exchange, the volumetric distribution coefficients for cesium in neutralized Darex waste were 104, 17, and 32 for the ion exchangers Zeo-Dur, Duolite C-3, and Duolite S-30, respectively. For cesium in neutralized TBP-25 waste the distribution coefficients were 150, 39, and 43, respectively, for the same three exchangers. Zeo-Dur, an aluminosilicate, has the highest distribution coefficients but is not easily regenerated. Duolite S-30, a phenolic resin, is probably to be preferred over Duolite C-3, a sulfonated phenolic resin, since it not only has as high or higher distribution coefficients but also has a lower sodium capacity, on account of the absence of the sulfonic groups. For ruthenium in acid TBP-25 waste, Duolite A-40 and Dowex 21K showed distribution coefficients of 12 and 13, respectively.

In the evaporation of nonradioactive, simulated TBP-25 waste, the condensate from unneutralized solution was 4.0 M in H^+, while the condensate from neutralized solution was only 0.5 M. In the former, 57% of the NO_3^- went to the condensate. (AEC Activity 4352)

Long-Range Planning Studies. — Studies have been conducted on the fluidization of thoria spheres in water. A 4-in.-dia column having a length of 108 cm was employed, and the mean particle diameter of the thoria was about 20 μ. At low fluid flow rates the interface between the fluidized bed and the supernatant water was quite sharp (fluidized bed density of about 1200 g of Th per liter), while at flow rates corresponding to a bed density less than about 300 g of Th per liter, the interface was poorly defined. The thoria concentration decreased with increasing bed height; at an average bed concentration of about 400 g of Th per liter, the thorium concentration decreased about 1 g/liter per centimeter of bed height. However, the particle-size distribution was nearly independent of bed height. It was found that the fluid velocity required for fluidization was about the same as the slurry settling rate following flow stoppage. Tilting the column at an angle of 15 deg from vertical resulted in convection patters in the fluidized bed, with thoria particles traveling upward on the high side of the column and settling downward on the low side. (AEC Activity 4510)

PROGRAM 5000 — PHYSICAL RESEARCH

Reactor Operations. — The ORR has operated through two complete cycles. Each cycle consists of three weeks of operation and one week of shutdown to provide time for the installation of large experiments. Trouble was encountered in the second cycle with an excessive number of scrams. This was corrected by increasing the magnet currents and by providing longer release times for the shim rods. During the third cycle (in effect at present) only one scram has occurred. Corrosion of aluminum pipes in concrete is being reduced by pumping on the annular spaces around the pipes, thus keeping the pipes dry on the outside. A shortage of capacity in the ORR air coolers requires the reactor power to be reduced whenever the outside temperature reaches approximately 85°F. The manufacturer is taking steps to correct the shortage.

Preliminary bids have been received on enriched fuel elements for the Graphite Reactor. A test of a procedure for annealing the graphite has been completed with hot air supplied to the graphite through tubes extending through the shield. In a five-channel test the graphite temperature did not reach the desired values, and it appears that a larger heat source will be required. However, the problem of getting the heat into the graphite without overheating the concrete appears to be solved.

Laboratory Facilities. — The first year of operation of the Process Waste Treatment Plant was completed in August. During this period the total activity in low-level wastes discharged to White Oak Creek was the lowest on record, even though the levels of activity processed throughout the Laboratory appeared to be at their highest peak. The removal of $Sr^{89,90}$, considered the most hazardous of the contaminants, has been consistently at 85%, while the gross beta decontamination has been over 50%. The lime—soda ash process was used exclusively during the first year of operation. The use of clay as a decontaminant is now being tested on a full scale. Although the results are incomplete, they are very encouraging.

PHYSICS

High-Voltage Experimental Program. — The cross section for the reaction $Li^6(n,\alpha)H^3$ has been measured as a function of neutron energy in the range $1.2 \leq E_n \leq 8$ Mev. An $Li^6I(E_n)$ scintillation crystal was used to detect the $Li^6(n,\alpha)$ events; pulse-height analysis permitted determination of those (n,α) events induced by primary neutrons. The absolute magnitude of the $Li^6(n,\alpha)H^3$ cross section as measured in this experiment depends only on the absolute value of the fission cross section of U^{238}, while the shape of the curve for cross section vs energy depends on the known energy dependence of the fission cross sections of U^{238} and Np^{237}. The $Li^6(n,\alpha)H^3$ cross section obtained in these measurements is generally consistent with earlier less-detailed measurements; in addition, however, a broad hump at $E_n \cong 2$ Mev is found.

Absolute neutron production cross sections have been measured for targets of H^2, H^3, Li^7, Be^9, B^{11}, C^{13}, C^{14}, and F^{19} under proton bombardment and of Li^7, Be^9, B^{10}, and Si^{29} under alpha-particle bombardment. The energy ranges differ but are contained between threshold and 5 Mev for protons and between threshold

and 9 Mev for alpha particles. Cross sections for the inverse reactions, (n,p) and (n,α), have been computed and were compared, where possible, with direct measurements. (AEC Activity 5220)

Neutron Diffraction. — A neutron diffraction investigation was made of anhydrous $CrCl_3$ and $FeCl_3$ to determine the type of magnetic ordering in these hexagonal layer-type structures. Antiferromagnetic reflections were observed from $CrCl_3$ below 17°K, and these are in qualitative agreement with a model in which the moments within the hexagonal layers are aligned parallel but in which there is antiparallel alignment of adjacent layers. Anhydrous $FeCl_3$ becomes antiferromagnetic at 16°K and, in addition, exhibits antiferromagnetic short-range order up to 43°K. Preliminary attempts to determine the configuration of the moments have been unsuccessful, but the over-all behavior is indicative of a structure of the $MnBr_2$ type (Phys. Rev. 110, 638, 1958), for which single-crystal data were required in the structure determination.

The individual atomic moments were determined from the paramagnetic scattering. In both compounds these values correspond to the spin-only values for the respective ions. (AEC Activity 5220)

CHEMISTRY

Extraction Reagent Performance: Radiation Damage. — The total yields of acid components (dibutylphosphoric acid, monobutylphosphoric acid, and phosphoric acid) from the electron radiolysis of solutions of tributyl phosphate (TBP) in Amsco 125-82, at a radiation level of 400 whr/liter, are nearly proportional to the weight fraction or electron fraction of TBP in the solution. In terms of TBP destruction, $G_{-TBP} = 2.7W_{TBP}$ molecules per 100 ev of energy absorbed by the solution, where W_{TBP} is the weight fraction of TBP in the solution.

The electron irradiation of a branched twelve-carbon hydrocarbon, 2,2,4,6,6-pentamethylheptane (PMH), produces an unsaturated polymer, other unsaturated hydrocarbons, and gaseous products. The polymer contains approximately six PMH units per molecule. The G values for unsaturation and for PMH converted to polymer are 3 to 8 carbon-carbon double bonds and 1.8 to 4.6 molecules of PMH per 100 ev of energy absorbed, respectively. (AEC Activity 5310)

Feed Materials Processing: Hermex Process. — The solids were recovered from an aqueous slurry resulting from the washing of uranium amalgam by settling or centrifugation after adjustment to a pH of 8. The losses to the supernatant were <0.25% for uranium and 0.001% for mercury. Approximately 75% of the LiF was found in the supernatant. Centrifugation appears preferable because the solids are concentrated into ~2.5% of the volume in 3 min.

Mercury was >99.9% removed from the residual solids that remained after the washing of the amalgam by volatilization at 360°C. Fluorination at 500°C failed to separate UF_4 from LiF. (AEC Activity 5310)

Ion Exchange Technology. — Several runs were made in search of an expected maximum uranium loading for resin in equilibrium with 0.005 M uranyl sulfate solutions containing different total sulfate concentrations. The data obtained thus far do not indicate that a maximum occurs anywhere above a sulfate concentration of 0.03 M. (AEC Activity 5310)

High-Level Nuclear Chemistry. — Analyses of the fission product waste from the Thorex process plant for Pa^{231} showed that this material is a potential source of gram quantities of protactinium. A purified fraction containing Pa^{231} and Pa^{233}, taken from samples of about 3000 gal of stored raffinate resulting from the processing of 3 tons of irradiated thorium, was examined by alpha pulse analysis. The Pa^{231} content was determined as 3 to 4 g. This quantity is about half the amount expected on the basis of the accepted cross section of thorium for the (n,2n) reaction (0.005 to 0.010 barn) and is also about half the amount indicated by the U^{232} content of the U^{233} produced in the irradiation. The protactinium was found to be associated with a white gelatinous solid of the approximate composition of zirconium aluminum silicate, which can be filtered or centrifuged to recover most of the element. (AEC Activity 5330)

Chemistry of Corrosion. — The effect of anions on electrochemical processes associated with corrosion systems is under study. The reduction of cupric ion on passive stainless steel in 1×10^{-4} f H_2SO_4 + 9×10^{-4} f Na_2SO_4 at 67°C is accelerated by the addition of thiocyanate ion. It was found that the thiocyanate ion forms a 1:1 complex with cupric ion in the low concentrations used, and that the electrochemical specific rate constant for the reduction of the complex is two to three times greater than that for the reduction of uncomplexed cupric ion. A potentiostatic technique was developed by which the association quotient of the complex, as well as the specific rate constants for complexed and uncomplexed cupric ions, can be determined. The results of eight experiments show that the association quotient of the 1:1 complex is $(4.6 \pm 1.8) \times 10^3$ at 67°C and that the reduction of the complex proceeds by a mechanism involving consecutive charge-transfer steps. The mechanism is similar to that for the reduction of uncomplexed cupric ion, although it is energetically different. (AEC Activity 5330)

Chemistry of Technetium. — When a 2 M H_2SO_4 solution of K_2ReI_6 is shaken with ether, all the rhenium and five-sixths of the iodine are extracted into the organic phase. This reaction is specific for K_2ReI_6; the chloride and bromide compounds are not extracted. It was found that K_2TcI_6 behaves in a similar manner. The reaction is not given by K_2TcCl_6 or K_2TcBr_6; thus again it is specific for the iodide. The spectra of the technetium and rhenium compounds in the organic phase are different from the spectra obtained in the aqueous phase, indicating that two distinct species are present in the two phases. The principal species present in the 2 M H_2SO_4, however, are the same as those present in concentrated HI (as shown by their spectra), which are presumably ReI_6^{--} and TcI_6^{--}. The extractability of the rhenium and technetium from the dilute sulfuric acid solution with ether and the nonextractability from a solution of concentrated HI suggests that an equilibrium such as $ReI_6^{--} \rightleftharpoons I^- + ReI_5^-$ exists. In concentrated HI the equilibrium is shifted far to the left,

but in sulfuric acid solution an appreciable concentration of ReI_5^- or $HReI_5$ exists and is extractable into the organic phase. (AEC Activity 5330)

Chemical Separation of Isotopes. — The isotopic fractionation of carbon isotopes was measured at 25°C for two systems involving gaseous carbon monoxide. The equilibration of CO with an aqueous solution of its complex with cuprous ammonium lactate gave a single-stage separation factor of 1.012 ± 0.002 (95% confidence interval). In the exchange of CO with $Fe(CO)_5$, the separation factor was 1.020 ± 0.003 (95% C.I.). In both experiments, C^{13} was concentrated in the liquid phase.

The effect of complexing lithium in the aqueous phase was studied as part of the program for separating lithium isotopes by ion exchange chromatography. Ethylenediaminetetraacetic acid was used as the complexing agent. The first system studied was $LiEDTA^{3-}$ in aqueous solution at pH 10 vs $LiEDTA^{3-}$ on Dowex 1. The affinity of the lithium isotopes for the anion exchange resin was the reverse of that previously observed for Li^+ on cation exchange resins; Li^7 was concentrated in the resin phase to a small extent (separation factor 0.9995), indicating little difference in the bonding of the lithium species in the two phases. With the same $LiEDTA^{3-}$ solution and with Dowex 50 as the resin phase, the concentrating of Li^7 on the resin was much greater (separation factor 0.9942). (AEC Activity 5340)

METALLURGY

High-Temperature Reactions of Metals and Ceramics. — A profile analysis of overlapping absorption bands has, for the first time, been carried out in an exact way. The case treated was the simple one of a low-intensity band overlapped by the adsorption edge of a high-intensity band. The examples treated numerically were the near-ultraviolet absorption spectra of the pure, fused alkali-metal nitrates. It was shown that any of several functions gave a proper representation of the spectral profile. The most useful of these functions was the following:

$$a_M = a_1 \exp\left(-U_j \left|E - E_1\right|^{N_j}\right) + a_2 \exp(qE),$$

where $j = 1$ when $E \leq E_1$, $j = h$ when $E \geq E_1$, a_M is the molar absorbance index, and E is the photon energy. The first term gives the profile of the low-intensity band as a nonsymmetrical Gaussian, while the second term gives the profile of the absorption edge of the high-intensity band in terms of the exponential approximation to a Gaussian. The constants a_1 and E_1 are the coordinates of the maximum of the low-intensity band, the constants U_j and N_j define the half-width and the moments of the low-intensity band, while a_2 and q are empirical constants, without a simple physical significance, which define the absorption edge. Case study showed that the dispersion-theory profile did not make a measurable contribution.

Calculations made on six spectra to three iterations with a desk calculator gave fits in which the standard deviation between the computed and measured profiles was less than 0.5% and the maximum deviation was less than 1%. These computations are now being coded for the Oracle. (AEC Activity 5420)

BIOLOGY

Cytology and Genetics: Insects. — It has now been established that bone marrow chimeras, produced by the administration of homologous or heterologous marrow to lethally irradiated recipients, survive with a generally incapacitated immune response. Nevertheless there are persistent reports in the literature which purport to show by means of skin grafting that the impairment of the immune response is specific; that is, that a state of immunological tolerance exists such that the response of the host is impaired with respect to the graft alone and the response of the graft is impaired with respect to the host alone. The graft combinations heretofore used, however, have been such that the survival of the graft is expected whether the impairment of the response is specific or general. Attempts were therefore made to graft onto 101 x C3H mice which had survived 1050 r and the administration of rat bone marrow, and which had only rat erythrocytes in the circulation, skin of a genotype which should be rejected by the tissues of both donor and recipient. Of 21 animals grafted, 10 survived the operation; of these, 9 accepted the graft and 1 rejected it. This result confirms, by the skin-grafting technique, the general impairment of the immune response which accompanies the transplantation of heterologous bone marrow. (AEC Activity 6130)

Pathology and Physiology. — Transmembrane potentials in fibers and changes in potassium content were measured at intervals after irradiation in frog sartorius muscles. Statistically significant reductions in the median potentials of the irradiated muscles were observed within a few hours after exposures above ~75 kr; the latent period was shortened and the severity of response was intensified with increasing exposure. Irradiated fibers showed wide individual variations in the rate of loss of transmembrane potentials relative to the controls. The decline of potential was, in general, nonuniform from point to point along an affected fiber, and regions of low potential appeared to be sites for subsequent development of histological lesions. Radiation-induced changes in potassium were not detected below ~150 kr; at higher levels potassium loss was augmented with increasing exposure and time after treatment. The visible pathological changes resembled, in part, Zenker degeneration in intact muscle tissue. Radiation-induced changes were markedly slowed by posttreatment storage at 2 to 3°C. It is suggested that radiation injury in the excised muscle is reflected initially by focal changes in ionic permeability that, with sufficiently high exposures, spread progressively with a resulting loss of fiber potassium. Subsequently, structural alterations become visible, leading rapidly to irreversible coagulation of fiber material and other terminal changes. (AEC Activity 6130)

Biochemistry: Nucleoproteins, Amino Acids, and Enzymes. — A new nucleotide, other than the usual cytidylic, adenylic, uridylic, and guanylic acids, which has been observed in alkaline hydrolysate of ribonucleic acids since 1951, has been prepared in quantity and studied chemically. This nucleotide exhibits many unorthodox properties, such as resistance to the usual degradation procedures, the occurrence of three nucleoside forms in addition to phosphate isomerism, and

possession of the spectral properties of a pyrimidine base. Degradation of the nucleoside by a series of periodate oxidations and $NaBH_4$ reductions has yielded 5-hydroxymethyluracil. Nuclear magnetic resonance spectra indicate a substitution at C_5 in a uracil nucleus. An isomer of uridine is suggested by the elementary analysis (C:N:P = 9:2:1), chromatographic behavior, and ultraviolet absorption spectrum. The nucleoside is therefore formulated as 5-ribosyluracil and becomes the first carbon-carbon glycosyl compound to be found in nucleic acids. (AEC Activity 6130)

Plant Physiology and Photosynthesis. — Several investigators have reported that many species of seeds appear to have a relatively high R.Q. (respiratory quotient) soon after the beginning of water imbibition; the R.Q. decreases and finally levels off with increasing time. These investigators assumed that such observed variations in R.Q. were indicative of shifting metabolic pathways within the seeds during the course of germination. In this laboratory, a large volume of gas was released from seeds as they became wet. A similar gas evolution was observed when nonviable seeds, dried tea leaves, and powdered potato starch were moistened. The gas from viable seeds was not absorbed by KOH, and consequently was most probably not respiratory. In view of the volume of gas released upon wetting, the temperature dependency of the effect, and the general production of gas upon wetting dry plant material, it was concluded that the gas released was air which had been physically adsorbed upon surfaces within the seeds. When seeds were moistened slowly, the duration of the nonrespiratory gas output was lengthened, although the total amount of gas so produced was unaltered. Examination of the literature strongly suggested that this unrecognized nonrespiratory gas output led to mistakenly high apparent R.Q. values of seeds before water imbibition had been completed. (AEC Activity 6130)

Biophysics: Electron Spin Resonance Studies. — The preliminary measurements of the dependence of the production of free radicals in amino acids on linear energy transfer (LET) have been confirmed and extended. The results show definitely a decreasing radical production per unit energy absorbed as LET is increased. The relative effectiveness for the production of radicals was found to be 1.0 for cobalt gamma rays, 0.7 for 14-Mev neutrons, and 0.3 for 5.3-Mev polonium alpha particles.

A definite dependence of the lifetimes of the radicals in irradiated glycine on the crystal size of the irradiated material has been observed. This finding is in agreement with the hypothesis that the magnetic centers induced by radiation are destroyed by oxygen diffusing into the crystals. (AEC Activity 6130)

Biophysics: Silver-Activated Phosphate Glass. — The fluorescence induced by ultraviolet rays in silver-activated phosphate glass dosimeters that had been treated with gamma rays was found to be very stable under conditions of high-temperature storage. The fluorescent response is also relatively independent of the temperature of irradiation, decreasing by less than 10% over the range from 20 to 100°C. These findings mean that the phosphate glass is a very stable radiation dosimeter. Preliminary tests of the applicability of this glass to alpha-particle measurements are quite promising. (AEC Activity 6130)

Biophysics: Deviation from Inverse-Square Law. — The variation in the current of an ionization chamber with the distance between the chamber and the source was measured. A spherical ionization chamber about 10 cm in diameter and a very small Co^{60} source were used. The deviation from the inverse-square law (due to the finite size of the chamber) reached 60% at the closest distance used. A theory of the effect of chamber size was developed. The disagreement between the values based on the theory and the above experiments is only ±1%. Also, the disagreement between the theory and the experimental data is less than ±5% for the sideward and endward positioning of the large Victoreen 0.25-r chamber. (AEC Activity 6130)

Biophysics: Point Source Alpha and Proton Irradiation Facilities. — Use of the Cockcroft-Walton accelerator as a point source of the charged particles copiously produced by the nuclear reaction $H^3(d,n)He^4$ and by the reactions $H^2(d,n)He^3$ and $H^2(d,p)H^3$ is being developed. As a source of 4-Mev alpha particles, with present accelerator yields, this scheme approximates a half-curie point source; with materials placed at 10 cm from the target, the dose rate should be about the same as that from common extended 5-mc radioactive sources plated onto metal foils, but with less ambiguity concerning the energy spectrum and uniformity and with no risk of radioactive contamination. As a proton source, the Cockcroft-Walton could be used in preparation for studies with the external beam of protons from the 86-in. cyclotron. Because of the difference in absorption coefficients, the contamination of the beam by neutrons and gamma rays should not contribute as much as 1% of the biological dose. (AEC Activity 6130)

Microbial Protection and Recovery. — Preliminary studies suggested that unirradiated cells of the H_7 strain of *Escherichia coli* are not killed by concentrations of H_2O_2 generated in water or phosphate buffer by x-ray doses up to 26 kr. These experiments involved incubation of this strain, previously grown with or without hemin, for 60 min at 25°C in 10^{-5} M H_2O_2 (supplied either by x irradiation of water or by addition of reagent H_2O_2). Kinetic studies of the inactivation by H_2O_2 of this organism grown without hemin (catalase-negative) have now been completed over a range of H_2O_2 concentration from 10^{-5} to 10^{-2} M and for time periods up to 120 min. The time course of survival is represented by a family of threshold-type survival curves. The slopes of the curves are proportional to the H_2O_2 concentration, and the threshold times are inversely proportional to the H_2O_2 concentration.

Heretofore the H_7 strain has been grown in a natural medium composed of buffered peptone and glucose. For a number of experiments it is important to be able to grow the cells in a chemically defined medium. The organism will grow well in an elaborate *Lactobacillus* medium. The growth requirements are resolved to the sulfhydryl amino acid cysteine if the organism is grown aerobically with added hemin, and to cysteine plus acetate if the organism is grown without added hemin. Anaerobic culturing precludes the acetate requirement for cells grown without hemin. It is of interest that the final titer for anaerobic cultures grown without hemin is much greater than for aerated or static cultures, indicating that oxygen may actually be toxic for this type of organism. (AEC Activity 6230)

Mammalian Recovery. — Further studies showed that homologous bone marrow cells taken from fetal mice are greatly superior to adult homologous bone marrow, not only in causing greater long-term survival of lethally irradiated mice, but also in that the donor cells persisted in all animals tested. Lymphatic tissues, which are thought to be the main seat of disease in the reaction to foreign bone marrow, returned to a normal-looking state after showing mild evidence of the reaction.

A special chambered microscope slide for work with phase contrast was invented.

The life span of the red blood cells was measured by the Cr^{51} method in the (C3H x 101)F_1 mouse and was found to be about 55 days. This is the same as the value found earlier in other hybrid mice. Red blood cells of irradiated mice receiving isologous bone marrow showed a normal life span.

Further studies on the effectiveness of normal mouse tissues for preventing protection by rat bone marrow in the lethally irradiated mouse showed that spleen, whole blood, lymph nodes, thymus, liver, and kidney are effective. Brain tissue and muscle are less effective. (AEC Activity 6230)

Radiation Immunology. — In an attempt to study the mechanism of antibody production in mice, 12 x 10^6 nucleated spleen and bone marrow cells from normal and from preimmunized isologous donors were injected intravenously into (101 x C3H)F_1 mice that had been exposed to 950 r. Rat red blood cell antigen was injected intraperitoneally at about the same time the spleen or bone marrow cells were administered. Spleen cells, but not bone marrow cells, of normal donors were capable of initiating immediate, primary antibody production. Bone marrow cells of preimmunized donors initiated antibody production in recipients exposed to 950 r, but this response was relatively weak. In contrast, 12 x 10^6 spleen cells of preimmunized donors were capable of synthesizing circulating antibodies in an amount comparable to that observed in a normal, secondary antibody response. This would indicate that the total amount of circulating antibodies synthesized by a normal mouse may involve only a fraction of the total number of antibody-producing cells present.

When LAF_1 mice were exposed to 640 r, none died, and only 1 out of 20 mice treated with 640 r and 100 x 10^6 rat bone marrow cells died. However, 16 out of 16 mice treated with 640 r and 240 x 10^6 rat bone marrow cells died within 30 days after treatment. These results are comparable to those demonstrated previously in (C3H x 101)F_1 mice. (AEC Activity 6230)

PROGRAM 8000 — WORK FOR OTHERS

Oak Ridge School of Reactor Technology. — Sixty-four students completed the second session of the ORSORT-University Cooperative Program on August 22.

September 8 was the starting date for the first all-Carbide ORSORT session. Sixty-eight students from ORNL, Y-12, and ORGDP are enrolled in one or more courses. The session will run for a full year.

In August, ORNL agreed to conduct two special programs intended primarily for noncitizens. The duration of Reactor Operations Supervision will be nine months and that of Reactor Hazards Evaluation will be a full year; both courses will start in February 1959. Descriptive material was distributed at the Geneva Conference. (AEC Activity 8712)

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OAK RIDGE NATIONAL LABORATORY

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