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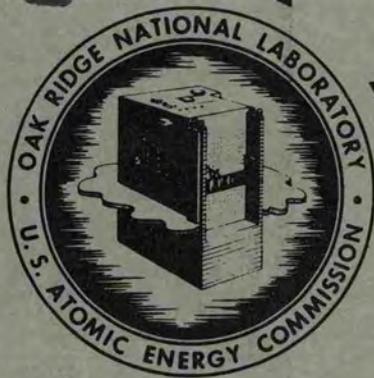
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OAK RIDGE NATIONAL LABORATORY
 STATUS AND PROGRESS REPORT

JANUARY 1957

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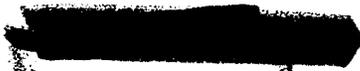


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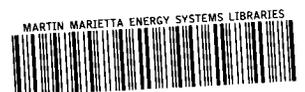
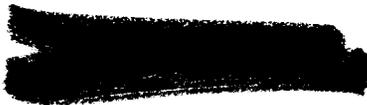
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OAK RIDGE NATIONAL LABORATORY
STATUS AND PROGRESS REPORT

January, 1957

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UNION CARBIDE NUCLEAR COMPANY
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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

January, 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

January, 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

Excer Process - In application of the Excer process to recovery of uranium from sulfate ore concentrates, the uranyl sulfate is converted to uranyl chloride by ion exchange, electrolytically reduced to UCl_4 , and converted to UF_4 by addition of HF . Reduction of UO_2Cl_2 by iron filings was shown to be feasible; this may make the electrolytic cell unnecessary. Reduction was ~100% complete. The feed to the iron filings bed was ~4 M in HCl and contained 100 g of uranium per liter. The iron contamination of the $UF_4 \cdot 3/3H_2O$ precipitated from the UCl_4 by HF was less than that permitted by specifications. The $UF_4 \cdot 3/4H_2O$ had a tap density of 1.5-2.0 g/cc, which was increased to 3.7-4.0 g/cc by pressing at 10 psi. (AEC Activity 2702)

Fluorox Process - In the Fluorox process uranium oxides are simultaneously reduced and hydrofluorinated to UF_4 , which may be oxidized to UF_6 with dry oxygen. Approximate reaction rate constants for the oxidation step were calculated for the temperature range 600-900°C (published in ORNL-2180). The activation energy for the oxidation reaction was calculated to be 30-40 kcal/mole in the temperature range 600-900°C. Extrapolation of these values indicates the rate of reaction to be very slow below 600°C, which was confirmed by experiments with pure UF_4 . Earlier low-temperature data obtained with UF_4 containing 0.4% carbon had indicated a fairly rapid reaction under some conditions. This rapid reaction was shown to be due to a high local heat of oxidation of the carbon, with surface temperatures as high as 900°C. (AEC Activity 2702)

Metallex Process - In the Metallex process thorium chloride is reduced to thorium metal by sodium amalgam and separated from the reaction mixture by filtering and pressing. Oxide impurities in the product are thought to result from the aqueous washing step used to remove unreduced $ThCl_4$, $NaCl$, and other impurities from the $ThHg_3$ -bearing amalgam. Attempts to eliminate the aqueous washing step by hot filtration of the reaction mixture were partially successful. Sixty percent of the thorium in the mercury phase from a reduction run passed through the filter; ~99% of the impurities remained on the filter. Scrubbing of the reaction product with 50-50 mole % $AlCl_3$ - $NaCl$ at 250°C removed impurities, but thorium recovery was only about 20%. One-inch-dia

PROGRAM 2000 - SPECIAL NUCLEAR MATERIALS (Continued)

thorium billets prepared by sintering were successfully extruded to 0.25-in.-dia rods. The extruded rod could be rolled and drawn satisfactorily. (AEC Activity 2704)

Power Reactor Fuel Processing: Hermex Process - In the Hermex process uranium fuel or scrap is dissolved in boiling mercury, and the uranium is separated by filtering and pressing. The process was satisfactorily demonstrated in small-scale glass apparatus. In an initial run in larger scale stainless steel equipment performance was satisfactory. The relative effectiveness of the dissolution-slugging, cold filtration, and aqueous-washing steps in removing fission products was 42:5:1 for gross γ activity and 22:1.4:1 for gross β . (AEC Activity 2924)

Power Reactor Fuel Processing: Zircex Process - In the Zircex process a fuel element is hydrochloriated to form a volatile compound of the diluent and/or cladding, and the uranium or thorium is recovered from the residue by dissolution and solvent extraction. The presence of carbonaceous impurities in the HCl gas used for the hydrochlorination increased the uranium losses in the insoluble residue. With pure HCl losses were 1.7-2.7%; with commercial HCl, losses were 4.2-7.7%. The residue from hydrochlorination with pure HCl was readily slurried with water, while that from impure HCl was not. (AEC Activity 2924)

PROGRAM 4000 - REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test - In preparation for the extended oxygenated-water run, final repairs to the HRT system were completed. These included the installation of natural-convection circulating loops on both heat exchanger flanges and on the reactor dome flange. The dome flange was reassembled after the removal of pits and imperfections in the ring groove by lapping to a depth of approximately 0.01 in. New pressurizer bleed valves with larger ports were installed, and the oxygen-metering stations were replaced. The leak-detector system was charged with deaerated condensate and pressurized with helium.

During the month, 335 hr of operation at 1500 psi and 280°C were logged before a scheduled shutdown was made on January 21. At this time, it was necessary to replace one fuel feed-pump head, install new suction check valves on the other head, and replace the fuel letdown valve and one convection-loop cooler. The Freon-11 refrigerant for the cold traps was replaced with Amsco 125-82. Two pressurizer venting tests and one dump test were made from 1500 psi and 280°C. The operation of the pressure-balancing controls during the tests was smooth and very satisfactory. The reactor was restarted on January 23 for an additional one-week run at 1500 psi and 280°C. (AEC Activity 4103.3)

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

HRT Chemical Pilot Plant - All operations in the chemical processing plant have ceased pending completion of the modifications to the low-pressure system. All process equipment in the revised system, except the dissolver, has been installed. Work to be completed includes steam, water, and refrigerant service lines in the processing cell and additional instrumentation required for the dissolver system. (AEC Activity 4103.1)

Mathematics and Computation--Homogeneous Reactor Development - An Oracle code was written for calculating the steady-state fuel costs in two-region thorium breeder reactors. It takes into consideration the concentration of U^{233} , U^{234} , U^{235} , U^{236} , Th^{232} , Pa^{233} , and fission-product poisons. Included in the input numbers (which may be considered parameters) are unit fuel value, unit inventory charge, unit chemical-processing charges, reactor power level, poison fraction, reactor diameter (core and over-all), thorium concentration (core and blanket), and nuclear values. (AEC Activity 4103.1)

Reactor Analysis - To facilitate the development of maintenance procedures for the HRT, the fraction of gamma rays which would escape through a biological-shield opening was calculated as a function of source position and size of opening.

Nuclear calculations were made for two-region spherical reactors containing D_2O - ThO_2 - $U^{233}O_2$ slurries in both the core and blanket regions for the purpose of comparing their nuclear characteristics with similar type reactors having solution-type core regions.

Preliminary results were obtained for steady-state fuel costs in two-region thorium breeder reactors (thorium in both core and blanket). Results indicate that fuel costs will be 1 to 2 mills/kwhr if inventory charges are between 4 and 12% per year.

The effects of neutron leakage and neutron resonance absorption in fuel upon breeding ratio were studied for single-region ThO_2 - D_2O - $U^{233}O_2$ reactors. For a given reactor size, if the resonance value of η^{233} is less than the thermal value, a finite thorium concentration exists for which the breeding ratio will be a maximum.

The cost of electrical power associated with the use of $Th(N^{15}O_3)_4$ in a thorium-breeder power reactor was estimated. On the basis of present data, the cost would be excessive because of the high charge for recovery and re-conversion of the decomposed nitrate.

An economic evaluation of organic-moderated homogeneous power-breeder reactors was made. Based on present data, the costs associated with radiation damage to the deuterated hydrocarbons appear to increase the power costs by >10 mills/kwhr and >1 mill/kwhr for one- and two-region reactors, respectively. (AEC Activity 4103.1)

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

Homogeneous Reactor Instrumentation - The effects of pressure and temperature on the recording range and zero point of the HRT pressurizer-level transmitter were studied. The shift of indication with pressure was found to be linear and amounted to 1% of the full-scale reading (5 in. H₂O) per 500 psi change in pressure. Temperature effects were found to be greater, and they would be most serious when temporary local temperature differences occur in the transmitter during periods of heating or cooling of the reactor system.

Special high-level gamma ionization chambers for measurement of ambient radiation inside the HRT reactor cell were developed to measure radiation levels to 10⁷ r/hr. Preliminary tests indicate that these waterproof nitrogen-filled chambers are sensitive down to background radiation levels.

Design of the instrumentation and controls for the revised HRT cooling-water system was completed.

An instrument system has been installed which will continuously compute heat balances on the coolers and heaters of the HRT feed and purge pumps.

A set of dump-valve trim (a 17-4 PH plug hardened to RC-38 and a 347 stainless steel seat) tested in the valve test loop duplicated the good performance of a set tested earlier.

Two sets of valve trim, designed for tight shutoff, which incorporated a gold gasket recessed in a groove in the plug and mating with an annular ring on the seat, were tested in the valve-test loop. The first set failed to perform satisfactorily, but the second set, of improved design, showed less leakage than solid plugs after 404 dumping cycles with uranyl sulfate at 1250 psi and 275°C.

The control panel for the LITR HB-5 rocking-bomb test and the identical panel for the checkout facility were completed. (AEC Activity 4103.1)

HRP Design - The investigation of possible substitutes for Freon-11 as the secondary refrigerant for the HRT was completed, and Amsco 125-82 was recommended for this purpose.

The use of hydrazine for the control of oxygen concentration and a coordinated phosphate treatment for control of pH in the HRT steam system feed-water was recommended. An initially intensive sampling program was suggested, as the behavior of these materials under HRT conditions is unknown.

An investigation indicates that the precipitation of uranyl peroxide in the motor portion of the HRT fuel circulating pump will not be a problem as long as adequate purge flow to the pump is maintained.

The requirement for a delay period during a dump of the HRT was re-evaluated because in the original investigation it was pessimistically assumed that the gas-liquid equilibrium between the vapor and the total body of reactor fluid was achieved instantaneously on initiating a dump. The necessity

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

for a delay period of 2 min was confirmed; this allows time for sufficient recombination of D_2 to prevent the accumulation of an explosive mixture of D_2 and O_2 . The solubility of D_2 was found to be the determining factor; no delay would be required if gas-liquid equilibria, rate equations, and material-energy balances were to be considered alone. (AEC Activity 4103.1)

HRP Metallurgy - Zirconium-niobium alloys, which have been shown to have a lower in-pile corrosion rate than Zircaloy-2, undergo complex transitions. There appear to be three different transformation mechanisms:

- 1) Above $500^{\circ}C$, a simple transition from retained beta to alpha,
- 2) In the range 250 to $500^{\circ}C$, a metastable transition phase similar to the "omega" phase in titanium alloys, and
- 3) Below $250^{\circ}C$, a Widmanstätten platelet transformation structure, which is not understood.

The "omega" transition, which occurs in the operating-temperature range of interest for homogeneous reactors, results in hardnesses as great as 400 DPH and a complete loss of ductility. This transformation can be delayed by the addition of small amounts of iron, palladium, or platinum, but additional work is necessary to determine whether the delay will be sufficient to permit welding, which could then be followed by an overaging heat treatment.

A welding procedure was developed and qualified which permits the use of Carpenter-20 stainless steel in the HRP chemical plant. (AEC Activity 4103.1)

Radiation Damage--HRP - The problem of irradiating large numbers of mechanical test specimens at controlled, elevated temperatures in high-flux regions of the MTR was partially solved. Formerly, the gradients in the gamma-ray heating and the limited space for heaters prevented exposure of suitably large numbers of test specimens. An apparatus is now operating in the MTR in which the gamma heat produced in a massive block of metal is conducted to a water jacket through a stack of specimens. Currently, 267 tensile and notch-impact specimens are being irradiated at temperature levels between 480 and $690^{\circ}F$ in the temperature gradient between heater block and water jacket.

Data on the tensile properties of irradiated welds in Zircaloy-2 and both high- and low-ferrite welds in austenite stainless steels showed that radiation causes greater losses in ductility in the weld and weld zone than in the wrought base material. (AEC Activity 4103.1)

Laboratory Corrosion Studies - Cracking of annealed type-347 stainless steel stressed at 15,000 and 30,000 psi has not occurred after 2000 hr in boiling and aerated $0.04 \text{ m } UO_2SO_4$ - $0.02 \text{ m } H_2SO_4$ - $0.005 \text{ m } CuSO_4$ solutions containing either 0, 5, 10, or 100 ppm of chloride or 100 ppm of bromide or iodide; cracking was found after 200 hr in solution containing 25 or 50 ppm of chloride. Tests under similar conditions show incipient cracking after 500 hr in

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

solution containing 200 or 500 ppm of chloride; no cracking has been found with 50 or 200 ppm of bromide present. Generalized corrosion rates were observed to increase with an increase in the chloride or bromide concentrations.

Stress-relieving heat treatments at 315, 400, and 677°C (600, 750, and 1250°F) failed to prevent stress-cracking of U-bends of type-347 stainless steel pipe, heated internally with steam at 153°C (307°F), during 1000 hr of continuous cooling of the external surfaces with chloride-containing tap water. U-bends annealed at 1950°F for 1/2 hr and a U-bend subjected to shot-peening over the external surface showed no cracking during the 1000-hr period. Modified type-430 stainless steel and MST grade-3 titanium likewise exhibited no cracking during the exposure period. (AEC Activity 4103.1)

Dynamic Solution Loop Corrosion Tests - The mockup of the HRT core - pressure-vessel flange and transition joint installed in a 100A corrosion loop has been tested through 100 daily thermal cycles and 150 mechanical deflections of the bellows. In the test, 0.04 m UO₂SO₄ containing 0.02 m H₂SO₄ was circulated around the outside of the bellows and joint. The inside of the bellows was filled with water at a pressure 35 to 50 psi below that on the outside of the bellows. No leaks were found and the operation of the flange and transition joint was completely satisfactory. A region of pitting attack on the bellows was observed, however, where a tightly fitting stainless steel ring prevents the bellows from flexing at the ends.

Runs with 0.5 m BeSO₄ containing 0.17 m UO₃ and with 0.2 m BeSO₄ containing 0.04 m UO₃ were made at 250°C. Although the room-temperature pH of the solutions was higher than that of uranyl sulfate solutions containing the same concentration of uranium, corrosion of stainless steel was slightly more severe in the beryllium-containing solutions. Runs at 225, 250, and 300°C with equimolar 0.04 m uranyl sulfate - beryllium sulfate (plus 0.005 m CuSO₄) showed that corrosion of stainless steel at low velocities was no greater and at high velocities less than in 0.04 m UO₂SO₄ containing 0.02 m H₂SO₄ and 0.005 m CuSO₄ (the solution proposed for the HRT). (AEC Activity 4103.1)

Dynamic Slurry Loop Corrosion Tests - Two tests to study the corrosivity of aqueous thorium oxide slurry under reducing conditions were made at 300°C in hydrogen-argon atmospheres. One test was of 139-hr duration at an average circulating concentration of 410 g Th/kg H₂O, and one was of 190-hr duration at an average concentration of 347 g Th/kg H₂O. In both tests the same batch of 800°C-calcined, ORNL-produced thoria was used. Small opalescent slurry spheroids formed during circulation in one test, but no caking occurred.

Corrosion pin specimens of austenitic stainless steels, titanium and titanium alloys, and mild steels were exposed to the slurry flowing at two different velocities. The corrosion rates were as follows:

Slurry velocity (ft/sec)	Corrosion rate (mil/yr)		
	Austenitic SS	Ti and alloys	Mild steels
10-12	0.6	1.5	21
20-23	1.0	2.4	40

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

Some embrittlement of thin-sheet-titanium pump seal rings appeared to be associated with hydrogen pickup. (AEC Activity 4103.1)

In-Pile Solution Corrosion Loops--LITR - Dismantling of loop L-2-10, the first loop experiment in the HB-2 hole of the LITR, was completed. Hole HB-2 has an available unperturbed thermal-neutron flux of $\sim 3 \times 10^{13}$ neutrons/cm²-sec, which is 2 to 3 times that in the HB-4 hole, where previous experiments were conducted. The solution, similar to proposed HRT solution, was 0.04 m UO₂SO₄, 0.0075 m CuSO₄, and 0.02 m H₂SO₄. The main-stream temperature was 280°C. Observed corrosion rates for the Zircaloy-2 core coupons varied from 3.6 mil/yr at 1 w/ml to 9.1 mil/yr at 3.6 w/ml. The relationship between Zircaloy-2 corrosion rate and power density in this experiment may be expressed by the equation:

$$CR = 3.2 PD (1 - e^{-40/CR^{1.5}}),$$

where: CR = corrosion rate, mil/yr
PD = power density, w/ml.

The results of an autoclave experiment performed under similar conditions but at a somewhat higher power density are also expressed by this equation.

Irradiation of loop L-2-15, the tenth in-pile loop experiment and the second in the HB-2 hole, was completed. The total circulation time was 792 hr, of which 717 hr were in the reactor. The energy output of the LITR during the experiment was 1632 Mwhr, essentially all of which was liberated at the 3-Mw level. The loop was fabricated from type-347 stainless steel and contained 0.17 m UO₂SO₄ solution at 278°C in the main stream. The over-all stainless steel corrosion rate was 1.5 mil/yr based on oxygen data and 0.5 mil/yr based on nickel data. (AEC Activity 4103.1)

Autoclave Radiation Corrosion Studies--LITR - Until recently the autoclave experiments were so assembled that about 2 cc (STP) of atmospheric nitrogen was included in the autoclave. In a recent Zircaloy-2 test, with a 0.17 m UO₂SO₄ solution without excess H₂SO₄, the autoclave was filled so that nitrogen was excluded; the corrosion rate was about 35% higher than predicted from experiments in which the nitrogen was included. Two other recent Zircaloy-2 experiments, with 0.17 m UO₂SO₄ and 0.04 m excess H₂SO₄ and filled to exclude nitrogen, showed no difference in corrosion behavior as compared with earlier experiments in which the nitrogen was included. These results imply that under certain conditions the nitrogen gas may beneficially affect the radiation corrosion of Zircaloy-2.

In an effort to determine the chemical form of the nitrogen after exposure to reactor radiation in the autoclave, a series of analyses were made on solution removed from a test in which 2 cc (STP) of nitrogen had been included. The analyses indicated that the nitrogen is fixed but not in the form of either nitrate or ammonia. (AEC Activity 4103.1)

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

Supporting Radiation Corrosion Studies - Irradiation studies performed on triethylphosphate and Amsco 125-82 indicate that either of these materials may be satisfactorily employed as the HRT secondary refrigerant in the cold traps. It was recommended that the refrigerant should be replaced periodically and the lines flushed out with fresh material to dissolve and remove any "polymer" formed. Problems which may arise from the use of either of these materials in the freeze-plug sections have not been evaluated. (AEC Activity 4103.1)

GENERAL REACTOR RESEARCH

Basic Reactor Research - The programming of a routine was initiated to obtain radiative capture cross sections for the Oracle master cross section tape which is being prepared for use with various reactor programs. The average radiative capture cross section is calculated according to the statistical theory of the nucleus with optical model penetrabilities based on a spherical square wall [see Dresner, Nucl. Sci. Eng. 1, 103 (1956) and Feshbach, Phys. Rev. 96, 448 (1954)].

Results of a brief study of the criticality of the ORR as a function of plutonium loading and time were used as a basis for a recommendation, by the Trans-Plutonic Isotope Production study group, of a 20% loading of the ORR with plutonium.

An attempt is being made to determine the Fourier transform of a thermal-neutron slowing-down kernel for an infinite water medium as a function of reactor buckling. Lid Tank Shielding Facility experimental data and indium resonance data of Hill, Roberts, and Fitch (ORNL-181) are being utilized. (AEC Activity 4520)

Radiation Damage--Advanced Engineering and Development - The transformation of tetragonal BaTiO_3 into cubic BaTiO_3 is effected by irradiation with fast neutrons at a temperature of approximately 100°C . Sufficient atomic displacements are produced by bombardment with 1.8×10^{20} nvt_f so that tetragonal single crystals ($c_0 = 4.0349 \text{ \AA}$ and $a_0 = 3.9923 \text{ \AA}$) expand anisotropically to form perovskite-type cubic single crystals with $a_0 = 4.0824 \text{ \AA}$. The transformed material has a defect structure that no longer possesses the temperature-structure behavior of unirradiated BaTiO_3 in that none of the low-temperature transitions can be thermally induced. X-ray, thermal, and optical methods were employed in studying these effects. (AEC Activity 4540)

Waste Studies - Laboratory experiments indicate that aluminum nitrate-containing wastes can be decontaminated from rare earths, strontium, and cesium by factors of $\sim 10^4$, $\sim 10^3$, and $\sim 10^3$, respectively, by a new scheme made up of previously investigated steps. The concentrated waste is added to 0.5 M NaOH. Iron hydroxide is precipitated, carrying $\sim 99\%$ of the rare earths, strontium, zirconium, and niobium and 90% of the ruthenium, but none of the cesium. The dried precipitate from 1 liter of 1 M $\text{Al}(\text{NO}_3)_3$ solution occupied 4 cc and was compressed to 2.5 cc, making a very small volume of material to be stored.

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

The supernatant is passed through phenolic cation-exchange resin, which sorbs 100% of the cesium and remaining strontium and rare earths. The cesium may be eluted from the resin and used in preparation of cesium gamma sources. Addition of CO_2 to the sodium aluminate effluent from cesium sorption coprecipitates $\text{Al}(\text{OH})_3$ and 75% of the ruthenium in this solution. This could be accumulated in asphalt-lined pits since long-lived isotopes have been removed. The final NaNO_3 - Na_2CO_3 solution, containing the remaining ruthenium, could be electrolyzed to produce NaOH and HNO_3 for reuse in radiochemical processing. This is not the most economical means of producing these chemicals but it eliminates the necessity for high decontamination of the solution. Most of the waste water may be recycled, also. (AEC Activity 4620)

School of Reactor Technology - In early December, 1956, the Oak Ridge School of Reactor Technology mailed literature describing the new ORSORT-University Cooperative Program to some 1500 industrial organizations and government agencies. In January of 1957, applications were received for the first session of the program and selected applicants were assigned to attend classes at Carnegie Institute of Technology, Case Institute of Technology, Union College, University of California at Los Angeles, and University of Florida. Classes at these universities start during February; successful students will come to ORSORT in September. (AEC Activity 4841)

PROGRAM 5000 - PHYSICAL RESEARCH

Reactor Operations - Reactor operations were normal except for the continued occurrence of ruptured slugs in the Graphite Reactor. Three ruptured slugs were located and discharged in November and seven in December.

Investigation was resumed on the necessary reactor physics and controls system for an enriched loading of the Graphite Reactor.

Since the installation of a new bypass demineralizer in the LITR cooling water system, in November, the specific resistance of the water has increased by a factor of two and the gross activity has decreased by a factor of three. Decreased corrosion of reactor components and increased radiation safety are two primary effects.

The Oak Ridge Research Reactor (ORR) - Construction of the reactor building, shielding, and cooling system is estimated to be 92% complete.

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

The aluminum pool liner was erected, and the beam tubes and large facility liners were welded in place. Placement of the barytes concrete shielding is proceeding at the end of the pool away from the reactor.

Preassembly of the reactor core and reactor mechanical drive units was completed in the X-10 Graphite Reactor Building; tests are being made to check their operation.

Fabrication of the reactor vessel has progressed to the point where the large facility tubes and the six beam tubes have been attached to the core box; water jackets are being installed prior to welding the core section into the surrounding tank.

Design of a number of experiments is in progress and it is expected that these experiments will be set up during the final check-out of the reactor in order to be ready following initial full-power operation.

Procurement of equipment necessary for the air-conditioning system, elevator, hot cells, etc., was started; it is planned that this additional work, along with the construction of change-house facilities, will be started as soon as the present building contract is complete and the building turned over to the Laboratory.

ISOTOPE PRODUCTION

Radioisotope Production - Approximately 157,000 curies of Co^{60} in temporary storage in the Storage Garden and Irradiator at the end of December gave a gamma flux of 1.68×10^6 R/hr in the exposure cage. The irradiator facility was occupied by dry irradiation samples for 207 hours in November and 440 hours in December.

Thirty-four Co^{60} sources encapsulated in stainless steel were sealed by remotely controlled Heli-arc welding. (AEC Activity 4111)

Radioisotopes, Process Development - Phase-I construction of the Fission Product Pilot Plant is about 94% complete.

Over 10,000 curies of Cs^{137} was collected from waste fission-product solutions by the alum co-crystallization method. Final purification is under way to convert the Cs^{137} to the powdered chloride for preparation of source pellets.

A product solution containing 91-hr Re^{186} was prepared for the purpose of developing a processing procedure and assay method for this isotope. No difficulty was encountered in processing; however, the assay of Re^{186} is complicated by the presence of 17-hr Re^{188} .

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

PHYSICS

Neutron Diffraction - Diffraction studies of Ho_2O_3 were made at temperatures ranging from 4.2°K to 1.25°K and in applied fields extending to 16.3 kilo-oersteds. A complex series of magnetic ordering transitions, apparently field-induced was observed. From 4.2°K to 2.4°K the zero-field diffraction patterns exhibit broad diffuse maxima characteristic of short range antiferromagnetic ordering. At 1.8°K very weak coherent reflections appear which are only slightly more intense at 1.25°K . At 4.2°K , coherent (110), (112), (310) and (312) reflections are observed to grow in almost uniformly with applied field but there still remains a broad maximum centered between the (111) and (200) reflections. Above 1.4°K no reflections of the type (100), (120), etc. are found for any field value; below this temperature reflections of this type occur for fields smaller than 10.0 kilo-oersteds. At 1.25° and at 16.3 kilo-oersteds the observed reflections are of the type (200), (220), etc. and (110), (112), etc. A tentative interpretation of these results relative to the general problem of magnetic ordering on face centered cubic lattices has been made. (AEC Activity 5220)

Low Temperature, Nuclear and Solid State Physics - Observations of the anisotropy of fission fragments resulting from thermal neutron bombardment of aligned U^{233} nuclei were made. The ratio $W(0^\circ)/W(90^\circ)$ of the intensity at 0° and 90° to the crystalline c-axis of a single crystal of $\text{UO}_2\text{Rb}(\text{NO}_3)_3$ was found to decrease by $1.3\% \pm 0.6\%$ on cooling from 77°K to 1.2°K . The previously reported anisotropy in the α -particle emission from aligned U^{233} was observed in the same experiment and served as a thermometer measuring the actual surface temperature of the crystal. (AEC Activity 5220)

High Voltage Program - The total cross sections for dissociation of the hydrogen molecular ion bombarding hydrogen, helium, nitrogen, and argon gas targets were determined in the energy range 500 kev - 2.25 Mev. It was found that the cross sections decrease slowly with increasing ion energy. With hydrogen as the target gas the cross section decreases from $4.15 \times 10^{-17} \text{ cm}^2/\text{gas atom}$ at 500 kev to $2.12 \times 10^{-17} \text{ cm}^2/\text{gas atom}$ at 2.25 Mev. For argon the cross section decreases from $4.35 \times 10^{-16} \text{ cm}^2/\text{gas atom}$ at 500 kev to $3.5 \times 10^{-16} \text{ cm}^2/\text{gas atom}$ at 2.25 Mev. The dissociation reaction may proceed by either simple dissociation (i.e. $\text{H}_2^+ + \text{A} \rightarrow \text{H} + \text{H}^+ + \text{A}$) or by an ionization-type dissociation (i.e. $\text{H}_2^+ + \text{A} \rightarrow \text{H}^+ + \text{H}^+ + \text{e} + \text{A}$). Measurements indicate that for a hydrogen gas target 50% of the reactions result from simple dissociation, while for argon simple dissociation occurs 33% of the time. These percentages are independent of the molecular ion energy throughout the energy range studied.

Angular distributions of neutrons elastically scattered from carbon were measured at ten neutron energies ranging from 1.45 Mev to 3.77 Mev. The neutrons were produced by the $\text{T}(p,n)\text{He}^3$ reaction, with protons accelerated by the 5.5-Mv Van de Graaff generator onto a tritium gas target, and the scattered neutrons were detected by a paraffin-shielded propane recoil counter. Agreement between the presently measured distributions and earlier reported measurements (J. E. Wills, Bull. Am. Phys. Soc. 1, No. 4, 175) from this Laboratory were very good.

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

Enriched targets of the even-numbered tin isotopes were made by sintering metallic powder at room temperature. Coulomb excitation in these targets was studied by bombarding them with 8-, 9-, and 10-Mev α -particles accelerated by the 5.5-Mv electrostatic generator. The first 2^+ state was located in Sn^{116} , Sn^{118} , Sn^{120} , Sn^{122} , and Sn^{124} . These have energies, respectively, of 1.268-, 1.219-, 1.155-, 1.130-, and 1.128-Mev. From the measured γ -ray yields and the application of Coulomb excitation theory, the reduced E2 γ -ray transition probabilities and the half-lives of the states were obtained. The observed transition probabilities are approximately 10 times larger than those given by the Weisskopf independent-particle estimate.

The zero-degree yields of gamma rays from the reactions $\text{P}^{31}(\text{p}, \text{p}' 1.26 \text{ Mev})$ and $\text{P}^{31}(\text{p}, \alpha, \gamma 1.78 \text{ Mev})\text{Si}^{28}$ were measured for 3 to 4 Mev bombarding proton energies. A 3-in.-dia by 3-in. high cylindrical NaI crystal served as the γ -ray detector. Over 26 narrow resonances were observed in this interval. In addition, a spectrum at 3.72 Mev revealed the presence of a 2.24-Mev gamma ray from the second excited state of P^{31} . (AEC Activity 5220)

CHEMISTRY

Volatility Studies - In the fused salt--fluoride volatility process, uranium fuel elements are dissolved in molten NaF-ZrF_4 by means of flowing HF, and the UF_4 is fluorinated to volatile UF_6 , which is then absorbed in NaF cold traps. The process was developed with zirconium-containing fuels, but preliminary tests indicate that it may be applied to stainless steel-clad fuel elements. In 43% NaF-57% LiF the rate was 3.4 mg/m-cm² at 700°C; in 50-50 NaF-ZrF₄ at 700°C, the average dissolution rate was 1.4 mg/m-cm².

The gas phase oxidation resistance of types-316 and 347 stainless steel was very unsatisfactory in tests of their use as a possible container material for fused fluoride salt at 1200°F in the Volatility Pilot Plant. Inconel was also attacked by traces of oxygen in the helium or nitrogen blanket gas. Nickel exhibited the least oxidation effect. It is postulated that traces of fluoride vapor catalyzed the reaction, perhaps destroying the protective film of chromium oxide. This reaction suggests the possibility of vapor phase oxidation of stainless steel-clad fuel elements.

In runs with irradiated uranium, a small amount of the PuF_6 formed during the dissolution was volatilized, but was absorbed by the NaF traps. Passage of the desorbed UF_6 product through a nickel-packed column at 120°C gave an additional ruthenium decontamination factor of only 1.6.

NaF pellets and 12-20 mesh material from Harshaw Chemical Co. had a particle porosity of 48%, a bed porosity of 33%, and an overall porosity of 65%. A sample of crystalline NaF had an overall porosity of only 35%.

Sulfur contamination in the fluoride melt at 600°C results in embrittlement of nickel that is in contact with the salt. Under process conditions embrittlement is not noticeable with a single run and with less than 30 ppm

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

sulfur, but the effect is cumulative. A nickel foil test was developed which demonstrated embrittlement by as little as 1 ppm of sulfur. The high sensitivity is due to a high salt/metal ratio. Nickel packing with a relatively high surface area effectively removed sulfur from molten NaF-ZrF_4 . Inconel was much more resistant to sulfur embrittlement than ordinary nickel. (AEC Activity 5310)

Ion-Exchange Studies - Uranium was successfully separated from solutions of uranium scrap containing fluoride in a 2-in.-dia Higgins continuous ion-exchange contactor with Permutit-SK resin. The scrap was dissolved in dilute sulfuric acid. The uranous ion in the scrap solution was first oxidized to the uranyl form by heating 30 min with MnO_2 . To reduce corrosion, excess fluoride in the feed was precipitated, though not very efficiently, from the feed solution by magnesium sulfate, which was added before the oxidation. The uranium was converted on the resin to the chloride form with 10 M HCl and eluted with H_2O , with a consumption of about 5 lb HCl per pound of uranium. (AEC Activity 5310)

Chemical Engineering Research Studies - The zirconium cladding was successfully removed from a PWR blanket element. This tube, which is 0.41 in. o.d. and 10.25 in. long, contains UO_2 wafers. Two passes through the rollers were required. The end cap was snapped off after only 3 mils expansion of the zirconium tube. The core UO_2 was reduced to powder, which could be poured from the tube.

Equipment for continuously removing emulsified material from the interface of a pulsed solvent-extraction column, filtering it, and returning the filtrate to the column, was installed on a 2-in.-dia, 26 ft-high column. The system operated satisfactorily for several runs, but eventually the emulsion became too stable to be broken by the filter system. Cooling of the interface was partially successful in reducing the thickness of the emulsion layer.

Sieve-plate columns are less expensive, easier to decontaminate, and less subject to corrosion than the bubble-cap columns now used for removing tributyl phosphate from evaporator feed streams. In preliminary tests with a sieve-plate column, four actual plates reduced the TBP content of an aqueous solution from 200 ppm to less than 5 ppm, corresponding to an average plate efficiency of 25%. (AEC Activity 5310)

High Level Nuclear Chemistry - A series of experiments was performed which was designed to give general information on the potential hazard associated with a reactor incident in which fuel was melted. With miniature fuel plates, simulating the APPR, the average result upon melting at 1525°C (2 min heating in air) indicated the release of 48.4% of the rare gases, 33.5% of the iodine, 9.1% of the cesium, 0.02% of the strontium, and 4.5% of the total gamma activity. At 800°C , these values for aluminum alloy were 4.8% of the iodine and 1.8% of the total gamma. Experiments being continued to determine the effects of such variables as size of UO_2 particle, degree of burn-up, and cooling time. (AEC Activity 5330)

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

Chemistry of Corrosion - Experiments directed toward the demonstration of the Flade potential on iron in aerated solutions of the XO_4^{n-} inhibitors were extended to the use of chromate, molybdate, tungstate, and pertechnetate ions as inhibitors. The evidence indicates that the characteristic activating potential may be observed regardless of which inhibitor is used. Since the observed potentials fall approximately at the proper value and have the same dependence upon pH as the Flade potential, there seems little doubt that the surface state on the metal is electrochemically similar whether the metal is passivated by the usual procedures or inhibited under aerated conditions. (AEC Activity 5330)

Chemistry of Technetium - Low temperature heat capacity measurements were made on a second preparation (hypophosphorous acid reduction of $KReO_4$) of potassium hexachlororhenate, K_2ReCl_6 . The results confirm the existence of the anomalies (cooperative type) in the heat capacity of this substance at 76° , 103° , and $111^\circ K$. For this sample the shape of the heat capacity curve in the region of the anomalies does show significant differences from that obtained with the first sample. In each case the two curves agree to approximately 0.1% on the low temperature side of the anomaly, but above the peak of the anomaly the second curve is approximately 0.5% lower than the first in the trough of the anomaly. Also, the anomaly which has a peak at $103.0^\circ K$ for the first sample, has the peak at $102.5^\circ K$ for the second sample. Outside the anomalous region, the results on the two preparations of K_2ReCl_6 agree to 0.1%, the second sample results being about 0.1% higher than those of the first sample. (AEC Activity 5330)

Characterization of Short-Lived Fission Products - The previously reported study of the decay of 31.8-min Br^{84} was completed. The radiations were examined with single crystal and coincidence scintillation spectrometers. With a 3 x 3-in. NaI crystal spectrometer the decay showed gamma rays of 0.37, 0.43, 0.47, 0.52, 0.61, 0.73, 0.81, 0.879, 1.01, 1.21, 1.48, 1.57, 1.70, 1.90, 2.05, 2.17, 2.47, 2.84, 3.02, 3.29, and 3.93 Mev with indications for additional low energy gamma-ray components. The gamma-ray spectra in coincidence with the 0.879-, 1.90-, 2.47- and 3.93-Mev gamma rays were also measured. The intensities of the various gamma rays were calculated from a detailed analysis of single crystal and coincidence gamma-ray spectra.

The maximum beta-ray end-point energy measured with an anthracene crystal spectrometer was 4.76 Mev. This group is not in prompt coincidence with any of the gamma rays and is therefore believed to be the transition to the ground state of Kr^{84} . Beta-gamma coincidence measurements indicated other beta-ray components of 3.83, 2.80, 1.81, 1.39, and possibly 0.83 Mev. About 31% of the Br^{84} beta decays go to the ground state of Kr^{84} . A decay scheme for Br^{84} formulated on the basis of these data gives rise to levels in Kr^{84} at 0.88, 1.90, 2.17, 2.36, 2.62, 2.71, 2.91, 3.35, 3.70, 3.91, and 4.18 Mev. (AEC Activity 5330)

Chemical Separation of Isotopes - Nitrogen-15 produced by the Nitrox process was used to prepare $N^{15}O$. Since NO has an odd electron, it has a 2π electronic ground state, and the spectrum is more complicated than that of other diatomic

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

molecules. The fundamental rotation-vibration band of $N^{15}O$ was studied with the University of Tennessee's grating spectrometer. The molecular constants calculated from the spectral data are:

$$\begin{array}{ll} B_{01} = 1.6146 \text{ cm}^{-1} & B_{02} = 1.6577 \text{ cm}^{-1} \\ B_{11} = 1.5984 \text{ cm}^{-1} & B_{12} = 1.6410 \text{ cm}^{-1} \\ D_{01} = D_{11} = 3 \times 10^{-6} \text{ cm}^{-1} & D_{02} = D_{12} = 8 \times 10^{-6} \text{ cm}^{-1} \\ (B_{01} - B_{11}) = -0.01631 \text{ cm}^{-1} & (B_{02} - B_{12}) = -0.01695 \text{ cm}^{-1} \\ \Delta G_1(0) = 1843.05 \text{ cm}^{-1} & \Delta G_2(0) = 1842.79 \text{ cm}^{-1} \end{array}$$

The separation factor for oxygen isotopes between CO_2 gas and monoethanolamine carbamate dissolved in n-butyl alcohol was measured in a three-pass multistage experiment. The factor is 1.011 ± 0.002 (95% C.I.) at $25^\circ C$ and 740 mm of Hg, with oxygen-18 enriching in the gas phase. (AEC Activity 5340)

METALLURGY

Radiation Effects on Oxidation - An investigation is being undertaken to determine the changes produced by radiation fields in the basic oxidation mechanisms of metals. A preliminary series of experiments, designed to give a detailed characterization of oxide films formed on copper in the absence of radiation, is in progress. The results of these experiments will be used as a standard against which radiation-induced changes will be evaluated.

Electron microscope and diffraction data were obtained for oxide films formed on the (100), (111), (110), and (311) planes of a copper single crystal at 130 and $150^\circ C$. It was found that the oxide films with thicknesses ranging from about 50 to 500 Å were highly oriented with respect to the metal substrate. On the (100) and (111) faces of the copper crystals, the (111) plane of the oxide grew parallel to the metal surface; while the (110) plane of the oxide was parallel to the metal surface on the (110) and (311) faces of the crystals. Marked thickness inhomogeneities were also observed in the oxide films from all four crystal faces investigated. This result suggests that oxidation proceeds in a patch-wise fashion following nucleation at points on the oxide surface. Thus the assumption, implicit in all oxidation theories, of the uniform thickening of the oxide layer must be regarded as erroneous, at least for thin oxide films. (AEC Activity 5420)

PROGRAM 6000 - BIOLOGY AND MEDICINE

BIOLOGY

Cytology and Genetics--Paramecium - Laboratory populations of paramecia are easily kept and may be useful for investigating some aspects of chronic radiation damage. Preliminary information was obtained on unirradiated populations maintained for a year and a half that indicate both favorable and unfavorable features. The populations are primarily crossbreeding and not inbreeding; and, in this respect, are similar to populations of most higher organisms. The populations have spontaneously accumulated a large load of recessive lethal mutations. Obviously selection was not very effective in eliminating recessive lethals. This feature is, in some ways, favorable; but the rapid increase in lethals in unirradiated populations poses some technical problems for radiation studies. (AEC Activity 6130)

Cytology and Genetics--Plants and Fungi - Studies on maize cytogenetics and high dose seed radiation are being continued. The behavior of a highly mutable gene affecting aleurone coloration in the maize kernel is being analyzed. This unstable gene is a recessive \underline{c} which mutates at a very high frequency to both a stable dominant, \underline{C} , and to a stable recessive \underline{c} . The mutations are not associated with any observable chromosomal aberration. They occur during all stages in the life cycle. Late mutations to \underline{C} appear as small colored spots on the kernel. Early mutations form sectors of fully colored and completely colorless kernels on the ear. These early mutations are germinal and breed true. The time of mutation is subject to selection.

The growth of the wheat coleoptile and leaf show completely opposite responses to increasing dosage of radiation between 100,000 and 400,000 r. The coleoptilar length decreases whereas the leaf length increases with increased dosage. This difference in behavior is considered as being due to the masking of chromosomal damage by mitotic inhibition at high doses of radiation. There are no, or only very, few dividing cells in the coleoptile following germination. (AEC Activity 6130)

Cytology and Genetics--Insects - Previous work on the neuroblasts of the 14-day old grasshopper embryo has shown the pronounced effect of as little as 1 r of X rays in producing mitotic inhibition. In view of the extreme sensitivity of the neuroblasts, experiments were performed to determine the doses of X rays which are lethal to the embryos. All embryos in the present experiments were irradiated at 14 days development (room temperature).

When failure of the embryo to hatch is taken as a criterion of lethality, the LD_{50} to the embryo lies between 400-450 r; the LD_{100} is 600 r. Above this level, 600-800 r, the embryo develops to the point of hatching but is unable to emerge from the chorion. For exposures of from 800 to 8000 r, the embryos develop to stages which are comparable, morphologically, to 20-21 days of normal development. For doses between 8000 and 17,000 r, the appendages of the embryos continue development, i.e., differentiation of the parts continues, for a maximum of 2 days after which time degeneration of the embryo sets in. At doses of 17,000 r and above, no further development in terms of

PROGRAM 6000 - BIOLOGY AND MEDICINE (Continued)

gross morphological changes could be detected. Thus, we see that although the neuroblasts are extremely sensitive to radiation, the embryos are able to continue development after fairly high doses of X rays. (AEC Activity 6130)

Pathology and Physiology - The relative biological effectiveness (RBE) of Po-Be neutrons and of Co⁶⁰ gamma rays is being assayed in mice of the RF strain under conditions of chronic irradiation. The dose rate required to cause median lethality in 10-12 weeks was approximately 80 rad/day of gamma rays or 15 rad/day of neutrons (RBE = $80/15 = 5.3$), whereas that required to cause median lethality in 26 weeks was approximately 60 rad/day of gamma rays or 3.5 rad/day of neutrons (RBE = $60/3.5 = 17.1$). From these intensity ratios, it is apparent that the RBE of neutrons for lethality varies inversely with the dose rate. At low intensities it may exceed ten for the production of delayed injuries that shorten the life span.

The occurrence of mucopolysaccharide in the blood platelets of rats was reported previously. New information suggests the presence of large amounts of galactose and glucosamine in this material, as well as smaller amounts of glucose, mannose, and fucose. Procedures designed to characterize further the mucopolysaccharide are in progress. (AEC Activity 6130)

Biochemistry - It has been shown that the ribonucleic acid (RNA) in bacteriophage-infected Escherichia coli can incorporate and subsequently release P³²O₄ although the total amount of RNA remains constant. When P³² is presented to the infected bacteria, RNA incorporates more P³² than does desoxyribonucleic acid (DNA) although DNA, as the only nucleic acid end product of the infected cells' metabolism, will eventually incorporate far more P³² than the RNA. DNA synthesis is inhibited by chloramphenicol, which was added a few minutes after bacteriophage infection. This was followed by P³²O₄, the times of the two additions being chosen to allow incorporation of P³² into RNA but not into DNA. The culture was then divided into two parts. To part a was added excess P³¹O₄ to dilute out the P³²O₄, while part b was washed free of chloramphenicol before reincubation in excess P³¹O₄. The presence of chloramphenicol in a inhibited P³² release from RNA and prevented DNA synthesis. The infected bacteria in b, however, released P³² from RNA and concomitantly incorporated P³² into newly synthesized DNA. These results were qualitatively confirmed by using adenosine-C¹⁴ as a nucleic acid precursor; they indicate a relation between DNA synthesis and RNA turnover. (AEC Activity 6130)

Biophysics - The relative effect of a number of different ionizing radiations on free radical production is being systematically studied in a number of compounds of biological interest. In the case of amino acids the results show little or no difference in the effectiveness of X or gamma rays; D-T neutrons (14 Mev) are approximately 0.7 as efficient as gamma rays. The effects of α particles from polonium are currently being studied.

Pure, highly polymerized calf thymus DNA irradiated with large doses of ultraviolet showed the presence of radicals. The same material irradiated

PROGRAM 6000 - BIOLOGY AND MEDICINE (Continued)

with gamma rays (up to 10^7 r) showed no detectable radical production. Impure commercial DNA does give a radical signal when irradiated, presumably arising from protein impurities in this material. (AEC Activity 6130)

Microbial Protection and Recovery - Elucidation of the mechanism by which cysteamine (β -mercaptoethylamine) MEA protects Escherichia coli B/r still is a major effort for this group. Its influences in protective capacity is apparently not due to tight binding on any biological macro-molecule since the protective activity can be easily removed by washing or by dilution, even at temperatures near 0°C . Preliminary experiments indicate that this is not the case for AET, the S,2-aminoethylisothiuronium·Br·HBr compound (Doherty), for which the protective activity cannot be removed by washing.

The ability of yeast cells to retain potassium following radiation was examined by the yeast column technique (Bruce). The leakage of potassium by X-rayed cells has been shown previously to be a function of the metabolic activity of the cell and depends on the presence of oxygen during irradiation, being immeasurable from cells irradiated in a nitrogen saturated medium. It was found that ultraviolet (2537 Å) produces a similar effect as does also long ultraviolet and short visible radiation 3000-4000 Å. An attempt is being made to correlate the lethal effect with the membrane damage produced by these radiations. (AEC Activity 6230)

Mammalian Recovery - Relatively large numbers of lethally irradiated mice have survived for many months after treatment with foreign bone marrow. These animals were accumulated from many experiments. The factors controlling long-term survival after treatment with foreign bone marrow are still obscure. Mice given low doses of total-body radiation followed by rat bone marrow injection sometimes showed greater mortality than those given radiation alone. It was demonstrated that the rat bone marrow grew luxuriantly in the mice only temporarily and that death was caused by the secondary bone marrow failure.

The immune response studies on lethally X-irradiated mice pretreated with AET showed that the rate of recovery was not significantly different from that of lethally X-irradiated mice posttreated with isologous bone marrow.

The protective effectiveness of plasma-like cells obtained from tissue-cultured bone marrow cells incubated at 37°C is lost by the 14th day, even with supplementary antibiotic treatment. An effective bone marrow suspension from a 19-day, 25°C culture was obtained, and older cultures are being tested.

Bone marrow cells irradiated in vitro in the presence of AET were able to keep lethally irradiated mice alive. Without AET the bone marrow irradiated in vitro did not keep lethally irradiated mice alive. (AEC Activity 6230)

OPEN LITERATURE PUBLICATIONS

- Bair, J. K., H. O. Cohn, J. D. Kingston and H. B. Willard, "The Reaction $N^{14}(p,p'\gamma)N^{14}$ ", Phys. Rev. 104, 1595 (1956)
- Begun, G. M., "Nitrogen Isotope Effect in the Distillation of N_2O_4 ", J. Chem. Phys. 25, 1279 (1956)
- Begun, G. M. and C. E. Melton, "Nitrogen Isotopic Fractionation Between NO and NO_2 and Mass Discrimination in Mass Analysis of NO_2 ", J. Chem. Phys. 25, 1292 (1956)
- Blizard, E. P., "Reactor Shielding", A.S.M.E. Trans. 79, 35 (1957)
- Borkowski, C. J., "Low Energy Gamma Scintillation Spectrometry", I.R.E. Trans. on Nuc. Sci., Vol. NS-3, November 1956, No. 4
- Bredig, M. A., "Salt-Metal Liquid-Phase Equilibria", Proc. of Sym. on High Temperature--A Tool for the Future, Berkeley 1956, p. 111 (publ. Stanford Res. Institute)
- Burns, J. H. and M. A. Bredig, "Transformation of Calcite to Aragonite by Grinding", J. Chem. Phys. 25, 1281 (1956)
- Conte, F. P., G. S. Melville, Jr., and A. C. Upton, "Effects of Graded Doses of Whole-Body X Radiation on Mast Cells in the Rat Mesentery", Am. J. Physiol., 187, 160 (1956)
- Cormier, M. J. and H. H. Rostorfer, "Flavin Stimulation of Methemoglobin Reduction in Cell-Free Bacterial Extracts", Biochim. et Biophys. Acta 22, 292 (1956)
- Furth, J., R. F. Buffett, M. Banasiewicz-Rodrigues, and A. C. Upton, "Character of Agent Inducing Leukemia in Newborn Mice", Proc. Soc. Exptl. Biol. Med. 93, 165 (1956)
- Hollaender, A. and G. E. Stapleton, "The Influence of Chemical Pre- and Posttreatments on Radiosensitivity of Bacteria, and their Significance for Higher Organisms", Ciba Foundation Sym. on Ionizing Rad. and Cell Metabolism, pp 120-139 (1956) (publ. J. and A. Churchill Ltd., London)
- Householder, A. S., "Solving Problems With a Digital Computer", Control Eng. 4, No. 1 (1957)
- Householder, A. S., "Numerical Mathematics from the Viewpoint of Electronic Digital Computers", Electronic Digital Computers and Info. Proc., 4 (1956)
- Householder, A. S., "Opportunities for Mathematicians in Government Sponsored Research", Career Opportunities in Phys., Math., and Eng. March (1956)
- Householder, A. S., "Education for Automation", Computers and Automation 6, Pt. 2, 51 (1957)
- Lamphere, R. W., "Fission Cross Sections of the Uranium Isotopes, 233, 234, 236 and 238 for Fast Neutrons", Phys. Rev. 104, 1654 (1956)
- Macklin, R. L. and H. S. Pomerance, "Resonance Activation Integrals of U^{238} and Th^{232} ", J. of Nuc. Energy II, 243 (1956)
- Maizel, J. V., A. A. Benson, and N. E. Tolbert, "Identification of Phosphoryl Choline as an Important Constituent of Plant Saps", Plant Physiol. 31, 407 (1956)
- Menis, O., H. P. House, and T. C. Rains, "Indirect Flame Photometric Method for Determination of Halides", Anal. Chem. 29, 76 (1957)

OPEN LITERATURE PUBLICATIONS (Continued)

O'Kelley, G. D. and Q. V. Larson, "Half-Life of Tc^{98} and Its Abundance in Fission-Product Technetium", So. Chemist 16, 113 (1956)

Senftle, F. E., T. A. Farley and N. H. Lazar, "Half-Life of Th^{232} and the Branching Ratio of Bi^{212} ", Phys. Rev. 104, 1629 (1956)

Snell, A. H., "A Survey of the Particles of Physics", Am. Scientist 45, 44 (1957)

Taylor, E. H. and H. W. Kohn, "An Enhancement of Catalytic Activity by Gamma Radiation", J. Am. Chem. Soc. 79, 252 (1957)

Volkin, E. and L. Astrachan, "The Absence of Ribonucleic Acid in Bacteriophage T2r+", Virology 2, 594 (1956)

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RADIOISOTOPE SALES AND COSTS

<u>Type of Transaction</u>	<u>December 1956</u>	<u>FY 1957 to Date</u>
Domestic Sales	\$256,652	\$ 903,984
Foreign Sales	14,073	64,895
Project-Transfer	601	6,196
Project-Cash Sales	2,060	24,949
Technical Co-operation Program Credits	0	3,380
Plant Credits	3,252	27,541
AEC Credits	<u>12,712</u>	<u>97,626</u>
Total Radioisotope Income	\$289,350	\$1,128,571
Total Radioisotope Costs	\$ 92,090	\$ 667,562
Total Radioisotope Shipments	997	6,548
Helium		
Income	\$1,073	\$10,357
Costs	\$ 487	\$ 3,635
Shipments	3	14

GROSS OPERATING COSTS

	<u>Cost for December</u>	<u>FY 1957 Cost to Date</u>
Programmatic Operating Cost - Net	\$4,516,063	\$25,380,152
Equipment	163,103	1,325,165
Construction	125,719	921,401
Work for Others - Transfers	26,683	280,466
Inventory Changes	48,370	13,217
Reimbursable Work for Others	93,776	453,743
Deferred Charges	<u>(6,732)</u>	<u>(267,724)</u>
Total Laboratory Cost - Net	\$4,966,982	\$28,106,420
Estimated Cost for Next Month	\$5,000,000	\$33,106,420

() Credit

PERSONNEL SUMMARY

	<u>Number of Employees January, 1957</u>	<u>New Hires January</u>	<u>Terminations January</u>
Administration	73	0	0
Operations*	129	2	0
Engineering, Shops, and Mechanical	857	15	5
Laboratory and Research	2190	34	22
Protection	125	0	1
Service	<u>384</u>	<u>1</u>	<u>2</u>
	3758	52	30

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

930 Laboratory personnel are located in the Y-12 Area.

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Reports in this series issued during the past year:

January 1956	ORNL-2044
February 1956	ORNL-2062
March 1956	ORNL-2073
April 1956	ORNL-2082
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

Edited by F. T. Howard

Approved by Alvin M. Weinberg, Director