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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

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May, 1957

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

TABLE OF CONTENTS

	Page
PROGRAM 2000 - SPECIAL NUCLEAR MATERIALS	6
Waste Metal Recovery	6
Excer Process	6
Fluorox Process	7
Metallex Process	7
PROGRAM 4000 - REACTOR DEVELOPMENT	8
HOMOGENEOUS REACTOR PROJECT	8
Homogeneous Reactor Test	8
HRT Chemical Pilot Plant	8
Mathematics and Computation--Homogeneous Reactor Development	8
Reactor Analysis	9
Homogeneous Reactor Instrumentation	9
HRP Design	10
HRP Metallurgy	10
HRP Spectroscopy Development	10
Laboratory Corrosion Studies	10
Dynamic Solution Loop Corrosion Tests	11
Small-Scale Dynamic Slurry Corrosion Tests	11
Dynamic Slurry Loop Corrosion Tests	12
In-Pile Solution Corrosion Loops--LITR	12
In-Pile Solution Corrosion Loops--ORR	13
Autoclave Radiation Corrosion Studies--LITR	13
GENERAL REACTOR RESEARCH	14
Long-Range Planning Studies	14
Basic Reactor Research	14
Volatility Studies	15
Power Reactor Fuel Reprocessing: Aqueous Dissolution	15
Power Reactor Fuel Reprocessing: Darex Process	15
Power Reactor Fuel Reprocessing: Solvent Extraction	16
Power Reactor Fuel Reprocessing: Zircex Process	16
Power Reactor Fuel Reprocessing: Ion Exchange	16
Waste-Treatment Studies	17
School of Reactor Technology	17
PROGRAM 5000 - PHYSICAL RESEARCH	17
Reactor Operations	17
The Oak Ridge Research Reactor (ORR)	18

[redacted]

[redacted]

TABLE OF CONTENTS (Continued)

PROGRAM 5000 (Continued) — Page

ISOTOPE PRODUCTION 18
- Radioisotope Production 18
- Radioisotopes, Research and Development 18
- Stable Isotope Production 18
- Stable Isotopes, Research and Development 19

PHYSICS 19
- Neutron Velocity Selector 19
- High Voltage Program 19

CHEMISTRY 20
- Ion Exchange Studies 20
- Chemical Engineering Research Studies 20
- High-Level Nuclear Chemistry 20
- Chemistry of Corrosion 21
- Chemistry of Technetium 21
- High-Temperature Aqueous Solution Chemistry 22
- Chemical Separation of Isotopes 22

METALLURGY 23
- High-Temperature Reactions of Metal and Ceramics 23

PROGRAM 6000 - BIOLOGY AND MEDICINE 23

BIOLOGY 23
- Cytology and Genetics 23
- Cytology and Genetics--Insects 24
- Pathology and Physiology 24
- Cell Physiology 24
- Biochemistry 25
- Enzymology and Photosynthesis 25
- Biophysics 25
- Microbial Protection and Recovery 26
- Mammalian Recovery 27

OPEN LITERATURE PUBLICATIONS 28

VISITORS 31

RADIOISOTOPE SALES AND COSTS 32

GROSS OPERATING COSTS 32

PERSONNEL SUMMARY 33

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

May, 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 4400 is reported separately.

PROGRAM 2000 - SPECIAL NUCLEAR MATERIALS

Waste Metal Recovery - Eight tons of uranium and 3.54 g of neptunium were recovered from Canadian uranyl nitrate solution by a modified Purex process. The neptunium recovery was 91.8%, with 4.4% lost in the first-cycle aqueous waste and 3.8% remaining with the uranium product. The flowsheet used is given in ORNL-2235. During the last part of the program the addition of $NaNO_2$ to the feed and heating resulted in 99.5% neptunium recovery.

The recovery of 1900 lb of depleted uranium and 19 g of neptunium from 3188 lb of K-25 fluorination ash was completed. The ash was prepared for extraction by dissolution in 1 M $Al(NO_3)_3$--1 M HNO_3. (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 $UF_4 \cdot 3/4\ H_2O$. The first step of a program of preparing 60 lb of UF_4 for reduction tests was completed, namely, anion exchange of the chloride ore concentrate solution to remove impurities. Uranium losses in the 2-in.-dia Higgins continuous ion exchange contactor were 0.01 to 0.05%; the uranium concentrations in the uranyl chloride product solutions were 100 to 200 g/liter. The uranium production rate was 125 g/hr for most of the run but was increased to 187 g/hr toward the end. Two different schemes were used: in one the ore concentrate solution was saturated with sodium chloride and the loaded resin was scrubbed with saturated sodium chloride in an attempt to use a cheap source of chloride; in the other, strong hydrochloric acid was added to the feed and the loaded resin was scrubbed with hydrochloric acid to relieve the sodium burden in the subsequent cation exchange step. The second scheme appears preferable, since sodium was not satisfactorily removed in the cation exchange column. Attempts to load in saturated NaCl and scrub with strong HCl resulted in crystallization of salt in the column.

In further laboratory tests on iron reduction of UO_2Cl_2 to UCl_4, the rate of the reaction did not change with uranium concentrations of 50 to 180 g/liter.

Equipment for continuous precipitation, with a daily capacity of 25 lb of $UF_4 \cdot 3/4\ H_2O$, was designed and installed.

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In two dehydration runs in the continuous fluidized bed equipment at 350 ± 25°C, the UF_4 products met specifications for all impurities except carbon. (AEC Activity 2702)

Fluorox Process - In the Fluorox process, UF_6 is prepared by oxidation of UF_4 with dry air or oxygen. In oxidation runs in a fluidized-bed reactor totaling 2.6 hr, at 690 to 735°C, 6 lb of residue containing 95% UO_2F_2 was produced from a 10-lb charge containing 58% UO_2F_2, the remainder of the uranium having volatilized as UF_6. From data obtained in one 2.5-hr run at 700 to 725°C with Excer product UF_4 as the feed, a reaction velocity constant of 0.5 hr^{-1} was calculated. A solid that collected in the off-gas line was identified as U_4F_{17}, a UF_4-UF_6 intermediate.

The rates of vaporization of UF_4 and decomposition of UO_2F_2 over the temperature range 600 to 800°C, studied with a thermobalance, were very slow compared with the rate of reaction of UF_4 with dry oxygen; therefore these phenomena can be neglected when interpreting kinetic data for the oxidation reaction.

In a brief study of the dehydration of hydrated UF_4 (H_2O content 6.1%), initial drying at 200 to 250°C for 2 to 3 hr removed 75% of the water. Further drying at 300°C or higher removed an additional 20% of the original water content. Stearic acid (used as a lubricant in the UF_4 pelleting machine) could not be removed quantitatively from the UF_4 at temperatures up to 400°C.

Installation of the revised off-gas system and all fabricated parts of the flame reactor is complete. (AEC Activity 2702)

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. In reduction runs in the large-scale (2 lb/hr) continuous apparatus, changing the thorium production rates from 1.5 to 2.6 lb/hr did not affect the percentage reduction of $ThCl_4$ to metal. From 8385 lb of thorium amalgam produced in four reduction runs in this apparatus, 27 lb of thorium metal was recovered. Mercury balances were satisfactory, but only 31% of the thorium in the amalgam was recovered. The bulk density of the sintered massive metal was low.

Removal of impurities from the washed thorium amalgam by amalgamated barrier filtration followed by application of vacuum gave the best results of any method tested. The bulk density of massive metal from amalgam thus treated was 10.05 g/cc, with a voidage of 13.5%. Bulk densities of massive metal obtained following other treatments were 7.6 to 9.9 g/cc and voidages were 15 to 28%. Filtration of the thorium amalgam--mercury solution at 356°C was unsatisfactory, since thorium is not completely soluble in the mixture at this temperature. (AEC Activity 2704)

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test - A dye-penetrant inspection of all system flanges was made for evidence of cracking or severe pitting in the ring grooves. The following conditions were revealed:

	Accepted	Rejected	Inconclusive	Total
High-temperature flanges	30	30	23	83
Low-temperature flanges	137	37	2	176

As a result of the inspection, all high-temperature flanges (over 100°C) in the high-pressure system, except as noted below, were cut out for replacement. Where irreplaceable flanges (e.g., pressure-vessel nozzles) showed corrosion, the leak-detector lines will be isolated on a special header or the flange will be resurfaced. Thirty-seven low-temperature flanges will be replaced.

Work is currently in progress replacing flanges and leak-detector tubing, with 30% of the tubing and 40% of the new flanges presently in place. Other construction activities under way or completed are (1) revision of the cooling-water system (90% complete), (2) installation of sampling stations for the reactor steam system, and (3) insertion of bleed lines and valves at the feed pump outlets.

Testing during the shutdown period has included a checkout of the waste-evaporator system and experiments on proposed methods for internal cleaning of the steam-system piping. The bulk of operations work during the month was concentrated on the preparation of the HRT Operations Manual and testing procedures. (AEC Activity 4103.3)

HRT Chemical Pilot Plant - Construction of the low-pressure system was completed, and preliminary tests were made, including a hydrostatic test at 2500 psi and calibrations of various level-indicating instruments. Lead ferrules were substituted for the specified tantalum ferrules to alleviate temporarily the difficulties with sealing the special Swagelok fittings joining the tantalum tubes from the dissolver to the process piping above the dissolver. The low-pressure leak-detector lines were checked, and two of the approximately 40 lines were found to be contaminated with small quantities of chlorides.

Design of the closed-cycle cooling-water system is 80% complete. Preliminary design was started of a system for flame calcinations of ThO_2 particles. The objective is to fire-polish the particles, by passing them through the flame, above 1600°C, without fusion of the ThO_2. (AEC Activity 4103.1)

Mathematics and Computation--Homogeneous Reactor Development - An Oracle code was written for converting Oracle numerical results to graphical results. This code effectively normalizes all values and plots them on the Oracle curve plotter as discrete points. If enough points are plotted, a smooth curve is obtained. (AEC Activity 4103.1)

Reactor Analysis - Fuel costs were obtained for single-region reactors operating under non-steady-state conditions. Reactor fluids studied were UO_2SO_4-water, UO_2SO_4-Li_2SO_4-water, and UO_3-ThO_2-water systems; both D_2O and H_2O were considered. Power level, core diameter, fertile-material concentrations, inventory charge, cross section of fission products, fuel-processing charge, and fuel-processing cycle time were considered as parameters. Increasing the power from 100 to 1000 thermal Mw decreased the fuel cost by about 1 mill/kwhr for the D_2O systems, while increasing the inventory charge from 4 to 12% increased the fuel costs by about 0.5 mill/kwhr. The optimum reactor diameter increased and the fuel cycle time decreased as the power level was increased. Doubling the fuel-processing charges or the fission-product poisoning increased fuel costs by about 0.1 mill/kwhr.

Thermal fluxes and power densities were calculated for several multiregion research reactors, using a two-group, one-dimensionsl, multiregion model. The reactors were all variations of a basic type, namely, a three-region machine containing a central sphere of D_2O, an annulus containing U^{233} and D_2O, and an outer D_2O reflector. For all reactors considered, thermal fluxes of the order of 10^{15} neutrons/cm^2·sec would be available in the central region, assuming that 100 thermal Mw were generated in the fuel annulus. The power density at the inner wall of this annulus was about 180 kw/liter, for a 40-cm-radius central sphere, a 20-cm-thick fuel annulus, and a 90-cm-thick outer reflector. (AEC Activity 4103.1)

Homogeneous Reactor Instrumentation - Differential transformers suitable for sensing float motion in the HRT level transmitters and designed to be considerably more radiation resistant than those now installed on the HRT were received from two manufacturers.

After the completion of a literature survey, specifications were issued for an underwater-camera television system to be used as an aid to HRT maintenance.

A new preamplifier was developed to amplify the output voltage pulses from the two Westinghouse fission chambers used to monitor neutron flux in the HRT. The new model will give a much higher signal-to-noise ratio at the receiving end of the connecting cable.

A set of valve trim flame-plated with aluminum oxide by Linde was found to be susceptible to cracking and flaking. Flaking occurred after approximately 50 "dumps" in the valve test loop.

A set of valve trim fabricated from type 17-4 PH stainless steel hardened to R_c42 was substituted for type 347 stainless steel in an HRT fuel dump valve and gave satisfactory performance for 400 dumps.

Two sets of valve trim made from Baker and Company platinum alloy No. 130 (70% Pt, 20% Au, 10% Pd) were installed in the valve test loop and performed satisfactorily. Seat leakage before and after 400 dumps was approximately equal to that experienced with types 347 and 17-4 PH trim. The leak rates

after the tests were 1.3 cc of H_2O per minute at 3800 psig (ΔP) and 165 cc of N_2 per minute at 1500 psig (ΔP).

One set of trim made from Baker alloy No. 872 (80% Pt, 10% Au, 10% Pd) was subjected to 420 dumps, and the leak rate after the test was 1.5 cc of H_2O per minute at 3000 psig (ΔP). (AEC Activity 4103.1)

HRP Design - Experiments made on the flange test facility showed that, by initially stressing the bolts of a flanged joint to about double the minimum seating stress, the resultant gasket loading following several thermal cycles would be sufficient to seal the joint indefinitely. (AEC Activity 4103.1)

HRP Metallurgy - To determine the extent of the chloride-induced stress cracking previously found in the HRT, all permanent flanges in the system were inspected by use of a fluorescent penetrant with a postemulsification technique. In this inspection, 30 high-temperature flanges were considered acceptable, 30 were rejected, and 23 were rated as being questionable; in the low-temperature system the values were 137, 37, and 2, respectively.

Representative flanges (12 high-temperature, 21 low-temperature) were then removed and examined metallographically. It was shown that, despite the high rejection rate in the penetrant examination, some cracks had been missed by the penetrants. Cracks were found in 9 out of 12 high-temperature flanges, but in only 3 out of 21 low-temperature flanges.

Sixteen lengths of leak-detector tubing were also examined metallographically. Chloride cracks were found only in the hot ends of two of the lines. However, serious defects of other types (i.e., weld cracks, deep pits, carburized and etched surfaces, etc.) were found in all tubes.

Work has continued in the development of zirconium-niobium alloys as a more corrosion-resistant replacement for Zircaloy-2. Five different binary and ternary alloys were tested for resistance to in-pile corrosion by uranyl sulfate. When aged at low temperatures, all alloys showed considerable improvement in corrosion rate over Zircaloy-2; a Zr-15Nb-2Pd alloy, with a rate of only half that of Zircaloy, corroded at the lowest rate. All the alloys showed a higher rate when they were aged at high temperatures before being placed in the loops. Five 3-in. billets of Zr-15Nb alloys were successfully extruded bare to 1-in. rods. (AEC Activity 4103.1)

HRP Spectroscopy Development - X-ray diffraction compound identifications were made of numerous corrosion products, analytical development materials, and miscellaneous thorium and uranium compounds associated with the HRP program; the identification of a few compounds involving sodium, tungsten, and oxygen has not been possible because of the incompleteness of published literature. (AEC Activity 4103.1)

Laboratory Corrosion Studies - Stress-corrosion cracking of annealed type 347 stainless steel stressed at 15,000 and at 30,000 psi was observed in boiling and aerated 0.04 m UO_2SO_4--0.02 m H_2SO_4--0.005 m $CuSO_4$ solutions containing

25, 50, 100, 200, and 500 ppm chloride. No cracking was found in solutions containing 0, 5, and 10 ppm chloride. Generalized corrosion rates for unstressed type 347 stainless steel ranged from 10 to 16 mils/year after 2500 hr at chloride concentrations from 25 to 500 ppm. With chloride contents of 10 ppm and less, the generalized corrosion rates were less than 0.1 mil/year.

Pertechnetate concentrations of 60 ppm and less were found to be ineffective for eliminating stress-corrosion cracking of type 347 stainless steel in chloride-containing distilled water at 300°C, and a significant loss of pertechnetate was experienced in all tests. Pertechnetate concentrations of 500 to 825 ppm prevented cracking of the stainless steel in 350-hr tests; however, appreciable losses in pertechnetate concentrations were also encountered during these tests. (AEC Activity 4103.1)

Dynamic Solution Loop Corrosion Tests - The discrepancy observed between in-pile in-line (out of the high-flux field) and out-of-pile stainless steel corrosion rates was shown to be due to the effect of loop history. A run in a newly constructed, film-free 100A loop, duplicating as closely as possible an in-pile loop run (each in-pile loop is newly constructed and film-free) without, of course, the exposure to reactor radiation, gave very similar results to the in-pile in-line corrosion rates. That is, corrosion rates were very low and showed little velocity effect. The second run in the same 100A loop (now filmed over), duplicating the first run, gave high corrosion rates showing a sharp velocity effect similar to previous 100A loop runs. Therefore it was shown that a large area of film-free metal which actively corrodes during a run can in some way reduce corrosion of stainless steel specimens.

A run with 0.04 m UO_2SO_4 containing 0.02 m H_2SO_4 and 0.005 m $CuSO_4$ in heavy water showed that the bulk solution did not separate into two liquid phases at temperatures up to 333°C. However, on the loop mixing-line heater walls at a temperature substantially above 333°C, the solution did separate into two liquid phases, and corrosion of the type 347 stainless steel pipe was severe. Penetration of the 0.125-in.-thick pipe wall occurred within 50 hr. This result illustrates the necessity for preventing two-liquid-phase separation, even in dilute solutions. (AEC Activity 4103.1)

Small-Scale Dynamic Slurry Corrosion Tests - Two tests were completed in which 28-μ thorium oxide spheres, calcined at 1200, 1400, and 1600°C, were circulated as aqueous slurries at a concentration of 500 g of thorium per kilogram of water for 300 hr at 26 ft/sec and 250°C, with oxygen addition. Average attack rates were (in mills/year): type 347 stainless steel, 0.7; titanium 75A, 0.4; and SA 212 B carbon steel, 0.9. The thoria spheroids were unchanged during circulation.

Slurries of coprecipitated thorium-uranium oxide fired at 1000°C were circulated for 300 hr at 250°C and 26 ft/sec, with additions of oxygen, 3000 ppm sulfate as $Th(SO_4)_2$, and 0.05 m MoO_3, a proposed recombination catalyst. Specimens of type 347 stainless steel, titanium 75A, Zircaloy-2, and SA 212 B carbon steel exposed to the mixed-oxide slurry without addition of SO_4^{--} showed respective attack rates of 0.1, 1, 0.6, and 2.3 mils/year. With 3000

ppm of sulfate, rates of type 347 stainless steel and titanium 75A were approximately doubled; Zircaloy-2 was unaffected; and SA 212 B steel increased 35-fold. (AEC Activity 4103.1)

Dynamic Slurry Loop Corrosion Tests - In a 100-hr test at 300°C, oxygenated slurry prepared from ORNL-produced, 1600°C-calcined thoria was circulated at an average concentration of 740 g of thorium per kilogram of water. The average corrosion rates of pin specimens exposed at relative velocities of 10, 20, and 30 ft/sec were, respectively (in mils/year): austenitic stainless steels, 1, 4, and 4.5; Zircaloy-2, 0.0, 0.7, and 1.1; and titanium and alloys, 0.7, 5, and 5. The average particle size of the thoria before and after circulation was $1.3 \pm 0.2\ \mu$. Slurry handling characteristics during the run were satisfactory. The loop and pump components were found, after the test, to be quite clean and free of attack.

In a 501-hr test at 300°C with oxygenated 800°C-calcined thoria slurry at an average circulating concentration of 516 g of thorium per kilogram of water, corrosion rates of pin specimens exposed at relative velocities of 10, 30, and 40 ft/sec were moderate. At 46 ft/sec, corrosion rates of pin specimens of the austenitic stainless steels ranged from 12 to 20 mils/year; carbon steels, 33 mils/year; Zircaloy-2, 4 mils/year; and titanium alloys, 12 to 13 mils/year. Type 347 stainless steel coupon specimens contained in a variable-velocity specimen holder displayed rates from 0.2 to 17 mils/year over the velocity range 6 to 52 ft/sec. The thoria was degraded from an initial average particle size of $3.3\ \mu$ to a final $0.6\ \mu$.

In a 311-hr test in which prepumped slurry was circulated at an average concentration of 583 g of thorium per kilogram of water at 300°C in a hydrogen-argon atmosphere with ~ 0.2 m hydrazine added as an oxygen scavenger, corrosion rates of pin specimens exposed at 10, 30, 40, and 46 ft/sec, respectively, were (in mils/year): austenitic stainless steels, 0.2, 0.3, 27, and 32; carbon steels, 6, 6, 20, and 20; and Zircaloy-2, 0, 0, 2, and 2. Coupon specimens of Armco iron contained in a variable-velocity holder displayed rates of 4 to 140 mils/year over the velocity range 6 to 52 ft/sec. Localized cavitation-erosion attack occurred on the type 347 stainless steel impeller used in the circulating pump. (AEC Activity 4103.1)

In-Pile Solution Corrosion Loops--LITR - Dismantling of loops L-2-15 and L-4-16, which were irradiated in beam holes HB-2 and HB-4, respectively, was completed. The loops contained 0.17 m enriched UO_2SO_4 and 0.015 m $CuSO_4$. The H_2SO_4 concentration was maintained in the range of 0.02 to 0.03 m. The main-stream operating temperatures were 278 and 280°C, respectively. The core specimens in loop L-4-16 were exposed to solution power densities ranging from 1 to 5 w/ml; those in loop L-2-15 were exposed to 5 to 20 w/ml. The corrosion rates of the Zircaloy-2 core-holder specimens in these loops are expressed reasonably well by the following equation:

$$CR = 1.04\ PD(1-e^{-95/CR^{1.5}}),$$

where

CR = corrosion rate in mils/year,
PD = power density in w/ml.

All previous loop experiments containing 0.17 m UO_2SO_4 were operated with a main-stream temperature of 250°C. The Zircaloy-2 corrosion-rate data from these 250°C experiments are expressed by the following equation:

$$CR = 1.25\ PD(1-e^{-6.5/CR^{1.5}}).$$

(AEC Activity 4103.1)

In-Pile Solution Corrosion Loops--ORR - The design of the LITR-type loop core was modified for the ORR loop package to provide a more uniform flow pattern and increased solution velocity in the annulus region. The increased velocity is necessary in order to avoid an excessive rise of temperature in the specimens in the high radiation fields of the ORR. The more uniform flow pattern in the annulus will make possible more reliable specimen-temperature calculations. (AEC Activity 4103.1)

Autoclave Radiation Corrosion Studies--LITR - Two in-pile autoclave experiments have employed UO_2SO_4 solutions depleted in the U^{235} isotope. These experiments demonstrated an initial positive pressure excursion which was apparent only with these two depleted uranium experiments. In considering possible causes of the pressure excursion, it appears likely that the gas which supported the increase in pressure was oxygen. Each bomb contained excess oxygen at the start, and each solution was 0.02 m in $CuSO_4$. At the very low fission power densities which prevailed, molecular hydrogen was produced at a very low rate and a negligible steady-state radiolytic gas pressure would be expected. Furthermore, many of the pressure readings were taken after the reactor had been at zero power for times sufficient to permit the recombination of any radiolytic gas which may have been present.

If it is assumed that the increase in pressure represents an increase in oxygen pressure, then it appears that hydrogen was lost from the bomb in some manner during the initial part of the exposure. This loss would leave uncombined oxygen gas within the bomb. Since the excess pressure did not persist, most of the lost hydrogen was eventually recovered within the system. No mechanism is pictured for this process at this time other than that of the metal first absorbing hydrogen and later releasing it.

An experiment employing 1.3 m UO_2SO_4 (93% enriched in U^{235}), 0.04 m $CuSO_4$, and 0.04 m H_2SO_4 was conducted. Induced Zr^{95} activity in specimens indicated a fission power density in solution of about 109 w/ml. The corrosion rate calculated from pin weight losses (23 mils/year) is in near agreement with the rate of 21 mils/year predicted by use of the equation:

$$CR = A\ PD(1-e^{-B/CR^{1.5}}),$$

where A = 0.318 and B = 95. The constants were evaluated from observations from experiments at lower power densities and at 280°C. (AEC Activity 4103.1)

GENERAL REACTOR RESEARCH

Long-Range Planning Studies - Calculations concerning reactivity lifetimes in graphite-moderated heterogeneous reactors were analyzed. Reactors fueled with natural uranium and with plutonium obtained from previous fuel cycles were found to have reactivity lifetimes of about 13,000 Mwd/ton, comparable with those obtained for reactors initially fueled with 1.15% enriched uranium. With the plutonium fuel addition the initial multiplication constant was greater than that for the enriched-uranium system, but the conversion ratio was smaller. For slightly enriched and natural-uranium-fueled systems the conversion ratio was found to go through a minimum at exposures less than 1500 Mwd/ton and then to increase with increasing exposure times. The fuel costs for graphite-uranium systems producing power were found to increase steadily with fuel enrichment. With the use of natural uranium, the fuel costs were about one-half those for systems using 2% enriched fuel.

Preliminary results obtained for reactivity lifetimes in heterogeneous reactors containing Th, U^{233}, and D_2O indicate that exposures of 10,000 Mwd/ton may be possible with the average breeding ratio equal to 1 over this exposure time. (AEC Activity 4510)

Basic Reactor Research - The relative number of neutrons released per fission of U^{233}, U^{235}, Pu^{239}, and Pu^{241} was measured by a fast-coincidence technique. The values obtained are given below, as well as values obtained by previous workers. The agreement with the value given by the KAPL group is good. The disagreement with values found by other workers is not explained.

Researchers	ν^{23}/ν^{25}	ν^{41}/ν^{25}	ν^{49}/ν^{25}
USSR	1.03 ± 0.01	1.24 ± 0.01	1.19 ± 0.01
UK	1.005 ± 0.006	1.192 ± 0.011	1.168 ± 0.011
KAPL-1464	1.017 ± 0.022	1.305 ± 0.04	1.251 ± 0.02
BNL-325	1.02 ± 0.02	1.23 ± 0.02	1.18 ± 0.02
This work	1.024 ± 0.01	1.294 ± 0.02	1.23 ± 0.01

A previously reported study on the effects of fluctuations of the neutron widths on reaction cross sections is being continued. A Monte Carlo routine was written for the Oracle which calculates the quantity

$$\left(\frac{\Gamma_1 \, \Gamma_2}{\sum_{i=1}^{N} \Gamma_i} \right) \quad \frac{\sum_{i=1}^{N} \langle \Gamma_i \rangle}{\langle \Gamma_1 \rangle \langle \Gamma_2 \rangle} ,$$

when the Γ_i are distributed in chi-squared distributions of 1, 2, or infinitely many degrees of freedom. The routine is presently being "debugged".

In order to estimate the critical buckling of bare aqueous homogeneous reactors by using the recently computed Fourier transform of the neutron slowing down distribution as the nonescape probability, it has been found that a careful estimate of the fast fissions must be made. A computation of the resonance integral for U^{235} is now being made. (AEC Activity 4520)

Volatility Studies - In the fused salt--fluoride volatility process, uranium fuel elements are dissolved in HF in a fused fluoride mixture, and the UF_4 thus formed is fluorinated to UF_6, which volatilizes and is absorbed on NaF. In a second pilot-plant run on the volatility and absorption steps, uranium recovery was 98.6%. Losses in the absorption step were less than 0.1% and in the desorption step were less than 0.3%.

In further laboratory tests on the dissolution scheme, dissolution of fuel elements containing type 347 stainless steel did not appear feasible. The dissolution rate of this steel with HF in 53-47 mole % $NaF-ZrF_4$ was very slow, even at 700°C. Chromium in the stainless steel was preferentially attacked by HF, resulting in disintegration rather than in smooth dissolution of the fuel element and metallic nickel in the resulting melts. (AEC Activity 4610)

Power Reactor Fuel Reprocessing: Aqueous Dissolution - Preliminary experiments indicated that zirconium or Zircaloy-2 claddings may be stripped from UO_2, 90% U--10% Mo, and 90% U--10% Nb cores but not from 98% U--2% Zr cores. With the U-Zr alloy, voluminous amounts of insoluble UF_4 formed. The other core materials were attacked only very slowly by HF, ~ 0.1 mg/min-cm^2, while the claddings dissolved at practicable rates, >175 mg/min-cm^2. Core dissolution rates were consistently higher in 5 M HF than in 12 M at 90°C. The temperature coefficient of dissolution in 2 M acid was negative for UO_2 and for 90% U--10% Mo alloy.

Sulfuric acid dissolution of stainless steel claddings may be feasible. The stainless steel cladding of an APPR fuel element dissolved in 6 M H_2SO_4 at a rate of 4.53 mg/min-cm^2, with ~ 0.5% uranium loss from the UO_2 core.

Further investigation of the anodic dissolution of pieces of stainless steel in 3 M HCl confirmed the fact that 1 M is about the maximum practical concentration of dissolved metal. Investigation of electrode arrangement and configuration established the fact that larger pieces of metal were preferentially dissolved only when arranged so as to shield the smaller particles from the cathode.

Zircaloy-2 was dissolved anodically in 3 N HCl with and without addition of various amounts of HF and hydrogen peroxide. Current efficiencies decreased with time and varied between 95 and 178%. A black metallic sludge formed, which amounted to about 1.1% of the total zirconium. (AEC Activity 4610)

Power Reactor Fuel Reprocessing: Darex Process - In the Darex head-end treatment, fuel elements are dissolved in aqua regia, and the chloride is removed preparatory to solvent extraction. In further laboratory studies, dissolver-

solution metal concentrations increased as the ratio of acid feed rate to surface area increased. The hydrogen-ion consumption rate was independent of feed acid composition, but the nitrate consumption rate varied with this composition.

Chloride stripping with dilute nitric acid required many more stages than stripping with azeotropic nitric acid to reduce the chloride concentration to 85 ppm. Chloride loss with the dilute nitric acid strip was ~ 20%.

Results of corrosion studies indicated that titanium can be used in construction of equipment for any part of the Darex process. Failures occurred in atmospheres containing HCl and essentially no HNO_3 or oxides of nitrogen. Tests for possible hydrogen embrittlement of titanium in the Darex dissolver were inconclusive and are continuing. Haynes 21 in the rolled condition performed relatively well in most Darex solutions. (AEC Activity 4610)

Power Reactor Fuel Reprocessing: Solvent Extraction - A solvent extraction Purex-type flowsheet was designed for processing a nitric acid solution of the U-Mo core of the APDA fuel element. Hydrofluoric acid removal of the zirconium cladding was assumed. Results of batch countercurrent tests of this flowsheet in 0.75-in.-dia pulsed columns indicated that both the first extraction-decontamination cycle and the plutonium partitioning cycle will give satisfactorily high decontamination factors and low losses for both the uranium and plutonium products. (AEC Activity 4610)

Power Reactor Fuel Reprocessing: Zircex Process - In the Zircex head-end treatment, zirconium-containing fuel elements are hydrochlorinated to form volatile $ZrCl_4$, and the residue is processed for recovery of uranium.

The hydrochlorination rates of Zircaloy-2 with HCl gas at 474°C at partial pressures of anhydrous HCl gas of 0.425 and 0.198 were 0.91 and 0.63 mg/cm^2-min, respectively. A design study indicated that the hydrochlorination temperature may be controlled by recirculation of solid $ZrCl_4$.

In corrosion studies, Haynes 21 in the rolled condition performed relatively well in most Zircex solutions. (AEC Activity 4610)

Power Reactor Fuel Reprocessing: Ion Exchange - In scouting experiments on anion exchange head-end treatment of simulated fluoride solutions of uranium fuel elements, 99.9% of the uranium was sorbed from fluoride solutions of concentrations up to 6 M. Zirconium and niobium together with 2% of the iron present were sorbed, but none of the nickel, chromium, or manganese was sorbed. Plutonium(IV) was sorbed from 2 M fluoride solution. Addition of chloride to > 6 M and reduction of the fluoride to 2 M resulted in sorption of the uranium, but not of zirconium or niobium. Both U(IV) and U(VI) were sorbed from solutions of chloride more concentrated than 8 M. None of the fission or corrosion products were sorbed.

From a sulfate solution, uranyl ion was sorbed on anion exchange resin together with zirconyl. Plutonium(IV) was weakly sorbed, but none of the stainless steel components were sorbed. (AEC Activity 4610)

Waste-Treatment Studies - Dehydration of aqueous waste containing fission products and mixing of the solids with asphalt are being considered as a means of disposal. In tests on leaching of fission products from such a mixture, the activity in agitated water surrounding the solid mass built up in 3 to 4 weeks to gross beta and gamma values of 5×10^5 and 6×10^5 counts/min-ml, respectively, and then leveled off. Apparently little or no further leaching is taking place. (AEC Activity 4620)

School of Reactor Technology - During April and May, 24 lectures on reactor systems were presented at ORSORT by 17 lecturers from reactor sites throughout the United States. As an additional part of the program of familiarization with the state of the technology, 28 lectures on ORNL reactors, components, health physics, and other related subjects were presented by 18 lecturers from other divisions of ORNL.

Formal classes for the 1956-57 session end on May 31, at which time the students will start work on summer problems. Twelve group projects and ten individual assignments have been selected for study by this class.

More than 4000 brochures were mailed to 1600 industrial organizations and government agencies in preparation for the second session of the ORSORT-University Cooperative Program. Deadline for receipt of applications is May 27, 1957.

Members of the ORSORT staff traveled more than 15,000 miles, visiting universities in the cooperative program in order to evaluate the universities' pre-ORSORT programs, improve communications with teaching staffs, and assist universities in planning for future sessions. (AEC Activity 4841)

PROGRAM 5000 - PHYSICAL RESEARCH

Reactor Operations - The rate of fuel-element failures increased sharply at the ORNL Graphite Reactor. In April and May there were 13 ruptures. At the average usage of fuel elements over the last year, the present supply may be exhausted by November 1958.

A high rate of down time at the LITR in May was due to experiments, particularly to a miniature fused salt loop in position C-46 which successfully completed over 200 hr of operation.

The Oak Ridge Research Reactor (ORR) - Construction of the reactor building, shielding, and cooling system is estimated to be 99% complete; the contractor now estimates that the building will be released to the Laboratory on about June 15, 1957. The remaining work is primarily cleanup and testing of the various components and systems.

The reactor tank sections were machined at the Portsmouth Naval Shipyard and are now being joined together to form the complete tank. The remaining work consists in assembly of piping in and around the reactor tank and overall testing of the unit.

Fabrication of the large facility plugs was started at Paducah, and fabrication of the combination collimator-plugs for the horizontal beam holes is under way in the ORNL shops.

The preassembly of the reactor mechanical drives and reactor core showed that several small modifications were desirable. The holding magnets for the shim-safety rods were redesigned and are currently undergoing tests before being installed in the assembly.

ISOTOPE PRODUCTION

Radioisotope Production - In March, twenty-eight Co^{60} teletherapy sources were fabricated, ranging in activity from 600 to 1500 curies.

In April, approximately 5000 curies of pelletized $Cs^{137}Cl$ powder was encapsulated into 123 sources. (AEC Activity 5111)

Radioisotopes, Research and Development - Phase II equipment installation at the Fission Product Processing Plant is 21% complete.

Modified steam jet siphons with a straight-through opening 1/2 in. in diameter were selected after testing for installation in the F3P crystallizers for the transfer of solutions containing 10% excess cesium and ammonium alum crystals at temperatures up to 80°C at a rate of 15 gal/min.

The versatility of manipulator cell operations was demonstrated by the fabrication and solder sealing of a 500-mc Cs^{137} source in a container 1/16-in. ID by 1/2-in. long.

Krypton-79 was separated from cyclotron-irradiated KBr and purified with calcium metal so as to be free of carrier and radioactive contaminants. (AEC Activity 5112)

Stable Isotope Production - The processing of iron to separate the isotopes (masses 54, 56, 57, and 58) was completed. Monitored ion currents indicate a total separation of 486 g of material, of which 1.17 g is Fe^{58}. The separation was performed with an Alpha-2 type ion source, collecting the separated material on copper at the rate of 168 mg/hr.

Separation of the isotopes of titanium (masses 46, 47, 48, 49, and 50) is still in progress in the Beta calutrons. To date, monitored ion currents indicate that approximately 4 g of Ti^{50} has been collected. Total collection is 75 g.

Chemical refinement was completed for a new lot of enriched Cl^{35}. Returned lots of La^{139} and Pb^{208} were chemically reprocessed and made available for distribution.

Conversions of inventory forms were made as follows: elemental B^{10} to $B_2^{10}O_3$ and $H_3B^{10}O_3$; Li^6 metal and $Li_2^7CO_3$ to the corresponding sulfates; $Cu^{63}O$ and $Cu^{65}O$ to metal; eight isotopes of tin from SnO_2 to metal. (AEC Activity 5121)

Stable Isotopes, Research and Development - Certain parts of the carbon tube furnace used in the purification of calutron graphite collector pockets were subjected to corrosion by chlorine exhaust fumes. Redesign of the exhaust system was completed. At present the attainment of temperatures in excess of 1200°C is limited by inadequacy of the power supply.

The design work on a more versatile 800 to 1000°C Beta-type ion source is essentially complete, and some of the components are in fabrication.

The preliminary work on procedures for the separation and recovery of osmium isotopes has reached the stage where a recovery method has been standardized. Ignition of graphite pockets in oxygen, collection of the resulting OsO_4 in NH_4Br, and separation of the $(NH_4)_2OsBr_6$ formed gives a product which is stable, weighable, and quantitatively recoverable. The investigation of suitable charge materials has continued, with $OsCl_4$ now appearing to be better than $OsBr_4$. (AEC Activity 5250)

PHYSICS

Neutron Velocity Selector - The new LITR time-of-flight spectrometer is nearly completed and is scheduled for installation in July. Several BF_3 gas proportional counters filled to different pressures and with different-diameter center wires have been investigated for use as detectors at the LITR. It was observed that the counters exhibit multiple peaks in their differential pulse-height distributions at high gas multiplication. A teletype printer was installed in the 256-channel analyzer, and a data analysis code is now being prepared for the Oracle. (AEC Activity 5220)

High Voltage Program - Cross sections from threshold to 500 kev above threshold for (p,n) reactions in 12 intermediate nuclei having atomic weights from 37 to 93 were measured by a 4π detector. The detector was calibrated indirectly through a manganese bath to a standard Sb-Be source. These cross sections have been described by the statistical theory of the compound nucleus. If a black nucleus is assumed, the radius required is $1.5 \pm 0.05A^{1/3} \times 10^{-13}$ cm except for $65 \leq A \leq 82$. In that region a larger radius would be required; or, alternatively, a strength function about twice that of a black nucleus is indicated.

The millimicrosecond time-of-flight spectrometer was employed to measure neutron total cross sections of selected isotopes in the 2- to 20-kev range. Results are as follows, where the mannger of presentation is isotope: E_o (kev), Γ(ev); K^{39}: 3.4 (12), 9.2 (60); K^{41}: 5.4 (35), 16.2 (60); Rb^{85}: 3.3 (-), 4.1 (18), 4.9 (34), 5.8 (33), 6.9 (17), 9.0 (-); Rb^{87}: 5.0 (46), 6.6 (17), 7.35 (54), 8.55 (170); Sr^{86}: ~ 3.0, 4.3, 11.3; Sr^{88}: 13.65 (400); Y^{89}: 2.5 (6), 7.35 (55), 11.25 (60), 14, 17; Bi^{209}: 2.28 (24). The resonance at 2.8 kev in Na^{23} was found to have a peak cross section of 380 barns, corresponding to J = 1. A single-level Breit-Wigner fit of this level implies $\ell = 1$, in agreement with Block and Macklin (private communication) and with Harwell (ORNL-2309), and a width of about 375 ev. Some discrepancy exists between the measured width and the width derived from the Breit-Wigner fit.

A study with the millimicrosecond time-of-flight spectrometer is being made of primary neutrons from (d,n) reactions in light elements. One of the more interesting recent results concerns the level at 7.65 Mev in C^{12}. The corresponding group of neutrons from $B^{11}(d,n)C^{12}$ has been observed, and the angular distribution of these neutrons indicates stripping with $\ell = 0$. This result will remain tentative until more accurate detector efficiency data are obtained. (AEC Activity 5220)

CHEMISTRY

Ion Exchange Studies - A gear pump or a single-piston pump was used to move the resin in the smaller models of the Higgins continuous ion exchange contactor. These pumps did not appear feasible for moving the large bulk of resin in the 36-in.-dia column and a hydraulic accumulator was installed. In a 120-hr test the contactor was satisfactorily pulsed for time intervals of 1, 2, 3, 5, 7, 8, and 10 sec at pulse pressures of 20, 30, 40, 60, and 80 psig. For pulse pressures of 60 and 80 psig the slip-water ratio for all time periods was 2.0 or lower, which is in the desirable range.

Permutit SK (10 to 20 mesh) anion exchange resin did not decrease in ionic capacity or change in mechanical properties when it was subjected to 940 gamma watt-hours of radiation (3.5×10^8 r) per kilogram of dry resin. (AEC Activity 5310)

Chemical Engineering Research Studies - The separation factor of a hydroclone was affected appreciably by the type of pump and piping arrangement used in a pump-hydroclone mixer-settler solvent extraction contactor. Separation factors for a three-stage centrifugal pump were only about half those for a turbine pump. (AEC Activity 5310)

High-Level Nuclear Chemistry - In connection with the eventual large-scale recovery of neptunium in reactor fuel processing, an understanding was needed of the erratic "spontaneous" extraction which occurred recently for short periods in several extraction plants. Equally great importance as to solvent saturation and acid concentration was finally assigned to the trace quantities of nitrous acid which may be present as a normal part of the feed adjustment, as a result of the dissolution process, or as a result of radiation decomposition of nitrate.

It was shown in laboratory-scale demonstrations that nitrous acid added to feed solution containing neptunium promotes TBP extraction as Np(VI) without regard to its original oxidation state. When nitrous acid is added to Np(VI), an immediate reduction to Np(V) occurs, giving an initial low extraction coefficient. However, this is followed by a gradual increase in extractability as Np(VI).

In cooperation with the Chemical Technology Division's operation of the Metal Recovery Plant, an actual test of the behavior of nitrous acid was recently made when one special lot of feed material, free of nitrous acid and showing poor extractability, was adjusted with 0.05 M $NaNO_2$ in the column scrub. Immediate extraction was obtained and was shown to stop following removal of the nitrite. An explanation of this behavior in terms of an equilibrium of mixed states is being considered. (AEC Activity 5330)

Chemistry of Corrosion - A new apparatus was constructed and techniques were developed for the measurement of the d-c polarizability of zirconium electrodes in highly purified solutions and over an extremely wide range of current densities. Measurements were made in sulfuric acid and in sulfuric acid--sodium fluoride solutions at 25 and 85°C. Immediately after immersion in the solution, freshly prepared electrodes, upon cathodic polarization, exhibit the usual kinetics of hydrogen evolution with a Tafel slope of 0.12. After electrodes are exposed to oxygenated solutions or are allowed to stand in deoxygenated solutions for several days, a much more complex Tafel slope is obtained with unusually high overvoltages. (AEC Activity 5330)

Chemistry of Technetium - The ultraviolet and visible spectra of K_2TcCl_6 were measured. Absorption maxima occur at 2400, 3070, 3380, and 7050 Å, with molar extinction coefficients of 1.89×10^4, 6.56×10^3, 1.10×10^4, and 4.2, respectively. The solution (5.09×10^{-5} M K_2TcCl_6 in 1 M HCl) used for the ultraviolet spectra was not stable to hydrolysis; after a month the over-all absorption had decreased approximately 60%. A similar concentration of K_2ReCl_6 showed essentially no hydrolysis.

A previously unobserved strong absorption band was found in K_2ReBr_6 at 2180 Å with a molar extinction coefficient of 2.19×10^4; 1 M HCl instead of 1 M HBr was used, making measurements possible at lower wavelengths. No exchange between bromide and chloride was observed. The solution used (5.77×10^{-5} M K_2ReBr_6 in 1 M HCl) is unstable with respect to hydrolysis.

A spectrophotometric study of the reaction between TcO_4^- and hydrochloric acid was initiated. Preliminary results indicate that with 12 M HCl some of the technetium goes to a species intermediate between Tc(VII) and Tc(IV), probably Tc(V).

Rhenium(V) was prepared in 12 M HCl by reduction of ReO_4^- with H_3PO_2. The ultraviolet and visible spectra are identical with the Re(V) spectra obtained elsewhere by polarographic reduction in 8 M HCl. (AEC Activity 5330)

High-Temperature Aqueous Solution Chemistry - Studies of the hydrogen-oxygen reaction, homogeneously catalyzed by dissolved copper in aqueous solutions at elevated temperatures, were directed toward the determination of the detailed kinetics of the reaction. The previously established relationship between the geometry of the system and the observed rate of pressure decrease due to reaction was utilized to calculate the apparent hydrogen solubility and the catalytic activity of the solution. In the sulfate system (cupric sulfate--sulfuric acid--water) at 175°C and above 0.04 m acid, the apparent solubility of hydrogen thus calculated is several times as great as the reported solubility of hydrogen in water, is directly proportional to the square root of the cupric sulfate concentration, and is inversely proportional to the sulfuric acid concentration. The catalytic activity of the solution was found to be directly proportional to the cupric sulfate concentration and independent of the sulfuric acid concentration.

With the new high-temperature isopiestic unit, relative osmotic coefficients (compared with KCl) were obtained for the alkali chlorides and bromides, NaF, Na_2SO_4, $MgSO_4$, and UO_2SO_4 for one set of conditions at 91.5°C and one at 104.6°C. Osmotic coefficient ratios relative to KCl were also calculated from data in the literature at 25°C. From these figures and the few data in the literature on NaCl and KBr at elevated temperatures, it was concluded that the osmotic coefficients of the alkali halides, except for lithium salts and NaF, change relatively little with temperature; that the coefficients for lithium salts, NaF, and Na_2SO_4 increase significantly with temperature; and that the coefficients for $MgSO_4$ and UO_2SO_4 decrease markedly with increasing temperature. (AEC Activity 5330)

Chemical Separation of Isotopes - Single-stage separation factors for both oxygen and nitrogen isotopes were measured for two exchange systems involving NO. In the first experiment, NO gas was equilibrated with liquid NOCl for 4 hr at -50°C in a system designed to prevent the NOCl from coming in contact with any greased joints. In the second experiment, NO was equilibrated with an aqueous solution of $(FeNO)^{++}$ for 2-2/3 hr at 14°C. The mass spectrometer analyses performed on NO gave the following single-stage separation factors (95% C.I.):

$$\frac{NO^{16}}{NO^{18}} \Big/ \frac{NO^{16}Cl}{NO^{18}Cl} = 1.011 \pm 0.002 \qquad \frac{NO^{16}}{NO^{18}} \Big/ \frac{(FeNO^{16})^{++}}{(FeNO^{18})^{++}} = 1.000 \pm 0.002$$

$$\frac{N^{14}O}{N^{15}O} \Big/ \frac{N^{14}OCl}{N^{15}OCl} = 1.013 \pm 0.003 \qquad \frac{N^{14}O}{N^{15}O} \Big/ \frac{(FeN^{14}O)^{++}}{(FeN^{15}O)^{++}} = 1.011 \pm 0.004$$

(AEC Activity 5340)

METALLURGY

High-Temperature Reactions of Metal and Ceramics - Measurements are being made of the optical absorption spectra of fused salt solutions in order to assist in the elucidation of the electronic structures of these materials, with emphasis on the electronic structures of complex ions in fused salt melts. The system under current study is anhydrous $NiCl_2$ dissolved in the (Li,K)Cl eutectic. Measurements were made over the temperature range from 360 to 550°C, the concentration range of 0.0134 to 0.414 M $NiCl_2$, and the wavelength range of 220 to 750 mμ.

The absorption spectrum of nickel ions in this system was found to consist of five bands, I at about 260 mμ, II at about 510 mμ, III between II and IV, IV at about 625 mμ, and V at about 700 mμ. The absorption constant for band I was shown to be very large, almost 60 cm^{-1} for a $NiCl_2$ concentration of 0.016 M at 400°C, whereas remaining bands had absorption constants of the order of unity under similar conditions. The absorption constants were found to be proportional to the nickel concentration at constant temperature, as would be expected if all light-absorbing species derived from $NiCl_2$ were in equilibrium at constant temperature. The absorption coefficients also varied with temperature. Preliminary calculations based on this temperature variation indicate that at least two light-absorbing species are present in this solution and that the relative amounts of these species change with temperature. (AEC Activity 5420)

PROGRAM 6000 - BIOLOGY AND MEDICINE

BIOLOGY

Cytology and Genetics - It was found possible, by cytological observation of dividing cells, to determine the proportion of mouse and rat cells in bone marrow, spleen, lymph node, and thymus in lethally irradiated mice injected with rat bone marrow. Cytological preparations were made by the method of Ford and Hamerton (Stain Tech. 31, 247, 1956). Mouse and rat dividing cells are easily and unambiguously distinguished on the basis of chromosome morphology. The bone marrow and spleen are almost pure rat by the 7th day postirradiation. The thymus, however, remains pure mouse until about day 9, passes through the 50% point on day 18, and is pure rat by about day 21. There had been some doubt that injected bone marrow cells could repopulate the thymus (or other lymphatic tissue); apparently they can. (AEC Activity 6130)

Cytology and Genetics--Insects - A strain of *Drosophila melanogaster* was isolated which has the unusual property of causing the death of progeny from that strain, when such progeny carry chromosomes that are defective structurally. There is reason to believe that this strain differs from the normal in that the spindle apparatus produced during mitosis is subnormal, and that the defective (poorly transmissible) chromosomes are unable to reach opposite poles properly during cell division, and consequently death results. Careful selection over a number of generations yielded a strain which is uniform in its characteristics, and it has been possible to carry out a number of simple genetic tests designed to locate the factor or factors responsible. Curiously, it has not been possible to show any association of these factors with either the major autosomes, or the sex chromosome. Furthermore, the ratios of different types appearing when this strain is crossed in various ways with normal strains are unusual, not resembling ordinary Mendelian ratios. It is suspected that the factor may not be genic, but instead is associated with defective centrioles in the cell. If further tests now under way confirm these results, it appears that another major component of the living cells will be brought under experimental control. This will have a significant bearing not only on the study of the biological mechanisms involved in the proliferation of living cells, but may also have an immediate application in radiation studies where damage to the spindle mechanism has, up until now, been impervious to a detailed study. (AEC Activity 6130)

Pathology and Physiology - Comparison of the life span of mice exposed to fast neutrons from an experimental nuclear detonation (Operation Greenhouse) or from the ORNL 86-inch cyclotron with that of mice exposed to gamma rays indicates that low-energy fast neutrons are about twice as effective as gamma rays in reducing longevity. Since neutrons from the 86-inch cyclotron were also observed to be about twice as effective as gamma rays in causing 30-day lethality in mice, it appears that for both early and delayed mortality of mice the relative biological effectiveness (RBE) of fast neutrons is essentially the same. Under conditions of chronic irradiation, however, the RBE of fast neutrons has recently been observed to be appreciably higher, approaching 10 or more at low intensities, indicating that the RBE varies inversely with the rate at which the animals are exposed.

After the injection of Myleran (1,4-dimethanesulfonoxybutane) into rats, the bone marrow becomes aplastic, most of the animals dying from marrow damage within 3 weeks after a single dose of 20 mg/kg. When the rats treated with Myleran are injected 4 days later with isologous bone marrow, they are saved; however, when homologous marrow is injected, about 80% die. The failure to obtain 100% recovery with homologous marrow is attributed to rejection of the injected foreign cells by the immune mechanism of the recipient. These observations suggest that for the same degree of marrow damage Myleran causes relatively less depression of immunity than x irradiation. (AEC Activity 6130)

Cell Physiology - The heavy component of rat serum was isolated by repeated ultracentrifugation. In free solution, it was found to move electrophoretically as an alpha protein. Paper electrophoresis showed it to behave as a

gamma globulin since the protein adheres to paper. Ultracentrifugal analysis gave a sedimentation constant of 19.7 Svedberg units in water extrapolated to zero concentration. The concentration of 19.7 S protein was followed for 11 days in rats irradiated with 950 r. No change was observed. A new technique for observing refractive index gradients in ultracentrifuge tubes was devised to facilitate removal of various fractions. Following the discovery, in this laboratory, that proteins sediment more rapidly through starch than in free solution, a new method of separating proteins, termed "ultracentrifugal micro-decantation", was devised. Application of the principles to isotopic separation has been unsuccessful with lithium, but further experiments with heavier elements are planned. (AEC Activity 6130)

Biochemistry - S,2-Mercaptoethylguanidine·HBr (MEG), prepared from S,2-aminoethylisothiuronium·Br·HBr, is effective in providing survival to mice when given intraperitoneally prior to an otherwise lethal dose (500-1200 r) of x radiation. Examination of a series of mercaptoalkylguanidines yielded several compounds with a wide range of effectiveness and correlated chemical structure with protective activity. Determination of the distribution of several effective S^{35}-labeled compounds established that the spleen, bone marrow, and liver were the most highly labeled tissues. Intracellular distribution was therefore investigated to determine whether any selective absorption occurred. Nuclear, mitochondrial, microsomal, and soluble cytoplasmic fractions of the liver were prepared by the procedure of Hogeboom and Schneider, and the activity, dry weight, and nitrogen content of aliquots of these fractions were determined. When MEG-S^{35} was injected and the liver removed 45 minutes later, a preferential distribution of the activity was observed. When a pair of optical isomers--injected at the dose where the D isomer was effective and the L isomer ineffective--was examined, it was found that the activity of the microsomal fraction obtained with the D isomer was twice that of the L isomer. Doubling the L isomer dose (an effective protective level) increased the activity of the microsomal fraction to that of the D isomer. Similar results were obtained with C^{14}-labeled compounds. The major activity of all particulate fractions was tightly bound and could not be removed by dialysis against cyanide. (AEC Activity 6130)

Enzymology and Photosynthesis - We have shown previously that dried chloroplasts behave as semiconducting crystal. A preliminary determination was made of the distribution of electron trap depths necessary to explain the glow curves. This analysis shows that there are at least five different traps involved in the storage of light energy. It is planned to present these measurements at the Symposium on the Photochemical Storage of Energy, sponsored by the National Research Council of the National Academy of Science in Dedham, Massachusetts, this September. (AEC Activity 6130)

Biophysics - Paramagnetic resonance techniques are being applied to the study of radiation protection phenomena. The presence of the protective compound S,2-aminoethylisothiuronium (AET) in *Escherichia coli* reduces the free radical content of these cells as compared to unprotected controls. This reduction in free radical content may be correlated with increased survival of protected cells. Later experiments have shown, in addition, a change in the shape of

the resonance curves when the protective compound is present. A possible meaning of this result is that a new radical has been formed through the intermediacy of the AET. This new radical then shows a characteristic difference such that resonance does not occur at precisely the same magnetic field strength as for other radicals in the cell. Experiments are now in progress to test the validity of this hypothesis.

Comparisons of the elaborate calculations of the 14-Mev dose-rate-to-flux ratio and LET spectrum in tissue are being made with measurements in other laboratories. The dose-rate-to-flux ratio is very close to that measured at Los Alamos. There is qualitative agreement with a test of the LET spectrum measurements at Columbia. Possible explanations of the differences are under investigation. The accelerator has been in regular operation for studies on genetic effects in Drosophila virilis (both d-d and d-t neutrons), tumors in mice, recovery from radiation injury in mice, and Tradescantia buds previously heat treated to induce mixed diploid and haploid microspores. An optional auxiliary low-current regulating circuit has been put in operation on the G-E Maxitron x-ray machine to make studies possible at one-tenth to one-fiftieth the previous dose rates without change in beam quality. (AEC Activity 6130)

Microbial Protection and Recovery - In an effort to determine the radiosensitive critical stages in the bacterial cell division process, synchronous cultures are being employed. In order that the irradiation period be relatively short as compared with the duration of the cycle, x rays are being used at 8000 r/min, with an irradiation time of 2 or 3 min. To date the technique has consisted in inoculating a thymineless medium with logarithmic phase cells of the 15_{T-} strain and, after an incubation period of 30 min in the absence of thymine, this nucleic acid precursor is added (2 μg/ml) to the culture, and the culture is then incubated for an additional 60 min. At 10-min intervals an aliquot is removed for determination of ribonucleic acid, deoxyribose nucleic acid, and cell titer. Simultaneously, a small aliquot is removed and irradiated, and the surviving fraction of cells is determined by plate count. In an attempt to maintain the irradiated cells under similar conditions as the mass culture, the irradiation is carried out at 37°C with aeration. In several preliminary experiments rather dramatic differences in the surviving fraction of cells at a constant x-ray dose have been obtained, and every attempt is being made to obtain sufficient data to permit a correlation with measurable synthetic processes in these cells. It will be necessary in future experiments to reduce the exposure time and increase the frequency of sampling the culture for radiosensitivity. It is also important now to measure protein synthesis in these cells, which will require an increase in size of sample and therefore an increase in total volume of culture.

The relation of aerobiosis and anaerobiosis to the survival of and the retentivity of potassium in irradiated baker's yeast was explored. Under anaerobic condition survival is exponential with a dose-reduction factor of about two as compared with aerobic irradiation. On the other hand, potassium retentivity shows a very peculiar relationship. Aerobically irradiated cells show exponential loss of retentivity with dose, while anaerobically irradiated

cells show only slight loss of retentivity up to 160 kv, where the curve breaks sharply and proceeds with a slope essentially like that of aerobically irradiated cells. The nature of this curve is being explored.

The heminless strain of E. coli is unique among the strains so far tested in this laboratory in that one can readily show an extracellular indirect effect of x and gamma rays, the magnitude of which can be as large as or larger than the intracellular effect, depending on the length of time irradiated cells are held in the presence of irradiated medium. It is now established that the "after effect" can be removed by dilution or by washing irradiated cells and resuspending in nonirradiated medium. Water or phosphate buffer irradiated, without cells present, will bring about the after effect on irradiated cells suspended therein. Preliminary experiments indicate a lethal effect of irradiated medium on nonirradiated cells. There are basic similarities between this bacterial system and the bacteriophage system with respect to ionizing radiation. The nature of the toxic substances produced in irradiated water or buffer which brings about the "after effect" is now being studied. (AEC Activity 6230)

Mammalian Recovery - Further studies on the thymus of irradiated mice treated with rat bone marrow showed by agglutination tests that it contained rat-type thymocytes for at least 284 days after exposure. Pathologic studies indicated that changes developing within seven days after treatment in the lymph nodes of irradiated mice treated with foreign bone marrow were characteristic of the foreign bone marrow experiment.

Effective suspensions of bone marrow cells were maintained at 25°C for 24 days. A 28-day culture was not effective. CF1C9 cells derived from bone marrow that gave slight prolongation of survival time on preliminary tests were not effective when tested more extensively.

Separation of isologous bone marrow cells was studied by centrifuging bone marrow on a density gradient. The layers obtained were effective in causing recovery of lethally irradiated mice. Concentration of effective cells was not obtained in these preliminary experiments.

Electrophoresis studies revealed that the change in the albumin-globulin (A/G) ratio of sera of lethally irradiated mice treated with rat bone marrow coincided with the change in the body weight pattern. During the most critical period of the delayed foreign bone marrow reaction, the decrease in the A/G ratio was found to be due to an absolute increase in the gamma globulin and a decrease in albumin.

Further studies on the effect of varying doses of x rays on the delayed death pattern of mice treated with a constant dose of rat bone marrow showed that the time of delayed foreign bone marrow death is a function of the x-ray dose. When mice were exposed to a constant dose of x rays and treated with varying doses of rat bone marrow, it was found that the mortality did not increase with increase in the bone marrow dose. These results are consistent with our hypothesis that the delayed foreign bone marrow is due to an antibody-antigen reaction involving the host antibody-producing cells and the transplanted foreign bone marrow. (AEC Activity 6230)

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Duncan, J. F., University of Melbourne, Australia
Frauenfelder, H., University of Illinois (Swiss Citizen)
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Hsu, T., Taiwan Cement Corp., Taiwan
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Kawaguchi, M., Purdue University (Citizen of Japan)
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RADIOISOTOPE SALES AND COSTS

Type of Transaction	April 1957	FY 1957 to Date
Domestic Sales	$177,771	$1,626,590
Foreign Sales	47,585	153,089
Project-Transfer	1,566	12,275
Project-Cash Sales	7,066	55,191
Technical Co-operation Program Credits	0	3,395
Plant Credits	3,633	30,721
AEC Credits	13,765	172,142
Total Radioisotope Income	$251,386	$2,053,403
Total Radioisotope Costs	$129,564	$1,240,229
Total Radioisotope Shipments	1,288	11,377
Helium		
Income	$13,365	$38,517
Costs	53	3,262
Shipments	7	32

GROSS OPERATING COSTS

	Cost for April	FY 1957 Cost to Date
Programmic Operating Cost - Net	$4,133,564	$42,839,828
Equipment	225,844	2,150,923
Construction	203,907	1,614,478
Work for Others - Transfers	52,595	564,381
Inventory Changes	(39,633)	(57,799)
Reimbursable Work for Others	64,738	697,242
Deferred Charges	(2,148)	(255,355)
Total Laboratory Cost - Net	$4,638,867	$47,553,698
Estimated Cost for Next Month	$5,000,000	$52,533,698

Credit ()

PERSONNEL SUMMARY

	Number of Employees May, 1957	New Hires May	Terminations May
Administration	71	1	2
Operations*	132	0	0
Engineering, Shops, and Mechanical	862	3	3
Laboratory and Research	2195	31	24
Protection	117	0	0
Service	373	5	6
	3750	40	35

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

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

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Reports in this series issued during the past year:

May 1956	ORNL-2109
June 1956	ORNL-2123
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

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