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Progress

AEC RESEARCH AND DEVELOPMENT REPORT

OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

MARCH 1955

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
CARBIDE AND CARBON CHEMICALS COMPANY
A DIVISION OF UNION CARBIDE AND CARBON CORPORATION

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

March, 1955

F. T. Howard

and

W. H Sullivan

Date Issued: APR 7 1955

OAK RIDGE NATIONAL LABORATORY
Operated by
CARBIDE AND CARBON CHEMICALS COMPANY
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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

March, 1955

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STATUS AND PROGRESS REPORT

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

March, 1955

This status and progress report presents material on approximately one-half the Laboratory's program, which is covered, with some exceptions, on a bimonthly schedule.

PROGRAM 2000 - SOURCE AND FISSIONABLE MATERIALS

Metallex Process - In further studies on the Metallex process, 25 lb of thorium metal, in the form of a 1% thorium quasi amalgam, was produced by sodium amalgam reduction of $ThCl_4$ in propylenediamine. From this amalgam, a 15% thorium amalgam cake was produced by a combined filtration-pressing operation in a Carver pressure filter. All but a few parts per million of mercury was removed from the pressed pieces by vacuum-retorting at a temperature above 1000°C. The product thorium was sintered to a density approaching theoretical and was not pyrophoric. Small quantities of this metal were arc-melted, and, on the basis of a limited number of tests, appeared to be of the desired quality.

In small-scale experiments, solid anhydrous $ThCl_4$ was reduced with sodium amalgam. Yields varied from 0 to 90%, and the optimum combination of variables has not yet been determined. The experimental variables were: temperature, 25° to 350°C; contact time, 5 min to 5.5 hr; sodium excesses, 7 to 145%. Various types of laboratory mixing equipment were used. Tentative specifications for $ThCl_4$ to be used in this process are: Cl/Th atom ratio greater than 3.8, water, less than 0.5%, and less than 5% insoluble in anhydrous methanol.

Thorium tetrachloride, in 0.5-kg batches, was prepared in 99% yield by a 2.5-hr chlorination of thorium oxalate at 600° to 650°C. The chlorinating agent was 15-85 mole % CCl_4-Cl_2. Equipment was installed for performing this process continuously on a 20-lb/day scale. (AEC Activity 2132)

Waste Metal Recovery - A modified Purex flowsheet is being used in the recovery of 13.5 tons of uranium and 3.3 kg of plutonium from Brookhaven reactor fuel elements. This program will be completed April 15, and irradiated slugs from the ORNL graphite reactor will then be processed to recover about 60 tons of uranium and 7 kg of plutonium. (AEC Activity 2344)

Excer Program - As a result of studies of moving-bed techniques made in the Excer program, the Fluorox process for preparing UF_6 from concentrated uranium solutions or solids was developed. The flowsheet provides for three steps: feed preparation, which includes conversion of the uranium solution or solid to a compound that can be fluorinated and pelleted; simultaneous

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hydrofluorination and reduction to UF_4 with NH_3 and HF; and oxidation by air or oxygen of the UF_4 to UF_6 + UO_2F_2, the latter being recycled. This last step, which eliminates the need for using free fluorine, should cut costs considerably.

The pelleting procedure was demonstrated on a production scale and the satisfactory denitration of uranyl nitrate to UO_3, a compound suitable for feed to the process was demonstrated on a 25-lb/hr scale (ORNL-1849). A pilot plant for the denitration is being designed. Simultaneous hydrofluorination and reduction of the UO_3 pellets thus prepared was performed with HF and NH_3 at 700°C on an 8-lb/hr scale. In preliminary studies, dry air was passed over UF_4 pellets in a vertical moving bed reactor at 800°C to form UF_6 and porous uranyl fluoride pellets. The uranyl fluoride was repelletized with 50% UO_3 or 50% ammonium diuranate, to form material suitable for recycle. (AEC Activity 2602)

PROGRAM 3000 - WEAPONS

Neptunium Recovery - Preliminary investigation with Np^{239} tracer indicated that more than 99% of the neptunium and uranium may be recovered from depleted MTR fuel elements by a modified 25 process. The tentative flowsheet conditions are: feed, 1.8 M $Al(NO_3)_3$, 0.25 M HNO_3, 0.005 M ferrous sulfamate; scrub, 1.8 M $Al(NO_3)_3$, 0.5 M HNO_3, 0.005 M ferrous sulfamate; extractant, 6% tributyl phosphate in a hydrocarbon diluent. The ferrous sulfamate reduction of the neptunium and plutonium to the tetra- and trivalent states, respectively, results in the efficient extraction of neptunium without plutonium. Losses to the aqueous waste stream were 0.02% for both the neptunium and uranium. Fission product decontamination data have not yet been obtained. (AEC Activity 3641)

RaLa Production - Run No. 59 was started on March 1, and 20,000 curies of product was shipped on March 8. Measurements made by Los Alamos showed there was less than 20,000 curies, but the quality of the product was satisfactory and the amount was sufficient for their needs. (AEC Activity 3702)

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test - The contractor completed all the work previously contracted for to construct the reactor cell. During the month it was decided that the contractor would assume responsibility for a number of items which previously had been planned for execution by ORNL forces. The additional work includes (1) installation of anchor bolts to strengthen the main columns of the cell, (2) installation of all lines which penetrate the four walls of the reactor tank, (3) construction of the west steam valve pit and the east waste valve pit, (4) Amercoating of all interior surfaces in the cell, and (5) installation of the reactor steam system. Because of this additional work, the contractor's time will be extended to about September 1, although the steel reactor pit is scheduled for completion and transfer to ORNL forces about July 1.

The fabrication of reactor components is on schedule, and it appears that all components will be on hand and ready for installation when the steel cell is finished. According to the new schedule, the installation of prefabricated reactor components will begin in July, while the contractor is installing the steam system outside the reactor building. (AEC Activity 4109.11)

Homogeneous Reactor Analysis - The HRT was analyzed with respect to its stability against "walk-away". The results indicate stability at average core temperatures below 290°C at 5 Mw, and below 270°C at 10 Mw if enough copper is used to recombine all the gas produced in excess of the corresponding to 1-Mw operation. If decomposition gas is never produced, the HRT will not "walk-away". If a small amount of decomposition gas is produced, parameter values can be adjusted to increase stability. The effects (upon reactor stability) of changes in the fuel pump feed rate, over-pressure, ratio of mass of fuel solution in the high-pressure system to that in the low-pressure system, and the rate of addition of pure heavy water to the high-pressure system have all been analyzed over a range of values. Any procedure which keeps the fuel concentration from rising will restrain "walk-away". Of the parameters investigated, over-pressure had the greatest influence upon stability conditions; stability increased with increasing over-pressure.

The analysis of the economics of one-region thorium power-breeder reactors is essentially complete. Where possible, the same bases were used as in the two-region studies so that direct comparison of the two reactor types can be made. The apparent optimum-cost reactor was one about 12 ft in diameter, operating with 260 g Th/liter and a chemical processing cycle of about 450 days. The unit cost of electricity was rather insensitive to fairly large changes in process variables. The unit cost is 0.9 mill/kwh higher than the optimum two-region reactor, if the fixed costs for both reactor types are considered equal.

Continued studies on HRT safety indicate that the 400A pump should be stopped if the steam pressure on the shell side of the core heat exchanger drops at a rate greater than 20 psi/second. Such a rate corresponds to a reactivity rate addition of 0.005 Δk_e/second.

An expression for the (n,2n) cross section of fissionable nuclei was derived and applied to the TBR to give the ratio of U^{232}/U^{233}. For an average thermal blanket flux of 5×10^{13} n/cm^2-sec and a chemical processing cycle time of 120 days, the U^{232}/U^{233} ratio was estimated as 4×10^{-5} atoms/atom. The ratio is roughly directly proportional to the thermal flux and the chemical processing cycle time. (AEC Activity 4109.2)

HRP Chemistry--Radiation Corrosion - Exposure of three additional "rocking-bomb" experiments in the LITR was completed. The experiments and the results of the oxygen depletion measurements are summarized below. All of the irradiations were done in the HB-6 facility with the exception of experiment Z-3, which was in the HB-5 facility. The exposure temperature was 250° in each case.

(H-76) - This experiment was with a titanium bomb. The test solution was 0.16 M in UO_2SO_4 (93% enriched in U^{235}), 0.02 M in $CuSO_4$, and 0.04 M in H_2SO_4. The radiation exposure period of 1871 Mw-hr of LITR operation. The overall corrosion rate under irradiation was 1.7 mpy (mills per year) compared with 6.4 mpy for a Zircaloy-2 bomb under the same conditions.

(Z-8) - This experiment was with a Zircaloy-2 bomb. The solution initially charged was the same as that for H-76 except that 195 ppm of Cr (VI) was present. The radiation exposure period was 1105 Mw-hr. The overall corrosion rate under irradiation was 5.7 mpy versus 6.4 mpy for the comparable experiment without added chromium.

(Z-3) - This experiment was with a Zircaloy-2 bomb. The test solution was 0.16 M in UO_2SO_4 (20% enriched in U^{235}), 0.02 M in $CuSO_4$, and 0.44 M in H_2SO_4. The radiation exposure period was 1387 Mw-hr. It is estimated that, because of the lower enrichment, the fission power density in this bomb at a given pile power was a factor of 2 less than that for the above experiments. The overall corrosion rate under irradiation was approximately 2.2 mpy.

(Z-5) - This experiment, to test the effect of power density on the corrosion of Zircaloy-2, is in progress. The test solution is the same as that for H-76 except that the uranium employed is 45% U^{235} and the solution contains no added acid. After approximately 300 hours of irradiation at a reactor power of 3 Mw the overall corrosion rate under irradiation is approximately 5 mpy.

The design of a rocking bomb experiment for insertion in the MTR to study the effect of high fission density on the corrosion of Zircaloy-2 by uranly sulfate solutions is essentially complete. Detailed drawings are being completed and fabrication has started. The insertion is tentatively scheduled for the first MTR shutdown in May.

Equipment is under construction for out-of-pile studies of the corrosion of stainless steel by uranyl sulfate solutions which are free of Cr(VI) and by others which contain controlled low concentrations of the ion. (AEC Activity 4109.31)

Laboratory Service Corrosion Tests - HRP-specification boiling nitric acid tests of austenitic stainless steels for HRT use were completed on 109 materials not tested by the vendor. Sixty-five percent of the submitted specimens passed this test, which evaluates the general quality of the metal, the adequacy of columbium stabilization when present, and the sensitivity to heat effects and welding.

Sustained and more nearly complete corrosion inhibition of simulated HRT maintenance pool water was obtained by increasing the sodium chromate concentration from 50 ppm to 300 ppm. Although 50 ppm was effective for a moderate period, rusting of iron-copper and other couples began after several weeks exposure in inhibited stagnant tap water. This behavior was not observed under similar conditions with 300 ppm sodium chromate added. Visibility was very satisfactory through 15 ft of tap water containing 300 ppm sodium chromate.

Partially-hardened (heat treated 2 hr at 1000°F) type-17-4PH stainless steel, to be fabricated into core bolts for the HRT, showed good corrosion resistance after 500 hours in (a) aerated, boiling 0.04 $\underline{m}$ UO_2SO_4 with 0.006 $\underline{m}$ H_2SO_4, (b) oxygenated 0.04 $\underline{m}$ UO_2SO_4 with 0.006 $\underline{m}$ H_2SO_4 at 250°C, and (c) this solution at 300°C. The specimens, stressed at room temperature to 80,000 psi, showed no evidence of stress corrosion cracking or pitting during this period. The corrosion resistance of fully hardened types-17-4PH and 17-7PH stainless steels remained unsatisfactory, however, after 2000-2300 hours in aerated, boiling solutions of: (a) 0.02 $\underline{m}$ UO_2SO_4 with 0.005 $\underline{m}$ H_2SO_4, (b) 0.17 $\underline{m}$ UO_2SO_4, and (c) 1.3 $\underline{m}$ UO_2SO_4. Corrosion rates for specimens which had not been defilmed ranged between 2 and 75 mpy; frequent cracking and blistering were observed. Corrosion rates of non-hardened specimens were not greater than 0.1 mpy (undefilmed) under any test condition. In similar oxygenated solutions at 250° and 300°C, corrosion attack after 1100 hours, though more severe on the fully hardened specimens, was not nearly as intense as at 100°C, being less than 1 mpy (undefilmed) for the hardened specimens. An exception was a specimen of 17-4PH in 1.3 $\underline{m}$ UO_2SO_4 at 250°C; it had a corrosion rate of 10 mpy.

Corrosion of type-347 stainless steel by thorium oxide (100 g Th/kg water) slurries, circulated at 250°C, 26 fps, and 100 psi oxygen for 1 week in type-347 stainless steel toroids, was less than 7 mpy for oxides from 9 different sources. Titanium 75A and Zircaloy-2 corrode less. Due to charges in colloidal properties, however, some of the slurries could not be poured from the toroid after the run. (AEC Activity 4109.4

HRP In-Pile Loop - Loop FF, containing Zircaloy-2 corrosion specimens, was dismantled and is being examined. Preliminary data indicate negligible attack on the "in-line" specimens but measurable attack on the core specimens. Corrosion rates, based on measured weight losses and total circulation time, are 2.3 mpy for the specimen in the forward position in the core and 0.7 mpy for the specimen in the rear. The rates for specimens in intermediate positions are between these extremes. The LITR was held at 3 Mw for approximately two-thirds of the total circulation time. Hence, the calculated corrosion rates based on radiation time are 50% greater than the above values.

A third loop, designated GG, is now in operation in the LITR. This loop also contains Zircaloy-2 specimens, and the experiment is very similar to the preceding loop experiment, FF. At present, the loop has operated in-pile for a total of 850 hours. Approximately 2000 Mw-hr of LITR energy have been expended during this time. It is planned to continue the operation for several more weeks.

A fourth loop is in preparation and will be available when the exposure of GG has been terminated. (AEC Activity 4109.4)

HRP Metallurgy - Metallurgical assistance was given the design group in maintaining metallurgical control of the subcontractor's fabrication of the Zircaloy-2 HRT core tank, which has now been sucessfully completed and pressure tested. The subcontractor completed the initial weld qualification test on full-thickness clad material for the final girth weld of the HRT pressure vessel. Difficulty was encountered due to cracking in the transition layer of low-carbon iron weld metal. A modification was made in the coated electrode to be used for these passes and a second weld qualification test is being made.

A tentative procedure specification was prepared for the welding of high purity commercial titanium, and it is now being evaluated.

Equipment was constructed for use in connection with a study of the effects of alloying elements and surface condition on the rate of absorption of hydrogen by zirconium and its alloys. Similarly, an apparatus was completed to be used for the cathodic treatment of zirconium specimens in sulfuric acid at temperatures up to 300°C to study the extent and nature of hydrogen penetration and embrittlement. (AEC Activity 4109.4)

HRP Radiation Damage - Yield points in irradiated austenitic stainless steels, types 304L and 347, were observed during room temperature tensile testing. Furthermore, the stress level at 0.2% offset was found to be more strongly strain-rate dependent in irradiated types-301 and 347 stainless steels than in the unirradiated metals. Discontinuities at the start of plastic flow in types 301, 302, and 302B indicate that the yield phenomenon will be observed in these materials after long irradiation or during testing at higher strain rates. All materials were irradiated in the MTR at cooling-water temperature; the integrated fluxes were from 1 to 8 x 10^{19} nvt (fast). (AEC Activity 4109.4)

HRT Instrumentation - The vendor's design for the low-pressure valve, 1/2-in.-500 psi-250°C, was approved for construction. This design features integral ring-joint flanges. A prototype was received and thermal cycles to test for flange leaks. The unit was cooled from 150°C to 30°C in 6 minutes by the introduction of cold water and found to be leak tight. The bolting materials are ASTM A-139 Grade B7, and A-194 Grade 2H for the bolts and nuts, respectively.

Satisfactory preliminary drawings were received from vendors for the construction of the pressure and differential pressure transmitter. Tests are being conducted on the samples of materials submitted for evaluation of their corrosion resistance.

Development work is underway on the pressurizer level transmitter. A new design is being fabricated for testing.

Specifications were written for all components with the exceptions of two auxiliary systems, the waste and refrigeration systems, which are now being designed. (AEC Activity 4109.6)

AIRCRAFT NUCLEAR PROPULSION PROJECT

ANP Experimental Engineering--Basic Developments - The following table gives the status of the program under way for testing corrosion and mass transfer in Inconel systems with a fluoride mixture or sodium as the circulated fluid. The standard operating time for each loop is 1000 hr. The maximum fluid temperature used in these tests was 1500°F.

Loop Material	Fluid Circ.	Type of Heating	Temp. Diff (°F)	Reynolds Number	Optg period (hr)
Inconel	Fluorides	Elec res	300	1,000	1,000
Inconel	Fluorides	Gas	300	1,000	1,000
Inconel	Fluorides	Elec res	200	15,000	1,000
Inconel	Fluorides	Gas	200	5,000	In Test
Inconel	Fluorides	Elec res	300	10,000	In Test
Inconel	Fluorides	Gas	100	1,000	In Test
Inconel	Fluorides	Elec res	200	5,000	In Test
Inconel	Fluorides	Elec res	200	10,000	In Test
Inconel	Fluorides	Elec res	200	10,000	In Test
Inconel w/type 316	Sodium stainless steel inserts*	Elec res	300	66,000	1,000
Inconel	Sodium	Elec res	200	60,000	480**
Inconel	Sodium	Elec res	300	60,000	In Test

* Two idential loops operated.
** Terminated because of a small sodium leak at the electromagnetic pump cell.
*** Two identical loops now being operated.

For some results of these tests see "ANP Corrosion Studies" below. (AEC Activity 4401.1)

ANP Experimental Engineering--In-Pile Loop Components - Tests of seals for the regenerative turbine-type pump are under way, and one seal has now operated at 3000 rpm for 200 hr with no detectable leakage. Neutron-flux measurements made at the MTR indicated that the power generation in the in-pile loop would be 30% below the specified power. Modifications are being made in the forward end of the loop so that the desired power generation level can be attained. (AEC Activity 4401.1)

ANP Reactor Chemistry - Since operations were resumed in the large-scale production unit on March 1, nine 250-lb batches of purified NaF-ZrF_4-UF_4 (50-46-4 mole %) have been supplied for engineering experiments. To meet the requirements for UF_3 as a corrosion inhibitor in fluoride mixtures, the rate of production of UF_3 was accelerated to 8 lb/week, and a stock of about 30 lb is on hand.

The search for fluoride mixtures having improved heat transfer properties continued, with emphasis on mixtures containing LiF and BeF_2. A eutectic containing NaF-LiF-BeF_2 (56-16-28 mole %) that melts at 480°C was located.

Eutectic mixtures in the NaF-LiF-ZrF_4 system were found at the compositions listed below:

Composition (mole %)			Melting Point (°C)	Phases Present
NaF	LiF	ZrF_4		
51	38	11	600	NaF-LiF-Na_3ZrF_4
47	38	15	625	LiF-Na_3ZrF_7
22	55	23	575	LiF-Na_3ZrF_7-Li_3ZrF_7
25	50	25	590	Na_2ZrF_7-Li_3ZrF_7
34	28	38	425	Na_2ZrF_6-$Na_7Zr_6F_{31}$-Li_2ZrF_6
31	28	41	455	$Na_7Zr_6F_{31}$-Li_2ZrF_6
25	27	48	445	$Na_3Zr_4F_7$-$Li_3Zr_4F_7$-Li_2ZrF_6

A possible eutectic at about 30 mole % ZrF_4 containing Na_3ZrF_7-Li_3ZrF_7 and Li_2ZrF_6 that melts at about 500°C was not established with certainty; otherwise the list includes all the eutectics which appeared in the system. Since in many cases UF_4 can substitute for ZrF_4 in solid solutions, mixtures produced by replacing 4 mole % of the ZrF_4 with 4 mole % of UF_4 are being checked as possible fuel compositions. The 600° and 625°C eutectics were shifted to 590° and 615°C, respectively, by including 4 mole % UF_4. The 575° and 590°C eutectics disappeared by submerging in the LiF phase field; however, the resulting freezing points were sufficiently low for possible use. A mixture containing LiF-NaF-ZrF_4-UF_4 (50-25-21-4 mole %) and melting completely at 545°C, was prepared for physical property studies.

Emf measurements on the concentration cell

$$Zr/ZrF_4(C_1) \text{ in NaF } //\ ZrF_4(C_2 \text{ in NaF}/Zr,$$

made by using a ZrO_2 bridge impregnated with $NaF\text{-}ZrF_4$ to connect the half cells, gave consistent results. Activity ratios estimated from the emf measurements, by making assumptions regarding transference numbers, were in qualitative agreement with results from vapor pressure and from equilibrium measurements.

The vapor pressure of Li_2ZrF_6 in the range from 900° to 1200°C is given by the equation - Log $P_{mm} = -833/T(^oK) + 7.967$. Comparison with previous measurements shows that the vapor pressures of ZrF_4 mixtures containing LiF will be higher than those of the corresponding NaF mixtures; however, compositions containing 33 mole % ZrF_4 or less will have acceptable vapor pressures for use as fuel solvents.

Studies of the disproportionation of dissolved UF_3 to UF_4 and uranium metal in molten fluorides indicated that alloying of uranium metal with the container material is of controlling importance. Nickel is much more effective than copper in reducing the activity of uranium metal and thereby increasing the extent of disproportionation. (AEC Activity 4401.5)

ANP Corrosion Studies - Difficulty has been encountered recently in obtaining reproducibile corrosion results from tests with Inconel thermal-convection loops in which fluoride mixtures are circulated. Also, the maximum depth of attack has shown a gradual increase. Three thermal loops were filled from the same batch of $NaF\text{-}ZrF_4\text{-}UF_4$ (50-46-4 mole %) and operated for 500 hr at 1500°F. The maximum depths of attack found in these loops, in the order filled, were 8, 14, and 11 mils, instead of the 7 to 8 previously found. Despite a careful study, no explanation has yet been found for this discrepancy.

Favorable metallographic results were obtained from three Inconel thermal-convection loops in which alkali-metal-base fluoride mixtures with low UF_3 additions (1 to 2 wt % U^{3+}, with 10% total uranium) were circulated. The depth of attack in the "hot legs" was only to 1 to 2 mils, and no hot leg layers were present. A very thin unidentified layer was present in the "cold legs".

Several forced-circulation loops in which sodium was circulated at 1500°F were terminated after 1000 hr of operation. These included Inconel loops with 200° and 300°F temperature drops and two loops of Inconel with varying lengths of type-316 stainless steel in the cold leg, both of which had 300°F temperature drops. In every case a heavy deposit of magnetic metallic crystals was found in the cold leg. Very little hot-leg attack was found in the first loop examined. Oxygen analyses of the sodium before and after operation are not yet available but samples from the original material have shown about 0.02%.

The corrosive effect of Versene (disodium versenate) on beryllium in a dynamic system was studied in a loop constructed of Inconel with a beryllium insert. A 1% Versene solution was pumped through the loop at a moderate rate by a centrifugal pump for 24 hr at 180°F. No macroscopic effects were seen on either the Inconel or the beryllium insert.

A program is under way to evaluate cermets as possible bearing and valve materials. The degree to which these materials will self-weld at elevated temperatures under reducing conditions is an important criterion for judging their ultimate usefulness. A creep-rupture machine used for stress-testing in fused salts was modified so that bearing pressures could be applied to four samples of cermet materials in the presence of fused fluorides. Tests with pressures up to 50,000 psi indicated that self-welding of these materials did not occur in 100 hr at 1500°F, although welding of the cermets to Inconel was observed. A 200-hr static test of the effect of lead on Inconel at 1400°F substantiated the results at other temperatures in both static and dynamic systems; the attack was quite severe and appreciable mass transfer occurred. (AEC Activity 4401.5)

ANP Metallurgy--Fabrication - The program to develop superior alloys for reactor applications continues. Hardness measurements on a 10% Cr-20% Mo-70% Ni alloy, aged at 1500°F and a 5% Cr-20% Mo-75% Ni alloy aged at 1300°F for periods up to 500 hr, were completed. Neither alloy is subject to age hardening at these test temperatures. The average Vickers hardness number for both alloys in the annealed condition is 175. This value does not change for either of the alloys over a 500-hr aging period at the test temperatures. The work hardening characteristics were determined for 3, 5, and 10% Cr-20% Mo-balance Ni alloys. The alloys were subjected to a total reduction of 60% in intervals of 10%. Hardness measurements were taken after each reduction interval. The three alloys had a Vickers hardness of about 480 at 60% reduction, that is, a value similar to the value obtained for the 24% Mo-76% Ni alloy. An alloy containing 15% Mo-85% Ni is being investigated to determine the effect of molybdenum concentration on the corrosion characteristics. Tubing for two thermal convection loops was made and is being fabricated into loops. The oxidation rate is similar to that of 20% Mo-80% Ni. Room temperature and elevated temperature tensile tests of this alloy showed that, as expected, the strengths were low, as was the elevated-temperature ductility.

Experiments were started to develop methods for the extrusion of two-ply and three-ply tubes. Such tubes would be of interest in the production of stainless steel fuel elements and the fabrication of composite materials of unique properties. So far, two different types of extrusions have been made. The initial experiments were made to determine the variations in, and the ability to control, the thickness of the layers. A two-ply extrusion of mild steel clad outside with stainless steel produced a tube 1-1/4-in.-OD with a 0.220-in. wall. On the basis of deviations from the desired measurements, the thickness of the layers was adjusted in the extrusion billets and another extrusion made. The adjusted extrusion produced a much more uniform tube.

A tube 1-1/4-in.-OD with a 0.235-in. wall was made in a three-ply extrusion of mild steel clad with type-347 stainless steel inside and out. In the subsequent extrusion the thickness of the various layers was adjusted and the extrusion was much more uniform. It appears that with further development, multi-ply extrusions will be feasible for the production of unique tubings. (AEC Activity 4401.5)

ANP Metallurgy--Welding and Brazing - The fabrication of the 500-kw NaK-to-air radiators continued. The extreme difficulties involved in the bending of the tubes and assembly of the cylindrical headers on these tubes necessitated a new header design that utilizes a 3-in. schedule-40 pipe. All tubes except the two outside rows on each radiator half-section will enter the headers without being bent. This should facilitate assembly to a considerable degree. Careful polishing of each of the 144 tubes is required to permit assembly of the split headers without the use of a press. Hand fitting is desirable to prevent severe bending and distortion of the thin-walled Inconel tubes.

The two 100-tube sodium-to-fluoride heat exchangers were completed, and the units were Heliarc welded together to form the assembly.

After four unsuccessful attempts to obtain leak-tight tube-to-header joints by brazing, it was decided to discontinue further fabrication of the Boeing 500-kw radiator. A few of the tubes could be wetted by the braze metal. Even with extremely pure hydrogen as the brazing atmosphere, brazing was unsuccessful. Severe dilution from the repeated brazing cycles resulted in the formation of leaks.

The fabrication of the Cornell Aeronautical Laboratory sodium-to-air radiator was completed, and the radiator was shipped to Cornell Aeronautical Laboratory.

The program to develop superior alloys continued. In oxidation tests, a number of high-temperature brazing alloys were cycled from 1500°F to room temperature 190 times and accumulated 500 hr at 1500°F. The alloys which were found to have good oxidation resistance are now being studied for corrosion resistance in sodium and fused fluorides.

The use of sintered brazing-alloy rings of consistent size should serve as an excellent method for preplacing alloys in controlled quantities. An investigation of this technique was initiated and preliminary results are very promising. The brazing alloy powder was packed into circular grooves in a carbon block and then sintered in dry hydrogen. The rings were strong enough for preplacement but lacked consistent dimensions. Further work will be done with baked Lavite dies.

The satisfactory brazing of cermets to Inconel would facilitate the fabrication of corrosion resistant valves for use in fused fluoride salts. Since the cermets may contain as little as 5% nickel binder, it is desirable to bond directly to the titanium carbide as well as to the nickel. Wetting

tests were therefore conducted with a number of brazing alloys on blocks of sintered titanium carbide. Of the 19 brazing alloys tested, nickel-phosphorus and nickel-phosphorus-copper alloys appeared to be best; they will be investigated further. (AEC Activity 4401.5)

ANP Metallurgy--Mechanical Properties - A series of tests is now being conducted to determine the creep-rupture properties of Hastelloy B at 1300°F. The preliminary results obtained for solution-annealed sheet material in both fused salts and argon show very small elongations at rupture compared with tests run at 1500° and 1650°F. A summary of the tests completed to date is given below:

Stress (psi)	Rupture Time (hr)	Elongation (%)	Environment
40,000	41	7	Argon
30,000	185	6	Argon
40,000	56	7	Fused salts
30,000	240	7	Fused salts

Elongations up to 45% were obtained for similar specimens stressed to rupture in 100 hr at 1500°F.

Several specimens of high-purity Inconel produced by vacuum melting were creep-tested in argon at 1500°F. The results of these tests showed lower strengths and ductility for the vacuum-melted material than for the commercially produced Inconel. A test completed in fused salts indicated a decrease in strength properties for the high-purity material similar to that which is observed for commercial Inconel when compared to tests in argon. (AEC Activity 4401.5)

ANP Fuel Recovery - In tests on the fluorination step of the fused salt--fluoride volatility process for recovery of ARE fuel at 650°C in a nickel reactor, serious corrosion was observed at the line between the liquid and gaseous phases and on the discharge end of the fluorine inlet tube.

In experiments at different temperatures, sodium fluoride in the absence of excess fluorine absorbed uranium hexafluoride to the extent of 100% of its weight at 70° to 200°C. At these low temperatures, sodium fluoride should be satisfactory for use in a chemical trap following the cold traps to absorb the UF_6 product in the case of failure of the cold traps in the proposed plant flowsheet. (AEC Activity 4401.81)

GENERAL REACTOR RESEARCH

Reactor Physics and Shielding - The attenuation, by water, of the gamma-ray dose rate and thermal-neutron flux from the Bulk Shielding Reactor (BSR) was measured out to distances of 770 and 470 cm, respectively. Beyond a distance of 200 cm from the reactor, the slopes of plots of the two measurements are similar; this results from the fact that essentially all neutrons beyond 200 cm are photoneutrons produced by gamma rays in the naturally-occurring deuterium in the pool water. With the photoneutrons subtracted, the true thermal-neutron attenuation curve is exponential with a relaxation length that varies between 6 and 9 cm over a reduction of 10^{10}. From these measurements it was determined that for 1-megawatt operation the thermal-neutron leakage flux at the reactor surface (reactor was loaded with 28 fuel elements containing a total of 3.6 kg of U^{235}, water-reflected) was 1.1×10^{13} n/cm^2-sec; the gamma-ray dose rate at the reactor surface was 8×10^7 r/hr.

The regulating and safety rods of the BSR were calibrated for several reactor loadings with reflectors of water, beryllium oxide, and combinations of the two. The two calibration methods used involved (1) applying the usual inhour equation, and (2) uniformly poisoning the reactor with a known amount of gold and calculating the change in reactivity from $\Delta\Sigma/\Sigma$, the change in reactor absorption cross section. Method (1) was used for Loading 22A, a H_2O-reflected 5 by 6 fuel-element arrangement with two Cd-Pb safety rods and a Cd-Pb regulating rod. Measurements of the change in reactivity showed that each of the safety rods was worth 1.3%Δk/k and that the regulating rod was worth 0.6%. Method (2) was applied in Loading 32, a BeO-reflected 4 by 5 fuel element arrangement with two B_4C safety rods and a stainless steel regulating rod. Each safety rod was worth 3.8%Δk/k and the regulating rod was worth 1.2%.

These two loadings were later used to determine the changes in reactivity produced by placing beam holes and partial reflectors adjacent to the BSR. The beam holes consisted of cylinders (1/16-in.-thick walls and ends) placed against the reactor in Loading 22A and against the reflector in Loading 32. Changes in reactivity were measured as follows:

	Reactivity Change (%Δk/k)	
Beam Hole Description	Loading 22A	Loading 32
6 in. O.D. x 47-3/4 in.*		
Air-filled	-0.36	-0.25
Filled with boric acid solution		-0.245
6 in. O.D. x 12 in., air-filled		-0.26
8 1/8 in. O.D. x 47 3/4 in., air-filled	-0.55	-0.47
17 3/4 in. O.D. x 36 3/4 in., air-filled	-1.4	-1.12

*Held 1/8 in. from reactor (22A) or reflector (32).

The effects of partial reflectors against the core in Loading 22A or against the reflector in Loading 32 were as follows:

Reflector Description	Reactivity Change (%Δk/k) Loading 22A	Loading 32
Boral sheet, 1/4 in. thick		-1.36
Graphite slab, 1 ft thick		+0.68
Lead slab, 1 7/8 in. thick	+0.38	

In a continuing program at the Bulk Shielding Facility to determine the spectrum of prompt-fission gamma rays given off with the fission of U^{235}, preliminary measurements were made for the energy interval between 0.5 and 2.3 Mev. The results for this interval indicate 5.0 photons/fission for a total energy of 5.1 Mev/fission.

The fission neutron spectrum of U^{233} was measured at the BSF with the proton recoil neutron spectrometer for the energy region between 1.3 and 10 Mev. (AEC Activity 4570)

School of Reactor Technology - The deadline date for receipt of applications for the 1955-56 session was March 14. The Committee on Admissions met on March 25. The 1955-56 class will be composed of 20 recent college graduates and not more than 60 industry-sponsored students. (AEC Activity 4841)

PROGRAM 5000 - PHYSICAL RESEARCH

Reactor Operations - Operation of the graphite reactor was normal, with no unusual incidents to report. The LITR "down-time" continued to be high (35%) because of ANP and HRP research work in progress in holes HB 4, 5, and 6.

The Oak Ridge Research Reactor (ORR) - The design of the ORR building, shielding structure, and cooling system was completed and is now being reviewed prior to requesting bids from prospective construction contractors. The present schedule calls for sending out drawings on April 15, 1955 and opening bids on May 31, 1955. A satisfactory arrangement was reached with members of the Advisory Committee on Reactor Safeguards. An essentially gas-tight building will contain provisions for safely disposing of any radioactive gases which might be released as a result of an accident. Preliminary contacts were made with fabricators concerning construction of the reactor tank sections.

ISOTOPE PRODUCTION

Radioisotope Production - ORNL's part in making the first cesium-137 teletherapy unit was completed with the installation of the 1540-curie source in the head of the ORINS teletherapy machine. Although this source was completed approximately one year ago it had been held in storage since then until the rest of the unit was completed. Periodic tests had shown no leakage of activity, and there appeared to be no distortion or obvious radiation damage to the container.

The loading of cobalt-60 teletherapy units was continued in the old manipulator cell; construction of the new one is behind schedule (85% complete) and will probably not be ready until the end of April.

Plans are being made for a C^{14}-organics sale to dispose of miscellaneous labelled compounds, since commercial laboratories now supply most of these compounds. Issuance of the new edition of the Radioisotope Catalog is being held up until the AEC issues its new licensing procedure.

Cesium-137 production has been stepped up since the fission-produce semiworks resumed operation January 2; approximately 2,000 curies of Cs^{137} has been separated from Metal Recovery Plant waste. (AEC Activity 5111)

Radioisotope Process Development - It was found that technetium is carried down in good yield on especially-formed iron hydroxide precipitates at pH 2.5 (homogeneous $Fe(OH)_3$ precipitation, using airborne NH_3 gas). This step has been included in the fission product plant process.

The alum process can be used to separate cesium from rubidium by fractional crystallization. Cesium-137 containing $<3\%$ by weight of rubidium is made by the routine alum process; the rubidium content can be reduced by further crystallizations of Cs-alum. Fractions of Cs-NH_4-Rb alum enriched in rubidium ($>50\%$) are removed from the system to prevent a build-up of rubidium.

Studies indicated that a capacity of 200,000 curies of Cs^{137} per year is possible in the new Fission Product Pilot Plant if Purex-type waste is used; the capacity will be lowered, however, if other highly-salted types of wastes are processed. Evaporation of the input material will be used in the F3P process, especially for Purex-type wastes. With Redox waste, the alum precipitation will remove Al^{+++} and $SO_4^{=}$ and generate HNO_3, which will be recycled to the evaporators for acid removal. Duriron vessels are being studied for this highly corrosive evaporator service. (AEC Activity 5112)

PHYSICS

Nutrino Recoil Spectrometry - An analysis with high-resolution of the line width of the singly-charged recoils (9.6-ev energy) resulting from neutrino emission from argon-37 indicated an experimental half-width of 1.6 ev. The natural half-width expected from thermal motion alone is also 1.6 ev. There

is therefore no room for a contribution from randomly-directed emission of the most energetic Auger electrons (2300 ev). A plausible argument can be made that the singly-charged recoils result predominantly from processes involving only low-energy Auger electrons, and a preliminary look at the triply-charged recoil line seems to indicate that it is indeed appreciably wider than the singly-charged recoil line. (AEC Activity 5200)

Neutron Diffraction - The basic magnetic properties of a series of solid solutions of the perovskite-type compounds, $LaMnO_3$, were studied with the aid of neutron diffraction, X-ray diffraction, and the more usual magnetic techniques. These compounds exhibit unusual magnetic structure changes with variation of the ionic content of Mn^{+4} and Mn^{+3} associated with the sample composition. An antiferromagnetic layer structure is observed for pure $LaMnO_3$ and this changes continuously to a purely ferromagnetic structure at a Mn^{+4} content of about 30%. In the range from 50% to 100% Mn^{+4} these compounds pass through various antiferromagnetic structure states. A system of magnetic structures was deduced from the neutron data and these are correlated with crystal structure modifications obtained from X-ray studies. The experiments also give information on the exchange coupling between the magnetic manganese ions, and these results have furnished a good basis for a recent theory of the coupling mechanism. (AEC Activity 5200)

Low Temperature, Nuclear, and Solid State Physics - In connection with a study of the magnetic ordering transition in $MnCl_2$, the Weiss molecular field theory was applied to the $MnCl_2$-type lattice. The results indicate the possibility of several types of antiferromagnetic order in addition to a ferromagnetic state. The effect of crystalline electric field splittings on an antiferromagnetic transition in a Mn^{++} compound was also investigated theoretically by including an electric field-splitting term in the spin Hamiltonian used in the Van Vleck theory of antiferromagnetism. This calculation indicates that relatively small splittings may have a strong effect of the antiferromagnetic transition temperature. (AEC Activity 5200)

Nuclear Alignment - Indium-115 nuclei were polarized by the direct interaction of an external magnetic field with the nucleus at a very low temperature in experiments which constitute the first demonstration of a "brute force" nuclear polarization. This was accomplished by thermally attaching indium metal to a paramagnetic material which was cooled to about 0.035°K by adiabatic demagnetization and then kept in a low field region while a magnetic field of 11,150 gauss was applied to the indium sample some 12 cm away. The polarization was measured by determining the change in transmission of the indium sample for polarized 0.075-ev neutrons when the relative spin orientations of the neutrons and indium nuclei were changed from parallel to antiparallel. The maximum change in transmission observed was $7.0 \pm 0.9\%$, corresponding to a temperature of 0.043 ± 0.005°K, and a nuclear polarization of 2.1%. In contrast, at 4.2°K with all other conditions the same a change of $0.035 \pm 0.52\%$ was observed. At this temperature an effect of 0.07% is predicted theoretically. The direction of the change in transmission establishes the angular momentum of the compound nucleus for the level corresponding to the

1.458-ev resonance in In^{115} as J = I + 1/2 = 5, which is in disagreement with published data (B. N. Brockhouse, Can. J. Phys. 31, 432, 1953). (AEC Activity 5200)

Heavy-Ion Physics - Electron-capture cross sections were measured for protons passing through hydrogen, helium, nitrogen, oxygen, neon, and argon for the energy range 4 to 30 kev. An analyzed proton beam was deflected within a differentially pumped gas cell by a radial electrostatic field. Neutral atoms formed by electron capture collisions were undeflected and did not enter the detector. The cross section for electron capture was calculated from the observed attenuation as a function of pressure. The results join smoothly the curves obtained at higher energies by using the Cockcroft-Walton accelerator. The cross sections are large for the more easily ionized gases (e.g. 14×10^{16} cm^2 at 4 kev in argon) but are small and approach zero at low energies in gases of high ionization potential (e.g. helium). (AEC Activity 5200)

High Voltage Physics - A survey of results on the U^{235} fission integral revealed that values in the literature ranged from 20 to 1100 barns. The experimental values are complicated by a negative energy resonance and another resonance below the cadmium cutoff which makes the subtraction of a 1/v component from the measured activities rather uncertain. The procedure adopted in analyzing previous work was to subtract twice the BNL-250 fission cross section at the equivalent cadmium cutoff energy. The results for the integral found were: Popovic (Physica 20, 406, 1954) 106 b., preliminary results at ORNL, 110 ± 40 b., and a recent Hanford (HW-34509) measurement, 101 ± 30 b.

Calculated integrals based on the BNL-250 data have been given by Dresner (ORNL-55-1-160 and ORNL-55-3-17). His later value of 185 b. agrees well with a graphical integration value of 170 b. The possibility of a small discrepancy between the calculated and measured integrals remains unresolved pending more accurate measurements relative to gold.

The yields of gamma-rays resulting from coulomb excitation were measured for the eight isotopes of cadmium. The rather complex spectrum of normal cadmium was resolved into the contributions of the different isotopes by the use of isotopically enriched targets. Thick metallic targets were prepared by electrodeposition on nickel. Approximately 50 mg of the enriched metal was required for each target. One state in each of the even isotopes was observed to be excited. These states are as follows: Cd^{116}, 517-kev; Cd^{114}, 555-kev; Cd^{112}, 610-kev; Cd^{110}, 656-kev; Cd^{108}, 630-kev; and Cd^{106}, 630-kev. In Cd^{113}, states with energies of 300- and 582-kev are excited. In Cd^{111}, states with energies of 250-, 342-, and 610-kev are excited. The reduced transition probabilities were obtained from measurements of the yields of the gamma-rays. The half-lives, the electric quadrupole moments derived from excitation energies, the electric quadrupole moments derived from the reduced transition probabilities, and the ratios of the observed transition probabilities to those expected for single particle transitions are obtained.

In the process of measuring the $Li^7(d,n)Be^8$ cross section, a preliminary value for the $F^{19}(d,n)Ne^{20}$ cross section was also obtained. Monoenergetic

2-Mev deuterons from the 2.5-Mv Van de Graaff bombarded both a Li and a LiF target. A proton-recoil telescope which operated as a neutron spectrometer was placed at 0° to the proton beam. Most of the neutron spectra were obtained from the Li target which had been evaporated in place; however, absolute cross section measurements were made only with the weighed LiF target. Since the reaction energy for the $Li^7(d,n)Be^8$ reaction is about 5 Mev greater than for the $F^{19}(d,n)Ne^{20}$ reaction the neutrons leaving Be^8 in its ground state are well isolated from neutrons from the F^{19} reaction. A comparison of the spectra from the two targets indicates two neutron groups from $F^{19}(d,n)Ne^{20}$ with energies corresponding to the ground state and 1.63-Mev state of Ne^{20}. Cross sections for the ground and 1.63-Mev state are 0.63 ± 0.3 and 2.1 ± 0.2 millibarn/steradian, respectively. (AEC Activity 5200)

Theoretical Physics - A new series of possible fixed-frequency cyclotron designs was investigated on the Oracle. In all these machines, the vertical focussing was strongly enhanced by causing the lines of maximum and minimum magnetic field to spiral with various pitches. These machines appear very promising, with large average fields (small orbit radius) for a given energy.

Essentially exact expressions were found for the nucleon mass-correction and the differential cross section for nucleon-nucleon scattering in the pseudoscaler meson theory. Numerical results require the solution of a set of total differential equations; this work is being programmed for the Oracle. (AEC Activity 5200)

CHEMISTRY

Chemical Separation of Isotopes - Nitrogen tetroxide (N_2O_4) is partially dissociated into the dioxide (NO_2) in the gaseous phase. The isotopic separation factor between this gaseous mixture and liquid N_2O_4 was measured. Liquid N_2O_4 was distilled at total reflux (atmospheric pressure and 21°C) in a column containing 30 bubble caps. Isotopic analyses of samples from the top and bottom of the column gave a total separation of 1.070, $\left[(N^{15}/N^{14})_{Bottom}/(N^{15}/N^{14})_{Top}\right]$. The N^{15} concentrates in the liquid phase. If a plate efficiency of 60 % is assumed, this yields a single-stage distillation factor of 1.0038. A batch experiment, in which gas and liquid in equilibrium were sampled, yielded a value of $\alpha = 1.0031 \pm 0.0015$ (95% C.I.). If one assumes the separation factor between liquid N_2O_4 and gaseous N_2O_4 to be small and the N_2O_4 vapor to be 16.5% dissociated at 21°C, a value of 1.018 to 1.023 can be calculated for the isotopic fractionation between $NO_{2\,(gas)}$ and $N_2O_{4\,(liquid)}$.

Kinetic measurements of the BF_3-BCl_3 exchange performed in the mass spectrometer show the reaction to be largely heterogeneous. It appears that the uncatalyzed reaction is too slow to be of interest for a countercurrent isotope separation system. (AEC Activity 5300)

Hot Laboratory Research - Single composite crystals, neptunium uranyl nitrate on rubidium uranyl nitrate, were grown for an experiment on anisotropy of alpha decay in the neptunium. Since the experiments will be performed near 1°K, the internal heating from alpha activity was minimized by growing the bulk of each crystal from rubidium uranyl nitrate, and supplying the neptunyl salt on the outside by further crystal growth from a mixed uranly-neptunyl solution. $RbUO_2(NO_3)_3$ crystals up to about 1 cm across were grown on platinum wires. Analytical data show the proper ratios of $Rb:UO_2:NO_3$. The crystals were oriented by using X-ray diffraction. Up to 30-40 mg of Np^{237} was grown onto the surface as a dark reddish-brown solid solution containing about 25% $RbUO_2(NO_3)_3$. Such composite crystals give adequate counting rates for proposed experiments. (AEC Activity 5300)

Chemistry of Corrosion - In studying the degree of reversibility of the process by which the pertechnetate ion inhibits corrosion, the electrode potential of electrolytic iron was measured in the inhibiting solution to which varying amounts of other electrolytes were added. The measurements were made both in air and in a nitrogen atmosphere. The results confirm the existence at the metal-solution interface of a labile state which responds rapidly to addition or removal of oxygen and is modified by other electrolytes in sufficient concentration. In connection with these measurements it was found that the value reported in the literature for the standard potential of the $TcO_2(c) \rightarrow TcO_4^-$ electrode had been determined in air and was consequently appreciably in error. A redetermination in an atmosphere of nitrogen gave -0.738 v as the E° value for the half-reaction $TcO_2(c) + 2\ H_2O \rightleftarrows TcO_4^- + 4\ H^+ + 3\ e$. (AEC Activity 5300)

Hope Project - Both an air lift and a pulse-pumping device were demonstrated to be satisfactory for pumping metered radioactive liquid. Either method should significantly reduce maintenance and installation costs over those for mechanical pumps because of the elimination of either moving parts or the need for gravity-cascading of liquids between columns. The air lift studied was of the conventional type. Maximum flow deviation was ±5%, air demand was low, and air contamination was slight. The pulse-pumping device consists of check valves in the lines between pulse columns which make it possible to use the pulse energy of the columns to obtain inter-column flow.

The cost of reprocessing fissionable fuels can be significantly lowered by reducing the volume of radioactive waste. The currently produced wastes, which are rich in nitric acid, aluminum nitrate, or both, can be reduced in volume twofold or more by destructive distillation. The nitrate ion concentration is reduced and dibasic aluminum nitrate, which can be neutralized with caustic for alkaline-waste storage, is formed. A probable drawback is corrosion of the distillation equipment. (AEC Activity 5300)

Ion Exchange Technology - Sulfuric acid--leached Utex ore containing 0.2 M sulfate ion and 7 to 11% suspended solids were satisfactorily processed through 10-20 mesh Permutit SK anion exchange resin in 2- and 6-in.-dia Higgins continuous ion exchange contactors. No mechanical difficulties

were encountered if less than 0.3% of the solids was over 200 mesh. Uranium losses averaged 0.4%. The production rate for the 6-in.-dia column was 1.25 tons of ore per day. The major chemical cost in this scheme is the eluant, 1.0 M NH_4NO_3, amounting to $0.07 to $0.10 per pound of uranium when used in a recycle system. Kinetic studies with clarified solutions in the 2-in.-dia column at a feed rate of 400 gal/hr-ft^2 showed that a 4-ft resin bed loaded up to 50 g of uranium per liter with a loss of 0.2%. The concentration of the uranium product eluted from this column was 20 g/liter.

Mallinckrodt leach slurries of MgF_2 in carbonate, obtained by treating uranium reduction-bomb liners with sodium carbonate and diluting to 0.3M carbonate, were processed on the 2-in.-dia column at a rate of 280 gal/hr-ft^2 with uranium losses of 0.2% and product concentrations up to 28 g/liter. The eluant was 1.0 M $NaHCO_3$. Permanganate, which had been added in the leach operation to oxidize uranium, was reduced to MnO_2 solids prior to ion exchange processing since the permanganate ion competes for the anion exchange position. It was not necessary to remove the MnO_2 solids before processing. (AEC Activity 5300)

Feed Materials Processing - The Monex process for recovery of thorium from Brazilian sludge was developed at the request of Mound Laboratory. Digestion and solvent extraction studies indicated that after a 3-hr digestion of the sludge at 90°C, the thorium could be extracted successfully from the unclarified liquor with 40% tributyl phosphate in Amsco in a pulsed column. With the aqueous phase continuous, thorium losses were satisfactorily low (1.2 to 2.4% with a 22-ft extraction height and a flow rate of 388 gal/hr-ft^2). The flooding rate for the column was determined to be 610 gal/hr-ft^2 at 60 cycles per minute. The details of the work are reported in ORNL-1873. (AEC Activity 5300)

PROGRAM 6000 - BIOLOGY AND MEDICINE

BIOLOGY

Cytogenetics - Previous experiments had shown that when oxygen (by itself) causes chromosome breakage in the dry pollen grains of Tradescantia, it does not do so directly, but via some physiological reaction of the cell itself. It was suspected that the oxygen reacted with some terminal oxidase enzyme system, and the enzymatic reaction was responsible for the agents which broke the chromosomes. In cooperation with the Enzymology Group, the cells were examined for the presence of oxidative enzymes; cytochrome c, cytochrome oxidase, and a flavoprotein terminal oxidase were found, demonstrating that enzymes were present which could account for the postulated reaction.

When an actively-growing mycelium of Neurospora is X-rayed, dominant lethal nuclei are eliminated immediately, but recessive lethals persist indefinitely and can be recovered in conidia formed at a great distance from the site of irradiation. The induced mutation rate in the growing mycelium is lower than in conidia, possibly because of the presence of resistant prophase nuclei. Mycelium irradiated repeatedly with short intervening growth periods shows the expected accumulation of recessive lethals, whereas irradiated conidia show a saturation effect at 15-20% recessive lethals.

The sensitivity of cells to radiation has been shown to be related to the phase of the division cycle at which the cell is irradiated. The various phases of this cycle are characterized by varying degrees of condensation of the chromosomes. The effects of agmatine sulfate on cell division in the grasshopper neuroblast were studied in an effort to determine, if possible, the factors involved in the condensation and extension of chromosomes. This compound was used because it is a physiologically divalent cation which should have a charge-reversing effect on acidic cell aolloids. It was found that agmatine sulfate greatly accelerates the rate at which cells go through the phases of chromosome condensation. These data make feasible experiments designed to counteract the reversal of chromosome condensation which occurs following exposure to radiation.

Studies are under way to determine the structure in mature sperm of the heterochromatic Y chromosome of Drosophila. A Y chromosome with 5 genetic markers is being exposed to X-rays, and independent or concomittant loss of one or more of the markers is being determined by genetic tests. The results indicate that this heterochromatic chromosome is split into chromatids in the mature sperm and that the loss of some markers and not others is probably accompanied by the formation of small ring chromosomes. These marked ring Y chromosomes will be of great use in other radiation genetics experiments. (AEC Activity 6400)

Radiation Protection - It has been reported previously that exposure to H_2O_2 either before or after X irradiation of Paramecium decreases the amount of detectable mutation which is induced. One of the effects of peroxide treatment is a delay in the first cell division after the exposure. It has now been found that two other procedures which delay cell division--withholding food before or after irradiation and exposure to low temperature after irradiation--cause a small but detectable decrease in the amount of mutation. Thus the data suggest, though they do not prove, that the longer the time between irradiation and the first cell division following it, the less the induced mutation. In any case, they show that at least some of the mutational changes in Paramecium are not irrevocably determined at the time of irradiation but involve processes which are amenable to subsequent modification.

Biochemically deficient mutants pass through a limited number of residual divisions when plated on a medium to which the required nutrient has not been added. The number of residual divisions is dependent on the number of viable cells added to each plate. Experiments are being carried out to determine

the influence of such growth on the relation between X-ray killing and the induced reversion rates observed in Escherichia coli, strain T83-8. The number of residual divisions was increased by the addition of suboptimal amounts of tyrosine to the minimal plates. By comparing the reversion rate obtained from such supplemented plates with those obtained from unsupplemented plates, it was determined that residual divisions play a relatively minor role in the relation observed to exist between survival and reversion rates in T83-8 exposed to X-rays in oxygen vs nitrogen atmospheres.

Escherichia coli B/r has been used in studies related to "recovery" from damaging effects produced by ionizing radiations. This strain of bacteria under proper conditions (nutritional and temperature) shows a reversal of 50% or more of the potentially lethal damage produced by the radiation. At a dose of 15 kr of gamma rays, these cells plated on (1) an inorganic salts-glucose medium at 37°C are about 1% viable, whereas on (2) yeast extract medium at 18°C they are about 30% viable. The same quantitative effect is obtained if the cells are held on liquid or solid medium. In a liquid medium, the effect can be followed as a function of time. Experiments are in progress to compare the rates of synthesis of nucleic acids and proteins under conditions (1) and (2) described above, where in one case recovery does not take place, and in the other it does. At present attention is being given chiefly to those compounds which are synthesized and retained by the cell. A chemical analysis of synthesized compounds released to the medium by irradiated cells may turn out to be an equally profitable study. (AEC Activity 6400)

Biophysics - The experimental induction of metamorphosis of the neotenic cave salamander by thyrovin is being continued. The chromosome number and morphology of a second related species, Gyronophilus danielsi dunni, was found to be very similar to the cave salamander, G. palleucus. A study of mitosis inhibition in the regenerating tail-tip cells of G. danielsi dunni following 100 r of X-rays is in progress. (AEC Activity 6400)

Pathology and Physiology - Comparison of lens opacities in adult RF mice resulting from exposure to a single, whole-body, sublethal dose of fast neutrons (ORNL 86-inch cyclotron) or to 250-kvp X-rays indicates a relative biological effectiveness (for cataract induction) of neutrons approximately three times that of X-rays (RBE $\sim$ 3). A substantially higher RBE (approximately 9) was obtained, however, with small doses of neutrons of higher energy (Po-B source) administered at lower dose rates. Preliminary data disclose no significant difference between the RBE (for lens damage) of 250-kvp X-rays and that of Co^{60} gamma rays. In long-term studies of lens opacities in mice, less injury resulted from a dose of fast neutrons or gamma rays administered in exposures fractionated over a period of a few days or weeks than from the same total dose given in a single brief exposure. The lens of the rat was observed to be much less radiosensitive than that of the mouse, a dose of 333 r of gamma rays or 35 rep of fast neutrons resulting in only minimal opacities. Observations to date indicate that the lens of the guinea pig or the rabbit is even less radiosensitive than that of the rat.

Since the additive effect of successive doses of radiation is believed to be inversely proportional to the amount of recovery occurring between exposures, attempts were made to compare recovery rates following exposure to divided doses of X-rays and of fast neutrons (ORNL 86-inch cyclotron). Initial studies in adult female RF mice indicate that if the $LD_{50}/30$ days is divided into two equal fractions, the total dose rises with increasing time between exposures. The observed $LD_{50}/30$ days for a single exposure was approximately 560 r of X-rays or 335 rep of fast neutrons. With paired doses of X-rays, the median lethal dose was approximately 690, 1000, and 790 r for intervals of 2, 5, and 8 days, respectively, between exposures; with paired doses of fast neutrons, the $LD_{50}/30$ days increased proportionally at corresponding intervals, indicating recovery comparable to that which occurred after X irradiation. The marked reduction in radiosensitivity observed on reirradiation at 5 days, in contrast to 2 or 8 days, after exposure to the first dose of either fast neutrons or X-rays is significant but as yet unexplained; it indicates that recovery, if measured by decreasing radiosensitivity (in terms of $LD_{50}/30$ days), does not occur as an exponential function of time post-irradiation.

The effect of injecting nucleoprotein, extracted from ascites tumor cells, on the mean survival of mice exposed to ascites tumor was investigated further. Rabbit antisera to whole ascites cells and to components were prepared and are in the process of being tested. Whole-cell antisera agglutinate cell suspensions, and antinuclei sera agglutinate nuclear suspensions. Anti-nucleoprotein sera agglutinate neither. The anticell agglutinin does not fix complement in the standard complement-fixation reaction. (AEC Activity 6400)

Enzyme Chemistry - An organism unable to survive the effects of γ irradiation displays normal respiration for a short time but loses its ability to synthesize deoxyribonucleic acid (DNA) very quickly. This phenomenon was used as a means of determining the metabolic "stability" of the DNA molecule. Escherichia coli B/r were given a dose of radiation such that fewer than 1% were able to survive and form colonies. The irradiated cells were placed in a glucose-salts medium containing 8-C^{14}-adenine and P^{32}-phosphate. The rates of uptake of the two isotopes were measured by differential counting of DNA isolated from aliquots of the cells removed during a three-hour growth. Because the phosphorus atoms in DNA do not exchange, the uptake of P^{32} was a direct measure of net DNA synthesis. The rate of uptake of the C^{14}-adenine into DNA measured, besides DNA synthesis, the exchange of this molecule for nonlabeled adenine originally in the DNA of the cells. The finding that the rate of P^{32} incorporation is higher than the rate of C^{14} incorporation was taken as evidence that adenine entered the DNA molecule by new synthesis only. (AEC Activity 6400)

RADIOISOTOPE SALES AND COSTS

Type of Transaction	February 1955	FY 1955 to Date
Domestic Sales	$87,043	$788,848
Foreign Sales	5,361	38,110
Project-Cash Sales	3,042	37,776
Project-Transfer	0	1,720
Technical Cooperation Program Credits	0	1,510
Plant Credits	611	23,465
Civilian Defense Credits	0	105
Cancer Program Credits	22,928	163,670
*Miscellaneous	0	58
Total Income	$118,985	$1,055,262
**Income - No Production Costs Incurred Subtract from Total Income	-15,815	32,052
Radioisotope Income	$134,800	$1,023,210
Radioisotope Costs	74,641	655,781
Radioisotope Shipments	1,132	8,255

*Miscellaneous - Freight and Missing Parts
**Income from H^3, He^3, B^{10} and miscellaneous items in excess of handling costs.

GROSS OPERATING COSTS

	Cost for February	FY 1955 Cost to Date
Programmatic Operating Cost - Net	$2,427,631	$20,096,504
Plant and Equipment Cost	303,458	2,124,043
Construction Program "H"	42,258	122,089
Work for Other Parties - Transfers	28,297	291,408
Inventory Changes	3,479	74,886*
Reimbursable Work for Other Parties	152,201	1,340,773
Deferred Charges	287*	5,424*
Total Laboratory Cost - Net	$2,957,037	$23,894,507
Estimated Cost for Next Month - Net	$3,100,000	$26,994,507

*Credit

[redacted]

PERSONNEL SUMMARY

	Number of Employees March, 1955	New Hires March	Terminations March
Administration	60	1	1
Operations*	121	1	1
Engineering, Shops and Mechanical	743	5	17
Laboratory and Research	1901	23	26
Protection	145	0	0
Service	369	1	3
	3339	31	48

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

A total of 784 Laboratory personnel are located in the Y-12 Area.

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