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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

JANUARY 1956

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# OAK RIDGE NATIONAL LABORATORY

# STATUS AND PROGRESS REPORT

January, 1956

F. T. Howard

and

W. H Sullivan

Date Issued: FEB 7 1956

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January, 1956

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

January, 1956

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

## PROGRAM 2000 - SPECIAL NUCLEAR MATERIALS

Waste Metal Recovery - The processing of accumulated ORNL Graphite Reactor slugs was completed; a total of 60 tons of uranium and 7.1 kg of plutonium were recovered. - - - - The chemical processing of BNL uranium slugs was started. - - - - The central sections (thirds) of four NRX rods were processed to provide high-burnup plutonium for the Special Separations program. The dissolved rods were processed through two cycles of solvent extraction; a Purex-type chemical flowsheet was used. About 143 grams of plutonium was separated from 162 lb of uranium; 18 grams of plutonium remained in process equipment and will be removed in subsequent plant operations. (AEC Activity 2450)

Metallex Process - The Metallex process is being developed for the preparation of thorium metal by the sodium amalgam reduction of $ThCl_4$. In studies on dry reduction at 100°-130°C with high-shear agitation, the reaction products separated into a liquid (75%) and a frothy semi-solid (25%) phase, the latter containing 90-99% of the unreduced thorium chloride, 80-90% of the quasi-amalgam (reduced thorium) product, and essentially 100% of the by-product NaCl. The components could not be separated by filtration of centrifugation. More than 98% of the chloride salts was removed from the pressed, unwashed quasi-amalgam by vacuum distillation at 100°C, but the residual sintered product contained 10-30% $ThO_2$ and was too porous for satisfactory metallurgical processing. The chlorides were washed from the amalgam with water; however, thorium chloride thus recovered would have to be converted to thorium oxalate and rechlorinated before it could be recycled.

Thorough mechanical agitation of the quasi-amalgams with de-aerated water or 1-3 N aqueous HCl and rigid avoidance of contact with dissolved or atmospheric oxygen during washing, storage, and pressing produced thorium metal containing only 0.27-0.3% acid-insoluble ($ThO_2$) residue. Vacuum drying of the washed amalgams and storage under argon also produced metal with less than 0.5% $ThO_2$. Losses of reduced thorium in the washing step were less than 0.2% when de-areated water was used and less than 0.3% when 1-3 N de-aerated HCl was used. Losses were increased to as high as 2% when 6-12 N HCl, aerated water, methanol, or acetone were used. The equilibrium time for the reaction at 130°C was about 7 min. Dry reduction at 200°-300°C yielded products four times as reactive to atmospheric oxyben during the washing, storage, and cold-pressing steps as those reduced at 100°-130°C. (AEC Activity 2704)



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Power Reactor Fuel Reprocessing - The Hermex process was developed for processing irradiated uranium fuel elements. The uranium is dissolved in boiling mercury (350°C), the dilute uranium amalgam is concentrated by vacuum filtration at 25°C to a quasi-amalgam which is washed with dilute acid or water, the mercury is volatilized, and the uranium sponge is melted to dense metal. In two preliminary experiments with uranium from an irradiated, 3-year-decayed ORNL Graphite Reactor slug, approximately 86% of the fission products were removed in an oxide slag during the mercury dissolution, and almost all the remaining activity was removed in the acid washing of the quasi-amalgam. The uranium product contained twice the gross $\gamma$ activity and less than the gross $\beta$ activity of natural uranium. Gross $\gamma$ decontamination factors were 100-200 and gross $\beta$, 400-500. - - - - Aluminum jackets were readily removed from cylindrical fuel elements by rolling. Jacketed fuel in other shapes had to be sheared to expose the core to chemical attack.

In studies on dissolution of fuel elements containing passive components, uranium was readily leached from zirconium and niobium alloys that had been oxidized in air. Uranium losses to the insoluble residue decreased regularly as the uranium content increased. With 1.5% uranium--2% tin--96.5% zirconium alloys the loss was 30%; with 15% zirconium or niobium alloys losses were 0.1% and 2%, respectively. Oxidation rates with 85-98% uranium alloys were 6-7 mg/min-cm$^2$ at 500°C and were lower at both 350° and 700°C.

Four percent zirconium--95% uranium alloy dissolved in 2 M HCl--5 M $HNO_3$ at a rate of 100 mg/min-cm$^2$. An insoluble residue, in which the Zr/U atom ratio was about 3/1, contained 1.8% of the total uranium. Zircaloy-2 dissolved readily in 3 M HCl on anodic electrolysis with a current density of 0.27 amp/cm$^2$. At lower current densities, black insoluble zirconium metal separated from the massive Zircaloy-2.

Hydrochloric acid was removed from HCl-$HNO_3$ solutions of nichrome and stainless steel by distillation with excess nitric acid. At acid concentrations over 5.3 M, the HCl was destroyed by oxidation and removed as NOCl and $Cl_2$. At lower acid concentrations aqueous HCl was recoverable in the distillate. No chloride was detectable in the residue.

In a solvent extraction run on a nitric acid solution of irradiated 10% uranium--90% molybdenum alloy, the uranium extraction loss was 0.01% in four stages. After five stripping stages the uranium loss to the solvent stream was 0.03%. Gross $\beta$ and $\gamma$ decontamination factors were 7800 and 3400, respectively. The feed, 3 M in $HNO_3$, contained 5.79 mg of uranium and 0.71 g of molybdenum. In the solvent extraction processing of a nitric acid solution of an STR fuel element with five extraction and five stripping stages, the uranium losses were 0.01% in each step. (AEC Activity 2924)

## PROGRAM 3000 - WEAPONS

RaLa Production - A run was completed and 16,300 curies of product was shipped on January 30, 1956. (AEC Activity 3702)

## HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Test - The installation of the fuel and blanket low-pressure piping is complete except for the electrical conduits, the valves, and the air lines to the valves. The HRT construction effort is now centered on the high-pressure circulating fuel and blanket systems. Modification of the joint between the Zircaloy-2 core tank and the stainless steel portion of the pressure vessel was completed; the flanges were machined to accommodate a laminated titanium cylinder fitting in grooves with flat gold foil gaskets at the bottom of each groove. The assembly was cleaned and installed in position within the completed thermal shield in the reactor bay of the shield tank. Installation of blast shields on both heat exchangers was completed at the Nooter plant in St. Louis; one exchanger was received at ORNL and was operated as a part of a 400-gpm circulation loop at elevated temperature for final clean-up; it was then installed in the blanket-system side of the reactor shield tank. The other exchanger is en route to the Laboratory. One of the reactor circulating pumps was installed; the interconnecting prefabricated high-pressure pipe is being welded into the blanket circulating loop. The refrigeration system for the cold traps and the freeze-valves was installed in the control room area. The overall construction program is within approximately one working month of the schedule. (AEC Activity 4103.4)

HRT Chemical Pilot Plant - The heating and ventilating system for the office and control room was completed. The walls and ceilings of cells A and D were painted with a white waterproof paint and the lighting for these cells is now being installed. The sleeves, which penetrate the concrete shielding wall and carrying the service piping from the building supply through cells A and D to cell C, were prefabricated in the shop and installed.

The shop fabrication of equipment components is approximately 50% complete. The layout design for process equipment is in a final stage; the overall equipment design is an estimated 85% complete. (AEC Activity 4103.1)

HR Physical Chemistry--Aqueous Reactor Systems - Measurements of the solubility of $Li_2CO_3$ in water disclosed that the lithium ion concentration is proportional to the one-fourth power of the carbon dioxide pressure, for the temperature range from 40° to 290°C and a range of $CO_2$ pressures from 200 to 2500 psi. This indicates that the principal ionic species in solution are the lithium and the bicarbonate ions. The solubility of $UO_3$ in such solutions may be accounted for by assuming the existence of complex bicarbonate ions such as $UO_2(HCO_3)_2(CO_3)_2^{-3}$ and $UO_2(HCO_3)(CO_3)_2^{-4}$.

The 100°C isotherm for the base-saturated region of the $CuO$-$UO_3$-$SO_3$-$H_2O$ system was completed. All five solid phases were identified and the liquidus surface completely defined.

A study of the physical and chemical properties of $ThO_2$ sols was initiated. A particular sol, 2.5 M in thorium and stabilized with $Th(NO_3)_4$, was characterized by measurement of its pH, density, and viscosity and by observations based on x-ray analysis and electron micrographs. The thermal

stability of the sol decreased upon addition of more $Th(NO_3)_4$ solution, but in no case was it sufficient to make the sol of interest as a reactor blanket.

The determination of isotherms from 260° to 360°C for the adsorption of water on $ThO_2$ disclosed no evidence for the existence of a stable hydrate. (AEC Activity 4103.1)

Reactor Analysis - A study of fuel costs was made for power-only reactor systems fueled with $UO_2SO_4$-$Li_2SO_4$-$D_2O$ solutions. One-region reactors, operating at 330°C, producing 1000 Mw thermal energy, and delivering 300 Mw of electricity, were considered. Fuel costs were obtained for both a 12% inventory charge with a $40/lb cost for $D_2O$ and a 4% inventory charge with a $28/lb cost for $D_2O$. The minimum asymtotic fuel cost for the higher charge was 2.5 mills/kwh, which is about the same as found for $UO_3$-$PuO_2$-$D_2O$ slurry reactors operating at 280°C. With the lower charge, the fuel cost was reduced to 1.7 mills/kwh. The optimum reactor diameter was about 14 ft for the higher charge and about 17 ft for the lower charge. For either charge, the optimum uranium concentration was about 200 gm/liter and the poison cross section about 5% of the fission cross section.

Two-group nuclear calculations were completed for two-region, cylindrical thorium breeder reactors, over a range of parameter values. These results are being used in an economic evaluation of cylindrical reactor systems.

Nuclear calculations were performed, and are continuing, for a series of $D_2O$-moderated, thorium breeder reactors, using the multi-group, multi-region method. For all cases the inside diameter of the pressure vessel was assumed to be 6 ft. The results were compared with those obtained by the two-group, two-region method. The breeding ratios and critical concentrations obtained by the two methods were in good agreement down to core diameters of about 2.5 ft.

The reactivity change associated with settling of the $ThO_2$ slurry was calculated for the TBR. For a blanket initially containing 500 gm of thorium per liter, an 8.7% increase in reactivity was obtained if the slurry settled to a uniform concentration of 1000 gm of thorium per liter. Experimental data on settling rates indicate that no reactor safety problem would be involved. However, appreciable changes in operating conditions would accompany slurry settling. (AEC Activity 4103.1)

Reactor Instrumentation - Costs for materials ordered now total $184,000; $75,000 of this is for the reactor core and blanket system valves, and $29,000 is for steam and auxiliary system valves. The instrument application tabulation, which relates the flow sheet to the specification sheets and reactor installation drawings, was issued.

Two prototype pressurizer level controllers, incorporating different damping mechanisms, exhibited stability sufficient for control of the let-

down valve. The material for the float suspension spring is yet to be specified. Elgiloy spring alloy showed excellent corrosion resistance without a protective plating and will be tested as soon as suitable quantities are received.

Delivery and testing of the HRT low-pressure valves is 90% complete. Exceptionally low leak rates were obtained after hand lapping of the seating surfaces.

Sixty percent of the high-pressure system valves is now on hand with complete delivery scheduled for February 1. A valve identical to that specified for the HRT was installed on the fuel-system mockup where it is now in operation.

A prototype model of the dump valve operator was cycled 20,000 times without failure, and a small valve operator (let-down, pressurizer-bleed, etc.) was cycled 60,000 times without failure.

The valve trim material testing program, utilizing the valve test loop, is under way with eight trim material combinations tested to date. Best performance was obtained with a set of trim fabricated from titanium alloy TI-130A. After the possible materials have been screened, trim geometrics will be changed in an effort to establish the best dump valve trim configuration. (AEC Activity 4103.1)

HR Design - The following items in design of the HRT were completed. Instrument cubicle piping; oxygen metering system; electrical and thermocouple conduit drawings; air lines to instruments, valves, and weigh cells; waste evaporator and associated piping; pulsafeeder drive unit installation; and pressurizer redesign.

Approximately 95% of the working drawings for construction of the reactor are complete. Some minor design revisions were made throughout the system as construction progressed, and a major redesign of the pressurizer was found necessary. The new design boils condensate instead of uranyl sulfate solution to obtain the pressure system. The redesigned pressurizer was installed in the mockup loop and is running smoothly. A contract was entered into with Arthur D. Little, Inc., for the process design of a gas pressurization system for the HRT. Their proposal is based on the use of oxygen, stored at about 3000 psi, as the pressurizing medium. Excess oxygen is removed by burning with hydrogen and concensing the water prior to entry of the off-gases into the charcoal beds. (AEC Activity 4103.1)

HR Metallurgy - A metallographic technique (anodizing) was developed by which the hydrides in zirconium and Zircaloy-2 may be located and identified. With this technique, it was shown that the hydride forms preferentially in the grain boundaries of the alloys but within the grains in crystal bar material.

In an effort to establish the most desirable fabrication procedure for zirconium alloys, an extensive heat treating and metallographic study is being made. It was determined that a fine-grained, randomly oriented, equiaxed, alpha structure can be obtained by beta quenching, cold rolling, and alpha annealing. Other treatments resulted in either a preferred orientation or large grains.

No systematic variations in the tensile properties of Zircaloy-2 were found in samples aged up to 1585 hr at 250°C.

Successful Heliarc welds were made in titanium by the use of three different procedures, (1) dry box welding; (2) protective trailers; and (3) air welding. Two loops were fabricated with the welds made in air; only the torch gas and internal purging gas were used for protection. These two loops were fabricated in different shops, but in both cases the welds appeared to be of high quality. (AEC Activity 4103.1)

In-Pile Autoclave Tests - A rocking bomb test in the MTR to determine the effect of reactor radiation alone on the corrosion of Zircaloy-2 by uranyl sulfate solution was completed. The solution employed was 0.04 m in $UO_2SO_4$ (0.03% $U^{235}$) and 0.02 m in $H_2SO_4$. No copper was added. The enrichment was such that the contribution of fission fragments to the total intensity of radiation was less than 0.02 watt/ml. The estimated average power density in the solution due to the absorption of fast neutrons and gamma ray energy was 8 w/ml (4 w/ml from neutrons and 4 w/ml from gamma rays). The exposure to radiation was for a period of 50 hr at the test temperature of 280°C. The average corrosion rate during this time as indicated by oxygen consumption data was 11 mil/yr. This rate is about the same as that observed in the LITR experiment Z-12 in which the fission power density in solution was about 4 w/ml but in which the neutron and gamma ray intensities were relatively small. The other test conditions for Z-12, with the exception that the solution was 0.05 m in $CuSO_4$, were the same as those described for this MTR experiment.

A fairly large accelerating effect on the corrosion of titanium 75A was observed in a test at the LITR for which corrosion specimen weight data have recently become available. Two pin corrosion specimens of each of three metals, titanium 75A, Zircaloy-2, and platinum were positioned in a rack in a Zircaloy-2 autoclave. The autoclave was charged with a solution 0.17 m in $UO_2SO_4$, 0.04 m in $H_2SO_4$, and 0.04 m in $CuSO_4$, and exposed in hole HB-5 of the LITR for approximately 102 hr at an estimated temperature of 280°C. The estimated fission power density during exposure was 17 w/ml. Corrosion rate values calculated from weight data for the various materials were 15.6 mil/yr for the Zircaloy-2, 5.2 mil/yr for the titanium 75A, and 0.4 mil/yr for the platinum. This value for titanium represents an appreciably greater rate of attack than the 1.5 mil/yr determined in a previous experiment (H-76) in which the temperature was only 250°C and the power density was lower. These results indicate that the radiation corrosion of Ti-75A increases with increasing power density and/or system temperature. (AEC Activity 4103.1)

In-Pile Loop Tests - The operation of loop L-4-11 was terminated after 1128 hr of in-pile circulation. A total of 2175 Mw-hr of LITR energy was accumulated during the operation. Inspection of the loop for corrosion is now in progress. Loop L-4-12 was installed in the LITR on January 24. The core of this loop and the circulating lines adjacent to the core and connecting with it are of titanium. The remainder of the loop is of stainless steel, as in previous loops. The core and in-line specimen holders are also of titanium. In most other respects, the design of this loop experiment is similar to that of previous experiments. (AEC Activity 4103.1)

Dynamic Loop Tests - Continued testing with uranyl sulfate solutions, containing 300 to 700 g U/liter plus an equimolar concentration of lithium sulfate, confirmed the previous finding that the presence of lithium sulfate causes a substantial reduction in the corrosion of stainless steel. One loop was operated with a solution containing 3.8 m uranyl sulfate and 3.8 m lithium sulfate at 350°C. Corrosion damage to stainless steel was low at all flow rates up to 70 ft/sec. The corrosion damage to titanium and zirconium was practically undetectable. Further experimentation failed to confirm the abnormally low vapor pressure previously reported for such systems. Recent experiments showed that the observed lowering of vapor pressure is approximately that expected from Raoult's law.

The corrosion resistance of a number of alloys was tested at 250°C in a system containing 0.03 m $UO_3$ and 0.17 m $Li_2CO_3$ with a partial pressure of 400 to 600 psi $CO_2$. Austenitic and ferritic stainless steels showed very high corrosion resistance up to 40 to 50 ft/sec, the highest flow rates investigated to date. Both carbon steel and nickel, which are very rapidly corroded by uranyl sulfate solutions, were quite resistant to attack by the carbonate solution. During short-term tests (200 to 500 hr) average corrosion rates of about 3 mil/yr for carbon steel and somewhat higher for nickel were observed. In both cases the rates appeared to be decreasing with time; corrosion rates in long-term tests would probably be considerably less than the reported values. (AEC Activity 4103.1)

Dynamic Slurry Tests - Two additional short runs to study corrosion by circulating thorium oxide slurries were completed in the 100A circulating loop at 300°C. Caking experienced in one run was relieved in the next by using more highly purified thorium oxide. Some plugs of thorium oxide were observed in this run, but operation was in general smooth. A correlation of corrosion data on pin specimens of type-347 stainless steel indicated a possible dependence on the square of slurry velocity and on the first power of slurry concentration. With this correlation, the comparative corrosion rates of pins of a number of materials at a slurry velocity of 20 ft/sec and a slurry concentration of 1000 g Th/kg $H_2O$, the following rates (in mil/yr) were obtained: platinum, 2; gold, 2; Zircaloy-2, 3; titanium and alloys, 4; type-347 and other stainless steels, 7; nickel, 12; and Stellites, 14-40.

The completion of corrosion runs with circulating thorium oxide slurries in toroids at 250°C and 1000 g Th/kg $H_2O$ permitted the comparison of attack rates at velocities of 5, 15, and 26 ft/sec by slurries calcined at 650,

800, 1000, 1200, and 1600°C. Generally, no particular effect of calcination temperature was observed on type-347 stainless steel, titanium-75A or Zircaloy-2. Attack rates increased with velocity, apparently with a dependence on the 3/2 power of velocity. (AEC Activity 4103.1)

HR Math and Computation - Three Oracle codes were completed: one evaluates the Bessel functions $I_o$, $I_1$, $J_o$, $J_1$, $K_o$, and $K_1$; another calculates the Fermi age of mixtures by using the energy distribution curve for fission neutrons; and the third calculates the time behavior of a batch-operated, regenerative reactor, and evaluates the economics of the associated system. (AEC Activity 4103.1)

## GENERAL REACTOR RESEARCH

Basic Reactor and Shielding Research - During the past month approximately 90 ORSORT students assembled BSR fuel elements in the BSR grid plate to determine the critical mass of a "swimming pool" reactor. The students worked in groups averaging about seven men each and were rotated so that each man gained a moderate amount of experience with each phase of the experiment. The arrangement of the fuel elements in the lattice was left to the students' discretion, with members of the BSF staff acting as instructors and supervisors to insure that all operations were conducted in a safe manner.

The attenuation by water of both gamma rays and thermal neutrons from a completely water-reflected BSR lattice (Loading 33) was published previously (ORNL-1891); however, the shape of the thermal-neutron curve in the region from the face of the reactor to about 10 cm away was not determined. This region has now been mapped with gold foils placed at 1-cm intervals. Complete gamma-ray and thermal-neutron attenuation curves will be published in the form of a large graph, when all of these results become available. (AEC Activity 4570)

Reactor Theory - Previously reported calculations of the effective resonance integrals of $U^{238}$ and $Th^{232}$ as functions of scattering cross section per absorbing nucleus (ORNL-1968, p. 12) were revised to include (1) the Doppler broadening of nuclear resonances and (2) the contributions of unresolved resonances. Agreement between theory and experiment was excellent for uranium; for thorium agreement was good except for the oxide where a discrepancy was noted. - - - - The temperature coefficients of the resonance integrals of pure uranium and thorium metals were calculated and found to be approximately 1.0% and 1.5% per 100°C, respectively.

An investigation of surface absorption in fuel lumps is being continued. Based on Wigner's theory, limits can be found for the effective mass absorption coefficient, $\mu$, which are independent of the details of resonance structure and which differ by about 35%. The values of $\mu$ derived from the activation experiments of Creutz et al. (J. Appl. Physics, 26, 271, 1955) and of

Arfken et al. (ORNL-758) are included between the theoretical limits for uranium metal and oxide. The calculations include the effects of Doppler broadening of resonance lines. (AEC Activity 4570)

School of Reactor Technology - The first semester of the 1955-56 session ended on January 13. Final exams for the semester were conducted the week of January 16. Applications for the 1956-57 session are now being accepted. (AEC Activity 4704)

## PROGRAM 5000 - PHYSICAL RESEARCH

Oak Ridge Research Reactor (ORR) - Construction of the reactor building is proceeding at a much slower rate than had been anticipated. Because of strikes, unexpected quantities of rock, and added excavation required for footings, contract extensions were granted. The scheduled completion date is now August 6, 1956. Structural steel is being erected, and excavation of pipe trenches connecting the reactor building and the pump house is nearly complete.

A contract was let to the O. G. Kelly Company, Boston, for fabrication of the aluminum reactor tank; shop drawings are now being reviewed. The reactor grid plate is being fabricated by an outside vendor, and the reactor mechanical controls assembly is being fabricated locally. Drawings for the reactor control system have been completed and are scheduled to go out to vendors for bids on February 3, 1956.

### ISOTOPE PRODUCTION

Radioisotope Production - The new radioisotope catalog is now being distributed; the present mailing list contains over 5000 names. - - - - The largest amount of $Kr^{85}$ handled so far (500 curies) was put through the purification equipment; practically all of it has been sold. (AEC Activity 5111)

Radioisotope Process Development - Two shipments of waste, containing ~5000 curies of fission products each, were shipped from the ICPP to ORNL in the 15-ton shielded transfer tank. No difficulty was experienced in filling, unloading, or transporting the material. The waste is being used for cesium production and process development studies.

Studies have shown that remove control welding of aluminum, nickel, or stainless steel, for use in sealing packages of 5000 - 10,000 curies of dried, compressed fission product chemicals, is feasible. A test machine is now being designed for this purpose.

The highly alkaline waste stream from the fission product plant will contain sodium aluminate and small amounts of $Sr^{90}$ and rare earths when the plant is operating on Redox waste as feed material. A procedure was developed for precipitating $Al(OH)_3$ by lowering the pH with $CO_2$ gas injection and passing the filtrate through an IRC-50 ion exchange resin which removes traces of $Sr^{90}$ from highly alkaline media. The filtrate can then be discharged to the river and the aluminum returned to the alum crystallizers. (AEC Activity 5112)

PHYSICS

Recoil Spectrometry - The charge spectrum of the product atoms of the decay of 12-day $Xe^{131m}$ was measured. This is an example of a process in which there is no nuclear charge change; what happens is that internal conversion of the 163-kev gamma ray creates a vacancy in the inner electron shells of the atom, and the filling of this vacancy starts an Auger cascade that ultimately results in throwing off several electrons, so that multiply-charged atoms are produced. The $Xe^{131}$ charge spectrum is as follows, where the intensity figures are given in terms of percent of decays:

| Charge | Intensity | Charge | Intensity |
|---|---|---|---|
| 1 | 0.62 | 14 | 1.05 |
| 2 | 0.97 | 15 | 0.55 |
| 3 | 1.54 | 16 | 0.24 |
| 4 | 4.21 | 17 | 0.094 |
| 5 | 5.38 | 18 | 0.034 |
| 6 | 10.41 | 19 | 0.021 |
| 7 | 15.77 | 20 | 0.013 |
| 8 | 20.99 | 21 | 0.013 |
| 9 | 15.74 | 22 | 0.013 |
| 10 | 11.30 | 23 | 0.004 |
| 11 | 6.25 | 24 | 0.013 |
| 12 | 3.00 | 25 | 0.000 |
| 13 | 1.76 | | |

The intensities of the very weak charge states above 20 are uncertain. The mean charge is 8.05. The most probable charge state (8) corresponds to the removal of all electrons in the outer shell.

The charge spectrum of 9.4-year $Kr^{85}$ is also under investigation. This is almost a pure beta emitter; the primary ionization results from the change of the nuclear charge by one unit. If the ionization takes place in an inner shell, Auger cascades can develop. The charge spectrum out to 10 was measured; there was no evidence of ions of charge 11. A comparison of the intensities of all charges above 1 with that of charge 1 shows that in 25% of the decays, some kind of ionizing event takes place. This is a striking result, because it is several times larger than would be suggested by present theory. There is no real conflict, however, because the shape of the charge spectrum indi-

cates that most of the electrons leave from the outer shells of the $Rb^{85}$, and the existing theory does not apply well outside of the L or M shells. Thus, the theory may be correct so far as it goes, but it misses what is by far the main effect in atoms as heavy as rubidium. (AEC Activity 5220)

Neutron Velocity Selector - A new fast chopper and the necessary electronic equipment are being designed to achieve an energy resolution of 0.01 microseconds per meter. The equipment will be installed at the new high flux research reactor which is scheduled to be operating early in 1957.

The old chopper and equipment at the LITR are being reactivated. The present flight path of 11.4 meters will be increased to 40 or 50 meters to improve the resolution. A new 256-channel time analyzer with magnetic core storage is being designed and is scheduled for delivery in July. (AEC Activity 5220)

Low Temperature, Nuclear, and Solid State Physics - The angular distributions of $\alpha$-particles emitted by aligned $Np^{237}$ nuclei were studied. The alignment was obtained by cooling a single crystal of $NpO_2Rb(NO_3)_3$ to temperatures near $1^oK$. The angular distribution was measured by rotating the crystal relative to a ZnS detector located within the cryostat, the light flashes being transmitted to a photomultiplier outside the cryostat. It was found that the detection efficiency of the ZnS scintillator near $1^oK$ is the same, within 1%, as at room temperature. The observed angular distribution may be fitted with the function

$$W(\vartheta,T) = 1 - \left(\frac{0.083}{T} + \frac{0.015}{T^2}\right) P_2(\cos\vartheta)$$

where $\vartheta$ is the angle of emission relative to the c-axis of the (hexagonal) crystal, and T is the absolute temperature in $^oK$. The coefficient of $P_2(\cos\vartheta)$ given above is proportional to the theoretical nuclear alignment expected in a "high" temperature approximation. These data are in excellent agreement with the measurements on $W(0^o,T)/W(90^o,T)$ made in another apparatus and reported here previously.

$U^{233}$ nuclei were also aligned in the isomorphous crystal $UO_2Rb(NO_3)_3$ in the same apparatus, and studies of the angular distributions $W(\vartheta,T)$ and the ratio $W(0^o,T)/W(90^o,T)$ were made over the same temperature range. The angular distribution is rather similar to that for $Np^{237}$; at the lowest temperature ($1.15^oK$) it can be approximately described by

$$W(\vartheta) = 1 - 0.05\, P_2(\cos\vartheta) + (0.01\ ?)\, P_4(\cos\vartheta).$$

The temperature dependence of the amplitude of the $P_2(\cos\vartheta)$ term appears, however, to show a trend toward saturation in contrast to the $Np^{237}$ case, where this amplitude was almost linear in 1/T over the range $300^oK$ - $1.2^oK$. Other differences between the $U^{233}$ experiments and those on $Np^{237}$ are (1) no magnetic hyperfine structure coupling is involved, thus the alignment is a "pure" Pound (Phys. Rev. 76, 1410, 1949) alignment; (2) there are at present no microwave data on the magnitude of the quadrupole coupling, but the present

result sets a lower limit of ~ 0.04 $cm^{-1}$ for this quantity; (3) the α-decay scheme in $U^{233}$ is much simpler (3 groups vs 9 groups in the $Np^{237}$ decay). (AEC Activity 5220)

High Voltage Program - The excitation of levels in the $Ru^{101}$ nucleus by Coulomb excitation was studied in some detail. From the γ-ray spectrum taken with a 3 x 3-in. NaI crystal spectrometer, it was possible to resolve γ-rays with energies of 131, 187, 303, 545, 720, and 820 kev. The yields of these γ-rays were studied as the incident proton energy was varied from 1.5 Mev to 3.0 Mev. Coincidence measurements were made at 3.0-Mev proton bombarding energy; two 3 x 3-in. NaI crystal spectrometers were mounted at 0 deg and 90 deg. A 1/4-in. thick lead shield was placed between the crystals to reduce spurious coincidences from Compton scattering. The coincidence measurements revealed several new γ-rays with rather weak intensities. It was found that the 131-kev γ-ray is in coincidence with γ-rays with energies of 187, 234, 293, and 495 kev. The 187-kev γ-ray is in coincidence with γ-rays with energies of 131, 234, 293, and 545 kev. In addition, the 720-kev γ-ray is in coincidence with a 125-kev γ-ray, and the 545-kev γ-ray is in coincidence with a 177-kev γ-ray. As a result of these measurements, a level scheme was deduced. From Coulomb excitation experiments, it is concluded that there are excited states in the $Ru^{101}$ nucleus at 131, 303, 318, 424, 545, 626, 720 and 840 kev.

The α-particle model for $C^{12}$ was re-examined. In addition to correlating the $0^+$, $2^+$, and $0^+$ states at 0, 4.43, and 7.65 Mev, respectively, two possible identifications are given for the 9.61-Mev level, $1^-$ or $2^+$. These levels completely determine the model. The main defect of the model is its prediction of a $3^-$ state, at 5.54 Mev, which has never been observed. The separation of the α-particles in $C^{12}$ is $3.75 \times 10^{-13}$ cm. (AEC Activity 5220)

## CHEMISTRY

Volatility Studies - The NaF absorption-desorption step for decontaminating $UF_6$ from fission product activity in the volatility process for recovering uranium from a fused fluoride solution of a fuel element resulted in a negligible uranium loss. In three successive process cycles with the two-bed NaF decontamination procedure, the total uranium loss on the first bed was 0.04% and on the second bed, less than 0.01%. Approximately the same losses were incurred in another case in which the NaF in the two beds was used in only one process cycle, thus indicating that the loss did not increase with repeated usage. Fluorine was used as the "sweep" gas during the desorption. However, use of a nitrogen-fluorine mixture appears practicable since, in one test with a 4/1 mixture of nitrogen and fluorine, the uranium remaining on the bed after desorption was only 0.08%. The vapor pressure of $UF_6$ in equilibrium with $UF_6$-NaF complex was determined to be less than 0.01 mm Hg at 100°C, but more than 760 mm Hg at 400°C. The heat of absorption of $UF_6$ on NaF at 100°C was shown to be approximately equal to the heat of condensation for $UF_6$, i.e., 11 kcal/mole. (AEC Activity 5310)

Chemical Engineering Research - A 3-in.-dia magnetic filter was satisfactorily demonstrated. The filter bed was a magnetizable powder held in place when the current to an electromagnet was turned on and discharged when the current was turned off. The metal powders used were stainless steel (types 302, 410, and 431), ferrosilicon, and Alnico. The type-431 stainless steel powder was found to be less corrosive in 6 M $HNO_3$. Tests with freshly precipitated barium sulfate demonstrated that a filter aid was required to obtain a clear filtrate.

Tests on the separation of immiscible liquids in a cyclone separator indicated that two cyclones with recycling between them will be required to obtain the required phase separation for solvent extraction application. If feasible, such a method of separation would decrease the phase contact time in solvent-extraction processes and therefore minimize radiation damage to the solvent. (AEC Activity 5310)

Feed Materials Processing - In studies on the Excer process for preparing $UF_4$ by electrolytic reduction of $UO_2(NO_3)_2$, an ion-exchange-membrane cell satisfactorily produced $UF_4 \cdot 3/4H_2O$ at a rate of 2.9 lb/hr. The cell had a falling-mercury cathode of 210 in.$^2$ area, and a lead anode; it operated at 95°-100°C with 8 volts and 1.3 amp/in.$^2$. The $UF_4 \cdot 3/4H_2O$ was dehydrated in a $N_2$ atmosphere at 350°-400°C for 2 hr to yield a non-oxidized, nonhydrolyzed $UF_4$ product containing less than 0.3% water. In air about 6% of the $UF_4$ was oxidized.

About 100 g of $UF_4$ that met almost all metallurgical processing purity specifications (exceptions: B, Na, Al, Ca) was prepared from Los Ochos ore leach pulp by ion exchange sorption of the uranium from unfiltered pulp and Excer reduction of the eluted uranium.

In the Fluorox process, $UF_4$, for eventual reduction to metal or oxidation to $UF_6$, is prepared from $UO_2(NO_3)_2$ by denitration to $UO_3$ followed by reduction with carbon (starch) and hydrofluorination. The conversion of $UO_3$ to $UF_4$ was satisfactorily demonstrated on a 30-lb/hr scale in moving bed reactors. This $UF_4$ was 90% converted to $UF_6$ and $UO_2F_2$ with oxygen on a 15-lb/hr scale. In laboratory studies, neither dry air nor oxygen at temperatures up to 600°C was able to remove completely residual carbon from the $UF_4$ that was to be reduced to metal. Above 400°C the $UF_4$ was oxidized to $UF_6$ and $UO_2F_2$. The amount of carbon removed in a 5-hr reaction was no more than that removed in 1 hr. The bulk of the carbon, which is easily removed by combustion, apparently is on the surface, and the remainder is occluded in the $UF_4$ particles. An attempt to eliminate carbon by reaction with steam in the presence of HF to form water gas resulted in pyrohydrolysis of the $UF_4$ with little or no carbon removal.

At 356°C, 1 mole of $UF_6$ was reduced to 3/4 mole of $UF_4$ and 1/4 mole of U metal by 4.0 M sodium amalgam in a Rushton contactor. No metal was recovered, probably because the finely divided metal was oxidized to $UO_2$ by leakage of air into the contactor through the gaskets, which charred at the high operating temperature. (AEC Activity 5310)

Hot Laboratory Research - In line with the recent discovery of the occurrence of a large percentage of the associated neptunium in a fairly pure state in the plutonium wastes of the ORNL Metal Recovery Purex Process, a similar investigation was made at the Savannah River Purex Plant. A favorable distribution, if found to occur in a production plant, would provide a permanent source of large quantites of this element. In order to obtain an approximate distribution, samples were examined from three points: (1) the second plutonium product (IIBP), (2) the plutonium ion exchange waste (IIBPW) including the uranium strip, and (3) the calcined depleted $UO_3$. The results show an entirely different distribution from that found at ORNL.

The plutonium product stream contained only 1% of the neptunium; therefore the wastes could be expected to contain only a fraction of this amount; it was actually found to be about 0.25%. On the other hand, of several samples of $UO_3$ analyzed, all contained large quantities of neptunium, ranging from 60% to 75% of the theoretical. This information confirms the belief that fluoridation residues at K-25 should prove a suitable source for the extraction of neptunium. (AEC Activity 5310)

Neptunium Studies - The Neptex solvent extraction (tributyl phosphate) process was used in the Thorex Pilot Plant to recover 2.3 g of $Np^{237}$ and 700 g of uranium from MTR fuel assemblies that had been irradiated to 50-100% burnup and had decayed 1 to 2 years. In one solvent-extraction cycle the neptunium and uranium were decontaminated from gross fission products by a factor of $2 \times 10^4$. The residue from the preparation of $UF_6$ is about 50% uranium and contains 0.4-34 g of neptunium per ton of ash. A feed suitable for the Neptex process was prepared by making a slurry of this ash with dibasic aluminum nitrate solution, dissolving in water, and adjusting to 1.8 M $Al(NO_3)_3$--1 M $HNO_3$. (AEC Activity 5310)

General Reactor Chemistry - The solubility of $Ag_2SO_4$ in water and in 0.1, 0.5 and 1.0 m $H_2SO_4$ was determined to above 250°C in order to evaluate the useful range of the Ag, $Ag_2SO_4$ electrode in acid solutions. The solubility was found to increase markedly with increasing temperature and $H_2SO_4$ concentration. Calculated solubilities in $H_2SO_4$ media, based on solubilities in water and on the decrease in the $HSO_4^-$ acid constant with temperature, agreed quite well with the observed values. (AEC Activity 5330)

Chemical Separation of Isotopes - A study of chemical methods for enriching the isotopes of oxygen was initiated because of increased interest in the use of $O^{17}$ in research. The single-stage separation factor between gaseous CO and the $Cu_2Cl_2 \cdot CO$ complex in acid solution was measured. The separation factor $[(CO^{16}/CO^{18})_{gas}/(CO^{16}/CO^{18})_{aq\ complex}]$ was 1.041 ± 0.003 (95% C.I.) at 28°C and a CO pressure of 68 cm. A factor of 1.019 ± 0.004 ($C^{13}$ concentrating in the aqueous phase) was determined for the fractionation of carbon isotopes in the above experiment. A separation factor of 1.013 ± 0.002 at 26°C was measured between $O_2$ gas at 75 cm pressure and the oxygen complex of solid cobalt di(salicylal)-ethylenediamine ("Salcomine"). In this experiment $O^{18}$ was enriched in the gaseous phase. The mixture stood for 48 hr with occasional shaking, and it is possible that isotopic equilibrium was not attained.

A nitrogen separation factor of 1.027 ($N^{15}$ concentrating in $NO_2$) was measured in a mass spectrometer between gaseous NO and $NO_2$ (using 15% $N^{15}$ produced in the "Nitrox" column). The isotopic abundance of the NO and $NO_2$ were measured in the same gas at equilibrium, with corrections for the $NO_2$ contribution to the NO peak. (AEC Activity 5340)

## OTHER PHYSICAL RESEARCH PROJECTS

Radiation Detector Development - A Monte Carlo calculation was initiated to determine the pulse-height spectra output from a single NaI(Tl) scintillation counter. All energy loss from the NaI(Tl) crystal due to Compton processes, secondary annihilation, and Bremsstrahlung radiation will be accounted for.

# PROGRAM 6000 - BIOLOGY AND MEDICINE

## BIOLOGY

Effects of Radiation on Paramecium - Previous work has shown that the amount of X-ray-induced mutation which can be detected in *Paramecium* can be decreased by several different post-irradiation treatments. Most of these procedures have proved difficult to use because the effects are small. Thus, a recent discovery that postirradiation treatment with streptomycin causes a 1.5-fold increase in mutation has made more-critical studies possible, even though the effect is an increase instead of a decrease. These studies show that the amount of mutation which is detected can be modified by post-treatments given before the next cell division occurs, but cannot be modified once a cell division has occurred. The simplest hypothesis is that some part of the mutation process is not complete until cell division has occurred, but other hypotheses cannot be entirely excluded as yet. (AEC Activity 6130)

Insect Cytology and Genetics - Embryos of the grasshopper *Chortophaga viridifasciata* were placed under anoxia or hypoxic conditions prior to and during irradiation. These conditions were obtained by allowing sodium hydrosulfite to combine chemically with the molecular oxygen dissolved in the culture medium. A concentration of $10^{-2}$ M sodium hydrosulfite removes sufficient oxygen to protect the neuroblasts almost completely from mitotic inhibition caused by 8 roentgens of X rays and to protect only partially against the mitotic inhibition caused by 32 roentgens of X rays. (AEC Activity 6130)

Biochemistry - Studies in this laboratory have established that a proteolytic enzyme, α-chymotrypsin, can hydrolyze a susceptible carbon-carbon bond (J. Am. Chem. Soc. 77, 4887, 1955). In an attempt to extend this observation to another system, trypsin was selected since it possessed the requisite specificity requirements; its simple substrates are bound to the enzyme on only one side of the susceptible bond (J. Biol. Chem., 179, 665, 1949). To simplify the synthetic approach to the β-keto ester, the hydrolysis of methyl-6-aminocaproate by trypsin was investigated. Contrary to a previous report, it proved to be readily susceptible to tryptic action. Methyl-5-aminovalerate was also slowly hydrolyzed by trypsin whereas methyl-4-aminobutyrate was completely resistant. The trypsin preparation used has no esterase activity, as evidenced by the failure to hydrolyze a series of fatty acid esters as well as the lack of inhibition of methyl-6-aminocaproate hydrolysis by sodium fluoride-treated trypsin. The desired keto ester, ethyl-3-keto-8-aminooctanoate, was synthesized from ε-carbobenzoxyaminocaproyl chloride and ethyl acetoacetate in the usual manner and subjected to tryptic action. The keto ester was slowly hydrolyzed in a manner similar to the α-chymotryptic hydrolysis of ethyl-5-(p-hydroxyphenyl)-3-ketovalerate to yield ε-aminocaproic acid. (AEC Activity 6130)

Pathology and Physiology - The previously reported damage of cells lining the crypts of the small bowel of the rat becomes evident within one hour after X irradiation; this provides a conveniently rapid and sensitive index of radiation injury. It was observed that chilling the small intestine immediately after irradiation, accomplished by applying cold compresses directly to the bowel, greatly retards the appearance of morphologic signs of radiation injury. The significance and mechanism of this effect are under study.

The induction of both myeloid and lymphoid leukemias in RF mice was greatly inhibited if the volume of tissue irradiated was reduced by partial shielding. Thus, when the lower extremities and pelvis were shielded by lead, the incidence of myeloid leukemia was only 8%, as compared to 23% in mice exposed over the entire body to the same dose (450 r); in nonirradiated controls the incidence was 1%. Similarly, the incidence of thymic lymphoid leukemia was 28% in the total-body-irradiated mice, 7% in the partially irradiated animals, and 2% in the controls. These experiments indicate that the induction of leukemia is not solely dependent upon the integral dose of radiation absorbed by the flood-forming tissues but that it may also be conditioned by the presence of nonirradiated cells.

It was reported previously that bone marrow from rats having erythrocytes of one antigenic type was successfully transplated into whole-body irradiated rats having erythrocytes of another antigenic type. Since then it has been found that erythrocytes of the foreign type can first be detected in the peripheral circulation eight days following injection of marrow, at which time they make up less than 1 or 2% of the total circulating erythrocytes. Their percentage increases thereafter, and after 35 days appears to remain the same. Some cases have now been followed for over 200 days. At the dose of radiation used (700 to 750 r), which is somewhat less than the $LD_{50}/30$ days

dose, there are more than 50% but less than 100% takes, and the final percentage of erythrocytes of the implanted type varies from 10-95% of the total erythrocyte population. (AEC Activity 6130)

Enzymology and Photosynthesis - The biosynthesis of thymine in Dowex-1-treated cell-free preparations of a luminous coccobacillus was very recently accomplished. A system containing pyridoxal phosphate, tetrahydrofolic acid, deoxycytidine, $C^{14}$-labeled formaldehyde, and the enzyme was employed. Thymine containing $C^{14}$ was isolated by Dowex-50 chromatography of the perchloric acid-hydrolyzed, acid-soluble portion of the incubate to which carrier thymine had been added. The isolated thymine was subjected to further purification and characterization by paper chromatography before counting. Studies are in progress to determine the mechanism of this $C_1$ fixation and the possible effects of antimetabolites and irradiation on this system.

A high-speed Becquerel-type phosphoroscope which gives up to 5000 flashes per second was constructed. Each flash lasts for one-fifth of the time between flashes. The intensity of the light from the sample is measured in the middle of the dark time by a photomultiplier. The early part of the decay curve for the delayed clight from Chlorella and from the chloroplasts of higher plants is being investigated with this device. (AEC Activity 6130)

General Physiology - An electroseparator for fractionating protein mixtures was developed and tested with serum proteins and rat liver soluble proteins. Preliminary studies indicate that gram quantities of serum albumin, for example, may be recovered in a few hours with the device.

The extent of transfer of $S^{35}$-azophenylsulfonate from beef serum albumin to normal liver protein of injected guinea pigs was determined. Preliminary findings indicate that one week after injection over 80% of the measured radioactivity in the total liver protein is bound to the injected protein. - - - - Serum proteins labeled with isotopic hydrogen in stable positions have been prepared for use in a study of the fate of unaltered injected proteins. (AEC Activity 6230)

Mammalian Radiation Recovery - Irradiated mice receiving rat bone marrow showed a progressive replacement of their entire complement of red blood cells by rat red blood cells. The poor survival observed in irradiated mice receiving foreign bone marrow cells is apparently due in part to a form of allergy or chronic anaphylaxis caused by the continued presence of the foreign cells; a few mice which survived the lethal irradiation exposure without treatment did not show the characteristic disorder. Tissue culture of bone marrow cells for four days demonstrated effectiveness in causing the survival of lethally-irradiated mice. Kineten (a new plant harmone) failed to cause recovery of lethally irradiated mice. (AEC Activity 6230)

## OPEN LITERATURE PUBLICATIONS


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Vander Sluis, K. L. and P. M. Griffin, "Nuclear Spin of Polonium-209", J. Opt. Soc. Am. 45, 1087 (1955).


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## STATUS OF CONSTRUCTION

During the month construction was completed on the high-radiation-level analytical facility, which was the final project in Program "H". The facility consisted of an 84 x 40 ft addition to the west end of the Chemical Processing Pilot Plant, Building No. 3019. A bank of shielded concrete cells extends lengthwise of the addition, with a storage cell of high-density concrete in the center of the bank. A non-browning lead glass viewing window and single manipulator are provided in this cell. Four analytical cells of ordinary concrete are on the north side of the storage cell and three, on the south. They have zinc bromide-filled viewing windows and each is equipped with two Model-8 Argonne-Type manipulators manufactured by The American Machine and Foundry Company. There is access to the rear of these cells for installation of equipment, maintenance, and repair by means of stacked-concrete block rollaway doors.

Samples in shielded carriers are moved to the storage cell on a dolly on a track below floor level; a hydraulic lift raises the carrier to floor level, and a two-ton hoist is used to remove the top of the carrier. The manipulator is used in transferring the samples to a storage rack which has the capacity for the storage of 1,500 samples. Two small conveyors within the cell bank, one serving the cells to the north, the other those to the south, provide means of transporting samples from the storage cell to the analytical cells.

Four hoods and two benches in front of the cell bank are provided for low-level analytical work. A hood located behind the cell bank is used for the decontamination of small carriers, tools, and equipment.

## VISITORS

Johnson, W. C., GAC Reactor Subcommittee
Mitchell, William, Office of General Council, Washington, D. C.
Murphree, E. V., GAC Reactor Subcommittee
Parker, F. C., Carbide and Carbon Chemicals Corp., So. Charleston
Rabi, I. I., Chairman, General Advisory Committee
Warner, J. C., GAC Reactor Subcommittee
Whitman, W. G., GAC Reactor Subcommittee
Wigner, E. P., GAC Reactor Subcommittee

FOREIGN VISITORS TO ORNL

Amelinckx, S., Ghent University, Antwerp, Belgium
Fradis-Inber, Ora, Tel-Aviv, Israel
Gibrat, Robert, Chairman, French Assoc. of Elec. Engrs., Paris, France
Henry, John R., Atomic Weapons Res. Estab., Basingstock, England
Langbein, F. A., Ministry of Works, New Zealand
Poole, M. J., AERE, Harwell, England

## RADIOISOTOPE SALES AND COSTS

| Type of Transaction | December 1955 | FY 1956 to Date |
|---|---|---|
| Domestic Sales | $156,313 | $707,259 |
| Foreign Sales | 5,090 | 48,057 |
| Project-Cash Sales | 2,312 | 23,186 |
| Project-Transfer | 785 | 5,678 |
| Technical Cooperation Program Credits | -0- | 640 |
| Plant Credits | 386 | 9,123 |
| AEC Credits | 18,368 | 74,347 |
| Total Radioisotope Income | $183,254 | $868,290 |
| Total Radioisotope Costs | $ 79,716 | $497,494 |
| Total Radioisotope Shipments | 1,078 | 6,327 |
| Boron and Helium | | |
| Income | $3,829 | $20,960 |
| Costs | 1,320 | 6,143 |
| Shipments | 9 | 43 |

## GROSS OPERATING COSTS

| | Cost for December | FY 1956 Cost to Date |
|---|---|---|
| Programmatic Operating Cost - Net | $3,226,522 | $18,737,692 |
| Plant and Equipment Cost | 315,366 | 1,780,492 |
| Program "H" | 4,661 | 92,568 |
| Work for Other Parties - Transfers | 792 | 79,235 |
| Inventory Changes | 26,838 | 56,246 |
| Reimbursable Work for Other Parties | 225,332 | 1,250,355 |
| Deferred Charges | 30,856 | 14,575* |
| Total Laboratory Cost - Net | $3,830,367 | $21,982,013 |
| Estimated Cost for Net Month - Net | $4,150,000 | $26,132,013 |

*Credit

## PERSONNEL SUMMARY

| | Number of Employees January, 1956 | New Hires January | Terminations January |
|---|---|---|---|
| Administration | 60 | 0 | 2 |
| Operations* | 127 | 2 | 0 |
| Engineering, Shops, and Mechanical | 796 | 12 | 3 |
| Laboratory and Research | 2005 | 30 | 14 |
| Protection | 131 | 0 | 0 |
| Service | 377 | 4 | 1 |
| | 3496 | 48 | 20 |

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

A total of 845 Laboratory personnel are located in the Y-12 Area.

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Reports in this series issued during the past year:

| | |
|---|---|
| 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 |
| August 1955 | ORNL-1968 |
| September 1955 | ORNL-1980 |
| October 1955 | ORNL-1995 |
| November 1955 | ORNL-2016 |
| December 1955 | ORNL-2032 |