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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

OCTOBER 1953

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

October, 1953

W. H Sullivan

and

F. T. Howard

Date Issued: NOV 6 1953

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October, 1953

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

October, 1953

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

PROGRAM 3000 - WEAPONS

Special Electromagnetic Separations - In the program to separate and purify plutonium isotopes, the first successful run was completed. From feed material containing 99.3% Pu^{239} and 0.7% Pu^{240}, approximately one gram of Pu^{239} product was enriched by a factor of 10 to 20 at an estimated process efficiency of 3%. Charge material containing 5% Pu^{240} is being prepared for a separation run to produce enriched Pu^{240}.

Thorium is now being processed for the purification of gram quantities of Th^{230} (ionium). (AEC Activity 3601)

PROGRAM 4000 - REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Experiment - A series of approximately 40 nuclear kinetic experiments was performed on the HRE during October to study the inherent stability of this type of reactor under rapidly impressed increases in reactivity. Reactivity increases by every method possible in the present reactor system were studied; these included shim rod position, reflector level, fuel concentration, and fuel cooling. The most severe experiment was begun at the low level of 20-watts power output, and the reactivity was increased at a rate of 0.8% per second by cooling the fuel as rapidly as possible through the heat exchanger. The reactor responded smoothly as predicted; the power rose to a peak of 11 megawatts in one second and immediately declined, without compensation by mechanical controls, to the equilibrium power of 1.5 megawatts which was the continuous power demand from cooling. The shortest period observed was 0.034 seconds, corresponding to a total reactivity 0.3%

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above that required for prompt criticality. The duration of the power surge above the equilibrium power level was of the order of 0.1 second. Preliminary analysis of the data indicates a fair agreement with the predicted behavior. The successful demonstration of inherent stability has already permitted the simplification of the reactor control circuits by the elimination of many interlocks. (AEC Activity 4103.10)

Engineering Investigation of Slurries - In a 100-gpm circulating loop, a slurry of UO_3 plus 10% uranyl phosphate has now been pumped continuously for 1000 hours at 250°C and 1000 psi. The concentration of the slurry is 150 g U/l, and the velocity through the loop averages about 20 fps (feet per second), with a maximum of ~90 fps through an orifice. To date there is no evidence of slurry accumulation at any point in the loop and no evidence of corrosion or abrasion.

About 500 hours of pumping experience have been accumulated in short runs with thoria slurries. Abrasion is observed in high-velocity regions, but when velocities are less than 20 fps there appears to be very little attack. Microscopic examination indicates that the observed attack is abrasion rather than corrosion; photomicrographs show that the particle sizes of the thoria used in the tests range from one micron down to less than 0.01 micron. Very little difficulty was experienced in maintaining the concentration of the thoria slurries, although in each run an initial change is observed, possibly because of some segregation occuring in the relatively stagnant material in the pressurizer. (AEC Activity 4109.31)

Chemical Investigation of Slurries - It was reported earlier (ORNL-1612) that thorium oxide slurries prepared by calcinaion of thorium oxalate at 500°C were less abrasive than those prepared by calcination at 650°C. Further studies on the effect of calcination temperatures on the properties of the oxide showed that, as the temperature of calcination increased from 300° to 900°C: the average particle diameter increased from slightly less than 2 to 5 μ (microns); the abrasiveness of the slurries prepared from these materials increased markedly; the crystallinity increased; the surface area decreased from 43.87 to 1.83 square meters per gram; and the densities of the oxide residues increased from 8.07 to 9.64 g/cc. That the abrasiveness of the slurries did not depend on the size of the thorium oxide particles was shown by the fact that: the abrasiveness of Ames oxide with an average particle diameter of 0.02 μ was reduced one half after a 4-day hydrolysis in water at either room temperature or 250°C, although the particle size was unchanged; and the abrasiveness of thorium oxide with an average particle diameter of 5 μ was not decreased when the particles were degraded to 0.1 μ size. (AEC Activity 4109.31)

Solution Chemistry - Several studies are being made to complete the phase diagram of the four component system, UO_3-NiO-SO_3-H_2O, which is of interest in determining the behavior of aqueous uranyl sulfate fuel solutions containing corrosion products from stainless steel. Continued studies of solid-

liquid equilibrium in the system UO_3 - NiO - SO_3 - H_2O disclosed several new solid phases and unsuspected complexities. Data were obtained for the solubility of UO_3 in uranyl sulfate solutions at 25°, 100°, 175°, and 250°C, but in all cases some discrepancies appeared. These may be the result of failure to reach true equilibrium because of the slowness of solid phase transformations, because of the tendency for some of the solid materials to become colloidal in nature, or simply because of sampling and analytical errors. The stoichiometric UO_2SO_4-$NiSO_4$-H_2O system has no double salts, basic salts, or acidic salts at 25°C. The only solid phases appear to be several different hydrates of uranyl sulfate and of nickel sulfate. (AEC Activity 4109.31)

Radiation Chemistry - Additional static studies of the effect of pile radiation on the corrosion of type-347 stainless steel by uranyl sulfate solutions indicate that at power densities below about 2 or 3 kw/l radiation has no appreciable effect. Single tests on titanium in and out of the pile showed markedly different results. The out-of-pile test gave high initial corrosion followed by essentially complete passivation. The in-pile test, initially at 6 kw per liter, displayed a much lower initial rate but never approached a passive state. (AEC Activity 4109.31)

Metallurgy - A study of the feasibility of producing crack-free, fully austenitic welds in type-347 stainless steels and a metallographic examination of the phase relationships in these welds emphasized the difficulty of obtaining completely ferrite-free welds from commercial grades of materials. Crack-free welds were produced, but in each case the resultant weld contained a small amount of ferrite.

Impact tests on control specimens of Zircalloy II (zirconium with 1½ percent tin and fractional percentages of iron, nickel, and chromium) indicate that the material is relatively "notch-sensitive" below about 50° to 100°C (under conditions of preparation and test) but that the impact resistance of the notched-bar specimens increased quite rapidly with increase in testing temperature. This work is preliminary to an investigation of the effects of composition, heat treatment, and exposure to corrosive environments on the temperature-sensitive, notch-brittle behavior, an important factor in the design of homogeneous reactor components operating under stress and temperature.

Continued work on the formation of corrosion-protective films on austenitic stainless steels by selective oxidation in moist hydrogen at elevated temperatures has indicated that the films contain compounds which are high in chromium and manganese but are relatively low in iron and nickel, together with possibly some silica. The composition of the films is related to the temperature of formation; work is continuing to evaluate the relative protection offered by films of different composition and to establish optimum conditions for film preparation. (AEC Activity 4109.4)

HR Fuel Reprocessing - Removal of fission products from the uranyl sulfate fuel solution of the homogeneous reactor by metathesis with calcium fluoride was studied further. In the contemplated process, 2 g/l of calcium fluoride is used to remove 90% of the fission products. Since this treatment introduces into the fuel solution 300 to 400 ppm each of fluoride and calcium, these ions must be removed before the fuel is reused, since fluoride would corrode the core tank of zirconium and calcium would precipitate in the reactor as calcium sulfate. The fluoride can be reduced to less than 100 ppm by adding thorium sulfate and precipitating thorium tetrafluoride. The calcium can be reduced to less than 20 ppm by passing the solution through a column packed with solid calcium sulfate and operated at 270 to 300°C. (AEC Activity 4109.8)

AIRCRAFT NUCLEAR PROPULSION PROJECT

Aircraft Reactor Experiment - There are no apparent outstanding technical problems which remain to be solved prior to the "shakedown" operation of the ARE. During the past month the major progress has been in the installation of equipment and associated plumbing. The lack of the pump sump tanks has delayed completion of both fuel and sodium systems, but, according to present estimates, the sump tanks should be received and both systems completed by the middle of November. Since acceptable Inconel impellors for these pumps have not been obtained from two batches of metal cast at International Nickel Co., the impellors will be fabricated at ORNL. Provision has been made to remove some 15,000 Btu/hr from the pump oil cooling system.

Three frangible disk valves are to be used in the fuel system; two for isolating the spare pump, and one in the hot-fuel dump tank line. Tests on these valves indicate that a 7 mil nickel disk will rupture with a total pressure of 9 lb. Nickel is used as the disk material rather than Inconel because the latter requires too high a rupture pressure even for a thin disk. The corrosion introduced by the use of the nickel disk in an Inconel system should be negligible, not only because Inconel is a nickel-base alloy but, in this particular instance, the nickel is located in a static section of the loop.

Operational tests of the bellows-valve in the fluoride fuel show that the valve will not leak or stick at temperatures up to 1200°F. At higher temperatures the valve sticks on opening, and subsequently leaks on closing. This leak rate is small, however, and decreases to nothing in two days. In the present ARE system, the valves are located in lines wherein the temperature can be maintained at 1200°F or below.

Instrumentation and control mechanisms for the ARE are largely complete. The instrumentation was revised in accordance with the recent design modification, and included changing the graphic panel which schematizes the major valve operations in both fuel and sodium systems. The control mechanism was found

to operate satisfactorily but, in order to shorten the fission chamber leads, is being relocated in the control housing. The flux servo mechanism is not yet installed but has been subjected to preliminary tests by the Control Group. (AEC Activity 4401.9)

Experimental Engineering - The four gas-seal sump-type centrifugal pumps for the ARE are about 60% completed. In the continuing tests with a prototype pump, sodium was pumped for 225 hours at temperatures up to 1500°F with a shaft speed of 1800 rpm and a flow rate of approximately 135 gpm (at 10 psi). The heat losses via the pump shaft and seal coolant systems were initially around 35,000 Btu/hr (at 1350°F operating temperature) but subsequently were reduced to 15,000 Btu/hr by providing a "slinger" on the shaft to divert the sodium from the superstructure of the pump. The lower shaft and seal loss permitted 1) elimination of the rotary union which had supplied coolant to the shaft, and 2) joining of the seal and shaft coolant circuits.

The frozen-sodium seal centrifugal pump operated 800 hours continuously with a seal leakage averaging only 3 grams per day.

An apparatus, for testing potential bearing materials in molten salts at high temperatures, was constructed and was satisfactorily "checked out" with several metals in oil at room temperature. In the apparatus a pin of the material to be tested was rotated in a sleeve and the surfaces examined metallographically for wear. (AEC Activity 4401.1)

Critical Experiments - One of the first critical assemblies simulating the three-region reflector-moderator fluid fuel-coolant reactor was rebuilt using a $NaF-ZrF_4-UF_4$ powder mixture having a uranium concentration of 0.4 gm U^{235}/cc in place of the 0.2 gm/cc used in the earlier assembly. With this increased uranium loading it was possible to measure the critical mass and to effect danger coefficient measurements when the core was enclosed in a 1/8" thick stainless steel shell simulating the aircraft reactor fuel container. The fuel was placed in a 3-3/4" thick annulus surrounding a central ellipsoid of beryllium (approximately 9" x 9" at midplane and 40" long). There was a thick composite reflector of beryllium and graphite around the fuel annulus. The critical mass of this assembly was 18.5 kg U^{235}. Measurements with a U^{235} fission chamber showed the neutron leakage through the end of the assembly to be about 77% of that through the side at the midplane. By surrounding the end of the core with boron this loss was reduced to 35%.

A preliminary assembly was made of the General Electric ANPP Reactor AC-1 in order to evaluate its static properties. This reactor is air cooled and water moderated and has the uranium fuel fabricated into wires which are then woven into screens. The arrangement of these screens in the aircraft reactor results in a non-uniform axial uranium density that is most concentrated at the midplane of the fuel element. The preliminary critical assembly employed uranium in the form of metal discs 0.01" thick which were appropriately spaced to simulate the fuel density distribution. In addition, the uranium

discs were enclosed in steel to resemble structural materials and methyl methacrylate plastic was substituted for water. The core was an approximate right cylinder 27" long and 30" in diameter and was surrounded on the sides only by a beryllium reflector 7-1/2" thick. The assembly was critical with a loading of 29.8 kg U^{235}, about 45% greater than predicted. The axial power and neutron flux, as measured in the experiment, were both depressed in the center of the core, a probable consequence of the concentration of uranium.

A method was developed for studying the delayed neutrons resulting from the interaction between beryllium and the hard gamma rays from some fission fragments. After a sharp drop in the power level of a critical assembly containing beryllium, certain precursor concentrations will be greater than their lower level saturation values. If the lower power level is to be kept constant, it is necessary to adjust the reactivity to compensate for the decay of these precursors and the decreasing excess reactivity is plotted as a function of time. Although analysis of the data is not complete, some precursors, including the $Kr^{88} \longrightarrow Rb^{88}$ decay chain, have been identified. (AEC Activity 4401.2)

Radiation Damage - When fluoride salt fuel mixtures, in Inconel containers, were exposed in the LITR to a flux of $> 10^{12}$ neutrons/cm^2/sec for periods up to 600 hours, the salts retained their original melting points and uranium concentrations (corrected for burnup) but the Inconel was attacked more severely than in out-of-pile control tests. The containers of the control samples showed a subsurface void formation type of corrosion to a depth of about 1 mil; irradiated samples showed intergranular corrosion to a depth of about 4 to 5 mils. A few capsules irradiated in the MTR (flux $\sim 10^{14}$ neutrons/cm^2/sec) exhibited intergranular penetration as deep as 13 mils. This type of attack occurred in Inconel with a larger than normal grain size.

A petrographic examination of irradiated salts containing ZrF_4, made one month after the capsules were opened, disclosed the presence of some ZrO_2 which did not appear in the control samples. Investigations are being made to determine whether the ZrO_2 is formed during irradiation or after the salt is removed from the capsule. (AEC Activity 4401.4)

Reactor Chemistry - Eight batches of ARE fuel concentrate (Na_2UF_6), using about 66 kg of U^{235}, were prepared by the Y-12 Production Division. Chemical analysis indicated that only one batch was unsatisfactory because of a relatively high ($\sim$2,000 ppm vs. 100 ppm desired) impurity level. If the required amount of U^{235} is made available soon, the necessary quantity of Na_2UF_6 for the ARE will be produced by November 15.

Continued examination of the solid phases in the NaF-ZrF_4-UF_4 system, from which the ARE fuel is taken, demonstrates that solid solutions exist on the UF_4-ZrF_4, $NaUF_5$-$NaZrF_5$, and Na_3UF_7-$NaZrF_7$ joins (a line joining two specific species, e.g. compounds, in a phase diagram). Limited solid solution of Na_2ZrF_6 in $NaZrF_5$ apparently occurs as well.

Upon spectrophotometric examination of melts which were quenched to form glasses, in an attempt to retain the liquid structure, it was observed that, when UF_4 was added to NaF, the absorption maxima shifted to a spectrum corresponding to that for $UF_6^=$. Since additions of UF_4 or UF_3 to ZrF_4 showed no shift from a pattern characteristic of the simple uranium fluoride, it appears that there is no complex formation involving Zr and U. (AEC Activity 4401.5)

Corrosion Research - Analyses of the mass-transferred material in the several quartz "loops," circulating lead and containing test specimens, were completed. Although the loop containing the 25 percent Mo-Ni alloy operated for 670 hours at 1500°F without plugging (exceptionally long for a Ni base alloy), the mass transferred-material consisted almost entirely of nickel with less than 35 ppm Mo. A Fe-Cr-Si (14-2-85 percent, respectively) specimen, also tested in a 1500°F loop circulating lead, showed several times the amount of mass transfer normally observed in the 400-series stainless steels, despite the fact that this silicon-base alloy supposedly had good corrosion resistance in lead.

Static tests in sodium, lead and lithium were made with several alloys, potentially useful as bearings, at a temperature of 1000°C. The alloys were plated on type 347 stainless steel as a hard-facing surface and placed in the various media for 100 hours. Of the various Stellites and Hastelloys tested, Stellites 14 and 12 were best in lead, Stellites 1, 6, 12 and 21, best in sodium, and Stellites 1, 12 and 21, best in lithium. In general, the corrosion resistance of the cobalt-base alloys was superior to that of the nickel-base alloys.

Other materials, including Metamic LT-1, Firth Sterling 27 and Kenametal 151A that might be used for bearings, were subjected to static tests for 100 hours at 816°C in the fluoride $NaF-ZrF_4-UF_4$ (50-46-4 mole percent). The results from the few tests to date show Kenametal 151A to have the best corrosion resistance.

A decrease by a factor of 10 (from 1200 ppm to 120 ppm) in the chromium concentration, after corrosion tests of the ARE fuel solvent (i.e. $NaZrF_5$) in Inconel convection loops, was realized as a result of the 20—30 hour hydrogenation at 800°C used to remove oxidizing impurities from the melt. The failure to find a corresponding decrease in the frequency and depth of occurrence of subsurface voids in Inconel implies the existence of a corrosion mechanism which is not directly related to the chromium pickup. (AEC Activity 4401.5)

Metallurgy - Work on the basic Ni-P and related brazing alloys was intensified since, to date, the only satisfactory high-temperature brazing alloys, which can be preplaced on tubes and fins, have been obtained from these systems. By combining electroplating of Cr with the deposition of Ni-P eutectic alloy by "electroless" plating methods, a whole series of alloys in

the Ni-Cr-P system can be obtained. These alloys, as well as the Ni-P alloy, effect good joints with any combination of Inconel, 310 stainless steel, 446 stainless steel, or copper clad variations of these materials. To understand the Ni-P binary system more completely, special ingots of "electroless" Ni-P were made, homogenized at 1500°F and examined metallographically to determine the type and amount of various microstructures (e.g. composition, grain size, etc.). Furthermore, increasing the amount of phosphorus from 2 to 8% in the Ni-P-Cr alloy was found to decrease the melting point of the alloy and to impair seriously its ductility.

In connection with the Ni-P alloys, it is interesting to note that small (~1%) additions of phosphorus to low-melting Nicrobraz (80Ni-5Cr-5Fe-5Si-5B) produces an alloy which will satisfactorily wet all useful combinations of tube and fin materials (listed above), whereas the Nicrobraz alone will not.

The best resistance to fluoride corrosion of any of the high temperature alloys under investigation was shown by the 60 Pd-40 Ni brazing alloy. However, its high flow-temperature of approximately 2300°F often makes it impractical for use. Since the binary phase diagrams of the Pd-Cr and Cr-Ni indicated that chromium additions might lower the melting of the Pd-Ni alloy, various ternary alloys were made and tested. The results were discouraging in that the alloys did not melt, even at temperatures as high as 2150°C. (AEC Activity 4401.5)

Physical Properties Research - Some of the physical properties of the new ARE fuel and fuel concentrate have been determined and are listed in the following table.

	Viscosity μ=centipoise	Density ρ=gm/cc	Heat Capacity C_p =Btu/lb·°F
Fuel Concentrate $NaF-UF_4$ (Na_2UF_6) 66.7-33.3 mole %	19.2 at 1290°F 13.8 at 1470°F 11.0 at 1650°F	ρ=5.60-.0012T 1220°F<T<1830°F	0.21 (liquid)
Fuel $NaF-ZrF_4-UF_4$ 53.5-40.0-6.5 mole %	11.0 at 1202°F 7.6 at 1380°F 6.3 at 1560°F	ρ=4.06-0.00097T 1110°F<T<1470°F	0.30 (liquid)

Thermal Conductivity k = Btu/hr·ft·°F
≅ .5 (estimated)
≅ 1.3 (estimated)

The heat capacity of LiCl-KCl (51-49 mole %) was measured and the following data in Btu/lb·°F were obtained:

$C_p = 0.24$ $207°F < T < 664°F$

$C_p = 0.33$ $664°F < T < 1544°F$

The thermal conductivity of solid fluorides is being measured by a transient cooling method. A sphere (made of the material to be studied) is suddenly moved from a calorimeter (which establishes an initial, uniform temperature) to a large, circulating bath at a lower temperature. A fine-gauge thermocouple at the center of the sphere is used to determine the time-temperature curve as the sphere cools. Classical transient temperature solutions in terms of the physical properties of the sphere are available and may be used to extract the thermal conductivity of the sphere from the experimental time-temperature data. The thermal conductivity of the solid fluoride mixture $NaF-KF-LiF-UF_4$ (10.9-43.5-44.5-1.1 mole %) was determined to be 1.7 Btu/hr ft·°F, as compared with a value of 2 Btu/hr·ft·°F measured for the same fluoride mixture in the liquid state. (AEC Activity 4401.5)

Analytical Studies - To achieve a better understanding of the detailed mechanism of corrosion in fluoride-Inconel systems, methods are being developed for the determination of the oxidation states of the elements used in the containers, as well as that of the uranium and zirconium in the ARE fluoride fuel solvent Na_2ZrF_5. The possibility of distinguishing between the oxidation states of chromium by measuring the absorption spectra of the disodium dihydrogen ethylenediamine tetraacetic acid (EDTA) complexes of divalent and trivalent chromium was eliminated when it was found that the spectra were identical. However, divalent chromium, as CrF_2 or $NaCrF_3$, may be oxidized by hydrogen ion and thus provide a means of measuring the oxidation state. The presence of any other species that liberate hydrogen under similar conditions will interfere in this determination.

An attempt is being made to establish a correlation between corrosion data and the total reducing ability of fused salts. Thus far, samples of $NaZrF_5$ have been treated with metallic zirconium and the subsequent reduction measured by two techniques. Although the hydrogen evolution technique, as well as a procedure involving oxidation with ceric sulfate, has been attempted, neither method indicates the presence of any substantial amount of reducing power. Essentially no residue remains after treatment of these samples with saturated oxalic acid, thus indicating the absence of zirconium oxide. Zirconium metal is oxidized rapidly with evolution of hydrogen by oxalic acid in the presence of $NaZrF_5$. (AEC Activity 4401.5)

Shielding Research - Although there is a considerable amount of interest in lithium as a shield component, the effective removal cross-section of Li alone has not yet been obtained because Li metal is difficult to handle. However, the cross section of Li can be obtained from that of lithium com-

pounds if 1) it is assumed that the total cross section of a compound is the sum of its constituent elements (a good assumption for shielding purposes) and 2) the cross sections of the other elements in the compounds are known or can be obtained. Actually, the effective removal cross section of LiF has been known for some time. The value for F can be obtained from a recent measurement of C_7F_{16} (since that for C has already been determined) which corroborates a previous measurement on that compound to within 5 percent.

The values for C and F are 0.81 barns and 1.33 barns respectively. Although these data indirectly yield a value for lithium of 1.47 barns, a better one will be obtained from measurements now in progress on the element itself.

Construction of the Tower Shielding Facility is proceeding satisfactorily. The tower structure itself is essentially complete with the exception of a few permanent guy wires. The concrete for the roof of the control building is now being poured. The reactor pool has been completed and water tested. There will be a delay of between one and two months in the delivery of the hoists. The critical experiments for the reactor in the tank have been completed. (AEC Activity 4401.7)

Reactor Physics - The reactivity calculations for the Aircraft Reactor Experiment included those of possible criticality in the fill-and-flush tanks and other large fuel volumes outside the reactor. The fill-and-flush tanks will not go critical with presently estimated fuel volumes and uranium concentrations, at least not unless fuel segregation occurs. A further point investigated was the influence of the partially fuel-filled reactor ends on the critical mass of the reactor itself.

Consideration of the inhour equation for the circulating-fuel ARE shows that a substantial amount of excess reactivity - 0.4% - is required for prompt criticality. However, only a small increase in reactivity will bring the reactor from just critical (infinite period) to a positive period of 10 seconds. "Reactor periods" between "infinite" and 10 seconds will be hard to measure because small reactivity fluctuations, which can be expected to occur at random in a circulating-fuel reactor, will cause wide fluctuations in the reactor period. (AEC Activity 4401.7)

GENERAL REACTOR RESEARCH

Package Reactor - The design study and cost estimate for a 10-megawatt package reactor was completed and a preliminary draft of the report (CF-53-10-106) was prepared. It is proposed that the plant produce 1000 kw of electricity and 3500 kw for steam heating. Stainless steel-clad fuel plates are specified and water, pressurized at 1200 psi to prevent boiling at the operating temperature of 450°F, is used as moderator, reflector, and heat transfer medium. The total cost of constructing the plant (at Oak Ridge) is estimated at $1.7 million. (AEC Activity 4510)

General Reactor Radiation Damage - Two peaks in the x-ray patterns of polyethylene correspond to peaks found for paraffin hydrocarbons. Polyethylene has a structure similar to that of the paraffins, except that the polyethylene has amorphous regions between minute crystallites. It was found that irradiation destroyed the crystalline peaks and increased the prominence of a halo on the plates at a wavelength of about 4.6 Å. For exposures in excess of 2.4×10^{18} nvt, the x-ray pattern changed very little. This result is taken to indicate that crystallinity is largely destroyed by an exposure of less than 2.4×10^{18} nvt. The x-ray pattern for nylon is affected similarly by irradiation. (AEC Activity 4540)

PROGRAM 5000 - PHYSICAL RESEARCH

Stable Isotope Production - Samarium was processed to produce an estimated 82.5 grams of separated isotopes; although output was low and beam focus apparently poor, spot assays indicated surprisingly high product purities. Three exploratory argon collection runs were made and the retention of argon in both palladium and silver was qualitatively observed. Bombardment-heated ion sources were used in the separation of 3.47 grams of iridium isotopes. High current drains resulting from vaporization of the graphite structure appear to place the upper temperature limit for this type of source at about 2800°C. In preparation for the collection of high purity K^{40}, preliminary runs were made with normal potassium. A charge enriched to 0.02% K^{40} will be used for the production runs.

The six isotopes of platinum and one of the isotopes of gadolinium were added to the inventory of stable isotopes. The inventory of sulfur isotopes was increased by four new lots and that of neodymium isotopes by seven new lots. Sixty-two shipments and transfers of forty-nine isotopes of twenty-seven elements were made. (AEC Activity 5121)

High Voltage Physics - The neutron spectrum from the reaction $Li^7(d,n)Be^8$ was studied to obtain the level structure of Be^8. Neutrons were detected by observing the proton recoils at zero degrees from a polyethylene radiator. The protons passed through a proportional counter and terminated in a thin NaI crystal. The scintillation pulses were analyzed with standard coincidence techniques. Preliminary results at 0° show only one level in Be^8 (at 2.94 Mev) between the ground state and 10 Mev. Better statistics will be necessary for conclusive results. (AEC Activity 5211)

Short Lived Isomers - An analysis of the results from the directional angular correlations of three different gamma ray cascades in Ta^{181} (following the β^- decay of Hf^{181}), together with measured K-shell internal conversion coefficients, indicates that an unambiguous assignment of the angular momenta of

the three excited states in Ta^{181} and a classification of the gamma-rays are possible. The spin sequences and the values of δ_γ (the square root of the intensity ratio of electric quadrupole radiation to magnetic dipole radiation) are listed in the following table.

Cascade	Spin Sequence	δ_γ
132-480 kev	5/2(E2)9/2(E2 + M1)7/2	$\delta_{480} = 1.25^{+0.29}_{-0.22}$
132-345 kev	5/2(E2)9/2(E2 + M1)9/2	$\delta_{345} = 1.0 \pm 0.2$
345-135 kev	9/2(E2 + M1)9/2(E2 + M1)7/2	$\delta_{345} = 0.95 \pm 0.10$ $\delta_{135} = 0.50 \pm 0.05$

The observed angular correlation functions for the 132-480 kev and 132-345 kev cascades indicate an appreciable attenuation by perturbing interactions in the intermediate state of the nucleus by its surroundings in the liquid and polycrystalline hafnium sources. For polycrystalline hafnium metal and hafnium compounds, the attenuation coefficients are smaller than the "hard core" values for a static electric quadrupole interaction. (AEC Activity 5211)

Nuclear Physics, 86-Inch Cyclotron - The following previously unknown isotopes were identified with certainty: 18-m Yb^{167}, 25-h Tm^{165}, 75-m Er^{163}, 3.6-h Er^{161}, 2.5-h Ho^{161}, 22.0-m K^{44}, and 1.5-m Mn^{57}. In all cases, the decay schemes were studied, and the work has been submitted for publication. The angular distributions of Ba, Sr, and Ag fission fragments from 22-Mev proton-induced thorium fission were measured. The data fits an equation of the form $I(\theta) = a(1 + b \cos^2 \theta)$ with $b = 0.26 \pm 0.02$ for barium and strontium, and $b = 0.11 \pm 0.04$ for silver. (AEC Activity 5211)

Fundamental Electromagnetic Research - Attention was concentrated on obtaining a system of mathematical equations which correspond to a physically satisfactory concept for a controlled thermonuclear reactor. Several concepts were considered. Currently under investigation is a system for describing the core (the region in which electron and ion densities are assumed equal) in which ion diffusion, electron diffusion, and the presence of a small number of neutral particles are accounted for. The solution of the equations for this system is to be joined to the solution of a set of equations for the sheath, in which the diffusion equation no longer exists but in which Poisson's equation must be taken into account. (AEC Activity 5261)

Electronuclear Machines - For deflecting the proton beam in the 86-inch cyclotron, it is proposed to add iron in the cyclotron gap to "bypass" magnetic flux and thus reduce the magnetic field in the deflected beam region. A method of compensating for the effect of the iron in the normal beam region by using electromagnetic coils is being studied. The experiments and calculations up to the present indicate that a magnetic field gradient of 3,500 oersteds per inch may be obtained for a power input of

150 kv, and that the magnetic field in the undeflected beam region can be compensated to within 1% by the coils alone in the median plane. The order for fabrication of the new dees has been placed and engineering on all other components of the radio-frequency system is nearing completion. (AEC Activity 5261)

Mass Spectrometer Laboratory - In examining the problem of detecting traces of nickel in HRE fuel solution, an investigation of the ease of production of nickel ions was conducted following the technique developed by Inghram and Chupka (Rev. Sci. Instr. 24, p. 518). An ion source, comprising three tungsten filaments, was constructed so that the vapor pressure of the sample on one side filament could be controlled separately from the much hotter central ionizing filament. The poor results obtained with this apparatus were thought to be due to reaction of NiO with (1) the sample filament to reduce the vapor pressure, or (2) the ionizing filament to change its work function. When platinum was substituted for tungsten in the sample filament there was no apparent reaction with NiO, but the observed nickel ion peaks were still very small. (AEC Activity 5261)

The 63-Inch Cyclotron - Improved deflector design and refinements in magnetic field shimming resulted in a marked increase in the deflected beam current; one microampere of 25 Mev N^{+++} is now obtained. A Faraday cup is used to measure the beam at the exit port. Gas targets of nitrogen and helium were bombarded with the external beam and reaction products examined by means of nuclear emulsions. Excitation functions for the reactions from carbon targets are also being studied with the deflected beam. (AEC Activity 5261)

Research and Development, Stable Isotopes - The development of a suitable outgassing system for the collection of inert gases was completed, and an evaluation of collection techniques is now in progress. It was observed that pre-outgassing the metallic silver collector used in the calutron for the collection of inert gases reduced the extraneous gas contamination in the inert gas subsequently outgassed from the target. At present, ion collectors of various materials, shapes, and sizes are being investigated; an ion beam of normal argon is used to determine the optimum geometry of the ion collector. The two metals, silver and palladium, used to date have given similar results.

Experiments using the Ranque-Hilsch tube as a mass separator have been unsuccessful and investigation of the mode of separation in the tube has led to the conclusion that the processes involved are not conducive to significant mass separation except as centrifugation, thermal diffusion, and/or other effects might enter into the picture in a secondary way. (AEC Activity 5261)

Inorganic Solution Chemistry - Strontium (as Sr^{89} tracer) was found to be strongly adsorbed from .01 to .1 M ammonium citrate solutions by the strong base anion exchange resin Dowex-1 near pH 7.5. This adsorption is large

even in the presence of appreciable amounts of lithium chloride. A similar adsorption was found for calcium. It was demonstrated that this high adsorbability of calcium and strontium, presumably as negatively charged citrate complexes, permits their separation from alkali metals. The removal of the alkaline earths from the column can be achieved with acid, e.g., 1-M HCl.

On the basis of earlier work, a number of conditions were found under which the separation of lead and bismuth in chloride solutions can be effectively achieved. It was shown also that both lead and bismuth can be adsorbed from nitric acid solutions, Bi(III) showing an adsorption maximum near 4 M HNO_3 with a distribution coefficient $\underline{D} = 26$, while Pb(II) shows maximum adsorption near 2 M HNO_3 with $\underline{D} = 4$. The differences in adsorbability of lead and bismuth permit their separation in nitrate solutions. Although the adsorption of lead is never high, it is sufficient to permit its separation from non-adsorbable elements. (AEC Activity 5311)

Chemical Physics - A molecular beam experiment with a new, wide-angle detector was completed in which reaction products were sought at angles up to 80° from a beam of K atoms scattered by a beam of HBr molecules. Conservation of momentum requires that practically all of any KBr formed should lie in the quadrant the equator of which can be scanned by the detector. The K and HBr were at about 500° and 420°K respectively, and, as in previous experiments within a more limited angle, no KBr was found. This result suggests that the reaction may have an activation energy greater than 5 kcal, or a surprisingly small frequency factor (large negative entropy of activation).

Zeeman studies on pure quadrupole spectra were continued for several chlorates; in sodium chlorate all features of the spectrum can be explained on the basis of the known crystal structure. Simple paramagnetic resonance absorption equipment was assembled and a variety of systems observed in a preliminary manner. A 0.07μg sample of α,α-diphenyl β-picryl hydrazyl gives an observable absorption due to its unpaired electron. Free radicals were observed in the course of the oxidation of diphenyl amine and also in a sample of glycerol at liquid nitrogen temperature after irradiation at 500r/min for almost a day in a cobalt source. Interesting absorption lines have been observed from paramagnetic salts absorbed on silica and charcoal. (AEC Activity 5311)

Chemistry of Solid State - The study of the miscibility of liquid sodium metal and fused sodium halides was extended to the determination of the solubilities of fused chloride, bromide, and iodide in the liquid metal at a temperature up to 950° C; they were found to be as high as 11 to 12 mole percent. These data, together with those for the solubilities of the metal in the fused salts, yield, by means of a rather tentative extrapolation, critical or consolute temperatures of 1060°, 1090° and 1110° C (all $\pm$ 50° C), respectively, for complete miscibility. They appear to indicate that complete miscibility of liquid salts and metals may not be a rare but rather a fairly general phenomenon, with the

critical solution temperature varying, however, over a wide range for different systems.

The metal vapor pressures of solutions of sodium chloride in sodium metal and of potassium fluoride in potassium metal were measured by observing boiling points under various pressures of an inert gas. Activity coefficients derived directly from these data were found to agree well with those calculated from the equilibrium concentrations. These vapor pressure measurements also established the fact that the experimental values for the boiling point of potassium given in the older literature, 758 ± 1° C, and a formula based directly thereon and on other vapor pressure data, namely, $\log P_{mm} = -\frac{4552}{T} - 0.5 \log T + 8.793$, is more accurate than a formula with a partially theoretical background, $\log P_{(atm)} = -\frac{4769}{T} - 1.375 \log T + 8.708$, proposed in 1936 by Kelly, which gives too high a boiling point (774° C). (AEC Activity 5311)

Radio-Organic Chemistry - In a 6-in. length of annular space-type diffusion column, liquid methanol-C^{14} was found to exhibit isotope fractionation. After standing six weeks, there was observed to be a 5-percent difference in carbon-14 concentration between the top and bottom of the column. Hydrogenation of cinnamic-β-C^{14} acid over nickel showed no appreciable isotope effect. Several elimination reactions involving derivatives of C^{14}-phenyl labeled and C^{14}-chain labeled 1,2,2-triphenylethanol were shown to result in products with nearly random distribution of the labeled carbon. (AEC Activity 5311)

Radiation Chemistry - The yields for several gamma-ray-induced reactions in aqueous sulfuric acid solutions were measured as a function of temperature with a precision of approximately 1 percent. The yield for ferrous sulfate oxidation in the presence of oxygen showed a small positive coefficient, with an increase in yield from 15.2 ferrous ions oxidized per 100 ev at 2° C to 16.2, at 65°C. The yield in helium-swept (oxygen-free) solutions increased from 7.4_8 at 2°C to 7.8_4 at 65°C. In the reduction of ceric sulfate, a negative coefficient was observed, with the yield decreasing from 2.61 ceric ions reduced per 100 ev at 2° C to 2.34, at 65° C. In the formation of hydrogen peroxide in sulfuric acid solutions containing oxygen, the yield dropped from 1.26 H_2O_2 atoms formed per 100 ev at 2° C to 1.17, at 65° C. These results were interpreted in terms of an effect of temperature on the yields of H, OH, H_2O_2, and H_2 produced in the primary reactions by the radiation. The net yield for H_2O_2 formation at any H_2O_2 concentration in dilute solutions containing oxygen can be given by the equation :

$$G(H_2O_2) = G(H_2O_2)_o - \frac{G(H_2O_2)_o}{(H_2O_2)_{\text{steady state}}} (H_2O_2)$$

where $G(H_2O_2)$ is the number of H_2O_2 molecules formed per 100 ev; $G(H_2O_2)_o$ is the initial rate (zero H_2O_2 present) of H_2O_2 formation, and (H_2O_2) is the concentration of H_2O_2 in micromoles per liter.

In water, saturated with oxygen at one atmosphere and at 25° C, this equation, using the known values for $G_{(H_2O_2)_o}$ and $(H_2O_2)_{steady\ state}$ becomes

$$G_{(H_2O_2)} = 1.35 - \frac{1.35}{506} (H_2O_2)$$

(AEC Activity 5311)

Chemistry of Fused Salts - The heat capacity of high purity crystalline cadmium iodide, chosen for study because of its high crystal anisotropy, was measured from 15°K to room temperature. Although calculations of the results are still incomplete, it is evident that the low temperature heat capacity follows neither the usual Debye T^3 law nor the T^2 relation found for certain extremely anisotropic layered structures. A detailed theoretical interpretation of this behavior may have to await heat capacity measurements in the range below 15°K.

Detailed highly reproducible measurements of the density and the electrical conductivity of the fused salt system LiCl - KCl were completed for the entire composition field and over wide temperature ranges. A very exact linear relation between molar volume and composition at any specified temperature indicates that no complex formation occurs in this molten system. On a molar basis, lithium chloride is a considerably better electrical conductor than potassium chloride. It was, therefore, significant to discover that substitution of lithium chloride for some of the potassium chloride actually lowered the equivalent conductance of the solution below that of pure KCl. This phenomenon was interpreted to be indicative of considerable short range order persisting in these high temperature fluids. A tentative further explanation of this behavior was based on the consideration of the relative sizes of the ions. Substitution of small Li^+ for some of the much larger K^+ ions will shrink the short range chloride semi-lattice of the fluid and make transport by K^+ appreciably more difficult. As more and more Li^+ is substituted for K^+ the conductivity will pass through a minimum and again increase until finally pure LiCl is present.

The depression of the freezing point of sodium nitrate was investigated with a wide variety of solutes. The results significantly substantiate the concept that fused salts are essentially totally ionized and behave as ideal electrolytes even at relatively high concentrations of the solute. Thus, e.g., calcium, strontium, barium, and lead chlorides are completely dissociated, as is $LaCl_3$. $FeCl_3$ seems to form two particles only, apparently $FeCl_2^+$ and Cl^-. Chromate, dichromate and bromate ions are stable in liquid sodium nitrate but the metaperiodate ion, IO_4^-, decomposes to yield oxygen and the iodate ion. (AEC Activity 5311)

Uranium Chemistry of Raw Materials - As reported previously, the long chain primary, secondary and tertiary amines in hydrocarbon diluents are effective extractants for uranium (VI) from acidic sulfate solutions. Recent tests show that the primary and secondary compounds are also effective extractants for uranium (IV) from these solutions, especially at lower acidities, i.e., pH = 1.6 and above. With tertiary amines, uranium (IV) may be extracted moderately well but the extraction coefficients are considerably less than those for uranium (VI).

In a fundamental investigation of the extraction of uranium by amines, di-n-decylamine in benzene is being studied in conjunction with uranyl sulfate-sulfuric acid solutions. In a preliminary study of the extraction behavior with sulfuric acid alone it was found that di-n-decylamine sulfate is the principal species formed in the benzene phase in the absence of excess acid. It is converted to the amine bisulfate at equilibrium acid concentrations greater than 0.01 M. The data thus far available indicate that the equilibrium concentration of acid in the more dilute range ($< 10^{-3}$ M) is determined only by the free amine concentration in the benzene phase, being independent of the amine sulfate concentration.

In an extraction process previously described, a solution of dialkylphosphoric acid in kerosene is used to recover uranium from leach liquors, and sodium carbonate or sodium hydroxide solution is used to strip the uranium from the organic phase. Modification of the kerosene with a small amount of a suitable alcohol prevents the formation of a third liquid phase during the stripping operation, as explained in report ORNL-1622. Recent measurements in multicycle extractions showed reagent losses of less than 0.04 lb di(2-ethylhexyl)phosphoric acid and 0.08 lb 2-ethylhexanol per lb uranium extracted from a 0.5 M sulfate liquor (pH 1, 1 g U/liter), with a 0.1 M solution of the reagent in kerosene containing 2% of the alcohol. In view of the expected price range for such reagents, these losses should comprise only a small fraction of the total operating costs.

Since recent geological explorations have shown a much larger uranium reserve in the sub-bituminous Wyoming coals than in the uraniferous Dakota lignites, the current uranium recovery studies have been concerned primarily with the former material. Preliminary tests indicate that some important differences between the coal and the lignite from the standpoint of uranium recovery operations, are: a lower concentration of uranium; a somewhat lower ash content; a lower slagging temperature, putting the limiting burning temperature at 1150-1200°C rather than 1300-1350°C; and a greater consumption of acid and a lower uranium recovery from leaching either the raw or ashed material. (AEC Activity 5361)

Electrochemical Studies - An analytical method for determining the amount of gas stored in a palladium cathode by measuring the resistance of the gas-charged cathode was developed. The method was found to be accurate to within 4 percent over a range of zero to 1000 cc of gas stored per cubic centimeter of palladium. In the previously accepted analytical method, in

which the amount of gas stored was calculated from the milliampere-hours of current that had passed through the solution, gas storage efficiency was assumed to be 100 percent, and this assumption could be in error by as much as 10 percent. The new method, with its greater accuracy, will make possible more accurate calculations of the hydrogen-deuterium separation factors in electrochemical studies. A maximum charging of the cathode caused an increase in resistance by a factor of 1.7 over an uncharged cathode with an apparent surface area of 1 cm^2. (AEC Activity 5361)

Thorex Process Development - A deep-blue undissolved material, remaining after dissolution of an irradiated thorium slug in a stoichiometric quantity of nitric acid, was identified by X-ray analysis as thorium oxide, containing U^{233}. Its color was attributed to electron displacement induced by irradiation. In irradiated thorium containing 300 g of U^{233} per ton, the insoluble residue represented 0.6 percent of the Th and U^{233}. To prevent the loss of this material in the Thorex pilot plant, it is planned to dissolve the aluminum jackets and the thorium slugs in twice the stoichiometric amount of nitric acid, i.e., 10 moles per mole of thorium and 7.5 moles per mole of aluminum. After slug dissolution, excess acid will be distilled off and siliceous material will be coagulated by refluxing the residual solution for 1 hr at 155°C. In tests of this process, a ruthenium decontamination factor of greater than 200 was consistently obtained in the extraction-scrub column. (AEC Activity 5361)

METALLURGY

Ceramics Research - No signs of segregation were observed during petrographic examinations of samples of ANP Fuel 30 (ZnF_4, UF_4, NaF-46-4-50 mol %) irradiated in the MTR for 600 hours; however, zirconium oxide was noted in all of the specimens examined, indicating that oxidizing conditions were present. Examination of unirradiated control samples showed no zirconium oxide present. Samples of Fuel 30 exposed to a gamma source at 6 x 10^5r/hr for varying periods up to 300 hours showed no evidence of segregation or zirconium oxide.

Eighteen specimens of UO_2 having an average density of 96 percent of the theoretical value were prepared in the form of rods 2" long x 0.3" in diameter. The rods were prepared by ball-milling fused UO_2 in a steel-lined mill, with steel balls; leaching in HCl; drying; hydrostatically pressing the powdered UO_2, without a binder, in the form of rods approximately 6" long and 0.5" in diameter; firing the rods in a hydrogen atmosphere to 1750°C, holding at this temperature for 65 minutes; and machining to the desired size. This work was done in cooperation with the Westinghouse Atomic Power Development (WAPD) in connection with investigations for the PWR (Pressurized Water Reactor). It was found that thorium oxide with a density 96 percent of the theoretical value (10.0) can be obtained by adding only 1% CaO and firing the material in an oxidizing atmosphere to 1800°C. With pure ThO_2, only 80 percent of the theoretical density was attained under the same conditions.

The work done with the rare earth oxide, Sm_2O_3, showed that dry-pressed bars acquired optimum density and strength at 1500°C. In boiling water the fired bars disintegrated to a white powder, indicating the formation of a hydrate. (AEC Activity 5411)

Physical Metallurgy of Reactor Materials - Examination of the microstructure of uranium specimens creep-tested at 500°C showed that the fast beta heat-treated (i.e., heated quickly, converted to β phase, and cooled) structure was not stable at this temperature; a polygonal-type of structure, very similar to alpha-rolled (uranium rolled while in alpha phase) material, was obtained. Stress-rupture results for fast beta heat-treated material indicated no significant difference as compared with the alpha-rolled uranium. On the other hand, uranium bars which were held in the beta phase temperature range for several hours and then furnace-cooled showed definite improvement in rupture strength as compared with either alpha-rolled or fast beta heat-treated material. These slowly cooled specimens also showed a coarse, beta-transformed structure which did not become polygonal during testing at 500°C. (AEC Activity 5411)

Fundamental Physico-Metallurgical Research - Thermal analysis of a new lot of pure (99.6 atomic percent) zirconium revealed that the α/β transformation occurs at 866 ± 1°C; the value of 866 ± 3°C was obtained on four earlier lots.

The limits of the homogeneity range of the γ phase in the Zr-Ag system (composition Zr_2Ag) have been found to be between 30.5 and 32.2 atomic percent silver at 1100°C. An alloy of 30.5 atomic percent, when slowly cooled from 1000°C into the $\gamma + \beta$ region did not develop the superlattice in the γ phase found earlier in an alloy quenched from the $\gamma + \delta$ region. The γ phase in the 30.5 atomic percent alloy had a disordered body-centered tetragonal structure.

The α phase in the Zr-Sb system is formed by the peritectoid reaction (0.1 atomic percent Sb) + $Zr_2Sb \rightarrow \alpha$ (0.6 atomic percent Sb) at 869°C. The solid solubility of antimony in α zirconium at 800°C is less than 0.25 atomic percent. A preliminary investigation of the Zr-Pb system indicated that the α phase is in equilibrium with the β phase at 900°C, thus it is probable that lead raises the α/β transformation in accordance with the general trends observed in zirconium alloy system.

A detailed analysis has been made on the preferred orientation developed in some 0.210" α-rolled uranium sheet that had been β heat-treated. One lot of the sheet had been straight-rolled 86.0 percent at approximately 600°C and stretch-straightened 1 percent at room temperature; another lot had been straight-rolled 85.3 percent at this temperature, cold-rolled 4.5 percent, and then stretch-straightened. All this material developed a texture in which the (001) plane was parallel to the rolling direction but tilted 45-70° from the plane of the sheet with the (110) pole in the major component and the (010) pole in the minor component being parallel to the rolling direction.

Some of this sheet was β heat-treated for 1 minute at 730°C and then water-quenched; some was β heat-treated 2 minutes at this temperature and water-quenched. Both treatments essentially destroyed the original preferred orientation but did not give a random orientation. In the first case five distinct components could be resolved, two of which were somewhat similar to the two of the original, as-rolled texture. In the latter, six components could be resolved, with one resembling a component in the as-rolled texture. (AEC Activity 5411)

Fundamental Investigation of Radiation Damage in Solids - The study of the properties of single crystals of irradiated copper was extended to 4.2°K. Previous studies have covered the temperature range between 78° and 300°K. The specimens were irradiated at reactor ambient temperature, then deformed at 4.2°K. It was found that for a given irradiation the critical shear stress measured at 4.2°K was much larger than at the higher temperatures.

The resistivity of irradiated specimens was also measured at 4.2°K. The measurement at this temperature yields the residual resistance directly. Since only the residual resistance is increased by bombardment and since it is only a small fraction of the room-temperature resistance, the accuracy of the determination of bombardment-produced changes is considerably improved at 4.2°K. The residual resistivity appears to increase at a rate proportional to the 2/3 power of the integrated flux. (AEC Activity 5411)

Research Participation and Traveling Lecture Programs - Under the Traveling Lecture Program for the academic year 1953-54, ORINS has submitted a list of lecturers to interested universities. Thus far, 21 requests for speakers have been received from 6 universities. (AEC Activity 5620)

PROGRAM 6000 - BIOLOGY AND MEDICINE

BIOPHYSICS

Waste Disposal Research - A 50-gallon composite sample of the settling basin effluent collected during the last week of August 1953 was concentrated and analyzed in the electrolytic-ion exchange cell. In this cell Permselective ion exchange membranes were employed to separate the central chamber from the anode and cathode compartments. Analysis of the cationic components indicated that Sr^{89} and Cs^{137} were present in excess of 90 percent of the total cationic radioactivity and that P^{32} accounted for all of the anionic radioactivity.

The Standard U.S. Army Field Set No. 1, a hand-operated, knapsack-pack, 1/4 gpm filter used in the field to provide potable water to small isolated troop units, was evaluated. The standard procedure was modified by the addition of a clay slurry.

When Ta^{182}, Zr^{95}-Nb^{95}, and waste evaporator concentrate were used as radioactive contaminants, 99.3, 95.5, and 91.0 percent, respectively, of the radioactivity was removed.

Theoretical Physics - The stopping power of a particle having charge Ze and moving with velocity v has been determined by Bohr for $\kappa = 2Ze^2/\hbar v > 1$ and $\eta_s = 2v/u_s > 2$ where u_s is the velocity of the orbital electron that is effective in stopping the particle. Bohr's results are formulated differently for $\kappa/u_s < 1$ and for $\kappa/u_s > 1$ and are based entirely on an orbital picture of the processes involved. An alternative method was developed in which the space surrounding the particle track was subdivided into three regions: (a) the region of validity of the Rutherford formula (adjacent to the track), (b) the intermediate region involving large perturbations for which no adequate theory exists at the present time, and (c) the region of validity of the quantum perturbation theory (the most remote from the track). By extrapolating the formulas valid in regions (a) and (c) into the region (b), the contribution to the stopping power due to the region (b) was evaluated, and, by adding the contributions of the three regions, an expression was derived for the total stopping power applicable for any $\kappa > 1$ and $\eta_s > 1$. The physical picture used for deriving this expression is somewhat similar to the one used by Bohr for $\kappa/\eta_s < 1$ but is different from the one used by Bohr for $\kappa/\eta_s > 1$. (AEC Activity 6510)

Physics of Nuclear Radiation - It is well known that fast neutrons scatter from walls and floors of a laboratory and the magnitude of this scattering depends on the geometry of source and detector, type and size of room, and energy of the neutrons. An experimental study is under way to determine the number of scattered neutrons received by a fast neutron tissue dosimeter of the proportional counter type as a function of (1) its height above a large cement slab and (2) of the separation of source (Po-B) and detector. The cement slab is in open space and the arrangement of source and detector is such that the likelihood of scattering from anything other than the slab and the intervening air is small. One important objective of this work is to demonstrate that a shadow cone of paraffin can be developed that will enable one to cut out the direct beam of neutrons, and hence measure directly the scattered component. With such a cone one can then correct for scattering under any condition of instrument calibration and, hence, use a first collision calculation to calibrate neutron dosimeters.

Preliminary results show that, with the source and detector separated by 20 cm, 40 cm, and 80 cm, scattering from the slab (when both source and detector are 15 cm above the slab) is 11, 28, and 33 percent of the direct dose, respectively. In all cases the scattering from the slab is small when the height becomes 5 meters or more.

In studies on the ionization by alpha particles in argon, it was observed that when the alpha particle ionized argon, an increase in the ionization was produced by the addition of a few percent of certain other gases. The increase in ionization depended on the ionization potential of the second gas. The pertinent data are shown in the accompanying table.

Increase in Ionization in Argon

Second Gas	Ionization Potential (volts)	Percent Increase in Ionization
Butane	10.8	11.0
Propane	11.2	11.0
Acetylene	11.45	22.4
Freon 12	11.7	1.8
Oxygen	12.5	1.6
CO_2	14.4	1.6
Methane	14.5	1.6
Hydrogen	15.4	0.0
Nitrogen	15.5	0.0

Argon has a known metastable state at 11.5 volts, and an ionization potential at 15.7 volts. Thus, the large increase in ionization in argon with the addition of gases, whose ionization potentials are less than 11.5 volts, is understandable on the basis that the energy transferred from the metastable state is sufficiently large to produce ionization. The small increases of ionization noted for gases with ionization potentials between 11.7 and 14.5 are not at present understood, but may indicate a second long-lived state (not necessarily metastable in the sense of a violation of a selection rule) between 14.5 and 15.4 volts. (AEC Activity 6510)

Physics of Radiation Dosimetry - Recent developments in film dosimetry of neutrons are: (1) A system of aluminum foil and paper laminations in the packet make the film an energy independent dosimeter. (2) By sealing the desiccated film in a moisture-proof envelope the life of the latent image is prolonged. (3) The improved technique in microscopy, that is, reading a traverse instead of discrete fields, increases the area of film read, and thereby increases the effective sensitivity of the film. (AEC Activity 6510)

Math for Health Physics - To obtain information on tissue damage due to fast neutrons, the first phase of a Monte Carlo calculation was performed on the Oracle; estimates were obtained for the spatial distributions of the average energy loss at high energies and for the collision density at thermal energies. In simplifying the configuration it was assumed that (1) an isotropic source of 0.3 Mev neutrons was placed axially to and 30 cm from the nearest face of a cylinder 30 cm in radius and 30 cm high and (2) the cylinder was shielded so that neutrons entered only through a circle 15 cm in diameter. The interactions considered were scattering with hydrogen, oxygen, carbon and nitrogen,

and absorption by hydrogen and nitrogen. A total of 2500 neutron histories were followed. Later calculations will be made for other angles of incidence. (AEC Activity 6510)

Experimental Radiation Measurements - The scintillation type equipment, which has been installed in a C-47 airplane for the U.S. Geological Survey, has been calibrated at Cherokee Lake and tested in Colorado. Four sources, one each of gold, cesium, cobalt, and radium, with source strengths between one and two curies, were placed on small islands in Cherokee Lake approximately one mile apart and in a straight line. To determine the response of the equipment and calibrate it for gamma rays of different energies as a function of altitude, flights were made along this line at various heights between 200 and 2000 ft, with a series of discriminator settings at each height. As a further test of shielding effects and energy sensitivity a series of flights was made over a simulated ore outcrop consisting of 44 tons of 0.35 percent U_3O_8 at Grand Junction, Colorado. The equipment could detect this outcrop at an altitude of 700 ft. (AEC Activity 6520)

Professional Health Physics Training - The 1953-54 group of AEC Fellows in Radiological Physics reported to Vanderbilt University September 28. Personnel from the Health Physics Division at the Laboratory assisted in planning their academic programs.

Of the 1952-53 group of AEC Radiological Fellows who completed their fellowship program at the Laboratory the last week in August, six are now on extensions of the fellowship (two others who were granted extensions resigned to accept positions in the field of health physics), three are working on research problems in the Health Physics Division, and three are at Vanderbilt University; one of the group is at Harvard on an AEC Industrial Hygiene Fellowship; two are continuing graduate work; and of the eleven who are employed, eight are in health physics work, five with AEC installations, two in government laboratories, and one in a university. (AEC Activity 7620)

Research Participation and Traveling Lecture Programs - Under the Traveling Lecture Program for the academic year 1953-54, ORINS has submitted a list of lecturers to interested universities. Thus far, one request for a speaker has been received. (AEC Activity 6720)

RADIOISOTOPE SALES AND COSTS

Type of Transaction	September	FY to Date
Domestic Sales (Included Cancer Cash)	$ 74,455	$245,583
Foreign Sales	3,075	13,477
Project-Cash Sales	11,762	24,670
Project-Transfer Credits	156	156
Technical Cooperation Program Credits	625	3,369
Plant Credits	7,543	35,541
Civilian Defense Credits	-----	520
Cancer Program Credits	18,414	51,930
*Miscellaneous Income	------	177
Total Income	$116,030	$375,393
**Income - No costs incurred	$ 2,824	$ 16,542
Radioisotope Income	$113,206	$358,851
Radioisotope Costs	$114,198	$298,921
Radioisotope Shipments	942	2,878

*Miscellaneous income - D_2O, Freight, Missing parts, TCP
**Income from H^3, He^3, B^{10} and miscellaneous items in excess of cost

GROSS OPERATING COSTS

	Cost for September	FY 1954 Cost to Date
Programmatic Operating Cost - Net	$ 2,622,364	$ 7,278,842
Plant and Equipment Cost	300,670	814,620
Construction Program "H"	4,452	12,799
Work for Other Parties - Transfers	35,613	163,652
Inventory Changes	28,299	48,759*
Reimbursable Work for Other Parties	131,786	406,670
Deferred Charges	522	2,340
Total Laboratory Cost - Net	$ 3,123,706	$ 8,630,164
Estimated Cost for Next Month - Net	$ 2,800,000	$11,430,164

*Credit

[redacted]

PERSONNEL SUMMARY

	Number of Employees October, 1953	New Hires October	Terminations October
Administration	60	0	2
Operations*	117	1	0
Engineering, Shops and Mechanical	714	1	4
Laboratory and Research	1642	11	4
Protection	172	0	0
Service	398	7	2
Total	3103	20	12

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

A total of 631 Laboratory personnel are located in the Y-12 Area.

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Previous reports in this series:

January 1953	ORNL-1486
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May 1953	ORNL-1562
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July 1953	ORNL-1600
August 1953	ORNL-1612
September 1953	ORNL-1622

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