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AEC RESEARCH AND DEVELOPMENT REPORT

LABORATORY RECORDS
1954

OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

APRIL 1953

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

April, 1953

W. H Sullivan

and

F. T. Howard

Date Issued: MAY 7 1953

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

April, 1953

The subject material of this report represents approximately half of the Laboratory's program, which is covered with some exceptions in a bimonthly schedule.

PROGRAM 3000 - WEAPONS

Special Electromagnetic Separation - The initial experience in operating a calutron for plutonium separation indicated the need for a better heating system; vaporization of plutonium trichloride requires a temperature in the range of 900 to 1100°C, whereas uranium tetrachloride is vaporized at less than 550°C. A modified heating system has been tested and found to be more reliable.

The first attempts at preparing plutonium trichloride by refluxing plutonium oxalate with hexachloropropene gave a yield of only 60 to 70%. The vapor phase chorination of this product with phosgene at 650°C gave essentially complete conversion. (AEC Activity 3601)

PROGRAM 4000 - REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Experiment - A failure of the motor windings in the HRE main fuel pump has required the pump to be replaced. Since the length of time the pump operated in the HRE corresponds very closely to the average lifetime of similar pumps in the dynamic corrosion loops, the failure was not unexpected. Even though a total of 15 megawatt hours of operating time had been accumulated recently, it was still possible to reduce the radiation level sufficiently to permit work on the pump by draining the fuel from the system and rinsing with water. With the top plug removed from the heat exchanger compartment, where the pump is located, the old pump and a pipe elbow containing pin-type corrosion samples were removed and replaced successfully by direct maintenance using long-handled tools.

The new pump has been aligned, balanced, tested, and shown to be properly installed and in good working condition. Although the reactor system is

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ready for operation, chemical analyses of the fuel have indicated that some uranium may have precipitated in the system, so dilute acid solutions are being charged into the reactor system to dissolve any uranium that may be present. (AEC Activity 4103.10)

HRP Critical Experiments - It has been shown that the reactivity of a critical volume of aqueous enriched UO_3 slurry is a function of its agitation. The critical mass at intermediate agitation was observed to be six to eight percent less than that found at those higher stirrer speeds where criticality was independent of the degree of agitation. The experiment has been repeated using an aqueous solution of UO_2F_2 instead of the slurry and measuring the critical mass as a function of mixing. As the stirrer speed is increased the critical mass also increases about two percent, due probably to the formation of ripples and a vortex in the surface at the higher speeds. No pronounced minimum in the critical mass-stirrer speed curve was observed as in the case of the slurry. The excursions of criticality in the slurry system are probably related to the density pattern in an inhomogeneous UO_3-H_2O mixture. (AEC Activity 4109.2)

HRP Chemistry—Radiation Studies - Experiments on the effect of reactor radiation on the static corrosion of type 347 stainless steel indicate that radiation may increase the corrosion rate. The initial corrosion rate (for several weeks) appears to be linear with the square root of time. The dependence of the corrosion rate on fission density remains uncertain.

Studies of the stability of the pertechnetate ion, TcO_4^-, under reactor radiation or γ-ray radiation show that, in the absence of hydrogen, there is either no reduction or there exists a steady state level of reduced technetium below the limits of detection. In the presence of hydrogen a brown colloidal material, presumably TcO_2, is produced, the initial yield of which is approximately 2.4 equivalents of technetium per 100 ev absorbed.

Continued studies on the mechanism of the hydrogen-oxygen recombination reaction in solutions indicate that, although the uncomplexed copper ion is very active catalytically, there exists some other species that is even more active.

An indirect method for measuring the solubility of hydrogen in uranyl sulfate solutions was developed in which data on the kinetics of liquid phase recombination of hydrogen and oxygen are used to calculate the solubility of the gas in the solution. Work on the solubility of UO_3 in dilute uranyl sulfate solutions at 175°C was completed. The mole ratio, U/SO_4, drops very sharply below unity at uranium concentrations less than approximately 0.01 molar. Hydrolytic precipitation of both copper and uranium occurs in low concentration ($\sim$ 0.01 M) solutions of the cations at 250°C, unless specified amounts of free acid are added. The required amounts of acid for several selected concentrations of copper and uranyl ion have been determined.

A single experiment to determine the distribution of fission product activity between the heavy (uranium-rich) phase and the light (water-rich) phase in the miscibility gap of the uranyl sulfate - water system indicates that the

activity is largely associated with the uranium-rich phase. This suggests the possible utilization of uranyl sulfate as a scavenger for decontamination.

Experiments are in progress to determine the feasibility of adding measured amounts of sulfur dioxide and oxygen to the "in-pile loop" to effect the equivalent of adding sulfuric acid to the system to correct the acid deficiency produced by corrosion. Results to date indicate that the uranyl ion is not reduced by sulfur dioxide and that the oxidation of the sulfur dioxide is complete and fairly rapid under the conditions of the experiment. (AEC Activity 4109.31)

Dynamic Corrosion Studies - Correlation of the data from a large number of runs in the 100-gpm loops shows that while the corrosion rate of stainless steel in uranyl sulfate solutions at 250°C is strongly influenced by the flow velocity of the solution, there is apparently a "critical velocity" below which the effect is much smaller. The "critical velocity" seems to be related inversely to the corrosiveness of the solution, mild solutions having a high "critical velocity" and corrosive solutions having a low "critical velocity." For example, a solution containing 15 grams of uranium per liter as UO_2SO_4 plus 25 mol percent excess sulfuric acid gives a corrosion rate of about 85-100 mils per year at velocities of the order of 50-60 feet per second, but the corrosion rate is less than 1 mil per year at 10-15 feet per second. The "critical velocity" at which the corrosion rate accelerates considerably seems to be about 25-30 feet per second. With a less corrosive solution containing 5 g U/l the corrosion rate is low at all velocities tested, indicating either that the "critical velocity" is greater than 70 feet per second or that there is no "critical velocity." (AEC Activity 4109.4)

Engineering Development - A 5-gallons per minute (gpm), canned-rotor pump, intended for operation with UO_2SO_4 solutions at 250°C in an "in-pile circulating loop," has been developed, constructed and tested at ORNL. The pump is 6-1/8 inches in diameter at the widest point and 12 inches long. Although tests with UO_2SO_4 at 250°C and 1000 psi pressure have not yet been performed, the tests at room temperature indicate a satisfactory performance.

A 4000-gpm fuel circulating loop for operation with UO_2SO_4 at 250°C and 1000 psi is under construction. It utilizes a Byron-Jackson canned-rotor pump in the system. This loop, which will use 6, 8, or 10-inch diameter heavy-wall stainless steel pipes, will supply information on corrosion and on the performance of scaled-up equipment items.

The 50,000-gpm pump loop, incorporating an 8-foot core with two tangential equatorial inlets and two polar outlets has been operated at full flow, and data on the flow pattern and pressure drop in the sphere have been obtained. The observed pressure drop across the sphere at a flow rate of 50,000-gpm is 35 psi, which agrees well with predictions. It was observed during operation that the sphere had two vortices instead of one, as expected, and this is attributed to the arrangement of vanes in the outlets. It is now planned to observe the flow pattern with the vanes removed.

An 18-inch plastic model has been used to show that very good flow distribution and low pressure drop can be obtained through a sphere with a bottom inlet and top outlet when inlet screens are used to direct the flow. A 4-foot sphere has been designed for straight-through flow on the basis of these tests and is now being fabricated for installation in the large loop system. Because of the lower pressure drop, straight-through flow is now favored over rotational flow, especially since small-scale tests indicate that suitable—and controllable—flow distributions can be obtained.

A pipeline gas separator that can be installed in the main fuel outlet pipe of a circulating fuel homogeneous reactor has been developed and tested in a 5-inch pipe model. Either vanes or volutes can be used to set up the rotation and retard and stop the rotation successfully. A gas take-off nozzle that has been developed allows nearly 100% separation of the gas with either large or small voids in the separator.

In studies to improve the performance and lifetime of the pulsafeeder pump used for the injection of fuel into the high pressure reactor system, tests on a stainless steel diaphragm have been made. From the metallurgical examination of such a diaphragm after several million flexing cycles in air, it appears that stainless steel exhibits very little fatigue. (AEC Activity 4109.5)

HRP Fuel Reprocessing - In February it was reported (ORNL-1516) that the efficiency and capacity of calcium fluoride for adsorbing rare earths made it an attractive material for processing the fuel of a thermal breeder. However, when contacted with a uranyl sulfate solution containing rare earths, calcium fluoride undergoes a metathesis in which the rare earths replace the calcium in the solid phase, and calcium transfers into the reactor solution. It is not yet known whether the solubility of the resulting calcium sulfate under these conditions is such that it will be objectionable in the fuel solution. Studies on other adsorbents showed that thorium fluoride removed rare earths from solution in the same manner as calcium fluoride, but its exchange capacity was lower at room temperature. The presence of thorium in the reactor fuel is not objectionable. (AEC Activity 4109.81)

HRP Fuel and Blanket Studies - Uranium trioxide monohydrate, $UO_3 \cdot H_2O$, of suitable purity for homogeneous reactor slurry use has been prepared by thermal decomposition of ammonium uranyl carbonate, $(NH_4)_2UO_2(CO_3)_3$, and subsequent hydrolysis of the oxide thus formed to the monohydrate in water at 250°C.

At the temperature of 250°C proposed for the slurry-type homogeneous reactor the stable crystalline form of $UO_3 \cdot H_2O$ in water is a platelet. In pumping and radiation experiments, it has been found that this form of uranium trioxide deposits out on the walls of the container under reactor conditions. Indications from engineering tests now underway are that such deposition may not occur with uranyl carbonate, UO_2CO_3, and consideration is being given to the use of this compound in homogeneous reactor slurries.

For use in thermal breeder reactors, a solid solution of uranium oxide in thorium oxide, having a uranium/thorium mole ratio of 0.03, was prepared by hydrolysis of the respective carbonates. This material exhibits excellent slurry-forming properties, and is chemically stable in water at 250°C and in boiling nitric acid.

Thorium oxide of sufficiently high bulk density to give a blanket slurry with a thorium concentration of 1000 to 2000 g/liter has been prepared from thorium oxalate by hydrolysis at 250°C. However, the slurry is abrasive to stainless steel. (AEC Activity 4112.31)

AIRCRAFT NUCLEAR PROPULSION PROJECT

Aircraft Reactor Experiment (ARE) - Welding of the serpentine coils for the pressure shell was completed and assembly of the core was started. The BeO blocks for the moderator will not need surface treatment or canning, since the extent of the static corrosion of BeO by sodium appears to be tolerable.

Strain gages have been installed on the fuel lines at the anchor points and installation of the fuel piping is continuing satisfactorily. Some of the heaters are in place and part of the insulation has been put on the fuel piping. About 40% of the thermocouple lines have been installed. Platforms for mounting the pumps have been installed. Surge tanks have been completed and await helium pressure testing before being placed in the circuit. Two of the Na-to-He heat exchangers were returned to the vendor for repairs. All fill and flush tanks were cleaned and are now ready to be connected to the system.

Procedures for cleaning the fuel and sodium systems have been established. The water system for the complete process water piping is being cleaned and checked for operational readiness. All valves have been removed for the flushing and cleaning operation and will be replaced only after the system has been thoroughly cleaned.

Control room wiring is nearing completion. One of the motors for the safety rod actuator drives has been rewired and the others will also be modified to permit unlimited frequency of reversal. The magnets for the safety rods have been fabricated and are ready for installation. (AEC Activity 4401.1)

Experimental Engineering—Mechanical Contrivances - The frozen-sodium-seal pump for the ARE reflector coolant system was operated somewhat over 500 hours, pumping sodium at 1250°F. At a shaft speed of 1700 rpm and at 21 psi and 100 gpm operation was smooth and conditions were reproducible after the cold end of the seal was blanketed with helium.

Seals packed with the materials listed below have been tested for sealing fluoride mixtures at 1200°F. The last two seals listed proved to be the most promising.

1. Copper sheath filled with MoS_2 powder
2. Alternate layers of graphite powder and MoS_2 powder
3. Inconel braid impregnated with MoS_2
4. Silicon bronze wool impregnated with MoS_2 powder
5. Silicon bronze wool impregnated with a 50-50 mixture of MoS_2 powder and graphite powder
6. Copper rope.

The ARE fuel, $NaF-ZrF_4-UF_4$ (50-46-4 mole %) was circulated at 1250°F through a centrifugal pump with a combination packed-frozen seal for test periods of 145 hours and 120 hours. The packing consisted of braided copper sleeving filled with MoS_2 powder. Although the pumps were successfully stopped and restarted several times, both tests were terminated because of excessive seal leakage. In a subsequent test there was less leakage through a pump seal packed with copper rope.

Seals, packed with six layers of BeF_2 and metal washers, have been tested to determine if a mixture of the fluoride fuel and BeF_2 of the interface will have sufficiently high viscosity to seal against the fuel at elevated temperatures. One test of a 1/2" diameter shaft turning at 440 rpm and with the fluoride fuel at 1350°F was terminated after 50 hours of satisfactory operation. Examination revealed that the fuel had penetrated only the two inner layers of the seal. Other tests with larger shaft sizes, smaller seal length-to-diameter ratios, and higher rotational speeds have resulted in failure because of seal leakage or shaft seizure.

The pressure of fluoride fuel mixtures at 1100°F has been measured satisfactorily with the Moore Nullmatic instrument, which balances the liquid pressure against a gas pressure through a bellows. One nickel bellows (0.005" wall) failed after 2500 hours of operation. When a diaphragm pressure transmitter of the null balance type (patterned after a GE design) was operated with 1050°F flourides for 700 hours, the reliability and response to pressure changes was excellent. However, the flow of the inert balancing gas is much greater with this instrument than with the Moore Nullmatic. (AEC Activity 4401.1)

Critical Experiments - Additional data, obtained with a second critical mock-up of the reflector-moderator fuel-coolant reactor, included the changes in reactivity effected by the insertion of various materials into the reactor. Samples of Li, KF, NaF, Ni, Zr, Cr, RbF, Pb, Bi, stainless steel, Inconel, and graphite (1.72 gm/cc) were placed in both the fuel and the reflector regions; the resulting changes in reactivity were measured with a previously calibrated reflector control. Additional measurements were made with BeO, Na, and graphite (2.0 gm/cc) in the reflector region only. Inconel and nickel gave the largest decrease in reactivity in the fuel region, and chromium gave

the largest decrease, in the reflector region. The increase in reactivity when 162 in^3 of D_2O replaced an equal volume of beryllium adjacent to the fuel was the same whether the D_2O was in the island or the reflector. However, on moving the D_2O radially outward, from the fuel reflector interface to the region where the thermal neutron flux in the reflector was the highest, a decrease in reactivity resulted.

The experimental study of the relationship between minimum critical mass and uniform thermal neutron flux in the core was continued with a more careful determination of the critical mass and flux patterns in the reactor.

The reactor core is a right circular cylinder 42.7 cm long by 15.2 cm in radius, with the core being subdivided into five concentric regions, in each of which the concentration of the uranium solution is uniform. The core is enclosed laterally in an effectively infinite water reflector but there is no reflector at the ends.

The concentrations were chosen so that the corresponding radial fuel loading curve approximated the theoretical loading curve for minimum critical mass; the experimental concentration gradient was step-wide whereas the theoretical gradient decreased continuously with the radius. The core regions were filled with the calculated concentrations until criticality was achieved when all core regions and the reflector region were at a common height. The theoretically predicted and experimentally determined values for core height, volume and critical mass agreed to within 2.5%.

The neutron flux of the critical reactor was measured by means of the usual indium and cadmium-covered indium foil technique. The radial distribution of thermal neutron flux, in the core, which should theoretically be uniform, was found to be constant within approximately 7%. (AEC Activity 4401.2)

Radiation Damage - Inspection of an Inconel capsule, containing the ARE fuel after irradiation in the MTR for 116 hr, at 2700 watts/cc, disclosed areas of the Inconel in which the grain size had been enlarged greatly. In the areas of increased grain size an intergranular penetration of 10 to 12 mils was noted, and in regions of normal grain size the wall contained uniform, dense, intergranular corrosion that averaged about 2 mils deep and subsurface voids that were 2 to 4 mils deep. Since excessive local heating may have been responsible for some of the observed results, another capsule, irradiated under the same conditions but with better control of the temperature, was examined. It showed neither local areas of increased grain size nor excessive corrosion, but the dense 2-mil intergranular corrosion was still present.

Cantilever creep tests on Inconel, maintained in a helium atmosphere at 1500°F in the LITR under stresses of both 2,000 and 4,000 psi, showed that under these conditions there was no increase in creep which could be attributed to the neutron bombardment. (AEC Activity 4401.4)

Reactor Chemistry - A more detailed study of the $NaF-ZrF_4-UF_4$ system at higher UF_4 concentrations has shown that there is no segregation of phases when a 65-15-20 mole percent mixture freezes. This particular composition is probably a pseudo-eutectic rather than a true ternary eutectic but its apparent homogeneity in the solid state should make it useful as a fuel concentrate for the ARE. Dilution of this fuel concentrate with $NaZrF_5$ yielded a 53-54-4 mole percent mixture which melted at 520°C and had a lower vapor pressure than the fuel mixture previously considered. These fluorides can be produced without modification of the available apparatus.

The reaction of hydrogen with structural metal fluoride contaminants that are dissolved in molten $NaZrF_5$ was studied by continuous analysis of the effluent gas stream for HF. While the reaction rates were observed to deviate appreciably from those expected for a first order reaction, the preliminary results indicated that the concentration of each of the contaminants, NiF_2, FeF_2 and CrF_3, was reduced by a factor of two by purging with 16, 60 and 170 liters of hydrogen, respectively. These tests were performed with 2 kg batches of solvent and a 5" bubble path for the hydrogen. (AEC Activity 4401.5)

Corrosion Studies - Lead at 810°C was circulated over type 446 stainless steel in a convection loop for 620 hours without plugging. The stainless steel specimens were mounted in a quartz convection loop which was maintained at a temperature ranging from 515 to 810°C. Upon subsequent examination a small partial plug was found at the bottom of the cold leg which was about 1/4 the size of the plugs found in previous tests. No appreciable amount of mass-transferred material was found in any other section of the loop.

Beryllium samples, electroplated with Cr and Ni, as well as unplated samples, were tested for 100 hours in sodium with a temperature of 530°C in the hot leg and 400°C in the cold leg of a rocking furnace. In all tests the specimens and sodium were contained in Inconel tubing. Results from these screening tests indicated that the bare beryllium suffers less attack by sodium at these temperatures than the electroplated specimens.

Tests for corrosion of Inconel by ARE fuel with either NiO or U_3O_8 additive substantiate the prior conclusion that most of the currently experienced corrosion by fluorides is due to selective oxidation of chromium by impurities. In a routine 100-hour rocking test, the addition of 1 wt % nickel oxide was found to cause heavy subsurface void formation in Inconel to a depth of 2 to 3.5 mils. This corrosion is attributed largely to the oxidation of Cr^o by Ni^{++}. Since the addition of 2 wt % nickel oxide did not increase the depth or severity of attack, it is possible that the rate decreased when the Cr^o was removed from a depth of more than 2 or 3 mils. When 0.5 wt % of U_3O_8 was added to the same fluoride mixture, there was light to moderate subsurface void formation to a depth of 0.5 to 1.5 mils. Increasing the U_3O_8 to 1% gave approximately twice as much corrosion. In these tests the reduction of the hexavalent uranium to tetravalent was responsible for the oxidation of the chromium. (AEC Activity 4401.5)

Metallurgy - High-conductivity fins for ANP-type radiators were constructed of copper clad with 310 stainless steel and Inconel. It was found that a 0.002" cladding of Inconel will offer sufficient oxidation resistance for 500 hours at 815°C.

Face seals for pumps have been made by hot pressing techniques. At present, work is centered on the production of molybdenum bearings hot-pressed in contact with sulfur to form a layer of MoS_2. It has been found that a temperature of approximately 750°C is best for the production of this layer.

The control rod developmental work for the GE-ANP project has shown that a mixture of B_4C and aluminum powder can be consolidated to a density of 95% of the theoretical maximum by hot swaging at a temperature of 600°C.

The effect of environment on the creep properties of the iron-base alloys is not as pronounced as it is with the nickel-base alloys. Preliminary experiments with the cobalt-base alloys show them to be as sensitive to the environment as the nickel-base alloys.

Assembly of the intricate "shower-head-type" liquid-liquid heat exchanger, for evaluation of the heat exchanger designed for the Fireball type reactor, has been completed. The tubes and headers were inert gas welded together in such a way as to provide a rigid assembly with uniform tube-to-tube spacing.

The diffusion of Nicrobraz in metals at brazed joints is being investigated by crystallographic examination and by measuring the variations in hardness across the joints. From these tests it is evident that Nicrobraz diffuses more readily into stainless steels than into Inconel; there is a greater increase in hardness of stainless steel than of Inconel. (AEC Activity 4401.5)

Heat Transfer and Physical Properties Research - Some preliminary tests of heat transfer from a forced-convection circulating-fuel system were completed. Heat was generated in the circulating fluid by passing an electric current through it. At present some temperature measurements have been made for power densities of a few tenths of a kilowatt per cubic centimeter. The flow conditions that can be obtained with this apparatus with regard to Prandtl's number, Reynold's number and power density are comparable to those expected in the ARE.

The heat-transfer and momentum-transfer equations which result from a comparison of the effectiveness of the various reactor coolants have been expressed in terms of dimensionless moduli. The solutions of the heat transfer equations have been evaluated, with the aid of the IBM machines, over a wide range of the parameters involved. After the momentum-transfer equations have been evaluated, the results of both sets of calculations can be used to compare the "effectiveness" of various reactor coolants.

Because of the possibility of foaming of the ARE fuel at the surge tank, the surface tension of the ARE fuel, $NaF-ZrF_4-UF_4$ (50-46-4 mole %), was measured and found to vary from 160 dynes/cm^2 at 530°C to 115 dynes/cm^2 at 730°C. This

value is sufficiently high to prevent deleterious foaming.

The thermal conductivity of molten sodium hydroxide was determined by utilizing three different types of conductivity devices, two based on steady flow of heat through a thin section of the liquid and the third involving the transient heat flow from an electrically heated tube to a surrounding liquid. The thermal conductivity of the hydroxide varied from about 0.4 Btu/hr·ft·°F at 650°F to about 0.8 Btu/hr·ft·°F at 1050°F. (AEC Activity 4401.5)

Analytical Studies - A method has been developed for the determination of oxygen (as metallic oxides) present in fluoride mixtures. The oxygen evolved during the high temperature fluorination of these oxides by bromine trifluoride is determined from the partial pressure of the oxygen. The apparatus has been calibrated for both ZrO_2 and UO_3 which are the common contaminants of the fluorides.

Procedures for colorimetric determination of the uranium and zirconium content of fluoride mixtures are being developed. Di-sodium, 1,2 dihydroxybenzene disulfonate, "Tiron", was found to be suitable for the colorimetric determination of uranium. Iron and titanium interfere in this analytical procedure. In the differential colorimetric determination of zirconium, zirconium-alizarin sulfonate was shown to exist as a true complex in 0.1 M perchloric acid. The complex exhibited no tendency toward "lake" formation after standing six days. A similar complex occurred in 0.01 M sulfuric acid. Stronger acid concentrations weaken the complex.

The recently developed high temperature ion source ovens have been used to complete the spectrographic investigation of the high valence constituents previously found in untreated UF_4. The UF_5^+ ions observed in the mass spectrometer were due to the reaction of UF_4 with the 1% uranyl fluoride present as a contaminant. A quantitative method of analysis has been developed for the UO_2F_2. (AEC Activity 4401.5)

Shielding Research - The calculations of the gamma-ray dose to be expected in a divided shield, based on the data obtained in the Bulk Shielding Facility with the gamma-ray spectrometer, are nearly complete. The penetration of the side walls of the crew shield remains to be calculated; this will be accomplished with the help of some recent slant-penetration experiments made at the Bureau of Standards.

The Lid Tank measurements on the "Fireball" shield have been continued to investigate the advantage to be expected from the substitution of various other materials for the iron in the pressure shells. The indications are that not much is to be gained from substitution of either copper or nickel.

Site preparation for the Tower Shielding Facility is well advanced. The concrete has been poured for all tower footings and some of the cable anchors are in place. Contracts for all construction work have been let and much of the work is now in progress.

A shield design has been developed for a water-moderated reactor, proposed for use in an airplane.

Arrangements are being made for a meeting on shielding in June 1953 for the purpose of agreeing on calculational methods to be used for divided-shield design and for demonstrating the proper use of these methods.

The mockup of the top plug for the Submarine Intermediate Reactor shield is still in the Bulk Shielding Facility being tested for radiation leaks. The major part of this work is now complete but the mockup will remain in the pool for a while longer so that some additional tests may be made. (AEC Activity 4401.7)

GENERAL REACTOR RESEARCH

General Reactor Radiation Damage - A study has been made of radiation effects on graphite-UO_2 bars as a function of size of the enriched UO_2 particles. All bars contained the same weight of UO_2 but the diameter of the UO_2 nodules varied from bar to bar. The bars that contained the smallest UO_2 particles suffered the greatest damage as measured by physical property changes, such as electrical resistivity and modulus of elasticity. After physical property changes were noted, one group of specimens was annealed for 18 hr at 425°C and another group was annealed for 12 hr at 750°C. Most of the damage by neutrons annealed out below 400°C. Fission fragment damage did not seem to anneal out below 750°C. The amount of fission damage, as determined by electrical conductivity changes, has been correlated fairly closely with the theoretical fraction of fissions that emerge from the different diameter UO_2 particles.

Fast neutron bombardment (1.35×10^{20} nvt) of single-crystal quartz results in permanent damage to the structure. It is believed that sufficient silicon-oxygen bonds are ruptured during irradiation so that the single-crystal lattice is transformed into a highly disordered polycrystalline material that can be annealed to a partially-ordered polycrystalline quartz at 900°C. (AEC Activity 4540)

Idaho Chemical Plant - The Idaho Chemical Processing Plant started full production during the month of March, 1953, and has been processing Hanford irradiated fuel at the rate of 1 kgU/day in the form of enriched uranium alloy. No serious problems have occurred from the time of startup until the present time. Product U^{235} shipped to Y-12 in Oak Ridge has met both radioactivity and ionic impurity specifications. This uranium has been decontaminated from fission products essentially to background. The ionic contaminants, principally aluminum and silicon, are present in quantities small enough that the material can be processed without additional purification in the Y-12 production procedure. ORNL will have completed its assignment on the Idaho Chemical Processing Plant by May 1, 1953, after two and one-half years of effort on design, construction, and preliminary testing. (AEC Activity 10543)

ISOTOPE PRODUCTION

Stable Isotope Production - Lithium, carbon, neodymium, palladium, and platinum were processed, the latter for the first time. The palladium and platinum metals were vaporized at 1750° and 2300°C, respectively, by bombardment with 35-kv electrons. An estimated 16 grams of palladium and 5 grams of platinum were collected.

A total of 4.2 amperes of lithium ions, as measured in the collector, was produced from Li metal charge in a single arc of a grid-type ion source for which the power supply had been enlarged.

The chemical refinement of eight lots of tin and neodymium isotopes was completed and progress was made in the refinement of isotopes of neodymium, sulfur, and palladium. Fifty-eight shipments and transfers of 48 isotopes of 27 elements were made.

Neodymium, samarium, and gadolinium oxides of 99% purity and enriched dysprosium concentrates were produced by liquid-liquid extraction with tributylphosphate and nitric acid. (AEC Activity 5121)

PHYSICS

Short Period Activities - A rapid chemical separation method has been used to show that the new 0.35-sec isomer found in germanium, irradiated by neutrons in the graphite reactor, may be identified with a metastable excited state of Ge^{73}. The same activity is produced in the electron-capture decay of the 76-day As^{73}. In the separation process which makes use of the well-known volatility of $GeCl_4$, gas was bubbled through a solution containing the radioactive As^{73}, and this gas swept $GeCl_4$ out of the solution into a NaI scintillation counter. Measurements of the decrease in the observed activity taken with the counter at various distances downstream from the bubbling solution, together with measurements of the gas flow, have given a preliminary value of 0.33 sec for the half life, which is in excellent agreement with the previous result. (AEC Activity 5211)

Scintillation Spectrometry and Instrument Development - Investigations were continued to obtain better energy resolution in scintillation crystals. For a sodium iodide crystal 4-3/4 inches in diameter with an effective thickness of 5 inches and with α Al_2O_3 as a reflector, a peak on the curve of intensity vs. energy with a resolution of 15.7% (full width at half maximum) was obtained in response to the 0.661 Mev gamma ray of Cs^{137}. Recent improved techniques for beta ray detection with anthracene crystals have resulted in a resolution of 8.8% for the 0.624 Mev conversion electrons of Cs^{137}, using 0.2-mil aluminum foil as a light reflector. (AEC Activity 5211)

Short Lived Isomers - The directional angular correlation of the 1.055-Mev and 0.555-Mev gamma-ray cascade in Pb^{207} was measured using sources of Bi^{207} which decay by K-capture to stable Pb^{207} via the 0.82-sec Pb^{207m} isomer.

The experimental correlation function obtained from 8×10^5 coincidence counts is $W_{exp}(\theta) = 1 + (0.197 \pm 0.003) P_2(\cos\theta) - (0.016 \pm 0.009) P_4(\cos\theta)$. This is in good agreement with the angular distribution expected from a decay sequence 13/2 (M4) 5/2 (E2) 1/2 for which the theoretical angular correlation function, smeared for the finite angular resolution of the detectors, is $W(\theta) = 1 + 0.2029 P_2(\cos\theta) - 0.0135 P_4(\cos\theta)$.

The K-shell internal conversion coefficients of the two gamma rays were measured with an anthracene and a NaI scintillation spectrometer. These coefficients, α^K_{exp}, together with the theoretical coefficients are listed in the following table.

γ-ray	α^K_{exp}	Theoretical Coefficients	Classification
1.055 Mev	0.096	$\alpha_5 = 0.0393, \beta_4 = 0.104, \beta_5 = 0.180$	M4
0.555 Mev	0.015	$\alpha_1 = 0.0064, \alpha_2 = 0.017, \beta_1 = 0.091$	E2

From intensity measurements of the gamma radiation it appears that Bi^{207} decays 81.5% to the 1.610-Mev excited state and 18.5% to the 0.555-Mev excited state in Pb^{207}. This long-lived (approximately 50 yrs.) Bi^{207} is an excellent source of monoenergetic conversion electrons with energies of 0.467 Mev and 0.967 Mev. (AEC Activity 5211)

86-Inch Cyclotron Nuclear Physics - The excitation functions for (p,pn) reactions on Cu, Cd, Ag, and Ta and for (p,αn) reactions on Zn, Nb, and Cd were measured with good precision. The measurement of angular distribution of tritons from (p,t) reactions was completed. Some preliminary measurements of deuteron yields from (p,d) reactions were obtained by angular distribution techniques.

Three previously unreported isotopes were discovered and their decay characteristics investigated. The positron-emitting 2.5m Ga^{64} was produced by the (p,n) reaction on both normal zinc and enriched Zn^{64}. Erbium-163 decays by K-capture with a half life of 7.5 minutes; it was produced by the (p,3n) reaction on Ho^{165}, as determined from the excitation function. The 24.5h Tm^{165} was produced by (p,2n) and (p,3n) reactions on Er^{166} and Er^{167}; it was identified from the daughter product, Er^{165}, to which it decays by K-capture. The measurement of yield distribution from proton-induced fission of U^{238} was completed. (AEC Activity 5211)

86-Inch Cyclotron - During March and April operation of the 86-inch cyclotron was interrupted for only one day to permit replacement of a ruptured water line within the vacuum system. A total of 222 runs were made during the period. In addition to the nuclear physics and isotope production runs, both guinea pigs and rats were exposed to fast neutrons for the Biology Division.

The cyclotron was shut down on April 20, 1953 for a scheduled five-weeks period to permit measurements and experimentation required for the design of a beam deflector system. (AEC Activity 5261)

Fundamental Electromagnetic Research - In preliminary tests of the apotron, a new type mass spectrograph being developed for the separation of isotopes of the lighter elements, a single apotron unit produced an ion current exceeding three amperes, as measured in the collector. The first collection run yielded lithium-7 of 99.8% purity and lithium-6 of 78% purity. The beam focus for this unit was obviously good, but there was some inadvertent contamination in the collector pockets by unseparated isotopes.

The first multiple unit with six apotrons mounted on a single faceplate was assembled and is ready for testing in a vacuum tank in a Beta magnet. The 600 kw power supply is also ready for the initial test runs. (AEC Activity 5261)

Electro-Nuclear Machines - A review of the design study of the variable energy cyclotron, which is intended to produce protons, deuterons, and tritons, at controlled energies between 5 and 10 Mev, has been completed and is being submitted to the AEC. The study shows that such a variable energy cyclotron is entirely practicable. It is believed that an energy resolution of better than ± 0.01 Mev can be achieved. A "breadboard" model of an electrical system for such a cyclotron has been constructed in order to study the development of an oscillator system that will reliably tune through the frequency range from 5 to 12.5 megacycles. This system uses a push-pull, self-excited oscillator incorporating a minimum of frequency-dependent parameters so that oscillator tuning is simplified. Now that the model system operates stably over the desired frequency range, modifications are now being made to provide for tuning the dee system and for increasing the power. (AEC Activity 5261)

Isotope Analysis Methods Laboratory - The final version of a table of nuclear moment data, complete through April 1, 1953, was prepared (ORNL-1469). Microwave studies were made of aluminum di-hydrogen iodide and vinyl fluoride; the former exists as a di-molecule in the vapor phase and gives a complicated microwave spectrum; the $J = 0 \rightarrow 1$ and $1 \rightarrow 2$ transition groups in the latter molecule were observed and preliminary values of rotational constants obtained. Two lithium alkyls, n-butyl lithium and isopropyl lithium, were chemically synthesized and their infrared spectra obtained. A simplified method for rapid focussing and alignment of the Perkin-Elmer monochrometer was devised. An improved hollow-cathode light source applied to isotope analysis of lithium gave a 0.10% standard mean deviation for five samples at the 15 per cent abundance level. A "modified-diode" type of arc filament operation of calutron ion sources continued to give increased filament life and greater ion output than observed in normal operation, (see ORNL-1525). A scintillation counter was used successfully to measure x-ray spectra from a G.E.XRD-3 X-ray spectrograph. (AEC Activity 5261)

Mass Spectrometer Laboratory - The recently developed high temperature oven for vaporizing solid materials in the ion source of the mass spectrometer was applied to the assay of separated isotopes, with successful analyses being made on molybdenum and boron isotopes, from MoO_3 and

H_3BO_3, respectively. Since these compounds were from the isotope inventory, all chemistry of special sample preparation was eliminated. This technique is being extended to other separated isotopes.

Eighty gaseous samples were analyzed on the General Electric mass spectrometer in connection with the Hilsch tube experiments (see Research and Development, Stable Isotopes below). The remainder of the analyses comprised hydrogen-deuterium calibration studies and investigations. To facilitate mass spectrometric analyses of heavy water-light water mixtures, a water decomposition apparatus, using metallic zinc and an automatic Toepler pump, was constructed and put in operation. An ion source gating circuit for precision measurement of potentials at which various ion species appear is being pre-tested prior to installation. (AEC Activity 5261)

63-Inch Cyclotron - Magnetic field measurements and beam attenuation studies have been made in order to increase the N^{+++} ion beam and to improve the conditions necessary for beam deflection. A magnetic shield has been fabricated which will make it possible to use a photo-multiplier tube in the 2000-oersted "fringing" field of the cyclotron. For use as scintillation detectors for heavy ions, thin sheets of various scintillators are being tested for pulse height and energy resolution. (AEC Activity 5261)

Research and Development, Stable Isotopes - The distillation procedure for purifying metallic lithium was used to prepare samples of high purity Li^6 and Li^7. The melting points of these isotopes were determined by a technique which was accurate to $\pm 0.15°C$. The fact that no difference in melting points could be shown rules out the previous suggestion that normal lithium metal is a eutectic of two isotopes with considerably different melting points.

The investigation of the feasibility of using the Hilsch tube for mass separation was continued. The recycling procedure gave results which still did not permit any conclusion that mass separation takes place. Other experiments were devised to emphasize the theoretical aspect of the problem, and to investigate the actual flow patterns. Some separation of isotopes by centrifugation may occur but separation by any sort of thermal diffusion is extremely unlikely, even as a secondary effect, because of the turbulence in the tube. (AEC Activity 5261)

CHEMISTRY

Inorganic Solution Chemistry - A method was developed for the isolation of neptunium from two types of processing solutions, i.e., a 4 M nitric acid solution, and a concentrated hydrochloric acid solution of cerium iodate. Quadrivalent neptunium was found to be adsorbed from a mixture of 2 M HNO_3 - 6 M HCl on the anion exchange resin Dowex-1 strongly enough to permit the processing of more than 50 column volumes of solution. The column was washed with 6 M HCl to remove a number of impurities, including rare earths, and the neptunium was removed with 0.5 M HCl. Further purification was achieved by reducing neptunium to Np(IV) with Fe(II), readsorbing Np(IV) on Dowex-1 from 6 M HCl and then eluting it with 6 M HCl - 0.1 M HF. Under these conditions a number of impurities including Fe(III) and U(VI) should remain on the column. In general, the elution bands were quite

sharp and only very few elements should remain with the neptunium after the two adsorptions and elutions. Purification from the "iodate — HCl solutions" is very similar since neptunium could be adsorbed directly from the solution and removed with 0.5 M HCl.

A number of elements are very strongly adsorbed on anion exchange resins from both dilute and concentrated hydrochloric acids. Experiments are under way to remove these from the column by displacement with other strongly adsorbed chloride complexes which, in turn, can be removed at low HCl concentrations or with water, e.g. complexes of Zn(II) or Cd(II). In exploratory experiments it was found possible to remove the strongly adsorbed mercuric ion in a reasonably narrow band by elution with 1 M $CdCl_2$ in 6 M HCl. Studies will be extended to the applicability of this method to the separation of other elements, particularly the platinum group. (AEC Activity 5311)

Chemical Physics - A full scale experiment for determining the spin and quadrupole moment of 8d I^{131} was carried out using 750 mc of I^{131}. The iodine was purified chemically with a yield estimated at over 80 percent and then converted to CH_3I. The yield of CH_3I, due to a chemical handling difficulty, was very low. However, extremely weak but sharp CH_3I adsorption lines were seen. The lines were all due to I^{127} indicating that the sample, although no I carrier had been added, contained roughly two or three times as much I^{127} as I^{129} or I^{131}. It is expected that with improved yield the I^{131} lines will be seen.

Preliminary work was done, in collaboration with the neutron diffraction group of Physics, on the Zeeman effect on the pure quadrupole spectra of a single crystal of iodic acid. An interesting line intensity variation with orientation of the specimen in the oscillator coil was observed, and in addition some of the Zeeman components were split into doublets due to the internal magnetic field of hydrogen atoms. A study of the doublet separation, in principle, should allow the determination of the hydrogen atom locations in the crystallographic cell.

Neutron diffraction data were collected from single crystals of ordinary ice, deutero-ice, and potassium dihydrogen arsenate. Interpretation of these data in terms of crystal structures is in progress. Refinement of structural parameters for oxalic acid dihydrate is nearly complete.

One scattering-reaction experiment with an atomic beam of potassium and an effusive spray of hydrogen bromide has now been performed. A detailed discussion is not warranted because of minor difficulties during the experiment, but the general behavior of the system surpassed expectations, and there are indications in the fragmentary data obtained that the method will easily yield information of value about the nature of the reaction. (AEC Activity 5311)

Radio-Organic Chemistry - An eleven percent intramolecular carbon isotope effect was demonstrated for the reaction of ethyl alcohol with benzoic $-\alpha-C^{14}$ anhydride. For a similar reaction of the anhydride with p-toluidine, the carbon isotope effect was shown to have a value of seven

percent. Both isotope effect values were shown to be temperature-independent.

Radiochemical confirmation was obtained for the existence of a symmetrical phenonium ion [>C----$\overset{+}{C}$----C< (similar to a pi bond complex)] in the Wagner-Meerwein Rearrangement, an intramolecular two-fold Walden Inversion. (AEC Activity 5311)

Radiation Chemistry - A systematic study of the importance of hydrogen peroxide as an intermediate in reduction reactions in acid solution with cobalt gamma rays is being conducted. Following complete reduction of ceric sulfate, hydrogen peroxide is formed at a rate equivalent to that for ceric ion reduction. This stoichiometry suggests that reduction may have occurred through the intermediate formation of hydrogen peroxide. The yield for reduction of dichromate ion in acid solutions was the same as that for ceric ion reduction (2.52 equivalents per 100 ev.) and also equivalent to the peroxide yield. The presence of dissolved hydrogen during irradiation produced the same increase in yield for dichromate ion reduction as was observed for peroxide formation and ceric ion reduction. Other solutions, such as permanganate, are being studied to determine whether this relationship is true for radiation-induced reduction reactions in general.

The enhancement of the photolytic decomposition of hydrogen peroxide by dissolved hydrogen showed a pH dependence similar to that observed in the radiation chemistry of solutions involving reactions with hydrogen. The enhancement by hydrogen decreased at pH less than 2, indicating that the reaction of H_2 with OH was inhibited in highly acid solutions. In solutions containing both hydrogen and oxygen, the photolytic decomposition of hydrogen peroxide is inhibited through reaction of O_2 with the H atoms produced by the hydrogen.

As part of a general program to determine the radiation stability of various anions, the gamma-ray induced decomposition of sulfuric acid solutions in the concentration range from 9 M up to slightly fuming acid was observed by measuring the SO_2 produced. With reagent grade acid, the measured initial yield of SO_2 increased linearly with the mole fraction of acid present. With acid which had been redistilled to remove the impurities indicated by ultraviolet absorption, the yield of SO_2 was 50 percent lower.

The radon collecting station was completed except for sealing on the radium chloride solution storage flask. Preliminary tests and "dry runs" indicate that the apparatus will perform satisfactorily. It is anticipated that a charge of approximately 100 mc. of radon will be available about May 1. (AEC Activity 5311)

Chemistry of Fused Salts - Determination of some thermodynamic properties of boron nitride was completed. The heat of formation of microcrystalline boron nitride is 62.8 kcal/mole. This heat of formation datum has considerable significance for interpreting the structure of boron nitride and this value may indicate an appreciable double bond character of the boron-nitrogen link.

Further work with one or two other nitrides is contemplated to try to clarify the bond type.

The cryoscopic constant of molten sodium nitrate was measured by studying the freezing point depression caused by low concentrations of various salts dissolved in the fused nitrate. It was demonstrated with several different salts that such cryoscopic measurements may be used to obtain information about the composition, stability and chemical reactivity of the ions of the dissolved salt. Only those dissolved ions which are not common with the solvent ions cause freezing point lowering. This work is being continued actively to determine the stability of a series of complex ions in a variety of molten ionic media at elevated temperatures. (AEC activity 5311)

Uranium Chemistry of Raw Materials - A process for recovering uranium from refractory, 1100°C lignite ash, by baking with a mixture of ammonium bisulfate and ammonium bifluoride and then leaching the material with ammonium carbonate, was studied further. A 90 percent extraction of uranium and an 85 percent extraction of molybdenum were regularly achieved with a fluorine loss to the barren tailings of less than 1% of the fluorine (as bifluoride) used. A recovery of 98 percent of the uranium was obtained from the ammonium carbonate solutions (60 mg U/l) used for the leaching operations by simply boiling off the ammonia and carbon dioxide.

The extraction coefficient of 0.004 M uranium(VI), from solutions containing 0.5 M sulfate ion at pH 1, by 0.1 M tridecylphosphine oxide in kerosene was increased from <0.01 to 23 by the addition of only 2% nitrate ion. Similarly, the extraction coefficient of vanadium(V) from 0.5 M sulfate solution at pH 1 by 0.4 M tridecylphosphine oxide in kerosene was increased from 0.1 to 5 by the addition of 2% nitrate ion.

A number of high boiling petroleum fractions were tested as diluents for amines in the extraction of uranium from sulfate liquors. Those petroleum fractions with a high degree of aromaticity appear to be suitable for use with several amines which ordinarily form a "third phase" in diluents of aliphatic character. Primary, secondary, and tertiary amines were found to extract vanadium from 1 M sulfate solution, especially at high pH. The extraction coefficients varied from ~0.5 at pH 1 to ~30 at pH 3 for 0.1 M solutions of amine in benzene.

On the basis of preliminary rate measurements in 3.7 M H_3PO_4, 0.36 M in H_2SO_4, the approach to equilibrium of the reaction

$$Fe(II) + U(VI) \longrightarrow Fe(III) + U(IV)$$

obeys a first order rate law within the accuracy of the data, such that

$$\frac{d[U(IV)]}{dt} = k\left\{[U(IV)]_{eq.} - [U(IV)]_t\right\}$$

The bracketted quantities denote concentrations (moles/liter) and the subscripts eq. and t signify concentrations at infinite time and time = t, respectively. The rates are such that at 25°C the quantity, $[U(IV)]_{eq} - [U(IV)]_t$, decreases by one-half every 160-170 minutes, and at 48°C, decreases by a half in about 15 minutes. (AEC Activity 5361)

Volatility Studies - The investigations have been concentrated on the chlorine trifluoride method of processing Hanford-type irradiated uranium slugs. The rate of reaction between the uranium metal and the chlorine trifluoride has been shown to be dependent largely on the metallurgical character of the uranium, particularly with respect to grain size and allotropic modification. The fine-grained material, which received the greatest amount of mechanical treatment in preparation, reacts at the highest rate; this result paralleled previous experience on metal dissolution in nitric acid. The attack on the metal was shown to proceed along grain boundaries, and hence the smaller the grain size, the larger the effective surface and thus the higher the reaction rate. Electropolishing to remove oxide scale, prior to reaction, was found to give about the same results as treatment with nitric acid.

For removal of fission products and the plutonium remaining in the reaction pot after the volatile UF_6 has been withdrawn, a fluidizing agent, preferably nonaqueous, is necessary. Studies of the compound perfluorotri-n-butyl amine and a fluorinated cyclic ether, (0-75), indicate that either may be stable enough for use as the fluidizing agent. (AEC Activity 5361)

Thorex Process Development - It was stated in an earlier report (ORNL-1486) that U^{233} could be adequately stripped from the solvent in the strip column (C column) and could be concentrated by ion exchange if excess acid was first removed from the solvent by contacting it with "acid-deficient" aluminum nitrate in an extra "N" column. The same result can be obtained by introducing water at the top of the B column, which precedes the C column, and then introducing 0.2 N nitric acid several stages lower down the column. Splitting the stripping solution in this way avoids the excessive uranium reflux that would occur if pure water in a single stream were used.

An economic study has been made of the continuous method of dissolving thorium slugs. Results indicate that for a 0.5 ton/day plant, the cost of continuous dissolution is approximately equal to that of batch dissolution. Since the scale of operation in the ORNL pilot plant will be less than 0.5 ton Th/day, and there is no economic advantage in using continuous dissolution, work on its development has been discontinued for the present. However, for larger plants, the continuous dissolver has definite economic advantages. (AEC Activity 5361)

METALLURGY

Ceramics Research -

Two cylindrical compacts, prepared for use as end caps to assure more uniform temperature distribution in uranium slugs, were sent to Hanford for evaluation. One compact consisted of a cold-pressed mixture of aluminum powder and 35-mesh bubble alumina, 50-50 by volume. The other compact contained a pocket of bubble elumina.

Silicon carbide-silicon cermets are being investigated for possible use in the fuel assemblies of gas-cooled reactors. Specimen fuel rods, cruciform in section and having 10 percent UO_2 in the core, have been prepared successfully. (AEC Activity 5411)

Physical Metallurgy of Reactor Materials - Thorium produced at Ames has been shown to have inordinately high creep strength at 300°C at stresses within 10 percent of the ultimate strength. Although the initial elongation is quite high, it appears to be decreased by cold working. An anomaly also occurs in the elevated temperature stress-strain behavior of Ames thorium containing 0.085 percent carbon. There appears to be an inflection in the curve of strength versus temperature in the region of 175° to 300°C, and the ductility in this region is less than at either lower or higher temperatures. Lastly, a significant temperature rise is noted in the tensile test specimens at the onset of plastic deformation. It is suspected that strain-aging is the cause of this phenomenon. Additional tests on low-carbon thorium (from ThI_4 process) should prove or disprove this point.

Analysis of the data on the yield point of thorium indicates that carbon must be in excess of 0.05 to 0.07% before a definite yield point is noted in specimens under tension. Chromium additions to thorium, in excess of about 2.4%, will eliminate the yield point; similar effects of titanium additions have been reported in the past. (AEC Activity 5411)

Fundamental Physico-Metallurgical Research - Recent results in the literature on the Hall coefficient of titanium suggest that the band structure of this Group-IVa element in the close-packed hexagonal crystal structure is divided into two parts, typical of an overlapped Brillouin zone. This phenomena would explain the high resistivity of Group-IVa elements in spite of a relatively high $N(E_{max})$ deduced from low temperature specific heat. The presence of holes in the lower zone would make the explanation similar to that of Mott and Jones for the higher resistivity of nickel than copper.

Tests on annealing pure zirconium in quartz bulbs have shown that it is possible to anneal for three days at 1200°C, when the specimen is wrapped in molybdenum and tantalum foil envelopes, without appreciable hardening of the zirconium, and that these metals form more suitable containers than any refractory oxide tried. This is in contrast to annealing at 1000°C where zirconium foil is the best envelope material.

X-ray work on the In-Zr alloys showed the γ-phase (23-27 atomic per cent indium) to have a face-centered cubic structure, in which the atoms are closer to each other (3.14Å) than in either pure element alone (Zr = 3.17Å, In = 3.24Å). The x-ray results are in agreement with the results of metallographic examination in that no other intermediate phase was found between the α and γ phases at 800°C.

For best representation of the fiber texture type of preferred orientation it is necessary that the experimental data on "pole" distribution of the diffracting planes with respect to the fiber axis be converted into data on the

fiber axis distribution with respect to the crystallographic axes. A direct method of conversion was developed for cubic metal systems. It involves the formulation of a matrix, representing a system of 190 equations in 190 unknowns, which upon inversion gives a set of equations by which the axis distribution chart may be determined directly and precisely from sets of pole-density data. (AEC Activity 5411)

Fundamental Investigations of Radiation Damage in Solids - A series of nine large single crystals of LiF were bombarded for various periods in the ORNL graphite reactor. The change of lattice parameter upon bombardment was determined for each crystal by x-ray diffraction and also by density measurement. Each function, lattice parameter vs irradiation, increased monotonically with irradiation, tending to saturate for long (several-day) exposures. However, the x-ray curve showed a more rapid increase of lattice parameter with irradiation that did the curve determined by density.

A plot of $\Delta a/a$ (fractional parameter change determined by x-rays) vs $\Delta l/l$ (the fractional parameter change determined from density measurements) shows an initial slope of about 2.4. This is in good quantitative agreement with the calculations of Miller and Russell (J. Appl. Phys. 23, 1163 (1952) which are based on the assumption that the distortion in a simple cubic crystallite having a lattice vacancy or interstitial atom is radial and of the form $\bar{r} + \Delta\bar{r} = \bar{r}\,(1 + f\,(r))$. From the theory of elasticity, f(r) is taken to vary with r^{-3}. For a dilute and non-interacting distribution of defects, these calculations indicate $\Delta a/a = 2.35\,\Delta l/l$.

A sample of N-type indium antimonide with an initial conductivity of 4360 $ohm^{-1}\ cm^{-1}$ was exposed in the low temperature facility of the graphite reactor at pile ambient temperature ($\sim 30^{o}C$). The conductivity decreased at an initial rate of $\sim 6.8\ ohm^{-1}\ cm^{-1}/hr$ at pile ambient temperature. The sample was removed after a total irradiation of $\sim 5 \times 10^{17}$ nvt with a final conductivity of 1360 $ohm^{-1}\ cm^{-1}$. Analysis of the data indicates that irradiation produces electron traps that decrease the conductivity but that this effect tends toward saturation long before any conversion from N type to P type material can take place for a starting material of such low resistivity. (AEC Activity 5411)

PROGRAM 6000 - BIOLOGY AND MEDICINE

BIOPHYSICS

Waste Disposal Research - Progress has been made in the water decontamination studies conducted jointly by the Engineer Research and Development Laboratories, U. S. Corps of Engineers, and ORNL. The purpose of these studies, which were initiated two-and-a-half years ago, is to evaluate the efficiencies of equipment and processes used by the military in the field for the removal of radio-

active contaminants from water and to develop modifications of the present procedures or supplementary processes that will increase the efficiencies of removal.

A four-month study of an Army type Thermo-Compression distillation unit was completed. The unit was operated with Oak Ridge tap water contaminated with various fission products and with RW agents. In normal operation the decontamination factors achieved were within the range of 350 - 5000 (99.7 - 99.98 percent removals) depending upon the radioisotopes' concentrations and chemical forms. With the addition of a glass-wool-packed reflux condenser, the efficiencies of removal were increased by factors of from five to ten.

A calibration of the scintillation detector in the continuous water monitoring and telemetering system at White Oak Dam was completed. A series of seven radioisotopes was used to determine the gamma counting efficiency of the detector. (AEC Activity 6510)

Radioactive Particulate Problem - The cooperative study of the radioparticulate air contamination at X-10 by the AEC-US Weather Bureau and the Health Physics Division has been reactivated. The immediate objective is to evaluate the degree of airborne contamination produced by reactor and plant operations at ORNL.

The data collected over a period of four years by ten continuous air monitors stationed throughout the area has been reduced to histogram form. Each histogram shows the number of particles per 1000 cu ft of air collected weekly by a constant air monitor (CAM) during the period of March 1949 to December 1952.

A log has been compiled of ORNL operations which may discharge radio-particulates into the atmosphere and an attempt is being made to correlate this log with the histograms. A preliminary survey indicates a significant correlation between the peaks of the histogram and the occurrence of certain operations.

A study of the location of the CAM stations as related to air movements indicates that additional stations are desirable.

In the development of a high-speed air-top aerosol generator, difficulties were encountered with the top precessing as it rotated on its axis; several designs of the top and stator have been tried in an effort to overcome this difficulty. One combination of stator and rotor, driven with compressed air at 30 psi, was found to be stable at speeds up to 100,000 rpm. The bursting speed of this particular rotor is estimated to be 400,000 rpm. (AEC Activity 6520)

Consultation and Special Problems - Calculations were made of the airborne hazards associated with two types of catastrophe postulated for the reactor of the Tower Shielding Facility. The first set of calculations assumed a power excursion sufficient only to melt the fuel plates, with the resultant total release of halogens and rare gas fission products as a thermally cold cloud. In the second case, it was assumed that an Al-H_2O reaction results,

permitting the total release of all fission products in a "hot" cloud of considerable thermal content. The resultant data, in terms of permissible concentrations, were supplied to the meteorologists for study and transmittal to the Reactor Safeguards Committee.

A detailed justification of the required fencing for the Tower Shielding Facility, based on direct radiation estimates, was prepared. (AEC Activity 6530)

RADIOISOTOPE SALES

Type of Transaction	March	FY to Date
*Domestic Sales	$102,701	$717,088
Foreign Sales	7,068	21,708
Project-Cash Sales	3,005	62,847
Project-Transfer Credits	366	4,227
Technical Cooperation Program Credits	1,597	2,589
Plant Credits	3,247	23,728
Civilian Defense Credits		575
Radioisotope Income	$117,984	$832,762
Other Income - No costs incurred	3,388	121,154
Total Income	$121,372	$953,916
Radioisotope Costs	$ 74,569	$766,935
*Cancer Program Costs	$ 24,620	$176,103
Radioisotope Shipments	1,113	8,067

*The Cancer Program costs subsidized by AEC included in "Domestic Sales"

GROSS OPERATING COSTS

	Cost for March	FY 1953 Cost to Date
Programmatic Operating Cost	$2,513,248	$22,062,610
Plant and Equipment Cost	321,767	3,253,007
Construction Program "H"	14,196	234,883
Work for Other Parties - Transfers	44,315	677,404
Inventory Changes	899*	270,272*
Reimbursable Work for Other Parties	49,492	682,412
Deferred Charges	9,706*	6,998*
Total Laboratory Cost	$2,932,413	$26,633,046
Estimated Cost for Next Month	$3,000,000	$29,633,046

*Credit

[redacted]

PERSONNEL SUMMARY

	Number of Employees April, 1953	New Hires April	Terminations April
Administration	75	1	0
Operations*	119	0	2
Engineering, Shops and Mechanical	885	1	18
Laboratory and Research	1496	15	10
Protection	176	0	0
Service	393	1	3
Total	3144	18	33

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

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