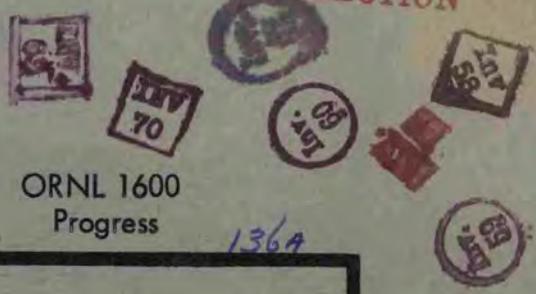


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OAK RIDGE NATIONAL LABORATORY
STATUS AND PROGRESS REPORT

JULY 1953

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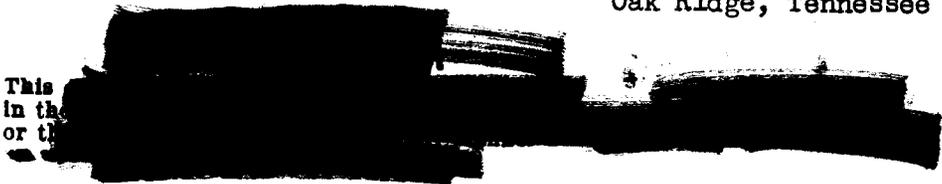
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STATUS AND PROGRESS REPORT

July, 1953

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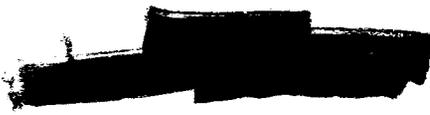


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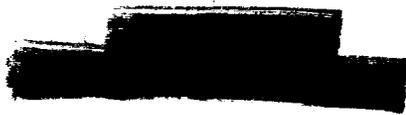




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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

July, 1953

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

PROGRAM 2000 - SOURCE AND FISSIONABLE MATERIALS

Waste Metal Recovery Plant - During June and July, 19,000 kilograms of uranium were recovered from material stored in the ORNL waste tanks. Plutonium was not recovered during this period because of a leak in the plutonium-solution evaporator, which has now been repaired. Most of the uranyl nitrate product had beta and gamma activity considerably lower than the maximum 10 and 100 per cent, respectively, of natural uranium as specified by K-25. The plutonium concentration was less than the 10 parts per billion specified as the maximum permissible. Only one batch of the product had a beta activity slightly higher than that in the K-25 specifications.

The rate of uranium processing was increased from 600 to 740 pounds per day. A total of 37,000 kilograms of uranium has been recovered from waste and shipped to the Mallinckrodt Chemical Company in St. Louis for denitration since the beginning of the program. Because of difficulties experienced by Mallinckrodt with foaming-over during denitration, a denitration run was made on the uranyl nitrate produced on a 3 kilogram (U) scale, using a 1-gallon Dopp kettle. There was a 2-inch layer of foam in the vessel during the test but no indication of a foam-over. (AEC Activity 2344)

Purex Process - The emulsification that occurs in the Purex solvent-recovery water-wash tower was shown to be caused by organic nitro compounds formed as a result of continuous degradation of the solvent, tributyl phosphate, and its diluent, Amsco 123-15, by nitric acid. The emulsification was minimized by setting the organic/aqueous volume ratio at greater than 1 and by washing the solvent with dilute nitric acid instead of with water. (AEC Activity 2802)

PROGRAM 3000 - WEAPONS

RaLa - A RaLa run of twice normal size yielded slightly more than 50,000 curies of activity; this amount is at least 20,000 curies above that produced in any previous run, and as a consequence it was necessary to divide the

PROGRAM 3000 - WEAPONS (Continued)

material into two shipments. Fortunately, the impurities contained in this product did not interfere with processing at Los Alamos.

The principal difficulty in making this run was the jamming of the slug chute, which occurred twice and caused a delay of thirty-seven hours. Only normal difficulties, characteristic of the equipment, were otherwise encountered. (AEC Activity 3702)

PROGRAM 4000 - REACTOR DEVELOPMENT

HOMOGENEOUS REACTOR PROJECT

Homogeneous Reactor Experiment - After thorough testing, a new pulsafeeder fuel injection pump was installed in the HRE system. Subsequent tests showed the installation to be satisfactory although a lower than normal pump output was noted.

After two days' operation with water, the system was charged with unenriched uranyl sulfate solution (40 grams of uranium per liter) for a corrosion test run. The pulsafeeder pump discharge line plugged after only two days' operation. The results of tests performed to locate and identify the trouble suggested that the check valve on the discharge line was jammed shut. The valve was cut out of the line, examined, and found to be faulty because of improper assembly. Repairs to the check valve are being made.

The program of operation and testing planned for the HRE consists of three major phases: 1) corrosion tests to determine the difference in corrosion rates with and without radiation exposure; 2) operational tests to determine the effectiveness of copper ions as an internal (dissolved in the fuel) recombination catalyst and to investigate the effect of copper on corrosion; and 3) nuclear characteristics investigations to obtain more information on the kinetic behavior of homogeneous systems. (AEC Activity 4103.1)

HRP Metallurgy - Dynamic corrosion tests on a series of welded pin-type specimens, under various conditions of uranyl sulfate concentration, flow rate, temperature and time, showed differences in corrosion behavior of several combinations of base metal (i.e. different types of stainless steel) and welding rod; but there was no consistent general superiority of any one combination. In higher concentration solutions at elevated temperatures, welds in austenitic stainless steel pins were generally much more seriously attacked than base metal, except in the case of a set of specimens in which the original base metal had an unusually high ferrite content.

Static and dynamic corrosion tests, in water and uranyl sulfate, or stainless steel specimens whose surfaces were prepared by various metallurgical treat-

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

ments, developed a general, but not entirely consistent, pattern. This pattern indicates a less severe corrosion attack on specimens, exposed 1) in the as-machined condition, or 2) after treatment at temperatures in the range of 1000° to 1900°F in hydrogen or helium with a limited moisture content, as compared with specimens fully annealed and commercially descaled.

Continued efforts to ascertain the possibility of intensifying the notch-sensitive brittle behavior of commercial purity titanium, by the introduction of hydrogen from aqueous environments in corrosion tests or by cathodic treatment, have produced no significant differences in impact behavior between cold worked material before and after cathodic treatment.

Specimens made from swaged high purity titanium sponge, obtained from the Bureau of Mines at Boulder City, Nevada, do not exhibit a ductile-to-brittle transition, even down to liquid nitrogen temperatures. (AEC Activity 4109.4)

Engineering Development - Tests with the eight-foot rotational flow reactor core model in the 50,000 gallons-per-minute water pumping loop were completed. The test data confirmed the prior indication, by extrapolation of test results with 6 to 18-inch cores, that the pressure drop in the rotational flow configuration is higher than desirable. A four-foot core model, utilizing straight-through flow directed by screens at the inlet end of the core, is being installed, utilizing the same 50,000 gallons-per-minute loop. This core has the inside dimensions now conceived for the intermediate scale homogeneous reactor (ISHR) and is to be tested at flow rates of the order of 5000-10,000 gallons per minute. A full-scale pipeline gas separator is now being constructed for installation in this loop so that tests on it can be conducted at the same time as the core tests.

The analysis of data obtained with small models indicated that the ISHR core design using straight-through flow directed by screens is very good with respect to nuclear stability in the core and elimination of possible local overheating. An alternate core design, using straight-through rotating flow directed by vanes in the inlet pipe, looks promising also and has the advantage of eliminating the screens from the core itself. Although this system develops a slight vortex, tests to date have given no indication of any trouble from local overheating.

A full scale mockup of the in-pile loop was operated successfully with water under design conditions. These tests have made possible some simplification in the design of the in-pile loop. According to present plans, a total of five loops are to be constructed during the development and testing of the in-pile loop, with the fifth loop being the first in actual use.

Tests with a miniature hydrogen-oxygen recombiner, operated at pressures up to 120 psi during short-term tests, indicate that a platinized activated-alumina catalyst is suitable for use at high pressures. (AEC Activity 4109.5)

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

URANIUM CONVERTER REACTOR

This activity was terminated as of June 30, 1953. In summary, techniques were developed for cladding thorium with aluminum for in-pile service at a temperature of 200°C for a period of at least two months. The 52S aluminum-clad plate is free of objectionable inter-metallic thorium-aluminum compounds, and of fairly uniform dimensions in spite of the difference in flow properties between the two metals.

The aluminum-clad plates will probably have to be mechanically assembled as the bond at the thorium-aluminum interface is not thermally stable at the elevated temperatures required for welding or brazing. (AEC Activity 4115)

AIRCRAFT NUCLEAR PROPULSION PROJECT

Aircraft Reactor Experiment - One important problem that has arisen recently with respect to the ARE is the uncertainty regarding the critical mass (see Reactor Physics, below). Should a significantly higher critical mass be required, it would probably affect the design of the external system and possibly the reactor itself. Modification of the reactor, to add reflector material or eliminate poisons, is contemplated. Also, several revisions of the external fuel circuit, in order to reduce the total fuel volume, are being evaluated.

The pumping of water, with added detergent, through the fuel system (for cleaning and testing) was continued. Such tests as 1) loading, 2) normal and abnormal operation, 3) "scram" responses, and 4) fuel "dumps" (i.e. draining fuel into dump tanks) were performed. These operations provided opportunity for training operators as well as "debugging" the system. The tests indicated that several of the 2-in. bellows valves leaked and will have to be replaced. However, flow, pressure, and liquid level instrumentation, as well as valve actuators, are functioning satisfactorily.

Installation of the sodium system piping is well under way and should be completed in August. The reactor pressure shell containing the core assembly was received from the shop but will not be installed until completion of tests on the fuel system, independent of the reactor. (AEC Activity 4401.1)

Aircraft Reactor General Design - The preliminary designs of a family of reflector-moderated reactors have been worked out to provide basic information for use by the Shielding Board. In this series of designs the reactor power outputs vary from 25 to 800 Mw; core diameters, from 14 in. to 45 in.; and fuel power densities, from 0.5 to 5 kw/cm³. In order to investigate the effects of these parameters and radiation level outside the crew compartment on shield weight, four shields were designed for each of the above reactors. The four shields were designed so that the dose, 50 ft. from the center of the reactor, would be 1, 10, 100 or 1000 r/hr except in the crew compartment wherein 1 r/hr was maintained. Preliminary results indicate that for core

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

diameters less than 30 inches the shield weight increases appreciably with power, but is relatively insensitive to power density. Furthermore, the total shield weight (which includes both the reactor and crew compartment shields) decreases rapidly as the radiation level 50 ft. from any reactor increases up to about 100 r/hr. One typical case is a 200-Mw reactor with an 18-in. diameter core for which the total weight of the reactor, intermediate heat exchanger, reactor shield, and crew shield was about 100,000 lb for 1 r/hr; 82,000 lb for 10 r/hr; 70,000 lb for 100 r/hr; and 68,000 lb for 1,000 r/hr, at 50 ft. from the center of the reactor.

Neutron activation of the NaK, used as a secondary coolant for the reflector-moderated reactor, poses a possibly annoying shielding problem. Rubidium has been suggested as an alternate coolant on the basis of an estimate of much reduced activation. In order to check the validity of this estimate, samples of RbF, NaF, and KF were irradiated at the Bulk Shielding Facility. The gamma dose from rubidium and potassium relative to that from sodium has been evaluated from these irradiations for two irradiation times (1 and 25 hours), three decay times (0, 4, and 50 hours), and with and without two inches of lead shielding. For all cases considered, the activity of potassium was less than 5% of that of sodium whereas the rubidium activity, though in most instances significantly less than that of sodium, was substantially higher for the condition after one hour of operation and no decay. (AEC Activity 4401.1)

Experimental Engineering - Mechanical Contrivances - The sump-type pump was selected as the fuel pump for the ARE since it is at this time the only pump that has demonstrated sufficient reliability for long time operation with molten fluoride salts. The power dissipated in the gas seal is low, the pump may be stopped and started easily, and operation is extremely smooth. The pump was operated for ~325 hours during this period at temperatures up to 1520°F. At present the pump is operating at 1470°F, pumping 68 gpm of the fluoride NaF-ZrF₄-UF₄ (50-46-4 mole %) at 57 psi developed head and a shaft speed of 1440 rpm. Two additional pumps of this model are being fabricated for the ARE.

Tests were continued on the "short" (1/2" long) frozen sodium seal for a sodium pump with a 2-1/2" diameter shaft to determine seal reliability, power requirement and leakage rate. There were no seal failures during operation at shaft speeds varying from 400 to 1700 rpm and seal pressures, from 5 to 10 psi. The power required was approximately one-half horsepower at 1700 rpm shaft speed. However, the seal leakage rates were not consistent. The average leakage rate for a period of 14 days was 67 cc/day with the shaft speed at 1700 rpm and the seal pressure, 5 psi; but there were periods of zero leakage as well as leakage rates of 100 cc/day.

The sump-type pump, which has been specified for the ARE fuel system, can only operate in the vertical position in order to maintain the liquid-gas interface below the gas seal. Fluoride pumps which do not have this limitation are desirable, however, and considerable effort is being expended in

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

the development of a more universal fluoride pump seal. The largest effort in this direction has been on various forms of packed-frozen seals where the packing materials tested included BeF_2 , bronze wool, graphite- MoS_2 , and NaBeF_3 in various combinations and in various seal glands. The tests have been conducted both on pump and seal testers, and with small (1-3/16") and large (2-1/2") diameter shafts. In general, tests with small diameter shafts have been the more satisfactory with extended periods of trouble-free operation and low ($< 10\text{g/day}$) leakage rates, while tests with the larger shafts have experienced periodic shaft seizure and higher leakage rates. (AEC Activity 4401.1)

Mathematics and Computation - The age-diffusion equation in multigroup form was programmed for the UNIVAC. For this work the general plan described in report ANP-58, as modified to adapt the IBM procedure to the high speed machine, was employed. The computation can be broken into five sections: 1) computation of the average macroscopic cross sections for each region; 2) computation of constants; 3) calculation of the group fluxes, assuming a fission source which is constant in space; 4) iteration of the source and fluxes until the eigenvalue (multiplication constant) and the fluxes are stationary; and 5) editing. The problem was initially coded for two regions, for 30 groups, and for 30 space points; in this form it has been run successfully many times. The average number of iterations required for good convergence is 5. The running time of an average problem is about 8 minutes.

In order to make the routine more flexible, the number of groups is being increased and four different thermal bases are being added. This will permit the complete calculation, as used by the ANP group, to be done on the UNIVAC. In addition, a program for computing the time behavior of non-stationary systems has also been coded and run successfully. (AEC Activity 4401.2)

Reactor Chemistry - The production of 14 batches, totalling about 3,250 lb, of the ARE fuel solvent, NaZrF_5 , was completed on July 10. The time required to strip the HF with hydrogen to a value of 10^{-4} moles HF/liter H_2 increased from 15 to about 30 hours as the equipment was reused. No difficulties were encountered in the operation of the equipment. The material produced contains about 35 ppm Fe, 25 ppm Ni, and 10 ppm Cr. The estimates indicate that, including complete amortization of the apparently undamaged equipment, this material was prepared for \$35.00 per lb.

Further purification of the ARE fuel solvent by treatment with zirconium metal appears to be feasible. Experiments in which crystal bar zirconium metal was added to the solvent, from which the HF had been stripped to 10^{-4} moles HF/mole H_2 , have showed a ten-fold reduction in the free HF content of the melt and a two-fold decrease in structural metal (i.e. Fe, Ni, and Cr) content.

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

The NaF-ZrF₄-UF₄ fuel mixture (53.5-40.0-6.5 mole %) melts at 543 ± 5°C, whereas the designated ARE fuel contained 4 mole % UF₄ and melted at about 515°C. Should the mixture containing the higher UF₄ concentration be required for the ARE to go critical, the melting point of the resulting fuel would not prevent its use. (AEC Activity 4401.5)

Corrosion Studies - Further information was obtained on the effect of "hot-leg" temperature on depth of attack by molten fluorides circulating in thermal convection loops. In two loops allowed to operate only 100 hours, the depth of corrosion was found to be 7 mils at 1650°F and 4 mils at 1500°F. Since similar depths of attack were found in both the 1500°F and 1650°F loops when operated for 500 hours, it may be concluded that the rate of corrosion is initially more rapid at elevated temperatures but that the total amount of corrosion is the same. However, with the maximum hot-leg temperature reduced to 1250°F for 500 hours, the attack was limited to the upper section of the hot-leg and was only 3 mils deep. It is expected that there will be little, if any, attack at temperatures below 1200°F.

As expected from theory, as well as from similar work with the fluoride mixture NaF-KF-LiF-UF₄ (10.9-43.5-44.5-1.1 mole %), a substantial reduction in depth of attack (from 9 to 5 mils) was achieved when NaK was added to the NaF-ZrF₄-UF₄ (50-46-4 mole %) mixture. The reduction was not as great as that obtained with additions of ZrH₂.

A series of de-scaling tests on Inconel were run to determine, 1) the effectiveness of scale removal by the fluoride, NaZrF₅, and 2) whether or not there is any detrimental effect resulting from such treatment. Inconel specimens oxidized for 24 hours at 1500°F were statically treated in the molten fluoride mixture for 4 hours at temperatures of 950°F to 1150°F (in 50°F intervals). Above 1000°F the specimens were entirely descaled. There was only minor attack of the Inconel surface by such treatment.

Since corrosion by hydroxide ion generates hydrogen the pressure of the hydrogen produced in some hydroxide-metal systems is being investigated. The equilibrium pressure of H₂ over NaOH in a gold container was found to be less than 1 mm at 850°C. Gold is, therefore considerably more stable to NaOH than is Ni, since the pressure of H₂ above the NaOH-Ni combination at this temperature was about 20 mm. (AEC Activity 4401.5)

Metallurgy - Tube-and-fin heat exchangers of 316 stainless steel were fabricated with a new high temperature brazing alloy, 69% Ni - 20% Cr - 11% Si, developed by GE. The preheating and brazing schedule used when brazing with this alloy must permit wetting of the tube, as well as the fin material, and yet not be at temperature long enough to allow diffusion of the brazing alloy into either the fin or tube material. With a schedule of heating to 900°C at 50°C per minute, holding for 30 minutes, then raising to 1150°C at 50°C per minute, a satisfactory test heat exchanger was fabricated. Leak testing after thermal cycling revealed no leaks and metallographic examination showed that complete wetting occurred.

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

In continuation of investigations for cladding OFHC copper, oxidation tests on type 310 stainless steel cladding were run for 100 and 500 hours at 1500°F. As in previous tests, diffusion was very minor and oxidation resistance was excellent. It may be concluded from these tests that type 310 stainless steel-clad OFHC copper would be suitable especially for liquid-to-air nuclear aircraft reactors. Type 446 stainless steel cladding is also being investigated as an alternate radiator metal since its oxidation resistance is very good. (AEC Activity 4401.5)

Reactor Control - Among several modifications of the ARE control system being contemplated are the addition of a flux-controlled servo mechanism for the regulating rod, regulating rod position recorder, and some indicating device to show which one of the three safety rods drops first. Operational tests on the two high-temperature fission chambers showed a loss of voltage plateau when more than 35 ft of signal cable was used. The cable path through the actuator is being shortened.

The regulating rod control-and-servo mechanism mockup for the Tower Shielding Facility was completed. Extensive tests of the modified mechanical layout indicate it is practically ready for tests at the Bulk Shielding Facility. The aerial cable terminations and junction boxes have been designed, and in addition several modifications recommended by the Design Review Committee are being incorporated in the design of the facility. (AEC Activity 4401.6)

Shielding Research - Since the reactor in the Bulk Shielding Facility (BSF) is very similar to that being constructed for the Tower Shielding Facility (TSF), the BSF is being used in critical experiments for the TSF. The power distribution for the core configuration of six rows, each containing five fuel elements, was measured with both gold and cobalt foils. In calibrating the control rod the reactor period was determined as a function of rod position. The temperature coefficient, which was measured by heating the water in which the reactor was submerged, was in the neighborhood of $-5 \cdot 10^{-5}$ (1/k/k per °F). This value was less negative by a small amount than that calculated previously.

Measurements on the energy distribution of neutrons in the BSF made with the recoil-photon spectrometer have recently been verified by data obtained from nuclear plates. This corroboration in both distribution and magnitude was gratifying since the spectrometer data had been somewhat in question because the shape of the spectrum did not agree with recent "moment-method" calculations carried out by Nuclear Development Associates on the NYU computer. The spectrometer was used also to measure the spectrum of fast neutrons emerging from one of the experimental holes in the LITR. The energy distribution appears to be identical to that measured at a corresponding location on the BSF.

The relatively large removal cross section of lithium suggests its consideration as shielding material. Two recent independent measurements gave values for this cross section of about 1.3 and 1.4 barns (10^{-24} cm²). (AEC Activity 4401.7)

PROGRAM 4000 - REACTOR DEVELOPMENT (Continued)

Design Physics - The critical mass of the ARE, as determined from extrapolation of data from the second critical experiment, appears to be greater than the original estimate of 28 lb. Although this estimate had been based upon the initial critical experiment and associated reactor physics calculations, this experiment was a crude approximation to the ARE. The second critical experiment, on the other hand, was a much better, though still not precise, mockup of the actual reactor. Machine calculations using data from this latter experiment will be made on the UNIVAC in New York in early August but the uncertainty will not be entirely resolved until the actual critical experiments are made on the ARE itself. (AEC Activity 4401.7)

PROGRAM 5000 - PHYSICAL RESEARCH

PHYSICS

Physics Math and Computation - Monte Carlo estimations of the fast neutron flux as a function of energy in the ORNL graphite pile were completed on the UNIVAC. The flux was estimated in each of three regions: (1) a cylindrical region near the center of the pile, symmetrically located with respect to four fuel rods; (2) a cylindrical region near the center of the pile symmetrically located with respect to two fuel rods; and (3) a cylindrical region adjacent to one fuel rod. Sample sizes were sufficiently large to obtain a standard error of about 3 percent for the energy range of greatest interest. (AEC Activity 5211)

Neutron Diffraction - Neutron diffraction experiments have been performed with single crystals of Mn_2Sb to obtain a more accurate determination of the atomic coordinates of this material. Previous x-ray data have shown that the unit cell is tetragonal and contains two Mn_2Sb molecules with the Mn atoms located at positions with coordinates of $(0,0,0)$; $(\frac{1}{2},\frac{1}{2},0)$; $(0,\frac{1}{2},z_1)$; $(\frac{1}{2},0,\bar{z}_1)$, while the Sb coordinates are $(0,\frac{1}{2},z_2)$; $(\frac{1}{2},0,\bar{z}_2)$ where $z_1 = 0.27$ and $z_2 = -0.30$. Neutron data obtained during magnetic structure studies with a polycrystalline sample indicated that the values of z_1 and z_2 were in error. The single crystal experiments have confirmed this discrepancy and preliminary calculations give values of z_1 and z_2 as 0.300 and -0.285, respectively.

Neutron diffraction measurements have also been made on metallic erbium in the temperature range from room temperature to 4.2°K, and these measurements indicate that erbium undergoes magnetic transitions at temperatures near 80°K and 35°K. At room temperature the metal is paramagnetic, and the magnitude and angular variation of the diffuse scattering are similar to those which have been observed previously in erbium sesquioxide, while the coherent nuclear reflections are those characteristic of the hexagonal close-packed

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

structure. At temperatures from 35°K to 4°K the data indicate that erbium is ferromagnetic with the atomic magnetic moments aligned parallel to the c-axis of the hexagonal unit cell. However, in the temperature region from 80°K to 35°K, there appears to be another phase which gives rise to extra reflections on the diffraction pattern. The complete interpretation of these data has not been accomplished at the present time. (AEC Activity 5211)

Low Temperature Physics - Small errors (about $\frac{1}{2}\%$) in the accepted liquid helium temperature scale (vapor pressure-temperature relationship from 1° - 4.2°K) were found experimentally, and a better vapor pressure temperature curve was obtained. Recently, using the previously measured specific heat and virial coefficients of liquid helium along with the suitable statistical mechanical function, a statistical mechanical calculation of this vapor pressure-temperature curve was made which is in excellent agreement (better than 0.1%) with the above experiment from 1° - 4.2°K.

In preparation for an experiment to polarize Sm^{149} nuclei, heat transfer studies were made in the temperature region 0.050°K to 0.20°K with samples of paramagnetic salts which were compressed into copper cups connected by a copper bar. In a number of the experiments the salt $\text{Mn}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6 \text{H}_2\text{O}$ was pressed into one cup while $\text{CuK}_2(\text{SO}_4)_2 \cdot 6 \text{H}_2\text{O}$ was pressed into the other. After both salts had been cooled initially to a temperature of about 1.1°K, the Mn salt was cooled by adiabatic demagnetization to 0.100°K, and the cooling of the Cu salt by heat transfer was observed. The heat transfer relaxation time was found to depend strongly on the temperature of the Cu salt, becoming longer as the temperature became lower. This relaxation time was also dependent on the size of the salt crystals which were pressed into the copper cups and it increased by about a factor of 10 when crystallites of 2 mm to 3 mm diameter were ground to a diameter of the order of 0.1mm. The temperature dependence of the diffusivity reflects the increase of the specific heat of the Cu salt with decreasing temperature due to the Schottky anomaly, while the dependence on the size of the crystallites demonstrates that the mean free path of the heat-carrying phonons (i.e. lattice vibrations) is about equal to the crystallite size at these low temperatures. With crystallites of 2 mm to 3 mm diameter, equilibrium between the two salts was attained at 0.1°K in about 15 minutes. As a result of these experiments a polarization of Sm^{149} nuclei of about 15% at 0.1°K in an applied magnetic field of 10,000 gauss may be expected. (AEC Activity 5211)

Theoretical Physics - The problem of the angular correlation between the β -particle and recoil nucleus, when no γ -ray follows the β -decay, has been re-examined. The role of the finite mass of the nucleus is shown to be non-essential. An analysis has been made whereby numerical evaluation of the correlation function should be simplified considerably. (AEC Activity 5211)

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

Time-Of-Flight Spectrometer - The transmission of technetium for neutrons was measured and resonances were observed at 405, 193, 113, 54.5, 39.5, 19.9, 5.65 and 2.17 electron volts. In extending the measurements down to 0.08 electron volt it was noted that inconsistent transmission values were obtained, depending on the resolution at which the measurements were made. These inconsistent results were due to improper gating of the counting channels at the high counting rates in the low resolution measurements. This error does not occur in the high energy measurements and in no way affects previously reported cross sections above 8 ev. (AEC Activity 5261)

High Voltage Program - Preliminary measurements of the angular distributions of neutrons scattered elastically by lithium, beryllium, boron, enriched boron-10, and carbon were made in the energy region between 0.2 and 1.5 Mev. Neutrons produced by the $\text{Li}^7(p,n)\text{Be}^7$ reaction were scattered by solid cylindrical samples of 7.5 cm height and such a diameter as to give an average transmission of about 70 per cent. The scattered neutrons were detected with a hydrogen (propane gas) recoil counter, shielded from the direct beam by a paraffin wedge shadow cone, at laboratory angles of 30° to 135° in 15° intervals. Backgrounds in this geometry averaged 50 per cent. Distributions were taken below, on, and above each resonance observed in this region with good energy resolution. In the cases of boron-10 and carbon, no resonances were found in this region, with the measurements being made at 0.5, 1.0, and 1.5 Mev.

The angular distribution of α -particles produced by the $\text{Na}^{23}(p,\alpha)\text{Ne}^{20}$ reaction and leading to the ground state of the residual Ne^{20} nucleus were measured at six different resonances. The particles were detected with a gas-filled counter fitted with a thin (0.5 air-cm thickness) nickel foil window. By means of pulse height selection those α -particles leaving Ne^{20} in the ground state could be clearly distinguished from those leading to the first excited state. The targets were prepared by evaporation in vacuo of NaI onto thin (25 micrograms/cm²) Formvar backings. The resonances at proton energies 1093, 1137 and 1166 keV were found to be isotropic. The resonances at 1287, 1012 and 1805 keV had minima at 90° . These three angular distributions are now being fitted with Legendre polynomials. It is hoped that from a study of the coefficients obtained, the character of these virtual states can be determined. (AEC Activity 5211)

CHEMISTRY

Chemical Separation of Isotopes - A study of methods of separating the isotopes of deuterium, nitrogen, chlorine, and boron was started with the objective of improving the economy and efficiency of existing methods, or of replacing them with superior systems. Literature surveys of the isotope chemistry of each of these elements have been initiated. In a qualitative examination, the system 4-chlorobutanol-1 (tetrahydrofuran) vs. hydrogen chloride (gas) was found to be of interest as a possible mechanism for separating the isotopes of chlorine and of hydrogen.

PROGRAM 5000 - PHYSICAL RESEARCH (continued)

A thermal conductivity cell was designed for the approximate analysis of hydrogen-deuterium samples.

A one-inch jacketed glass column, twenty feet in length, was designed to study countercurrent, gas-liquid and liquid-liquid systems for the separation of nitrogen isotopes. (AEC Activity 5361)

Uranium Chemistry of Raw Materials - A small gas-fired furnace, consisting essentially of an externally heated 5" alundum tube, was constructed to permit the continuous burning of powdered lignite at high temperatures. In preliminary tests, almost complete combustion of the lignite was accomplished in ~3 sec. burning time at a temperature of 1350°C, with a 20% surplus of air. Under these conditions a partially magnetic ash was formed indicating a lower oxidation state, at least, as far as iron is concerned. Upon leaching the ash with sulfuric acid, only 70% of the uranium was dissolved, whereas, previously extractions in the order of 85% were obtained from fully oxidized hematitic ashes, prepared under different conditions. The acid consumption by the new ash was also comparatively high.

Exceptionally promising results were obtained from tests using tri(n-octyl) amine as an extractant for uranium from sulfate liquors. In continuous countercurrent extractions of a typical sulfate leach liquor, 99% of the uranium was recovered with 0.1M amine in a hydrocarbon diluent. The product, obtained by stripping the organic phase with NH_4OH or 0.9M NH_4Cl - 0.1M HCl , analyzed 97% - 99% U_3O_8 after precipitation and ignition. This level of purity is exceptionally good, especially since the uranium-rich organic was not scrubbed prior to the stripping step. (AEC Activity 5361)

Instrumentation for Nuclear Chemistry - The first of two special cathode ray tubes, having as a target a grid structure consisting of 30 "webs" and 30 spaces (i.e. like a picket fence), was completed by the Allen B. DuMont Laboratories. From the initial tests of this 60-channel pulse amplitude analyzer tube the electron beam spot size appears to be about 0.004 inches in diameter or equivalent to eight spots per channel. This characteristic indicates that the stability of the circuit system will be good. At 3000 volts accelerating voltage the deflection sensitivity is about 3 volts per channel. The secondary electron emission ratio of the collector plate is about 7 but non-uniformity of the order of 20% is apparent across the two-inch length. With a beam current of 10 microamperes, adequate signal is obtained from the collector when the dead time of the system is three microseconds. The webs and spaces of the grid which are within 1% variation dimensionally are not this uniform when measured electrically. This variation may be due to the secondary electron emission from the grid itself. When the secondary emitting signal plate is positive with respect to the target grid then secondary emission electrons from the grid will be collected by this signal plate and the resultant output will appear as larger openings in the target grid. Some modifications will be required in the next tube to equalize the channels. (AEC Activity 5361)

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

Chemistry of Corrosion - Two specimens of carbon steel (SAE 1010), used in studying the inhibitory properties of the pertechnetate ion, have now been under observation for six and a half months. During the first three months the solutions were kept alternately at 100°C and 23°C with access of air; since that time they have stood at room temperature in loosely stoppered tubes. No corrosion has yet resulted; the metal has remained bright and the solutions water clear.

The study of possible inhibitor action was extended to additional elements (i.e. those near the line drawn on the periodic table through chromium, technetium, and osmium). Particularly interesting results were obtained with sodium tungstate, which other investigators have found to be an inhibitor at room temperature. It was found that a 0.01 f (formal) solution effectively inhibited the corrosion of carbon steel under the conditions used in the technetium work, that is, alternating between 100°C and 23°C, with as much as 20 ppm of chloride ion present in the solution. In this connection, a study of the solubility of tungstic acid in uranyl sulfate solutions was initiated.

Further work with osmium tetroxide showed a synergistic action when this compound and the pertechnetate ion were simultaneously present in the solution. Osmium tetroxide alone formed a fragile film which was protective at 100°C until broken, whereupon a pitting attack resulted that was very severe in the presence of electrolytes. The formation of this film reduced the deposition of technetium almost to zero when a solution containing both inhibitors was used. Pretreatment of the steel with pertechnetate ion decreased the rate of film formation when OsO_4 was subsequently added. There was no continuing corrosion in the mixed solution under the test conditions.

The study of effect of added ions on the electrode potential of type 347 stainless steel in 0.1 N H_2SO_4 at 85°C was extended to many additional ions since the last report. Except in those cases in which obvious chemical instability of the solutions was involved, the ions which show ennobling effects do so according to a Nernst-type equation relating potential and concentration. (AEC Activity 5361)

Ion Exchange Studies - Previous studies of self-diffusion in ion exchange resins were extended to the case of cation self-diffusion in linear polysulfonates in order to remove the complication of cross linking. Self-diffusion coefficients were determined for Na^+ , Cs^+ , and Ca^{++} ions, existing as the respective polysulfonate salts, with the diffusion of Na^+ and Cs^+ ions being measured at several concentrations.

While the data are not yet sufficiently complete for quantitative evaluation, some qualitative observations may be made. First, in line with the previously observed increase in diffusion rate with decreasing cross linking, the self-diffusion coefficients are approximately a factor of 10 greater than those in a 1% cross-linked resin. Second, the relative diffusion rates of the three ions are approximately the same as with the cross-linked resins,

PROGRAM 5000 - PHYSICAL RESEARCH (Continued)

probably indicating similar effects of concentration and of cross-linking as such upon all three cations. Third, the self-diffusion coefficients of Na^+ and Cs^+ ions in polysulfonate solutions are similar in magnitude to those in simple salt solutions while the value for Ca^{++} is several-fold smaller in the presence of polysulfonate. It appears probable then that the doubly-charged cation is considerably more associated with the poly-anion than are the singly-charged ions.

The osmotic coefficients for the A-2 type anion exchangers were measured. A relationship was found which enables one to calculate anion exchange selectivities from osmotic coefficient data. (AEC Activity 5361)

Isolation Processes for Uranium and Plutonium - Further studies, for possible application in the Thorex and 25 processes, were made on ion exchange isolation processes for uranium. The uranium was concentrated from a value of the order of 3 grams per liter to approximately 300 grams per liter by sorption on Dowex 50W resin and elution at 70°C with a solution of pH 5.2, comprising 1.5 M acetic acid, 0.75 M ammonium citrate, and 3.0 M ammonium acetate.

Decontamination of uranium from zirconium and niobium, by factors of 3.8 and 4.5, respectively, was achieved by selectively eluting with 0.005 M hydrofluoric acid these fission products from a uranium-loaded resin bed.

The design and testing of the ion exchange resin column for coupling the solvent extraction and precipitation operations for plutonium isolation at the Savannah River plant were completed. The column was found to be satisfactory, and pertinent data, useful for construction of this full-scale column, were transmitted to the duPont Company (ORNL memorandum CF-53-6-228). (AEC Activity 5361)

Ion Exchange Technology - A continuous ion exchange resin contactor two inches in diameter was constructed specifically for study of the conversion of uranyl nitrate to uranyl fluoride. The column has a rated capacity of 65 pounds of uranium per day. In test runs, the column and its accessories were operated satisfactorily for periods totalling several hundred hours. (AEC Activity 5361)

Economic Studies - A preliminary design and cost study (report ORNL-1558) of a hypothetical Purex plant for processing three metric tons of irradiated natural uranium per day, and designed for direct maintenance, was completed. The cost of such a plant was shown to be considerably less than any remote-maintenance plant of equivalent capacity now in existence or at present planned for construction. (AEC Activity 5361)

PROGRAM 6000 - BIOLOGY AND MEDICINE

BIOLOGY

Cytogenetics - It was demonstrated previously that hydrogen peroxide does not induce mutations in Paramecium even when the catalase in the cell is partially poisoned by cyanide. It has now been shown that neither peroxide nor cyanide present during X-irradiation modifies the induced mutation rate. Calculations show that the average concentration of peroxide inside a cell the size of a paramecium is a large fraction of that outside. The concentration of peroxide used in these experiments was more than thirty times that produced in pure water by the doses of X-rays normally used in mutation experiments. At these doses, more than half of the mutagenic effect is eliminated when irradiation occurs in the absence of oxygen. It must be concluded that oxygen does not exert its influence on the mutagenic action of X-rays by its influence on peroxide formation.

After extensive efforts to construct a genetic map of bacteriophage T4, three types of mutant markers were discovered which enable identification of phage particles containing any of eight possible combinations. By selection of appropriate markers these identifications are possible using either three linked or three unlinked markers. With such combinations it was possible to show that genetic markers can be individually inactivated with X irradiation. Unlinked markers appear to be inactivated independently of each other. When linked markers are used, however, the irradiation does not inactivate them independently. A rather direct relationship is observed between the closeness of the linkage and the frequency of simultaneous inactivation of two markers. Further experimental analysis of this material is required before an interpretation can be made. The ability to produce localized radiation damage within the genetic structure should be of importance in understanding radiation effects at the subcellular level.

The ratio of chromatid aberrations induced by X rays in Tradescantia in the presence of air and in pure nitrogen indicates a pronounced wave-length effect. For chromatid deletions the ratio increases from longer (50 kvp) to shorter wave lengths (gamma rays); with isochromatid deletions the ratio changes in the reverse direction. There is some indication that the number of chromatid deletions induced in N₂ is increased by the partial restitution of isochromatid deletions and exchanges. It was also shown that X-ray-induced "stickiness" of chromosomes is markedly reduced by irradiation in N₂.

Studies designed to determine the mitotic effects of beta radiation from C¹⁴, incorporated in the cell, were completed. Grasshopper embryos were incubated at 38°C for 30 minutes in 2.1 ml of culture medium containing 0.9 μM potassium formate labelled with C¹⁴ (7.6 μc). Cells of the embryos utilized the formate in synthesis of their nucleic acids. The mitotic rate of the cells containing C¹⁴ was found not to differ significantly from the mitotic rate of cells not containing C¹⁴. Since it does not itself induce mitotic effects, C¹⁴-labelled formate is then a permissible tool in studies correlating inhibiting effects of X rays on nucleic acid synthesis and on mitosis. (AEC Activity 6400)

PROGRAM 6000 - BIOLOGY AND MEDICINE (Continued)

Microbiology - The last report from this group (ORNL-1562) described the isolation of peroxidizing enzymes which carry out an oxidation of reduced diphospho-pyridine (DPNH₂) and involves an intermediate peroxidation. It is not yet established whether the DPNH₂ - cytochrome-c reductase is identical with the oxidase; however the apo-enzyme(s) were prepared by the method of Warburg and Christian and can be reactivated with flavin adenine-dinucleotide (FAD) but not with flavin mononucleotide. The cytochrome-c reductase of Escherichia coli is also FAD specific. The enzyme responsible for the peroxidation was completely separated from the oxidase by ammonium sulfate fractionation so that aerobically there is no reaction in the absence of added peroxide. However, there is as yet no evidence for the nature of the prosthetic group. Hematin catalysis seems unlikely since there is no inhibition by 0.01 M cyanide or 0.05 M azide. Present evidence rules out the intermediate reduction by DPNH₂ of the disulfide linkage in cystine, oxidized glutathione, and lipoic acid. The optimum pH of the peroxidation catalyzed by the partially purified (15-fold) enzyme lies between 5.0 and 5.7. The peroxidation demonstrated here represents a departure from the classical peroxidases and offers a mechanism for the peroxidation of organic compounds whose oxidation is DPN (diphospho-pyridine) coupled. (AEC Activity 6400)

Radiation Protection - An attempt was made to isolate from calf spleen the factor(s) required for bacterial recovery from ionizing radiations. It was found previously that mammalian spleen was a practical source material for the factor (report ORNL-1562). In a pilot experiment a kilogram of calf spleen was homogenized and a boiling-water extract obtained and purified by lead subacetate precipitation followed by lipid removal; the activity was found not to be precipitated by lead, insoluble in ether and other fat solvents, and soluble in 95% ethanol. The ethanol-soluble material was fractionated in a Craig countercurrent apparatus, using a butanol-water system. This purification procedure, designed to purify with respect to a single substance, yielded about 12.5 mg of water-soluble material, purified approximately five hundredfold with respect to the factor. The possibility of multiple factors might explain the less than 5 percent yield obtained. Experiments are being designed which will make it possible to assay the various fractions singly and in combination, and may permit some resolution of individual factors.

Studies of the effects of postirradiation (x-ray) treatment on the mutation rates of two additional auxotrophs of E. coli have revealed that the effects of such temperature treatment is specific for strains. Whereas, both a purine- and proline-requiring strain had been shown to have a minimal induced mutation rate at that temperature where survival was maximum (reports ORNL-1529 and ORNL-1562), the induced mutation rates of a tyrosine auxotroph and an arginine auxotroph were found to be maximal at those temperatures where survival was greatest (18-24°C). (AEC Activity 6400)

PROGRAM 6000 - BIOLOGY AND MEDICINE (Continued)

Biochemistry - Recent work with bacteriophage implicates bacterial nucleases (desoxyribo- and ribo-) in phage infection. The action of these enzymes in vitro is under investigation in order to define their function better. A bacterial preparation was found to hydrolyze purified T4r⁺ bacteriophage and calf thymus desoxy-ribonucleic acid (DNA), reducing 75% of the material to mononucleotides and nucleosides but leaving 25% in oligonucleotide form. The oligonucleotide fractions seem to be of tetranucleotide complexity or greater. A purified preparation of bacterial membranes, still active in adsorbing and liberating the DNA of phage, was found to contain a potent ribonuclease which hydrolyzed both bacterial and calf-liver ribonucleic acids (RNA). The products are, however, not the same as those obtained with the conventional crystalline pancreatic ribonuclease.

The cell-free bacterial luminescence recently produced in this laboratory (report ORNL-1529), was examined from the standpoint of emission spectrum, ultraviolet effect, and of its dependence upon temperature, pH, inhibitors, substrates, and cofactors. In addition to reduced coenzyme-I and riboflavin phosphate, it was found that a lipid-like substance, extractable from hog kidney cortex, stimulates the luminescence. This substance was isolated and purified to the extent that one microgram per milliliter will produce a ten-fold stimulation of luminescence. Its chemical structure is under investigation. (AEC Activity 6400)

Plant Biochemistry - Various solvent systems were tested for the paper chromatographic separation of organo-phosphorus compounds of biological significance. The most successful solvents were diethyl Cellosolve-water and an organic acid, phenol-formic acid-water, and butanol-acetic acid-water. This work was done in conjunction with a project on the ion-exchange separation of organic phosphate compounds.

In conjunction with the biosynthesis of sedoheptulose-C¹⁴, other C¹⁴-labeled compounds were isolated which are of use for metabolic studies. These compounds include glucose, fructose, sucrose, glyceric acid, and isocitric acid. An unknown substance present in considerable quantity was found to hydrolyze only to radioactive fructose, thus indicating the presence of a fructosan.

By analysis of the water in which Sedum spectabile plants were kept during the assimilation of C¹⁴O₂, a measure of translocation of C¹⁴ substances down the plant stem into the water could be made. It was found that the plant had secreted C¹⁴-labeled glucose, fructose, sedoheptulose, sucrose, and a material which did not move in the chromatographic solvent system. (AEC Activity 6400)

Biophysics - In testing the thesis that X-ray injury of selective potassium accumulation in erythrocytes involves an interference with acetylcholine turnover, a critical investigation was made of a report by Greig and Holland which states that extracts from human red cells can enzymatically produce synthesis of acetylcholine in vitro. Since the observation depends critically on the ultrasensitive method of bio-assay with the eserized frog

PROGRAM 6000 - BIOLOGY AND MEDICINE (Continued)

muscle (rectus) and since it also depends very critically on the nature of the synthetic system, considerable time was spent in obtaining optimal results with these procedures. The results confirm previous work showing that synthesis of small amounts of pharmacologically active material occurs. From a careful investigation of the assay method and its artifacts one cannot yet say with certainty that the activity is due to acetylcholine.

Preliminary results were obtained which indicate that the $\text{Li}^6 (n,\alpha) \text{H}^3$ reaction may be readily utilized in an autoradiographic technique for the detection of lithium localizations within tissues.

A water shield and system of remote controls were completed so that the Biology Division accelerator could be operated temporarily at low neutron levels. Fission counting equipment and other instrumentation were completed and are ready for physical calibration experiments; the beam alignment with a special target assembly for calibration experiments was completed. (AEC Activity 6400)

Pathology and Physiology - Nine months after irradiation, Grade I (mild) opacities of the lens are present in mice exposed to a single dose of fast neutrons, 10^8 n/cm^2 at 2.5 Mev. Comparable lesions are present in rats only after 10^{10} n/cm^2 , while in rabbits the corresponding dose is still higher. Observations to date reveal no loss of cataractogenicity with weekly fractionation of neutron dosage.

Mice, guinea pigs, and rats were exposed to cyclotron-produced neutrons and to 250-kvp X-rays in order to determine their relative biological effectiveness. The parameters studied thus far include $\text{LD}_{50/30}$ days, cataract induction, and bone-marrow activity, as indicated by Fe^{59} uptake in red blood cells and white cell counts. The preliminary LD_{50} studies are nearly completed; the others are in progress. The tentative neutron/X-ray ratios for acute lethality are as follows: in mice 1 rep neutrons equals about 3.4 rep X-rays; in rats 1 rep neutrons equals ~ 3.0 rep X-rays; and in guinea pigs 1 rep neutrons ~ 2.3 rep X-rays.

Observation of the mice surviving Operation Greenhouse continued. Pituitary tumors have occurred in significantly higher numbers among irradiated mice than among controls and are about four times as common in females as in males. The limited data suggest that these tumors are more common after neutron irradiation than after gamma irradiation and may result from doses as low as 40-70 rem.

Two pituitary tumors occurring in mice exposed to ionizing irradiation proved readily transplantable, causing in the recipients obesity with thymic atrophy, polyuria, sometimes with glycosuria, hyperglycemia, severe lymphocytopenia, and hypertrophy of the adrenal cortex. On the basis of these findings it is concluded that this tumor secretes ACTH. There is lack of evidence of stimulation of other endocrine organs.

PROGRAM 6000 - BIOLOGY AND MEDICINE (Continued)

Experiments concerning the fate of S^{35} - and C^{14} -labeled platelets in normal and X-rayed rats are continuing. It has recently been possible to obtain in vivo labeled platelets with a specific activity sufficiently high so they can be transfused into non-labeled rats and their fate followed. It was found also that prebleeding enhances the platelet yield in rats and has the added advantage of providing platelets of a more uniform age.

Enzyme Chemistry - The investigation of the relationship between molybdenum and xanthine oxidase, undertaken in collaboration with the UT-AEC group, was completed. It was not found possible to remove the Mo^{99} activity from the labeled enzyme either by means of exchange or by prolonged dialysis. Spectrophotometric measurements on the enzyme and chemical, spectrographic and radio-assay methods for determination of the associated molybdenum indicate that one atom of molybdenum is combined in a molecule containing two riboflavin residues. The minimum molecular weight of the xanthine oxidase is in the neighborhood of 200,000, a value which is in agreement with the results of ultracentrifuge measurements made in other laboratories.

In the investigation of the decay curve for the delayed light from green plants the Sandborn recorder was used in making decay curves for plants that have been illuminated with neon light for several minutes and compared with decay curves made after one flash of light that lasted about one five-thousandth of a second. The two curves are very similar.

It was also shown that for short times of illumination the delayed light production depends on the product of light intensity times the time of illumination; that is, it depends on the energy of the flash. (AEC Activity 6400)

Math for Biology - A general method was established for the solution of the rate equations for a set of consecutive, irreversible, first order reactions. The formulation provides for estimation of the initial concentrations as well as the rate constants. The stationary concentration of H_2O_2 in Paramecium aur. was computed. The problem was solved approximately for an ellipsoid and exactly for a uniform and for several non-uniform spheres.

Mass-action expressions were derived for chemical reactions in a phase which is in distribution equilibrium with a second phase in which only one reactant is soluble. Equilibrium constants and stoichiometric coefficients were estimated. (AEC Activity 6400)

RADIOISOTOPE SALES AND COSTS

<u>Type of Transaction</u>	<u>June</u>	<u>FY to Date</u>
*Domestic Sales	\$101,428	\$ 988,320
Foreign Sales	4,279	32,451
Project-Cash Sales	9,057	78,113
Project-Transfer Credits	---	4,031
Technical Cooperation Program Credits	709	4,984
Plant Credits	1,332	35,226
Civilian Defense Credits	<u>1,235</u>	<u>1,810</u>
Radioisotope Income	\$118,040	\$1,144,935
Other Income - No costs incurred	<u>797**</u>	<u>138,380</u>
Total Income	<u>\$117,243</u>	<u>\$1,283,315</u>
Radioisotope Costs	<u>\$101,496</u>	<u>\$1,039,355</u>
*Cancer Program Costs	<u>\$ 19,028</u>	<u>\$ 234,899</u>
Radioisotope Shipments	<u>1,075</u>	<u>11,153</u>

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

GROSS OPERATING COSTS

	<u>Cost for June</u>	<u>FY 1953 Cost to Date</u>
Programmatic Operating Cost	\$ 2,852,413	\$ 30,125,208
Plant and Equipment Cost	525,783	4,527,651
Construction Program "H"	19,031	309,113
Work for Other Parties - Transfers	99,235	889,727
Inventory Changes	1,751*	501,776*
Reimbursable Work for Other Parties	40,763	879,542
Deferred Charges	<u>1,507*</u>	<u>163</u>
Total Laboratory Cost	<u>\$ 3,533,967</u>	<u>\$ 36,229,628</u>
Estimated Cost for Next Month	<u>\$ 2,900,000</u>	<u>\$ 2,900,000</u>

*Credit


PERSONNEL SUMMARY

	<u>Number of Employees</u> <u>July, 1953</u>	<u>New Hires</u> <u>July</u>	<u>Terminations</u> <u>July</u>
Administration	57	0	19
Operations*	121	0	3
Engineering, Shops and Mechanical	732	0	10
Laboratory and Research	1728	17	19
Protection	172	0	2
Service	<u>408</u>	<u>20</u>	<u>8</u>
Total	3215	37	61

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

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Previous Reports in this series:

January 1953	ORNL-1486
February 1953	ORNL-1516
March 1953	ORNL-1529
April 1953	ORNL-1545
May 1953	ORNL-1562
June 1953	ORNL-1576