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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

MAY 1954

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

May, 1954

F. T. Howard

and

W. H Sullivan

Date Issued: JUN 7 1954

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OAK RIDGE NATIONAL LABORATORY

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

May, 1954

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 2000 - SOURCE AND FISSIONABLE MATERIALS

Waste Metal Recovery - Since beginning operation on March 10, the Metal Recovery Plant has isolated 13 kg of plutonium from Hanford metallurgical waste. The overall recovery was 97%. (AEC Activity 2344)

Amex Process - Approximately 2.75 g of americium has been recovered from Hanford metallurgical waste by the Amex process, which is being carried out in the Metal Recovery Plant. Periodic breakthrough of americium in the resin column, used for its isolation, necessitated frequent replacement of the column. (AEC Activity 2344)

Feed Materials - Studies on the proposed continuous alkali metal amalgam and electrolytic processes for the production of thorium metal showed that sodium amalgam would reduce $ThCl_4$, dissolved in propylenediamine (PDA), producing a quasi thorium amalgam. The use of sodium would effect a material decrease in cost for the step as compared to the use of lithium amalgam (ORNL-1703). Distillation of the thorium quasi amalgam under argon at 550°C (the highest temperature possible in the equipment available) did not produce thorium metal. The residue was pyrophoric and contained 27% mercury, thorium oxide, and a material unidentifiable by X-ray diffraction (probably $ThHg_x$). The substitution of dimethyl formamide for PDA as a $ThCl_4$ solvent was unsatisfactory owing to its reaction with alkali amalgams.

When thorium was electrodeposited into a molten-zinc cathode from a solution of thorium chloride in LiCl-KCl eutectic at 450°-525°C, a thorium-zinc alloy containing up to 3.8% thorium was produced; an additional thorium product, not wet by zinc, was recovered from the eutectic bath by filtration. Anhydrous thorium chloride suitable for electrolytic reduction was produced by gas-phase chlorination of a mixture of thorium oxide or thorium oxalate and carbon at 475° to 500°C with a mixture of chlorine and carbon tetrachloride. The product of this reaction contained 75 to 90% $ThCl_4$, which was recovered by leaching with PDA. The compound $NH_4Cl.ThCl_4.xH_2O$ was precipitated from HCl solution, dried, and heated in an atmosphere of anhydrous HCl and nitrogen to give $ThCl_4$. (AEC Activity 2601)

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PROGRAM 2000 - SOURCE AND FISSIONABLE MATERIALS (Continued)

Excer Process - Cost studies showed that by a moving-bed technique uranium can be processed for $0.20 per pound, which is $0.05 per pound less than the Excer cost.

In small-scale studies on the denitration step of the moving-bed process, $UO_2(NO_3)_2$ was continuously converted to UO_3 by heated air. The reactivity of the partially hydrated UO_3 product to HF was greater than that of the Mallinckrodt unhydrated UO_3 standard and closely approached that of the hydrated UO_3 standard now used. (AEC Activity 2604)

PROGRAM 3000 - WEAPONS

RaLa Processing - Run 56, started on April 26, was not completed because of the escape of dissolver gases during a rapid dissolving reaction; it is thought that the escape resulted from excess radiation heating of the uranium metal. The operating procedure followed was normal, but a longer than usual period between dissolvings allowed the temperature of the uranium metal to build up. The incident occurred at the start of the HNO_3 addition for the fourth dissolving cycle. No attempt has been made to continue the run or to decontaminate the building until the radiation background decreases sufficiently through decay to allow a reasonable working period. Approximately two months will be required before operations can be resumed. No serious radiation exposures were sustained by personnel. (AEC Activity 3702)

PROGRAM 4000 - REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Experiment (HRE) - Dismantling of the HRE was completed (eleven weeks after operation was discontinued) and all contaminated pieces of equipment were stored at the hot burial ground or in the water-shielded storage pool at the HRE building. Components are being dissected for information on corrosion and the distribution of fission-produce radioactivity. Excavation was begun in the main bay to remove contaminated earth in preparation for HRT construction, which will be done by a general contractor. (AEC Activity 4103.1)

Homogeneous Reactor Test (HRT) - During May, it was decided to specify an underground steel tank, instead of a concrete tank, for the HRT shield. Preliminary studies of the shield indicated that a considerable saving in cost could be effected by using a steel tank to meet the operating requirement of

7 psi below atmospheric pressure. Both X-10 and K-25 Engineering Departments are preparing a specification to cover the work necessary for installation of this tank by a general contractor.

Design of the HRT was continued; drawings are being completed for pressurizers, gas separators, dump tanks, and recombiner condensers. A contract for the 5-megawatt heat exchangers was awarded to the Foster-Wheeler Corp. on a bid of approximately $29,000 per unit. The Newport News Shipbuilding Co. has essentially completed design of the core and pressure vessel mockup for hydraulic testing. Revised flowsheets were issued for the reactor and steam systems, and an instrumentation flowsheet is almost completed. (AEC Activity 4103.1)

In-Pile Loop - Construction and installation of equipment at hole HB-4 in the LITR for in-pile loop operation is continuing as scheduled.

A second in-pile loop, complete with loop container and shield plug, was built for testing in the in-pile mock-up. Preliminary testing of this loop is complete. In order to check the liner and the loop assembly in the LITR, for proper size and alignment, the loop assembly was installed in the LITR. No difficulties were encountered in the installation of the loop assembly in the LITR with the exception of a rubber gasket ring around the loop container. The rubber gasket was turn during removal and jammed. After this situation is corrected, mock-up tests will be continued.

The present bearing combination in the pump used to circulated solution in the in-pile loop, stellite 98M2 against stellite 98M2, will support very little thrust loading. Test pumps are being modified to reduce thrust loading to an acceptably low value. One test pump, with thrust loading reduced to ~2 lbs, was very satisfactory from the standpoint of wear in a preliminary test run and is now being set up for a longer test period with uranyl sulfate solution.

Additional non-irradiation corrosion tests were completed to determine whether the effects on the metal test coupons in the tapered-channel specimen holders of the small in-pile developmental test-loops are comparable with the effects observed on the coupons in the larger loops of the dynamic corrosion test program. The results of these tests indicate that comparable velocity effects are observed when the environmental histories of the test coupons are similar. (AEC Activity 4109.4)

Dynamic Corrosion Loop Tests - Corrosion testing of austenitic stainless steel with 0.02m* uranyl sulfate containing 0.005m sulfuric acid has now been extended to cover the range of 200° to 320°C. At flow rates of 10 to 20 feet

*m = molal (moles solute per 1000 gms solvent). This method of specifying concentration is unaffected by changes in density which result from changes in temperature.

per second (fps) the corrosion rate of stainless steel is 0.6 mils per year (mpy) at 200°C and decreases to 0.1 mpy at 250°C. At temperatures above 250°C the corrosion rate is higher, being one mpy at 320°C. At high flow rates (70-80 fps) a similar pattern is observed except the highest corrosion rates are observed at 200° and 225°C because a film does not form on the steel under these conditions and the film-free metal corrodes at a high rate. At temperatures above 225°C a stable film forms at all velocities and the corrosion rates at 70-80 fps are 3 mpy at 250°C, 0.5 mpy at 300°C and 3 mpy at 320°C.

The corrosion resistance of austenitic stainless steel to 1.34m uranyl sulfate at temperatures of 200° to 275°C was shown to be very poor. Although experiments are still in progress, the data indicate that the critical velocity, the flow rate beyond which a stable protective film does not persist, is less than 15 fps. At 225°C corrosion rates as high as 30 mpy can be expected at flow rates as low as 10 fps. Neither titanium nor Zircalloy II corrodes to any measurable extent at any flow rate or temperature in 1.34m uranyl sulfate.

Specimens of titanium, Zircalloy II, and stainless steel showed no evidence of corrosion damage when exposed in the gas phase of a loop if the solution being circulated contained only uranyl sulfate and oxygen at temperatures as high as 320°C. However, if the solution contained only a small amount of iodine (~5 ppm as iodide or iodate ions), the steel specimens in the gas phase were severely pitted but the Zircalloy II and titanium specimens were unaffected. The fact that most of the iodine was in the gas phase may offer a way of removing iodine from a reactor solution continuously by means of suitable traps, thereby greatly decreasing the corrosion problem. The presence of iodine in the system had no effect on the specimens exposed in the solution. (AEC Activity 4109.4)

Engineering Development - As a reactor core design, alternate to the straight-through flow concept currently being planned for the HRT, spherical vessels 18, 32, and 48 in. dia., with concentric inlet and outlet pipes were studied. The efficiency of mixing was at least 90% of the theoretical value in all cases. The 48-in. core model required that the inlet pipe extend one-half a pipe diameter into the sphere in order to achieve thorough mixing.

Preliminary tests of an electrically heated pressurizer for the HRT were successful. The heating jacket consists of Calrod units in a split cylindrical aluminum casting, machined to fit closely around the pressurizer pipe. The clam-shell-like jacket permits simple remote installation or removal.

A plastic model of the proposed HRT gas separator was tested at atmospheric pressure. It consists of a length of 4-in. pipe with turning vanes to impart a rotational flow to the liquid, a central gas take-off in the void, and recovery vanes to remove the rotational flow component. In operation the separator was found to remove essentially all the gas with a pressure drop of about 5 psi, which is within the desired limits.

Component design for the mock-up of the HRT let-down system is 90% complete. All materials have been ordered for construction of the loop. This mock-up will provide a system for testing other HRT facilities such as feed pump, heat exchanger, gas separator, circulation pump, and pressurizer.

Proposals were received from Allis-Chalmers for fabrication and testing of a 500-gpm pump and a 20-cfm blower. An ORNL-design 5-gpm pump was converted for operation as a gas blower. Pump test loops of 400-gpm and 300-gpm capacities are being designed; material has been ordered for fabrication.

Leak testing of the 4000-gpm loop is under way. Only one small leak was found in the top flange of the Byron-Jackson pump with a helium leak detector. Equipment was installed for hydrostatic pressure testing after the vacuum tests are completed.

A system was constructed to simulate the conditions that might be expected in the HRT shield as a result of a ruptured pressure vessel. A boiler supplies water and steam at 1250 psi which can be flashed into a 1000-gallon tank (simulating the shield). Measurements of pressure and temperature rises from various types of discharge are to be used to evaluate the proposed shield design. (AEC Activity 4109.4)

Instrumentation and Controls - Two preliminary panel-board lay-outs were completed for the HRT; one graphic, the other non-graphic. A resume of factors affecting panel design was distributed and final selection of one of these concepts is underway.

Several makes of miniature pneumatic instrument systems were ordered for testing. These instruments have plug-in air connectors and may be replaced in an instrument panel in a matter of seconds without disturbing the process.

Bids were received for special ORNL-designed 1/2-in. prototype on-off valves for use at 2000 psi and 300°C. Valves, being purchased from four vendors for evaluation, should arrive within sixteen weeks.

An improved all-metal operator, employing a 68-square inch stainless steel bellows, was designed for actuating high-pressure valves in high irradiation fields. This operator is being fabricated in ORNL shops.

A study of the HRT nuclear instrumentation is essentially complete. One multi-channel monitoring unit was ordered for evaluation as a substitute for the single-channel Monitrons now in use.

A tank and stand pipe, 25-ft. high, were relocated and are available to simulate HRT flooded-cell conditions in waterproofing tests.

Wiring of the second in-pile loop instrument panel, which will be operated in the west room of the LITR, is complete and installation is underway. (AEC Activity 4109.6)

AIRCRAFT NUCLEAR PROPULSION PROJECT

Aircraft Reactor Experiment - Repair work on the sodium heat exchanger was completed and the unit reinstalled. One of the sodium pumps was installed, and the second will be in place by June 1. The pumps for the lubrication system to cool the main pump bearings were found to be inadequate and are being replaced. Water was circulated in the fuel circuit and performance was relatively free from difficulty. The over-all job of completing miscellaneous installation work is proceeding satisfactorily. (AEC Activity 4401.1)

General Design - A set of charts was prepared to facilitate determination of temperature distribution and thermal stress in flat plates, rods, thick-walled cylinders, and perforated slabs containing uniform volume-heat sources. These charts are presented in ORNL Memorandum CF-54-5-196.

An investigation is being made of the effects on reactor design of the physical properties of NaF-KF-LiF mixtures in comparison with $NaF-ZrF_4$ mixtures, used as fuel carriers. To meet the same prescribed stress and pumping power limitations, a 20% increase will be required in the volume of fuel in the heat exchanger, a 37% increase will be required in the temperature loss from the fuel to the secondary coolant, and an increase of as much as 60% will occur in the local temperatures in the fuel boundary layer in the core. (AEC Activity 4401.1)

Experimental Engineering - A unit for testing mass transfer of beryllium to Inconel in circulating sodium with a maximum temperature of 1200°F, a temperature drop of 300°F, and a flow rate of 20 fps through the 1/4-in.-ID beryllium insert was fabricated and placed in operation. Three ARE pumps passed all acceptance tests. (AEC Activity 4401.1)

Math and Computation - Calculations were made for the 60-Mw reflector-moderated circulating-fuel reactor as modified by the removal of the Inconel tubes from the reflector and the island; the voids were filled with beryllium. Removal of the Inconel decreased the critical mass by 29% from the original figure of 40.7 lb. Calculations on the two-region, Teflon and uranium-foil core, beryllium-reflected critical experiment gave a critical mass of 16.1 lb of U^{235}. (AEC Activity 4401.2)

Reactor Chemistry - The solubility of UF_3 in the NaF-LiF-RbF eutectic at 550°C was found to be 2.1 mole % (6.8 wt % U). In the $NaF-ZrF_4-UF_3$ system, the previously noted trend of decreasing UF_3 solubility with decreasing ZrF_4 content was investigated. In a mixture with 42 mole % ZrF_4, the solubility of UF_3 at 600°C was only 0.6 mole % (1.4 wt % U).

The reduction of UF_4 to UF_3 in $NaZrF_5$ was accomplished with sodium vapor at 800°C. However, plugging at the gas inlet occurred in each of three separate trials at different flow rates and sodium-vapor concentrations. As a result, the sodium-vapor reduction of fuel circulating in the ARE is not considered to be feasible.

Determination of decomposition potentials of UCl_3 in KCl at 850°C have thrown some light on the nature of electrode processes involving U^{3+} in a molten ionic solvent. At 33.3 mole % UCl_3, with a platinum cathode and either a nickel or a graphite anode, a decomposition potential of 0.8 volt is found; this corresponds to the reaction $4\ UCl_3 = 3UCl_4 + U^o$. On the other hand, at 2 mole % UCl_3, a graphite anode results in $2\ UCl_3 \longrightarrow 2\ U + 3\ Cl_2$ and a decomposition potential of 2.52 volts, whereas a nickel anode results in $2\ UCl_3 + 3\ Ni \longrightarrow 3\ NiCl_2 + 2\ U^o$ and a decomposition potential of 1.3 volts.

Vapor-pressure measurements with a 25 mole % NaF-75 mole % ZrF_4 mixture showed pressures varying from 37 mm at 769°C to 152 mm at 844°C. The log P versus 1/T plot of the data for this mixture intersects the ZrF_4 vapor-pressure line at 762°C, which would be the liquidus temperature, since ZrF_4 is the solid phase that precipitates. Previously obtained thermal analysis data indicated 755°C for the liquidus temperature. (AEC Activity 4401.5)

Corrosion Research - An Inconel thermal-convection loop, operated for 500 hr at 1500°F with $NaF-ZrF_4-UF_3-UF_4$ (1 mole % UF_3 and 4 mole % UF_4, 8.6 wt % total U), showed moderate "hot-leg" attack to a maximum depth of 4 mils in comparison with the usual attack to a depth of 8 to 10 mils. It was found that in a previously operated loop in which no attack was observed, the uranium in the fluoride mixture was actually one-half UF_3 rather than one-fourth, as previously reported. In a series of loop tests, operated for 1000 hr with $NaF-ZrF_4-UF_4$ to determine the effect of temperature drop through the loop on the depth of attack, it was found that the depth of attack varied from 5 mils for a temperature drop of 65°F to 12 mils for a 220°F drop.

The carburization of type 304 stainless steel by the carbon pickup of sodium, that had been in contact with C-18 graphite and with tar-impregnated and fired graphite, was investigated. It was originally thought that the tar-impregnated graphite, which has a much higher density, would give less carburization, but tests for 100 and 500 hr at 815°C indicated that both types of graphite caused the same degree of carburization.

Platinum specimens were tested in Inconel "seesaw" tests in $NaF-ZrF_4-UF_4$ at 1200° and 1500°F to determine whether there would be much difficulty from mass transfer, since in some applications it would be advantageous to use platinum electrodes. It was observed these materials do suffer from dissimilar-metal mass transfer; examination of the platinum specimen tested at 1200°F revealed a metallic layer approximately 0.2 mil in thickness. The specimen tested at 1500°F had a similar layer 0.5 mil in thickness. There were also metallic crystals present on the platinum strips in several places.

Bearing-compatibility tests using fused fluoride salts, sodium, lithium, and lead have shown that Al_2O_3, SiC, $MgO \cdot Al_2O_3$, MgO, and ZrO_2 are not satisfactory for use as bearing or seal materials in fluorides or lithium; Al_2O_3 and $MgO \cdot Al_2O_3$, however, show fair resistance to sodium and lead. (AEC Activity 4401.5)

Metallurgy--Fabrication - A very complicated beryllium heat exchanger, for use in determining the thermal stress properties and compatibility of beryllium, Inconel, and sodium, was fabricated by carefully controlled manual inert-arc welding. Associated parts of this test device were also fabricated, including a large copper bus bar and two electromagnetic pump cells, which were furnace-brazed. The following assemblies were also prepared: (1) three ARE pump impellers, (2) a fluoride-to-helium radiator (copper brazed), (3) ceramic-to-metal brazes, (4) thermal-conductivity test specimens (furnace-brazed), and (5) nickel power leads brazed to high-conductivity loop components. (AEC Activity 4401.5)

Reactor Physics - It is known that mechanical oscillations of a reactor can interact with the oscillations of the reactor power in such a manner that oscillations with increasing amplitude result. Such antidamped oscillations would destroy the reactor. It was shown that the conditions for antidamped oscillations are not fulfilled in the projected 60-Mw reflector-moderated circulating-fuel reactor. This is largely due to the compact design of the reactor and, in particular, the short distance between the reactor and the expansion tank. (AEC Activity 4401.7)

Shielding Research - The Tower Shielding Facility (TSF) reactor was operated at full power (100 kw) both in the pool and in the air. In a preliminary experiment with the reactor and detector tanks in the air, the short relaxation lengths associated with neutron attenuation in the front and sides of an aircraft crew shield were demonstrated for the first time. The neutron relaxation length determined from the TSF experiment is 5.3 cm, which is to be compared with the 4.5 cm from the Bulk Shielding Facility (BSF) "skyshine" experiment and the 5 cm used in the 1953 Summer Shielding Session. Measurements of slant neutron penetration in the more detailed program at the Lid Tank Facility are in good agreement, insofar as a comparison is possible, with these mockup type of measurements at the TSF.

The gamma radiation penetrating the ANP-53 plastic-and-lead crew shield was calculated by using spectroscopic data from mockup measurements at the BSF. This detailed calculation, which included air scattering and which was performed with the aid of a large computing machine, showed the extreme importance of radiation that bypasses the shadow shield. Therefore, the shadow shield is being redesigned to extend its radius by 50%. Since the shadow shield can taper in thickness towards the edge, the total weight penalty will be of the order of only 1000 lb.

Intercalibration of the TSF and BSF reactors was completed, and measurements at the facilities can now be correlated directly. This direct correlation is essential because the BSR will be used for spectroscopic measurements on reactor shields which subsequently will be used in gross measurements at the TSF.

The fast-neutron dose behind various thicknesses of graphite was measured at the BSF. Since the graphite perturbs the reactor flux distribution, it will be necessary to redetermine the reactor power distribution before analyses of the data can be made. These data will be used by Nuclear Development Associates in the design of a radiotherapeutic source of thermal neutrons to be used at Brookhaven National Laboratory. (AEC Activity 4401.7)

Fuel Recovery - Log-log plots of data obtained in solvent extraction experiments showed that the ruthenium and total rare earth beta activities have close to second-order dependence on tributyl phosphate (TBP) concentration. The equilibrium constant for this case is represented by the equation

$$K = \frac{\text{Distribution Coefficient}_{(\text{Ru } \beta \text{ or TRE* } \beta)}}{(\text{TBP concn})^n}$$

*Total Rare Earths

where n, the dependence, is equal to 2. A least-squares analysis showed the average dependence for all data in the case of ruthenium activity to be 2.10 and in the case of total rare earths to be 1.95. (AEC Activity 4401.81)

GENERAL REACTOR RESEARCH

Waste Treatment Studies - The use of gravel for thermally insulating the asphalt lining of an earth basin from the heat generated in Hope-type waste was shown not to be feasible. Calculations made on the Oracle indicated that the fall in temperature at steady state conditions between the waste and the lining, per foot of earth insulation, would be only 0.5°C at the center of the basin and 1.2°C at the edge. (AEC Activity 4582)

School of Reactor Technology - The Committee on Admissions of the Oak Ridge School of Reactor Technology met on April 9, 1954 and selected the students who will attend the 1954-55 session beginning next September.

The Academic portion of the 1953-54 session of the School will be completed June 4. Following the final examinations, ORSORT will recess during the week of June 7 through 11, with students reassembling on June 14 to begin work on assigned design problems or summer work in various groups within the Laboratory.

Nine design problems will be undertaken by the students, and will be prepared as "group theses" with group leaders selected by the ORSORT faculty. Tentative titles of the design problems are: "Fast Reactor for Power", "MTR Converter with Aqueous Blanket", "Rubidium-Vapor Aircraft Reactor", "Ceramics Gas-Cooled Power Breeder", "Boiling Homogeneous Reactor for Power and Pu Production", Boiling Homogeneous Reactor for Power and U^{233} Production", "Homogeneous Reactor for Ship Propulsion", "Ultimate Homogeneous Reactor", "Heterogeneous Boiling Package Reactor". (AEC Activity 4841)

Idaho Chemical Plant - Studies are being made for evaluating the pulsed solvent-extraction contractors for an expansion of the Idaho U^{235} processing plant in which the tributyl-phosphate process will be used. Because of the limitations imposed by the cell height of 27 ft, three columns will be used, one for extraction, one for scrubbing, and one for stripping; two columns are usually used, with the extraction and scrubbing combined. Preliminary indications are that flooding rates for the extraction, scrub, and strip columns will be 720, 700, and 800 gal/hr-ft^2, and the heights 22, 16, and 14 ft, respectively. (AEC Activity 10543)

PROGRAM 5000 - PHYSICAL RESEARCH

Reactor Operations - Operation of the graphite reactor (3700 Kw) and the LITR (3000 Kw) was satisfactory. It has been seven months since any slug ruptures occurred in the graphite reactor; the procedure in which the reactor is brought up to power more slowly after shutdowns appears to be responsible for the decrease in slug ruptures.

It was determined that the 200-gram fuel unit is more economical than the 168-gram unit for use in the LITR.

A reduced efficiency of the ion exchangers for the LITR circulating water was found to be due to radiation damage of the anion exchange resin in the mixed-bed unit. A small cation-exchange bed was placed ahead of the main unit to retain the bulk of the radioactivity and to reduce the damage in the mixed-bed unit.

ISOTOPE PRODUCTION

Radioisotope Research - Test runs were completed on the I^{131} plant, and equipment performance met or exceeded design specifications. Upon completion of the sampling equipment, the installation of which has been delayed because of more urgent work, the unit will start limited operations about June 15.

A new organic cation-exchange medium manufactured by Minnesota Mining and Manufacturing Company was tested for use in processes where radiation damage to ordinary organic ion exchange resins is a problem. Preliminary tests show that it has good radiation resistance, satisfactory capacity for absorbing fission products, and that it can be used for chromatagraphic-type separations. (AEC Activity 5131)

PHYSICS

Neutron Diffraction - Recent studies of the paramagnetic scattering of slow neutrons by substances possessing relatively high Néel or Curie temperatures resulted in observed paramagnetic scattering intensities considerably smaller than those calculated according to the theory of independent paramagnetic spins by Halpern and Johnson. In contrast to this situation, substances possessing low magnetic ordering temperatures seem to exhibit scattering intensities in the paramagnetic region in agreement with the calculated values. Data available in the literature and from unpublished work at this laboratory indicate that the ratio between the observed paramagnetic scattering level and the calculated value is strongly dependent on the ratio of the magnetic ordering temperature, T_c, to the equivalent temperature of the neutrons used in the scattering experiment, T_N. As the value of T_c approaches or exceeds T_N, there is a considerable reduction in the observed paramagnetic scattering relative to the calculated value. This attenuation of the scattering is undoubtedly a consequence of an inelastic scattering process when the magnetic exchange energy becomes comparable to the neutron energy. For substances of small exchange energy, the paramagnetic moments are essentially free, the degree of inelasticity is small, and the theory of independent spins is valid. (AEC Activity 5211)

High Voltage Program - The $Li^7(He^3,p)Be^{9*}$ reaction was studied further since the February report, ORNL-1695; the energy levels in Be^9 at 1.8, 2.4, 3.2, and 4.9 Mev were established. No evidence was found for the $Li^7(He^3,d)Be^{8*}$ reaction. The $Be^9(He^3,p)B^{11*}$ reaction was studied, and the structure observed in B^{11} is in close agreement with the levels already established for that nucleus. Differences were observed in the relative intensities of the proton groups from the $Be^9(He^3,p)B^{11*}$ and the $B^{10}(d,p)B^{11*}$ reactions. (AEC Activity 5211)

CHEMISTRY

Chemical Separation of Isotopes - Measurements were made of the Li^6-Li^7 isotopic fractionation for three systems. An α (single stage separation factor) of 1.049 $\pm$ 0.006 (95% C.I.) at 27°C was found for the system, lithium amalgam vs lithium bromide in liquid ammonia (the Li^6 concentrating in the amalgam). For the system sodium-lithium alloy vs lithium bromide in diethylcellosolve, a factor of 1.027 $\pm$ 0.006 (95% Confidence Interval) was found at 102°C. This is significantly higher than the factor of 1.020 $\pm$ 0.006 (95% C.I.) which was found, using lithium amalgam rather than the alloy (at the same temperature). The sodium lithium alloy used was a eutectic containing 94.6 atom percent sodium, which melted at 93.4°C. (AEC Activity 5361)

Hot Laboratory Research - Coincident with the mass assay of portions of the kilocurie samples of Xe^{135} from the Homogeneous Reactor, a measure of the residence time for xenon in the reactor was perceived: With the knowledge

of the exact fission yields of the Xe^{134}, 135 and 136 chains, a significant amount of capture occurring during its residence in the reactor would become apparent in an increase of the relative abundance of Xe^{136}. The samples mass assayed showed little deviation from the expected mass ratios, indicating little burn-up of Xe^{135} had occurred. On the other hand, an unexpectedly high and unexplainable yield (20%) in mass 131 (daughter of 8-day Iodine) was observed. (AEC Activity 5361)

General Reactor Chemistry - Investigations of some of the more common anion systems of thorium suitable for use in a thorium breeder blanket were concluded. The only systems that showed promise at high temperatures were solutions of $Th(NO_3)_4$ containing excess nitric acid and solutions of $Th_3(PO_4)_4$ in strong phosphoric acid. (AEC Activity 5361)

Chemistry of Corrosion - Additional measurements of the electrode potential of oxidized stainless steel demonstrated the existence of five or six well-defined regions of potential in the transition from the air-stable film to the state stable in dilute sulfuric acid in contact with air. Determination of the dissolved iron disclosed that little metal dissolved so oong as the potential was in the more noble regions. At the low potentials, dissolution was rapid and essentially linear over the limited duration of the experiments. The corrosion rate dropped greatly when the active specimen again became noble either spontaneously or by artificial means. (AEC Activity 5361)

Ion Exchange Technology - Design drawings were completed for a 6-in.-dia. continuous ion exchange contactor capable of recovering uranium from the ore pulp resulting from the sulfuric acid leach of ground carnotite ore (see ORNL-1703). The unit will have a capacity of 2.5 tons of ore per day. (AEC Activity 5361)

OTHER PHYSICAL RESEARCH PROJECTS

Critical Experiments - In the course of some routine measurements in the Critical Experiments Laboratory on May 26, 1954, an assembly accidentally became supercritical. The particular experiment was one in a series to study the effect of a cylinder of routine absorber placed co-axially within an aluminum cylinder containing an enriched uranium aqueous solution. The cause of the incident is believed to have been an equipment failure, although a detailed examination of the apparatus has not yet been made. There is no evidence of any personnel damage; the maximum exposure being less than 1 rem.

Oracle - During April and May, a total of 290 hours was used for computations on the Oracle. Since part of the regular day shift was used for routine maintenance, it was necessary to operate the computer an average of three evenings per week. The demand for computer time is steadily increasing as more persons within the Laboratory are trained to prepare problems for the Oracle.

The magnetic tape auxiliary memory unit is nearing completion at the Argonne National Laboratory, and will be shipped to Oak Ridge in June. Installation and testing of the unit is expected to take two to three months to complete, and the work will be done in a manner so as to interfere as little as possible with operation of the Oracle. (AEC Activity 5511)

PROGRAM 6000 - BIOLOGY AND MEDICINE

BIOLOGY

Cytogenetics - Work is continuing on the frequency and mode of detachment of attached-X chromosomes in *Drosophila melanogaster*. By use of six specially constructed X-on-Y chromosome attachments, it was shown that not only do X rays induce detachments with different frequencies, but also that the mode of detachment is affected. For example, when the sc^{VI} Y chromosome is used, the induced detachment frequency is about three times as great as when the Y^{LC} chromosome is present. In the former case most of the detachments involve a chromosome exchange with the Y chromosome while in the latter case the detachments are, in the main, the result of induced exchanges with the dot-like 4th chromosome.

Inflorescences of *Tradescantia* were irradiated with 200-r X rays. If the inflorescences were centrifuged within 30 sec after the cessation of irradiation, the number of two-hit chromosome aberrations was increased. This is explained as being due to the physical separation of broken chromosome ends which consequently reduced the amount of rejoining. Similar results could be attained with as much as a 10-minute interval between irradiation and centrifugation if the plants were kept at 7°C in order to prevent rejoining in this period of time. If, on the other hand, the plants were centrifuged previous to irradiation, the numbers of two-hit aberrations were reduced by a factor of two. At present this phenomenon is attributed to a centrifugal "packing" of the chromosomes, which is not cytologically detectable. This "packing" would restrict chromosome movement and hence decrease the probability of exchange formation. (AEC Activity 6400)

Microbiology - *Streptococcus faecalis* contains a series of enzymes catalyzing the oxidation of reduced diphosphonucleotide ($DPNH_2$). The oxidants utilized are O_2, cytochrome c, peroxidase or 2,6 dichlorophenol indophenol or ferricyanide. At present it appears that these reactions are due to different flavoprotein enzymes, except the last two oxidants appear to function with the same enzyme. The flavoprotein nature of all the enzymes except the

peroxidase can be demonstrated directly by preparing apoenzymes whose prosthetic groups have been split off at an acid pH. Such treatment inactivates the peroxidase, however growth experiments in riboflavin-deficient media implicate flavin in the peroxidation also. It has been possible to grow flavin-deficient preparations of S. faecalis by limiting the riboflavin in a synthetic medium to 5 milligamma/ml. Under such conditions, 70% of the normal yield of cells is obtained and the preparations are almost completely resolved for flavin. The cytochrome-c reductase and oxidase can be reactivated by flavin-adenine dinucleotide (FAD) but not flavine mononucleotide (FMN). Cell free extracts of the peroxidase are not, however, reactivated by these coenzymes but reactivation is obtained if vacuum-dried cells preparations of flavin-deficient cells are incubated with FAD before the cell-free extract is prepared. The results indicate that the coenzyme of the peroxidase may be a complex flavoprotein whose synthesis requires some component or synthetic system present in dried cells but not in cell-free extracts. A similar situation exists with regard to the lipoic acid coenzyme for pyruvic acid oxidation.

Further evidence to eliminate iron catalysis in the peroxidase was obtained from growth experiments employing media which contained no detectable inorganic or hematin iron. Growth of S faecalis in such media actually resulted in a 2.5-fold increase in the peroxidase level. Cytochrome-c reductase and $DPNH_2$ oxidase formation likewise did not require the presence of iron in the growth medium. (AEC Activity 6400)

Radiation Protection - Previous reports have described attempts to resolve the factors contained in extracts of biological materials which stimulate recovery in irradiated bacteria. Simultaneous with these experiments were attempts to design a complex chemically-defined medium which might simulate the activity of the natural materials. A modified Lactobacillus assay medium, containing amino acids, vitamins, purines, and pyrimidines, and inorganic salts, was found to be approximately as active as yeast extract in effecting recovery of irradiated Escherichia coli B/r. Deletion of the vitamins from this mixture resulted in no loss of activity. Deletion of the purines or pyrimidines or amino acids resulted in reduction of activity. The four amino acids, glutamic acid, serine, methionine and tryptophane, previously reported (ORNL-1693) to show stimulation, can replace the amino acid mixture in the medium. A mixture of inorganic salts plus guanine and uracil, with glutamic acid, its amide glutamine, or aspartic acid, is equally as active as yeast extract. The composition of 100 ml of this medium, double strength, is:

Guanine	300 μg
Uracil	300 μg
l-glutamic	1500 μg
or	
glutamine	1500 μg
or	
l-aspartic	1500 μg

Salts A	1 ml
Salts B	1 ml
Glucose	2 g
Agar	3.4 g
pH	6.8

Studies on the induced mutation rate of Escherichia coli Strain P62 (proline$^-$) as influenced by postirradiation temperature treatment show that the temperature effect in this strain is dependent on the gas phase present during exposure. Whereas strains P82/r (purine$^-$) and T83-8 (tyrosine$^-$) show an increasing induced mutation rate with increasing postirradiation temperature of incubation when exposed in either O_2 or N_2, strain P62 shows a maximum at 24°C if exposed in an atmosphere of O_2 and a maximum at 37°C in N_2. It has also been observed that exposure of strain P62 in either O_2 or N_2 to several doses of X rays produces coincidental induced mutation rate curves when plotted against surviving fraction. This is in agreement with similar data obtained on strains P82/r and T83-8 but differing with the data reported for a streptomycin-requiring mutant of E. coli. (AEC Activity 6400)

Biochemistry - The unique protective effect of β-mercaptoethylamine against radiation injury in mice has been examined extensively, principally by Bacq and co-workers, but its mechanism of action is not clearly understood nor has it been fully explored. In addition the instability, toxicity, and therapeutic index of this compound are not all that might be desired for a useful radiation protective agent. A systematic chemical modification of the parent compound which could uncover a more suitable substance and also shed some light on its action and the structure essential for protective effect has been initiated. The following compounds have been synthesized as a beginning for this program: N-acetyl-β-mercaptoethylamine, N,S-diacetyl-β-mercaptoethylamine, S-acetyl-β-mercaptoethylamine, di(β-acetylaminoethyl) disulfide, di(β-aminoethyl)disulfide, di(β-aminoethyl)sulfide, S-methyl-β-mercaptoethylamine, 2-mercaptothiazoline, γ-mercaptopropylamine, di(γ-mercaptopropyl)disulfide and di(γ-mercaptopropyl)sulfide. These compounds are at present being tested in both bacteria and mice for protective action.

The 5' ribonucleotides and 5' deoxyribonucleotides are not separable by ion-exchange elution with simple acids or salts. The borate ion at slightly alkaline pH values forms complexes with the α-cis-hydroxyls of the 5' ribonucleotides but fails to do so with the deoxy analogs or with the 2' and 3' ribonucleotides. Using borate, the 5' cytidylic acids are separated by a wide margin while the peak of adenosine-5'-phosphate is delayed by a factor of four, sufficient for a clean separation. (AEC Activity 6400)

Biophysics - Dry Tradescantia pollen, treated with visible and near-visible radiation over a wider dosage range than reported previously, showed no evidence of photorecovery in ultraviolet-irradiated material. These observa-

tions, coupled with our recent findings of no intensity effects in dry pollen for both X-ray and ultraviolet irradiations, suggest that very little recombination or rearrangement of broken chromosomes takes place in the dry pollen. The hypothesis that such recombination takes place only in the growing pollen-tube cultures is now being tested by irradiation of growing material.

Calibration work with the Cockcroft-Walton accelerator in its temporary location was completed. Preliminary intercomparisons of dosage from fast neutrons, measured with a polyethylene-ethylene ion chamber and with a Hurst dosimeter and as calculated from the neutron flux measurements, are in general agreement, indicating that these three methods can be brought into close agreement. Studies of the scattering of neutrons from "dummy" walls indicate that only a very small percentage of the dose received by biological targets will arise from the walls of the permanent facility. Installation of the accelerator in the well-shielded facility is in progress. (AEC Activity 6400)

Enzyme Chemistry - Following the demonstration that chick embryos incorporate adenine into deoxyribonucleic acid at an undiminished rate after gamma-ray irradiation (ORNL-1693), similar experiments were conducted on rabbit bone marrow. In contrast to the embryo experiments the incorporation of adenine into deoxyribonucleic acid purines was sharply reduced by gamma-ray irradiation of the marrow suspension. As in the previous experiments the irradiation was carried out just prior to incubation with 8-C^{14}-adenine. These results suggest that the reduction in formate incorporation after irradiation is not due to a radiosensitive step in the biosynthesis of purines. It appears more likely that in the chick embryo adenine may enter into preformed deoxyribonucleic acid by an exchange mechanism which is not radiosensitive. Such a mechanism must be lacking in bone marrow. With both materials, formate is incorporated only by a mechanism which involves a net synthesis of deoxyribonucleic acid.

A study of the red algae, *Porphyridium cruentum*, was completed during the last two months. The action spectrum for the production of delayed light was found to consist of a large band at 550 mμ showing the absorption of phycoerythrin, and a smaller band at approximately 620 mμ, showing the absorption of phycocyanin. No useful absorption in the position of the chlorophyll band, about 680 mμ, was observed in any of the cultures studied.

The emission spectrum for the delayed light production in the red algae was found to be identical with that of *Chlorella*, showing that the delayed light must be coming from the chlorophyll. (AEC Activity 6400)

Pathology and Physiology - In a study of the uptake of sulfur, rat platelets were labeled *in vivo* by injecting $Na_2S^{35}O_4$, intravenously. Since this isotope, when given in the form of sulfate, is significantly incorporated into only a few types of cells, it was possible to study the S^{35} uptake autoradiographically. Autoradiograms of bone marrow were prepared from rats sacrificed at intervals after injection, and simultaneously blood samples were separated

into plasma, platelet, and erythrocyte fractions for counting. The radioactivity of the plasma declined rapidly to low levels during the first 48 hours and more slowly thereafter. The activity of the platelets rose to a peak at 3 days, and then decreased gradually until after 8 days the curve flattened out at a low level. The bone marrow, as observed in autoradiograms, showed activity in the megakaryocytes, which was maximal at 18 hours and had virtually disappeared after 48 hours. The erythrocytes were not detectably labeled with $S^{35}O_4$. These findings demonstrate the uptake of $S^{35}O_4$ by the blood platelet. They also offer further evidence that the platelet is derived from the megakaryocyte and indicate the rate of megakaryocytic $S^{35}O_4$ turnover.

An adenocarcinoma of the Harderian gland induced in an LAF_1 mouse by ionizing radiation was successfully grafted into homologous recipients. The properties of this tumor are now being studied in serial passages.

Experiments showed that the upper limit for the rate of acetylcholine synthesis by human red cell preparations, previously shown to be 1 to 6 μg of acetylcholine per gram of red cell powder per hour, was not affected by increasing the potassium-to-sodium ion ratio in the standard acetylating medium.

Electrophoretic studies on erythrocyte histone from fowls showed that a reproducible pattern with two major and three minor peaks is obtained. Partial separation of the two chief components was achieved by ammonium sulfate fractionation methods. Attempts to apply ion-exchange methods were not entirely successful. By using XE-64, a weak cation exchanger, two peaks were obtained, but the major part of the histone remained on the column in spite of the use of vigorous elution procedures. Paper chromatography and paper electrophoresis were also explored and found unsuitable because of the strong adsorption of histones by filter paper. Exploration of the techniques mentioned is continuing. (AEC Activity 6400)

RADIOISOTOPE SALES AND COSTS

Type of Transaction	April	FY to Date
Domestic Sales	$ 62,394	$ 744,956
Foreign Sales	4,453	46,996
Project-Cash Sales	42,783	144,909
Project-Transfer Credits	183	4,283
Technical Cooperation Program Credits	401	8,095
Plant Credits	20,494	102,819
Civilian Defense Credits	---	390
Cancer Program Credits	23,506	201,830
*Miscellaneous Income	20	337
Total Income	$154,234	$1,254,615
**Income - No production costs incurred Subtract from Total Income	23,097	46,439
Net Radioisotope Income	$131,137	$1,208,176
Radioisotope Costs	$101,108	$ 943,153
Radioisotope Shipments	1,093	10,339

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

GROSS OPERATING COSTS

	Cost for April	FY 1954 Cost to Date
Programmatic Operating Cost - Net	$ 2,484,305	$ 23,802,974
Plant and Equipment Cost	370,430	2,888,781
Construction Program "H"	82,055	515,450
Work for Other Parties - Transfers	41,637	442,814
Inventory Changes	27,657	274,897*
Reimbursable Work for Other Parties	178,426	1,420,474
Deferred Charges	1,991*	4,176
Total Laboratory Cost - Net	$ 3,182,519	$28,799,772
Estimated Cost for Next Month - Net	$ 3,000,000	$31,799,772

*Credit

[redacted]

PERSONNEL SUMMARY

	Number of Employees May, 1954	New Hires May	Terminations May
Administration	63	0	1
Operations*	119	0	0
Engineering, Shops and Mechanical	809	15	2
Laboratory and Research	1759	44	6
Protection	149	2	0
Service	383	3	0
Total	3282	64	9

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

A total of 685 Laboratory personnel are located in the Y-12 Area.

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November 1953	ORNL-1651
December 1953	ORNL-1665
January 1953	ORNL-1676
February 1953	ORNL-1695
March 1953	ORNL-1703
April 1953	ORNL-1719

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