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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

AUGUST 1955

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

August, 1955

F. T. Howard

and

W. H Sullivan

Date Issued: SEP 7 1955

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STATUS AND PROGRESS REPORT

August, 1955

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

PROGRAM 2000 - SPECIAL NUCLEAR MATERIALS

ORNL Health Physics Research--Boston - In studies on the neutron therapy of brain tumors, the investigation of the metabolism and toxicity of uranium in terminal post-operative brain tumor patients was concluded except for completion of tissue analyses. Henceforth, pre-operative brain tumor patients will be injected with low levels of enriched uranium for evidence of uptake of uranium by brain tumor cells and for additional data on the excretion pattern. (AEC Activity 2120)

Recovery of U^{235} - In test dissolvings with Savannah River prototype tubular fuel elements and with tubular 2S aluminum, the reaction rate increased significantly when the concentration of the mercury catalyst was increased from 0.005 M to 0.01 and 0.02 M.

In tests on the variables affecting the tributyl phosphate extraction of uranium, losses of uranium were not significantly affected by increasing the throughput rate at rates considerably below flooding, but losses increased suddenly at about 90% of flooding. Uranium losses were decreased by increasing the pulse frequency or increasing the extraction height. For extraction heights of 8, 14, and 22 ft the uranium losses were 5.7, 0.5, and 0.67%, respectively, and increasing the pulse frequency from 60 to 70 cycles/min had the same effect as adding 8 ft of extraction height. Average HET's (height equivalent to a theoretical stage) for pulse frequencies of 50, 60, and 70 cycles/min were 7.4, 5.3, and 4.7 ft, respectively. (AEC Activity 2772)

PROGRAM 3000 - WEAPONS

Special Separations - Recovery and purification of the unresolved 3000 MWD/T plutonium from the sixth isotope separation run is proceeding satisfactorily, although some difficulty is being experienced in obtaining complete recovery from the vacuum tank liner; enough purified material will soon be available for another isotope separation run. Negotiations are being carried out through the AEC to obtain an additional 190 grams of 3900 MWD/T plutonium produced in the NRX reactor. The MTR plutonium fuel element program is now proceeding at a satisfactory rate; the fuel element specifications, together with the die

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and aluminum parts for production of the vacuum-tight jacketed cores, were shipped to Los Alamos where preliminary work was begun for the casting of the 10% PuAl alloy core material. (AEC Activity 3601)

PROGRAM 4000 - REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test - ORNL forces installed the fuel system low-pressure assembly (dump tanks, recombiner, condenser, etc.) on a test stand at the site, and preparations are being made for testing. The blanket system low-pressure assembly was completed and will also be moved to the site for testing. All component fabrication is now complete, and manpower has been diverted to the prefabrication of process piping. Completion of the installation of the reactor steam, cooling water, and electrical systems by the subcontractor, originally scheduled for September 1, was extended to October 1. The assembly of the reactor cell roof structure was completed to the point where a leakage test of the welds on the seal sheets can be made. The hydrostatic pressure test of the tank will follow this test early in September. (AEC Activity 4103)

HRT Chemical Pilot Plant - Liners were installed and leak-tested in the cell in which the HR fuel and blanket chemical processing facility is to be located. The barytes concrete shielding walls were poured, and equipment design is about 20% completed. Fabrication and installation of equipment are scheduled for completion by May 1, 1956, with initial operation on reactor fuel scheduled for September 1, 1956. (AEC Activity 4103)

HR Blanket Studies--Chemical Development - Thorex-product thorium nitrate was further decontaminated from gamma-emitting fission products by a factor of about 1.6 by precipitation of the oxalate at 40°C and three-stage calcination to thorium oxide at 375°, 520°, and 800°C. Essentially all the ruthenium, zirconium, and niobium were removed, but there was no detectable decontamination from protactinium or rare earths.

A slurry of 900°C-calcined thorium oxide, containing 660 g Th/kg H_2O and catalyzed with 0.02 m silver, combined hydrogen with stoichiometric oxygen, at the rate of 13 moles of hydrogen per hour per liter of slurry at 280°C and at a hydrogen partial pressure of 500 psi. Slurries of thorium oxide, containing metal and oxide powders of copper and nickel at 0.01 m concentration, had much lower catalytic activities.

Slurries of thorium oxide, prepared by thermal decomposition of the oxalate at 650° and 900°C, were irradiated at 300°C in the LITR for 288 and 115 hr, respectively, without apparent damage. Difficulties were encountered in stirring these slurries under irradiation but in an improved model of the dash-pot bomb a 500 g Th/kg H_2O slurry of 900°C-calcined oxide was stirred at 300°C in the LITR for one week without interruption. (AEC Activity 4103)

HR Fuel Reprocessing - The temperature distribution across a hydroclone underflow pot was nearly constant from center line to wall for a 2-kw heat input and constant center-line temperature while the hydroclone was in operation removing suspended solids from synthetic fuel solution. A titanium-lined hydroclone was operated for a total of 890 hr at 300°C with synthetic fuel solution with no detectable change in performance. Material, simulating that removed from the circulating stream in the hydroclone underflow, was concentrated fivefold by evaporation before the solids became difficult to handle.

In loop B-2, operating with uranyl sulfate solution containing neodymium sulfate, 98-99% of the neodymium sulfate that precipitated was removed by the 0.25-in.-dia hydroclone. When the circulating solution contained both neodymium and cerium sulfates, both precipitated, but cerium precipitation was less reversible than neodymium; only 75% of the cerium tracer in this experiment was recovered from the loop by repeated washes, while 90% of the neodymium was recovered.

Analyses indicated that the yellow crystals precipitated at 300°C from simulated fuel solution were $Nd_2(SO_4)_3 \cdot 3UO_2SO_4 \cdot 10H_2O$ when the initial neodymium sulfate concentration was 150 mg/kg H_2O, and $Nd_2(SO_4)_3 \cdot H_2O$ when it was more than 250 mg/kg H_2O. The latter material contained, for each 20 neodymium atoms, 1 uranium atom, probably a contaminant in residual fuel solution.

The water solubility of neodymium sulfate increased markedly in the presence of uranyl sulfate. The solubility at 275°C was only 1-2 mg/kg H_2O in water, but was 850 mg/kg H_2O in uranyl sulfate with a uranium concentration of 45 g/kg H_2O. In the presence of a rare earth mixture, approximating that expected from fission, the solubility values were about one-fourth these.

Iodate, 10^{-5} m, in 0.005 m $CuSO_4$ and in 0.005 m H_2SO_4 was 40-50% reduced by exposure to Co^{60} radiation. The amount of reduction was negligible in plain water and in uranyl sulfate solution. As expected, the amount of reduction appeared to be a function of dose rate. Vapor-liquid equilibrium studies using simulated fuel solution (5 g U/l with 0.005 m excess H_2SO_4) indicated that the mole fraction of iodine in the vapor phase was 21 times as large as the mole fraction of free iodine in the liquid phase at 280°C. (AEC Activity 4103)

Plutonium-Producer Blanket Processing - The adsorption of plutonium on titanium and Zircaloy-2 at 250°C was dependent on the concentration of the plutonium in 1.25 m UO_2SO_4 solution. A solution, containing 100 mg of plutonium per kilogram of H_2O, was passed through a vessel containing either titanium or Zircaloy-2 metal adsorption disks. The disks at the solution inlet adsorbed about 10 times as much plutonium as those at the outlet. Adsorption of plutonium was not uniform; small areas adsorbed large amounts. Analyses by x-ray diffraction indicated that most, if not all, of the adsorbed plutonium was present as PuO_2.

The results of two irradiation experiments in the LITR indicated the solubility of plutonium to be 0-10 mg/kg H_2O at 250°C in 1.26 m UO_2SO_4. This agrees with the solubility of approximately 3 mg Pu/kg H_2O in 1.26 m UO_2SO_4 at 250°C determined in out-of-pile tests.

Additional studies showed that recovery of protactinium from irradiated ThO_2 (calcined at 650°C) by refluxing in 14 N H_2SO_4 decreased as the amount of ThO_2 treated was increased. The recovery of protactinium from 0.015-, 0.106-, and 4.78-g batches of ThO_2 was 94, 79, and 50%, respectively. This was probably a result of poor mixing during the leaching. Removal of protactinium from irradiated ThO_2 was less effective for ThO_2 calcined at 900°C. A somewhat better recovery of protactinium was obtained by dissolving the ThO_2 and recrystallizing it as $Th(SO_4)_2$. Thorium sulfate was converted to the oxide by calcining at 900°C for 24 hr. This material contained 0.11% sulfate, but washing with cold water reduced the sulfate to 100 ppm. (AEC Activity 2723)

HR Blanket Engineering Development - The Westinghouse 200-gpm slurry pump was operated successfully for 234 hr at 300°C with ThO_2 slurry at a concentration of 500 g Th/kg H_2O.

A by-pass stream to the top of the pressurizer was found to maintain automatically the concentration of the slurry in a circulating loop.

No method was proved for keeping the solids suspended in full-size horizontal dump tanks. In a small model, bubbling steam through a sintered stainless steel plate on the bottom of the tank resuspended settled slurry and maintained the suspension but introduced a foaming problem.

It was found that the yield stress for some ThO_2 slurries increased as the temperature increased from 25° to 75°C.

It is concluded, based in part on previous analyses, that 8 to 10 kw of heat per liter can be removed as steam from a boiling reactor system ten feet high and operated at 1000 psi with a vapor fraction of 0.3. At 2000 psia, a similar system would release 15 to 20 kw/liter. (AEC Activity 4103)

HR Core and Blanket Systems Development Studies - The HRT pressure vessel was satisfactorily tested at a hydrostatic pressure of 4000 psi and the blast shield was assembled around the pressure vessel. (AEC Activity 4103)

HR Fuel Circulating Equipment - A 400A Westinghouse pump completed 860 hours of circulating a uranyl sulfate solution (30 g U/liter) at 250°C. There was evidence that the corrosive attack on the end of the back hub of the impeller and the adjacent wearing ring had increased over that observed after the 1000 hour run at 300°C. No other corrosive attack or abnormal wear was observed. A new type of thermal barrier was installed in the pump and proved to be successful. The temperature around the lower bearing appeared to be well below the specification of 100°C. The pump is now operating on 10 g/l solution with approximately 55 mole % excess sulfate ions. A total of approximately 3400 hours of operation has been accumulated on this pump.

The 300-gpm fuel mockup pump was converted to utilize the new type thermal barrier and to use a flat, gold-plated stainless steel gasket. After cold pressure tests, a few hours of hot operation, and one complete thermal cycle, the gasket appeared to be satisfactory. The pump has operated 650 hours.

The testing of the HRT sampler with a solution containing 0.1% ThO_2, showed the samples to be 40% low in solids. Redesign and modification of the isolating chamber reduced this error to about 15%.

The first phase of the HRT dump test, using a single vessel, was completed. Equations were developed to predict pressure-time curves for such a system. The equipment is now being rebuilt to test a system consisting of two concentric vessels which will be dumped either one at a time or concurrently.

The prototype model of the HRT purge pump was completed and is under test. The output at 2000 psi is 15-18 gph. Since this is considerably in excess of reactor requirements, the pump will be slowed down to prolong its life.

Contracts were let for the construction of test sections of titanium-lined pipe and a small titanium-lined heat exchanger. A fundamental program on cladding carbon steel with titanium at the Armour Research Foundation is under consideration.

A 2000 psi, 5-gpm pump has accumulated 1700 hours of operation with water. Operation has continued to be interrupted by leaks. Similarly, a 1000 psi, 5-gpm pump has accumulated 8050 hours of operation. The ORNL pump with stator windings connected in series has accumulated 3700 hours of operation with water. (AEC Activity 4103)

HR General Reactor Component Development - The valve test loop is in routine operation on 10 g/l UO_2SO_4 solution. About 100 dump tests are carried out per day. The total quantity of liquid dumped each time is about 1/10 of an HRT fuel "dump". The test period has been set at 200 loop dumps (equivalent to 20 HRT dumps). To date, the valve trims tested have shown very little damage.

Uranium precipitation in the HRT mockup, experienced in the previous run, was traced to insufficient O_2. The concentration, which was 50 ppm, will be doubled in a run now beginning. The 300A circulating pump was modified to include the new thermal barrier and closure designs. An HRT-type float level indicator was also added to the mockup. (AEC Activity 4103)

HR Heat Removal Equipment - The first HRT heat exchanger suffered cracks in four tube joints during the thermal cycle test. Other parts, including the head-closure seal weld, showed no signs of failure; leakage across the head gasket was experienced, however, during the cool part of the cycle. The tube joints were repaired.

The second heat exchanger was completed and given hydrostatic and helium leak tests. After one thermal cycle the gasket leaked and the test was stopped. The cycle tests will be resumed with a gold plated gasket and with extra long head bolts and ferrules to increase the flexibility of the bolting.

The Foster Wheeler Corporation is submitting a proposal to fabricate and install blast shields on the two heat exchangers. (AEC Activity 4103)

Gas Handling Equipment - The high-pressure recombiner loop was shut down temporarily because of extensive damage caused by stress corrosion cracking. This cracking is believed to have been caused by the chloride present in the loop. At present, methods of removing chloride from the KOH of the electrolytic cells are being investigated. When chloride-free caustic is obtained, the loop will be started again. The thermal convection recombiner is undergoing testing.

Multiple layers of aluminum foil were investigated as a possible insulating material for the HRT. For a 4-in. pipe at 620°F, the heat losses with 9 layers of foil were only 6% of the bare pipe losses. This compares to 11% for 2-in. of standard MgO insulation.

The design of a 20-cfm canned-rotor gas circulator, suitable for use in a high-pressure recombiner system, was approved. Material procurement was initiated by Allis-Chalmers. Delivery of the circulator is expected in about six months.

A 5-gpm ORNL pump, converted to a gas circulator, has accumulated some 5900 hours of operation, circulating saturated steam at 110 psi. (AEC Activity 4103)

GENERAL REACTOR RESEARCH

Radiation Damage--Advanced Engineering and Development - In zircon single crystals, the lattice expansion that results from fast-neutron bombardment exceeds 1% for both axes after an exposure of 2.8×10^{20} neutrons/cm^2. This expansion is accompanied by mosaic-block formation and disorientation which can be observed by rocking-curve measurements on (h00) and (00ℓ) reflections

by using conventional geiger-counter techniques. Preliminary measurements indicate the disorientation of mosaic blocks by as much as 6 degrees. Since considerable amounts of this lattice distortion can be removed by annealing at temperatures in excess of 1000°C, the kinetics of the annealing behavior are being observed. (AEC Activity 4540)

Basic Reactor and Shielding Research - An experiment was performed with the Bulk Shielding Reactor (BSF) to determine the linearity of the reactor controls at high power levels. Earlier experiments at lower power levels indicated linear response up to 10 kw, if the chambers were correctly compensated. The present measurement, with thermal neutron flux detectors external to the reactor, shows that the reactor power sags 3% at 100 kw, 8% at 500 kw and 11% at 1 Mw power demand. With a compensated chamber of the reactor control type positioned below the reactor, readings were obtained that were proportional to reactor power, as indicated by the external detectors. This fact supports the theory that the sag in power is the result of activated water rising past the control chambers. Water jets mounted to divert the rising hot water column away from the reactor control chambers did not, however, produce an anticipated increase in linearity. Further experiments will be required to explore the non-linearity.

Surface temperatures were measured with thermocouples on a fuel plate in an element positioned in three representative locations in the BSF reactor core. The tests were performed with the water inlet temperature constant at 30°C, and the following maximum differential temperatures were noted:

Measured Temperature Rise (°C)

Power	High Flux Position		Ave. Flux Position		Low Flux Position	
	Plate	Outlet Water	Plate	Outlet Water	Plate	Outlet Water
1 mw	55	36	43	- -	34	26
500 kw	36.5	26	29	- -	23.5	19.5
100 kw	13	12.5	11	- -	8	8
50 kw	8.2	8.2	7	- -	5.8	5.2
10 kw	4	4.0	3.7	- -	3.5	3

Thermocouples placed at seven other positions on the fuel plate gave results which were consistent with the results tabulated above. (AEC Activity 4570)

Reactor Theory - Estimates were made for the control rods necessary to suppress the excess reactivity which is planned for the Oak Ridge Research Reactor. Multiplication constants for various configurations were computed. Thus, data is at hand for determining fluxes for possible and likely loadings.

A calculation of the effective resonance integral of U^{238}, as a function of scattering cross section per uranium atom (for scattering cross sections

$\angle$2000 barns), was completed. The calculated curve differs systematically from the experimental values, being too low by ~40%. A similar calculation was made for Th^{232}.

Flow diagrams for the one-velocity reactor calculation based on the S_n method of approximating the transport equation were revised, and parts of the program were coded. Compilation of the cross section library on magnetic tape is continuing. The problem of determining the age of neutrons in mixtures by Monte Carlo methods is in the final coding stages. A revised code for the calculation of cross sections on the "cloudy crystal ball" model was programmed. A program for determination of the resonance escape probability in mixtures by Monte Carlo methods was coded. Investigation of multiple Coulomb scattering of protons in slit edges was initiated; the calculation will be performed by Monte Carlo methods on the Oracle. (AEC Activity 4570)

Power Reactor Waste Disposal Engineering Studies--Field Investigations and Explorations - A study of the geology and hydrology was begun at the proposed site for waste disposal pit No. 4, which will be an extension of the present two-pit system now in use in Melton Valley. The work so far has included drilling four 200-foot observation wells, each 125 feet from the pumping well.

Preliminary pumping of the central well shows a response strikingly similar to that obtained at the "Four-Acre" test area. The cores from the observation wells show a fairly uniform sequence of calcareous shale and thin layers of interbedded limestone; there are no easily distinguished key beds for use in structure studies. The exposure available when the pit is constructed, together with the electric logs which have been in part completed, should make possible a detailed study of the structure. The holes have not yet been pressure tested, but the fracturing of the cores is similar to that seen in the core holes near pit No. 3; in general, conditions at the two pits are apparently similar, except for the depth to the water table. Before Pit No. 3 was put in service, the depth to water was about 25 feet; as the pit filled the water table rose about 16 feet. At the site of pit No. 4 the depth to water is now 40 feet, and after the pit is filled the water table will be forced to rise about 30 feet. Because of this difference, and also because the site of pit No. 4 is surrounded on three sides by steep slopes, it is anticipated that pit No. 4 may loose liquid at a more rapid rate than the two pits now in use. (AEC Activity 4630)

Power Reactor Waste Disposal Engineering Studies--Chemistry and Soils Engineering - A procedure was developed for the precipitation of the major fission products from a simulated reactor fuel-element processing waste solution. With the lowest practical concentration of chemicals, removal of 95% of the added radionuclides was obtained. The nuclides added were Sr^{90} - Y^{90}, Zr^{95}-Nb^{95}, Ru^{106}, Cs^{137}, and Ce^{144}. The treatment consisted of the co-precipitation of ruthenium and cesium with copper ferrocyanide, of strontium with barium sulfate, of zirconium and niobium with zirconyl phosphate, and of the rare earths and yttrium with cerium oxalate. (AEC Activity 4630)

ISOTOPE PRODUCTION

Stable Isotope Production - Charge material enriched in Li^7 was processed in the Alpha calutron with a grid-type ion source. Approximately 35 grams of the collected material assayed 99.995% Li^7. Enriched Li^6 (96.5%) charge was processed in Beta equipment; 9.4 grams of product assayed from 99.990 to 99.999% Li^6.

In the collection of high-purity Li^6, an experiment was performed to check the possible pumping effect of neutral vapor by a high-energy low-density ion beam. During lithium collection in which the Li^6 ion current was 70 milliamperes, $FeCl_2$ was vaporized into the vacuum chamber from an auxiliary oven at approximately the same rate that LiCl was being vaporized from the ion source oven. $FeCl_2$ was then quantitatively recovered from the Li^6 pocket and from a control pocket located in the mass-5 position, out of the path of the lithium ion beam. Entry to both pockets was through 3/16-in. by 8-in. defining slits. Ten times as much iron was recovered from the lithium pocket as from the control pocket. This apparent pumping action of a low-density ion beam is being investigated further.

Molybdenum isotopes (masses 92, 94, 95, 96, 97, 98, and 100) are being separated in the low-temperature, two-arc Alpha-2 calutron. The isotopes of strontium (masses 84, 86, 87, and 88) and bromine (masses 79 and 81) are being collected simultaneously by using $SrBr_2$ charge in Beta high-temperature ion sources. Bromine ions are retained by chemical combination with magnesium contained in water-cooled copper collector pockets.

Ru^{100} was placed in the inventory for the first time. New lots of Li^6, Te^{120}, and Te^{122} were added to the inventory.

The accumulated production of 98+% Eu_2O_3 by TBP + HNO_3 extraction now exceeds 550 grams. (AEC Activity 5121)

PHYSICS

Scintillation Spectrometry - In a cooperative effort with the U. S. Geological Survey, the decay constant of Th^{232} was determined from a measurement of the intensity of the 2.62-Mev γ-ray in Tl^{208}(ThC") in weighed, equilibrium samples of thorium provided by the U. S. G. S. Preliminary results give a value of 1.55×10^{-18} sec^{-1} with an uncertainty of about 5%. To determine the activity of the parent thorium from the intensity of the γ-ray, it is necessary to know the branching ratio, $\frac{\alpha}{\alpha + \beta}$, of ThC($Bi^{212}$). This was determined by a measurement of the intensities of the α-particles from ThC and ThC' in an α-particle proportional counter. The preliminary value obtained for this ratio is 0.37. (AEC Activity 5220)

Scintillation Spectrometry for Medical Use - The 3-in. 61-hole focussing collimator described previously is now in use at the ORINS hospital. The localization which it gives is considerably better than that of the 2-in. collimator, and is somewhat better than was expected. The region of greater than 50% of maximum counting rate from a point source is 1/4 inch in diameter and 1-7/8 inches long centered at 2-5/8 in. from the surface of the collimator. The region of greater than 10% of maximum counting rate is about 1/2 in. in diameter and extends outward 5-1/4 in. from the surface of the collimator. The transmission is 46% at the point of maximum counting rate.

Final circuitry for the surgical probe is in satisfactory operation. This circuitry, using subminiature filamentary tubes, includes a linear amplifier, two discriminators, an anti-coincidence tube, the scaler, a pulse storage circuit, an audio generator, and the necessary power supplies. Power consumption is less than 12 watts - an important fact because the unit must be hermetically sealed for use in an operating room. A new probe was constructed with 1/8-in. outside diameter and containing a 0.1-in. by 1/4 in. crystal of cesium iodide-thallium. The length of the small diameter portion of the probe is 3-1/8 inches, permitting its use in brain surgery. (AEC Activity 5220)

High Voltage Program - In the study of the Coulomb excitation of molybdenum nuclei, metallic targets of enriched isotopes were prepared by flowing hydrogen over isotopically enriched oxides at an elevated temperature ($\sim 750^{\circ}C$); the metallic powders were then pressed into thin foils. These targets were bombarded by protons with energies 1.8- to 3.0-Mev, and the γ-rays were detected with a NaI scintillation spectrometer. The following states were excited by the Coulomb excitation process: Mo^{100}, 540-kev; Mo^{98}, 770-kev; Mo^{96}, 770 kev; Mo^{94}, 874-kev; Mo^{95}, 212-kev. No excitation was observed in Mo^{92} and Mo^{97}. The absolute γ-ray yields were measured at several incident proton energies.

A combination of Van de Graaff monoenergetic neutron technique with mμsec time-of-flight technique was investigated by observation of reported narrow resonances in the total cross section of bismuth (2-40 kev) and aluminum (4-8 kev). The measured width of the resonance in aluminum at 6 kev is 350 ev, which is the calculated resolution of the apparatus for the operating conditions used. Thus, the natural width of the resonance must be small compared to 350 ev. This result is in agreement with earlier estimates from activation analysis (R. H. Rohrer et al, Phys. Rev. 95, 302A, 1954). The total cross section of bismuth exhibited strong resonances at approximately 2.2, 13, 16, and 34 kev. All observed widths were roughly the instrumental resolution. The resolution at 13 kev was approximately 800 ev for operating conditions used.

The cascade generator was used for final tests on an ion-source pulsing system. The unit is to be used with the neutron time-of-flight spectrometer on the 2.5-Mv Van de Graaff accelerator. The pulsing system consists of a set of deflecting plates placed under the ion source in the lens section of the accelerator. The deflection plates are driven by a 0.5 megacycle oscillator.

The beam is swept back and forth across an aperture to produce beam pulses at the required one megacycle repetition rate. During tests on the cascade generator, the unit has delivered pulses of 16 mμsec duration with a peak current of 200 μa. (AEC Activity 5220)

Classification of Low-Lying Nuclear Energy Levels - The directional angular correlation of the 1367-605 kev γ-γ cascade in Ba^{134} was measured with a coincidence scintillation spectrometer, using NaI detectors. For a dilute cesium chloride aqueous solution source the observed correlation function, after correcting for the finite angular resolution of the detectors, is given by

$$W(\vartheta) = 1 + (0.090 \pm 0.0086)\ P_2\ (\cos\vartheta) - (0.004 \pm 0.013)\ P_4(\cos\vartheta).$$

From this result it is not possible to assign unambiguously a spin and parity to the 1972-kev level in Ba^{134}, from which the cascade originates. However, the present angular correlation data along with internal conversion coefficient data for the transitions from this level indicate that it very probably has spin 3 and odd parity. (AEC Activity 5220)

63-Inch Cyclotron, Physics - A NaI crystal and proportional counter telescope arrangement is being used in the investigation of the energy spectra of the light particles produced by the nitrogen bombardment of various light elements, including Li^6, Li^7, C^{12}, N^{14}, O^{16}, and Al^{27}. In general it is found that only alpha particles and protons are produced, the probability of He^3, H^3, and H^2 emission is very low. It is expected that an analysis of the energy spectra will give information on the level densities of the residual nuclei and the reaction mechanism for heavy particles.

A theoretical investigation of the previously measured 22-Mev nitrogen-nitrogen elastic scattering shows that the data can be fit very well with a semi-classical theory which assumes that particles with l wave values up to six are completely absorbed while the others are undisturbed by the nuclear field. Therefore, the total nuclear interaction cross section for nitrogen on nitrogen at 22 Mev is 3.6×10^{-25} cm^2. (AEC Activity 5220)

63-Inch Cyclotron, Operation - Attempts were made to increase the energy of the deflected beam particles by adjustment of the deflector. It was found that the deflector was already in the position for maximum energy but that the energy could be decreased by approximately 10% by appropriate deflector movements. An apparatus for the preparation of evaporated lithium targets after they are installed in the deflected beam position was constructed and is being used successfully. (AEC Activity 5220)

Spectroscopy Research Laboratory - The determination of D/H isotope ratios by infrared spectroscopy was performed to a precision of ± 0.02% in the 0 to 2% deuterium range. Improved photomultiplier testing procedures were developed, utilizing a constant intensity tritium light source. Spectrochemical detection of boron in reactor components is now being made to about 0.1 ppm.

Zeeman effects of tellurium at 33,600 oersteds were observed with a double wall discharge tube, in preparation for Po^{210} studies. Reduction of Zeeman data on neon, by means of a newly-developed least squares procedure, reveals that significant improvement of magnetic field determinations can be made by using theoretical g-sum rules rather than the g-factor data of previous investigators. Accurate determinations of L series lines of neptunium, plutonium, and americium show bias in previous measurements at other laboratories. Preliminary crystal spacings and theoretical perfect crystal densities of LiH (normal), LiD (normal) and LiD (95% Li^6) were determined as 4.0833 A, 4.0693 A, and 4.0714 A, and 0.775 gm/cc, 0.882 gm/cc, and 0.793 g/cc, respectively. (AEC Activity 5230)

Mass Spectrometer Laboratory - A number of substances were investigated to determine the degree of polymerization in the vapor phase; no polymerization was found in $NiCl_2$, $MnCl_2$, $FeCl_2$, SeO_2, and $PbCl_2$. Cupric chloride, $CuCl_2$, decomposes to CuCl and Cl_2. Stannous chloride, $SnCl_2$, shows polymerization, but the nature of the species is not yet clearly established. Trimeric species were found in copper iodide, silver chloride, silver bromide, and silver iodide; these substances are being studied further.

A careful study was made of the fraction of total ionization which appears as metastable transitions in the propane mass spectrum. Two new metastable transitions were found, as predicted by theory, at masses 17.8 and 42 respectively.

A technique was developed for the isotopic analysis of small samples of enriched isotopes of sulfur. The sulfur, as cadmium sulfide (CdS), is heated in the mass spectrometer in the presence of pure oxygen and examined immediately in the form of sulfur dioxide (SO_2). Samples of one or two milligrams of sulfur are easily handled by this technique. (AEC Activity 5250)

CHEMISTRY

Uranium Chemistry of Raw Materials - The amine extraction process was successfully tested in small continuous equipment for the recovery of uranium from several actual leach liquors procured from operating mills on the Colorado Plateau. The recovery of uranium was greater than 99.8%, in four-stage extraction. The purity and grade of the uranium product were within the specifications of refinery feed material.

In further studies of the amine extraction process, it was shown that aqueous slurries of magnesium oxide can be used to strip (in this case, precipitate) uranium from the solvent. When a high aqueous/organic phase ratio is maintained in the stripping system, the phase separations were rapid and clean. Complete removal of uranium is obtained with only a small excess of magnesium oxide.

Laboratory scale tests were made of a solvent extraction process for recovering both uranium and vanadium from sulfate liquor. The uranium and vanadium (IV) are co-extracted, with di(2-ethyl-hexyl) phosphoric acid in 97% kerosene - 3% TBP diluent, and separated by selective stripping. The stripping of vanadium is accomplished with 0.75M H_2SO_4 after which it is precipitated with ammonia and calcined to a V_2O_5 product. The uranium is stripped with a solution of sodium carbonate.

The distribution of uranium(VI) between aqueous perchlorate solutions (2M) and di(2-ethylhexyl)phosphoric acid/n-hexane at 25°C conforms well to the reaction

$$UO_2^{++}aq + 2HOPO(OR)_2org \rightleftharpoons UO_2\left[OPO(OR)_2\right]_2org + 2H^+aq$$

$$\frac{[UX_2]\,[H^+]}{[UO_2^{++}]\,[HX]^2} \approx 8 \times 10^3$$

over a range of acid, reagent, and uranium concentrations. This is in contrast to uranium extractions from some other types of acid solutions, which varied with a power of the organic reagent concentration somewhat greater than the square. (AEC Activity 5310)

Hope Project - Some reduction in the cost of chemical processing of fuel dissolved in nitric acid can be obtained by recovering the nitrogen oxide gases now vented to the stack. Nearly 100% of the recoverable nitrogen oxides (NO and NO_2) in dissolver off-gas was air-oxidized and dissolved in water to form reusable nitric acid.

A hydroclone, which has no moving parts, removed 99% of the water from approximately 85% of the simulated used solvent which was processed; the remaining 15% was recycled. Use of the hydroclone for recovering used radioactive solvent would eliminate the expensive maintenance required for the centrifuge now used for this purpose. (AEC Activity 5310)

Inorganic Solution Chemistry - The anion exchange behavior of certain Group III-a, IV-a, and V-a elements in HF-HCl solutions is being investigated. The elements studied include Ga(III), Ge(IV), As(III) and (V), In(III), Sn(IV), Sb(III) and (V), Tl(III), Pb(II), and Bi(III). Of these, Ga(III), Ge(IV), Sn(IV), and Sb(III) and (V) were found to adsorb quite differently in the presence of HF than in HCl alone. Use may be made of these adsorbability differences for making separations in HCl-HF solutions which are difficult with HCl alone.

A study of the anion exchange properties of zirconium hydroxide and the cation exchange properties of zirconium tungstate and zirconium phosphate continued. Zirconium hydroxide was found to adsorb Ag(I), Au(III), and Hg(II) from HCl solutions under conditions analogous to organic anion exchangers, though not so strongly. A separation of Ag(I) and Au(III) in 2 M HCl was effected. On the cation exchangers, separations for most of the ions of the alkali metals at tracer concentrations were effected. A good separation of Rb^+ and Cs^+ at

macro concentrations (70 λ 1 M RbCl + 70 λ 1 M CsCl) was obtained on a 0.128 cm^2 by 11.3 cm column of zirconium tungstate with NH_4Cl as eluent.

Further studies were made on soluble thorium "hydroxide" precipitates. It was earlier reported that hydroxide precipitated from chloride solutions with ammonia and then heated overnight at ca 300°C dispersed readily in water to give concentrated solutions, as high as 1.5 kg Th/kg water. It has been found that properties of the hydroxide are affected by the anion present during precipitation. If the hydroxide is prepared from throium nitrate, hydroxides of comparable solubility are obtained, but the highest solubility is obtained if the overnight heat treatment is at ca 150°, rather than 300°C. If the hydroxide is precipitated from sulfate, the solubilities are much lower. Up to now, no concentrated solutions prepared from these materials have shown long term stability against precipitation when heated to 250°C.

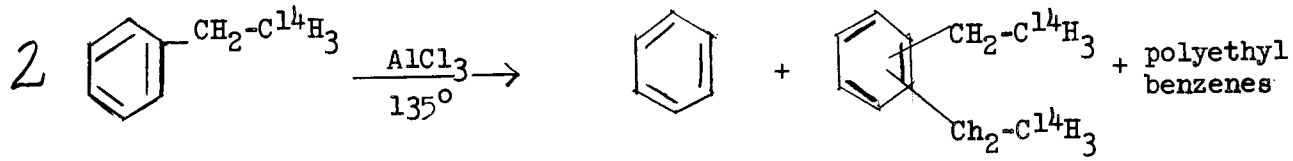
Equilibrium ultracentrifugations of the soluble material prepared from thorium chloride indicated a highly polydisperse distribution, of an average molecular weight of ca 10^5. Virtually the same result was obtained in water and in 1 M NaCl; the solute thus does not appear to carry a high charge. (AEC Activity 5330)

Chemical Physics - Paramagnetic resonance absorption is being studied in single crystals of calcium hydroxide after irradiation with gamma rays at liquid nitrogen temperature. Four absorption lines were observed; two of them result from a very small irradiation yield of atomic hydrogen, while a third broad line may be due to an F-type center. The fourth line was tentatively assigned to the OH-free radical. The g-factor is anisotropic with axial symmetry along the crystal trigonal axes having $g = 2.0749$ and g_{11}, within experimental error, that of the free electron. The line is a little too broad to resolve the expected hyperfine structure of OH. The g-values and symmetry properties are consistent with OH.

A neutron diffraction study of calcium hydroxide crystals at -140°C showed the structure to be similar to that at room temperature but with reduced amplitudes of thermal vibration. The O-H distance obtained was 0.945 Å. (AEC Activity 5330)

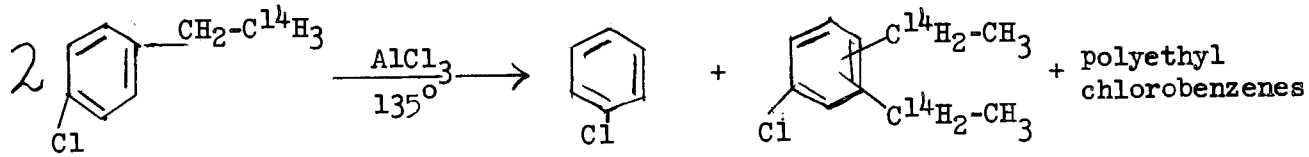
High Temperature and Structural Chemistry - Preliminary measurements of the electrical conductance at 800°C in molten KCl-K solutions, 0.5 and 3 mole % K, were made with a newly-constructed apparatus incorporating a beryllium oxide conductivity cell under an argon pressure of 40 psi. The measurements indicate that the conductivity is far lower, about 25 and 150 times, than expected for the usual additive behavior of a mixture of a metal with a salt. (AEC Activity 5330)

Radio-Organic Chemistry - An earlier study of the rearrangement of the side chain of ethylbenzene-β-C^{14} in the presence of aluminum chloride is being extended. It was shown earlier that the disproportionation reaction:



proceeds, as shown, without rearrangement of the side chain to give carbon-14 alpha to the ring. The absence of such carbon chain rearrangement was tentatively explained as due to the fact that the ethyl carbonium ions $[\oplus CH_2\text{-}C^{14}H_3]$ which formed as intermediates were too short-lived to permit a hydride shift giving $[CH_3\text{-}C^{14}H_2 \oplus]$.

An additional test has now been applied to this postulated mechanism by substituting a chlorine atom in the aromatic ring, with the expectation that the ethyl carbonium ion would be given more time to rearrange before reacting with another molecule of chloroethylbenzene. The presence of the chlorine atom in the ethylbenzene molecule could result in longer life for the ethyl carbonium ion. As expected, the reaction was shown to proceed with partial chain rearrangement as shown:



In two hours, 2% of the label had migrated from the beta to the alpha carbon of the side chain; in twenty hours, 5% had migrated. This slow rearrangement of the carbon chain together with the fact that all the ethyl groups were found to have the same percent of their activity in the alpha position, suggests that the ionization mechnism discussed above may be accompanied by a faster bimolecular exchange reaction. This bimolecular exchange would give all the ethyl groups in the various products the same distribution of activity, although it could not cause any shift of activity from the beta to the alpha position of the side chain. (AEC Activity 5330)

Radiation Chemistry - A radiation-induced reduction of Ce^{+4} by Tl^{+} increases the 100-ev yield of Ce^{+3} from 2.52 to 7.85 in 0.8 N sulfuric acid. The yield of Ce^{+3} is independent of the Tl^{+} concentration (10^{-5} to 10^{-2} molar), while the yield of Tl^{+3} is dependent on the Tl^{+} concentration. In a proposed mechanism, the OH radical (which would have otherwise oxidized Ce^{+3} to Ce^{+4}) oxidizes Tl^{+} to Tl^{+2} which reduces Ce^{+4} with resultant formation of Tl^{+3}. Tl^{+} decreases the yield of "molecular" H_2O_2 by reaction with OH radicals in regions of high ionization density before the OH radicals combine to form H_2O_2. This decrease of the yield of "molecular" H_2O_2 results in the dependence of the yield of Tl^{+3} on the Tl^{+} concentration. The yield of Ce^{+3}, both in the presence and absence of added Tl^{+}, is not sensitive to changes in sulfuric acid concentration from 0.8 N to 0.087 N.

One of the principal products in the gamma-ray decomposition of nitrate solutions is nitrite ion. The nitrite ion yield was determined for 10^{-2} M and 5 M $NaNO_3$ solutions over the pH range from 2 to 13.5. The yield (molecules of NO_2^- formed per 100 ev absorbed) in 10^{-2} M $NaNO_3$ increased from 0.4 at pH 2 to 0.9 at pH 11. The yield in 5 M $NaNO_3$ increased from 1.1 at pH 2 to 2.3 at pH 11. The difference in nitrite yield between 10^{-2} M and 5 M solutions was attributed to direct action by radiation on the nitrate ion. A sharp increase in nitrite yield in the pH range 11 to 13 was attributed to ionization of OH to O^- which reduced the nitrate ion.

The radiation decomposition of tri-n-butyl phosphate and other substituted butanes is under investigation. The G values (molecules of gas formed per 100 ev.) for gas production for several of these substances are: tri-n-butyl phosphate, 1.94; tri-isobutyl phosphate, 1.99; tri-sec. butyl phosphate, 2.30; di-n-butyl carbonate, 2.82. Mass spectrometric analysis of the gaseous decomposition products showed that the butane fraction from tri-n-butyl phosphate had suffered about 20% skeletal rearrangement. This suggests that positive butyl carbonium ions occur among the primary products of the radiolysis. Composition of these gases indicate also that in the radiolysis of tri-n-butyl phosphate relatively little fragmentation of the butyl group occurs, whereas, in the radiolysis of di-n-butyl carbonate fragmentation of the butyl group is almost the exclusive process.

A mixture of acetylene and benzene (approximately 3:1 by volume) was irradiated at 100°C by alpha particles from radon. Pressure measurements were made at 100°C and -78.5°C. The total pressure, the pressure of gas non-condensable at -78.5° and the pressure of gas condensable at -78.5° decreased so that the logs of the pressures were straight line functions of the quantity of radon remaining, until the total pressure was about 20% of the initial total pressure. A gas non-condensable at -195.8°C is evolved. Preliminary calculations give an ion yield of about 6 for the mixture, whereas the ion yield of pure acetylene is about 20 and that of benzene vapor about 1. There was no evidence of a liquid polymer as found in the case of benzene. (AEC Activity 5330)

Chemistry of Fused Salts - Measurements of the depression of the freezing point were used to establish the equilibria which obtain in solutions of $PbCl_2$, $CdCl_2$, $ZnCl_2$, and $CdBr_2$ in molten sodium nitrate. It appears that the following two equilibrium reactions are the most important

$$MX_2 = M^{++} + 2X^- \qquad (1)$$

$$MX_2 + 2X^- = MX_4^{--} \qquad (2)$$

Equilibrium constants for these reactions were calculated from the experimental data. The tendency of the metal ion to associate with chloride ion appears to increase in the order of Pb < Cd < Zn. Bromide ion associates more extensively with Cd than does chloride ion. The "common ion effect" is established as a general phenomenon, applicable to molten salts as well as aqueous solutions.

The electrical conductance and density have now been measured for all alkali halides except fluorides. A number of generalizations were made and a reasonable and unifying approach to an understanding is possible.

Improved tracer techniques, developed to measure self-diffusion in molten salts, were applied successfully to the two ions in fused sodium nitrate. The self-diffusion coefficient of the sodium ion is given by the equation

$$D_+ = 1.288 \times 10^{-3} \exp. (-4970/RT)$$

while that for the nitrate ion is

$$D_- = 8.974 \times 10^{-4} \exp. (-5083/RT)$$

The probable error in the heat of activation in each case is 80 cal/mole, while the probable errors in D_+ and D_- vary from 1.2 to 1.8% and from 0.7 to 1.1%, respectively. The temperature range of the measurements is 310° to 380°C. These results lead to three significant conclusions. (1) The Nernst-Einstein equation is not immediately applicable to this molten salt. (2) The heat of activation for self-diffusion is the same, within experimental error, for both cation and anion. This latter result shows that the coefficient of friction in this fused salt is the same for both cation and anion. (3) The ratio of the diffusion coefficients of the two ions is close to the inverse ratio of the square roots of their masses but must also be related to their sizes. This work is being extended to other salts in order to learn whether these phenomena are general. (AEC Activity 5330)

Chemical Research Math and Computation - Chemical kinetic formulations were made which allow prediction of results of "chain labeling" experiments from "ring labeling" and computation of "intrinsic migratory aptitude" in the pinacol rearrangement. (AEC Activity 5330)

METALLURGY

Ceramics Research - A mixture of 80% UO_2 and 20% glass was made up in the form of rods 3/8-in. O D by 4-in. long for study by the WAPD Fuel Group; the function of the glass is to provide a plastic mixture at elevated temperatures which might improve radiation stability and reduce thermal fracture. Dysprosium oxide is of interest for use in the measurement of pile flux; discs 0.24-in. in dia by 0.01-in. thick and containing approximately 1 mg of dysprosium per cm^2 were prepared for testing in criticality experiments. As part of the feed program a study is being made of the decrepitation temperature of spodumene (lithium ore) to improve the yield of the extractive process; it was found that the North Carolina ore decrepitated at 1030°C, much higher than reported in the literature. A ceramic mass containing mixed fission products in Hope solution, dried and fired to 570°C, showed practically no release of fission products when leached with tap water. Fuel-bearing SiC-Si plates containing 2 to 3 wt % uranium were fabricated.

In connection with the HRT corrosion program it was observed that cubic ZrO_2 is more stable under irradiation than monoclinic ZrO_2. Tests were made to obtain the cubic oxide on zirconium when it is oxidized in a uranyl sulfate solution. Zr-Cb alloys appear to show promise in forming the cubic oxides; further studies are being made on these materials. Single crystals of ThO_2, 150 microns in diameter, were grown from a ThO_2-ThF_4-LiF melt at a temperature between 980° and 1000°C. (AEC Activity 5420)

Fundamental Physico-Metallurgical Research - The use of an argon atmosphere in the floating-zone refining of zirconium has improved the stability of the molten zone, presumably as a result of more rapid heat removal and a shortening of zone length.

An investigation of the lattice spacing of zirconium-silver alpha solid solutions resulted in the following preliminary spacings:

	a_o	c_o	c/a
Pure Zr (vacuum filed)	3.2323	5.1479	1.5926
0.46 at % Ag	3.2307	5.1467	1.5930

These results show that silver probably expands the c/a ratio of zirconium, which is in agreement with the effect of silver on titanium. Other results obtained indicated that oxygen and nitrogen films on the surface of the filings did not affect the spacings unless they were dissolved by annealing at temperatures above 550°C:

		a_o	c_o	c/a
Air filed Zr	550°C anneal	3.2323	5.1479	1.5926
Air filed Zr	800°C anneal	3.2338	5.1498	1.5925

The distributions of fiber axes were determined for specimens of aluminum taken from the front of a rod extruded at 650°F at a speed of 0.2 fpm and from the back of a rod extruded at 650°F at a speed of 659 fpm. The specimen taken from the rod extruded at the slower rate was found to have a duplex ⟨111⟩ - ⟨001⟩ fiber texture; the former component constituting 43% and the latter 57% of the volume. An earlier determination of the fiber axis distribution for a specimen taken from the back of the same rod also revealed a duplex ⟨111⟩ - ⟨001⟩ texture; the volumes containing each component being 23% and 77%, respectively. These data are consistent with the observation that rods extruded at rates less than 0.3 fpm in the temperature range of 450° to 850°F exhibit duplex ⟨111⟩ -⟨001⟩ fiber textures with the amount of the ⟨001⟩ component increasing at the expense of the ⟨111⟩ component from the front to the back of the rod. The most preferred crystallographic directions of the fiber axis of the specimen taken from the rod extruded at the faster rate were ⟨111⟩ and ⟨115⟩. Only 3% of the material was associated with the ⟨111⟩ component and the remaining 97% was associated with the ⟨115⟩ component. The ⟨115⟩ component has not been observed in any other aluminum extrusion examined. Specimens taken from rods extruded at rates of 615 to 738 fpm exhibited a duplex ⟨111⟩ -⟨001⟩ fiber texture at 450°F, ⟨111⟩ -⟨115⟩ at 650°F, and ⟨118⟩ at 850°F. This apparent temperature dependence for the fast extrusion speeds is being studied. (AEC Activity 5420)

Fundamental Investigation of Radiation Damage in Solids - It is of considerable importance to a fundamental study of irradiation effects in metals to be able to bombard the samples at low temperatures. Samples can be bombarded at temperatures as low as 17°K in a cryostat that has been installed in the ORNL Graphite Reactor. Seven pure metals and two alloys were bombarded at this temperature and the change in resistivity was studied as a function of the neutron flux. It was found in all samples that the increase in the resistivity is a linear function of the neutron flux; the rate of change appears to depend on the crystal structure. The resistivities of hexagonal cobalt, zinc, and body-centered-cubic iron increased about 10 times as fast as that of the face-centered noble metals, gold and copper. The face-centered-cubic metals, nickel and aluminum, had a rate of change about three times that of the noble metals. The resistivity of α brass with 14% zinc increased at the same rate as the copper. The annealing kinetics showed that about 30% of the resistivity change could be recovered by annealing at temperatures in the neighborhood of 40°K for copper, nickel, cobalt, aluminum, α brass, and Cu_3Au. No annealing was observed in this region for iron, zinc, or gold. In all the metals less than 20% of the increased resistivity remained after a room-temperature anneal.

Changes in the properties of Au-Cd alloys induced by quenching are being studied by measuring electrical resistivity and density. The effects are being interpreted in terms of the quenching-in of lattice vacancies. The resistivity measurements indicate that the energy of formation of the vacancies is 0.38 ev. From the magnitude of the resistivity increase, it is estimated that approximately 0.7 at % vacancies are quenched-in by a quench from 450°C. Furthermore, the shape of the relaxation curve from the quenched to the slow-cooled state shows a characteristic incubation time. The density is found to decrease upon quench. The energy of formation obtained from measurements of the magnitude of the density decrease versus quench temperature was found to be 0.28 ev. A calculation of the vacancy concentration corresponding to the density decrease yields essentially the same value as is obtained from resistivity measurements. (AEC Activity 5430)

PROGRAM 6000 - BIOLOGY AND MEDICINE

Internal Dose Studies - An analytical procedure for the determination of radioactive strontium and barium in large volumes of urine was developed and is presently used in routine analysis at ORNL. This method is based on the preferential chelation of calcium over strontium, using versene. The separation of Sr and Ba isotopes from the calcium and magnesium is done on an ion exchange resin column. The procedure is specific for strontium and barium. Details of the method are reported in ORNL-1932. (AEC Activity 6240)

Sanitary Engineering Research--Chemistry and Soils Engineering - The methods developed for the radiochemical analysis of fission products adsorbed on soil (ORNL-1867) were used to identify the radionuclides absorbed on river mud. Duplicate analyses of twenty samples gave activities of approximately 8×10^{-8} curie/gm of dried mud for White Oak Lake, 5×10^{-11} curie/gm of dried mud for the Clinch River below the mouth of White Oak Creek, and less than 2×10^{-11} curie/gm of dried mud for the Tennessee River below the mouth of the Clinch River. The fission products found were mainly cesium and cerium. Following the development of a procedure for its analysis, radioactive cobalt was also found.

Recent cooperative studies of the Corps of Engineers (ERDL) at Oak Ridge National Laboratory included a preliminary evaluation of the flotation process as a possible means for water decontamination. This process as applied to water treatment includes dosage with a dispersing agent (cetylpridinium chloride), aeration, and decanting the froth by overflow. Results to date indicate that the percent removal by flotation is about the same as can be attained by coagulation processes (60-90%), depending upon the particular radioisotope present. (AEC Activity 6440)

Sanitary Engineering Research--Airborne Radioactivity Studies - The efficiency of sand beds as entrainment separators (aerosol filters) was determined for 8-12 mesh, 12-16 mesh, 16-20 mesh, and 20-30 mesh Pennsylvania quartz sand. For aerosol particle sizes in the range of $0.20 < r < 0.86$ micron radius, and for superficial linear flow rates of $0.05 < V < 2.0$ cm/sec, the results were correlated to within about $\pm$ 25% by the following equation:

$$1000\ KD_g = (1-\alpha) \left(1 + \frac{.087}{r/R}\right) \left(1.5V^{-0.50} + 12r^3 V^{-0.90}\right)$$

The symbol K is the natural log of the ratio of the effluent aerosol concentration to the influent concentration, divided by the height of the column in cm. D_g is the average diameter of the sand granule in each fraction (in cm), and α is the void fraction in the sand column, dimensionless. Over the range for which the equation was fitted, the aerosol particle size for maximum penetration is independent of sand granule size and varies montonically from 0.3 micron radius at V = 0.0545 cm/sec to 0.45 micron radius at V = 2.18 cm/sec. (AEC Activity 6440)

Health Physics Education, Training and Consultation - The 20 AEC Fellows completed their training in applied health physics during this period. Nine were granted and have accepted a 6-month extension of the Fellowship to enable them to complete the research requirements for the master's degree; five will do their research at the Oak Ridge National Laboratory, four at Vanderbilt University. Three are anticipating an early call to military service and the remainder have accepted positions in the health physics field. The demand for trained health physicists has been extremely high this year. (AEC Activity 6690)

RADIOISOTOPE SALES AND COSTS

Type of Transaction	July 1955	FY 1956 to Date
Domestic Sales	$ 99,286	$ 99,286
Foreign Sales	2,648	2,648
Project-Cash Sales	2,259	2,259
Project-Transfer	63	63
Technical Cooperation Program Credits	410	410
Plant Credits	1,198	1,198
AEC Credits	4,548	4,548
Total Radioisotope Income	$110,412	$110,412
Total Radioisotope Costs	60,926	60,926
Total Radioisotope Shipments	968	968
Boron and Helium		
Income	541	541
Costs	0	0
Shipments	3	3

GROSS OPERATING COSTS

	Cost for July	FY 1956 Cost to Date
Programmatic Operating Cost - Net	$ 2,816,482	$ 2,816,482
Plant and Equipment Cost	271,097	271,097
Program "H"	39,563	39,563
Work for Other Parties - Transfers	13,430	13,430
Inventory Changes	50,104*	50,104*
Reimbursable Work for Other Parties	151,197	151,197
Deferred Charges	6,023*	6,023*
Total Laboratory Cost - Net	$ 3,235,642	$ 3,235,642
Estimated Cost for Net Month - Net	$ 3,650,000	$ 6,885,642

*Credit

[redacted]

PERSONNEL SUMMARY

	Number of Employees August, 1955	New Hires August	Terminations August
Administration	63	3	2
Operations*	122	0	1
Engineering, Shops and Mechanical	766	13	5
Laboratory and Research	2034	38	92
Protection	142	2	0
Service	377	2	3
	3504	58	103

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

A total of 862 Laboratory personnel are located in the Y-12 Area.

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Reports in this series issued during the past year:

August 1954	ORNL-1781
September 1954	ORNL-1793
October 1954	ORNL-1805
November 1954	ORNL-1824
December 1954	ORNL-1838
January 1955	ORNL-1849
February 1955	ORNL-1867
March 1955	ORNL-1878
April 1955	ORNL-1886
May 1955	ORNL-1905
June 1955	ORNL-1920
July 1955	ORNL-1936

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