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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

MARCH 1962

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OAK RIDGE NATIONAL LABORATORY
STATUS AND PROGRESS REPORT
MARCH 1962

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

MARCH 1962

This Status and Progress Report summarizes the unclassified portion of the Laboratory's work. Some of the topics are included every month, but the majority are reported on a bimonthly schedule.

REACTOR DEVELOPMENT PROGRAM

GAS-COOLED REACTOR PROGRAM

EGCR Component Tests. — The control-rod-drive test vessel was completed, and the lower portion of the vessel was installed in the test facility. The heater and graphite assemblies are essentially complete. Installation of heater-assembly insulation was started.

EGCR top- and bottom-dummy flow distribution tests were continued. A final test with a bottom-dummy fixed orifice of 0.187 in. made possible the selection of a suitable fixed-orifice size. Flow tests were then performed on the mocked-up top dummy and sleeve for the concentric, eccentric, and slanted positions. A smooth annulus 7.000 in. long was tested by using a 5.222-in.-diam dummy and an annulus width of 0.0125 in. in the concentric position. The pressure drop as a function of flow rate for this configuration was too high to meet the design requirements. The flow at a given pressure differential for the eccentric position increased approximately 50% above that for the concentric position. The slanted and concentric positions gave roughly the same performance.

In order to change the characteristics of the pressure drop vs flow relationship across the top dummy, the 5.222-in.-diam, 7.0-in.-long land on the dummy was machined to contain 21 grooves, 0.200 in. wide and 0.025 in. deep. Following tests of this geometry, the groove depth was increased to 0.050 in., and the tests were repeated. As expected, for both grooved geometries, the measured pressure drop for a given flow increased over values for the smooth annulus; the rate of increase in pressure drop with flow also increased. Since binding of the top dummy had been experienced in hot mechanical tests at the vendor's plant, the clearance between the dummy and the sleeve was increased to a total of 0.035 to 0.039 in. Tests of a dummy with the 21 grooves 0.048 in. deep and the new clearance were then performed. Results of the tests are being analyzed.

Irradiation Program. — GCR-ORR loop No. 1 is running well with fuel element 7B, an instrumented EGCR-type fuel assembly designed for operation at a power level of 35,000 Btu hr^{-1} ft^{-1}, but the measured power of this element is only 24,000 to 26,000 Btu hr^{-1} ft^{-1}. Only two of the five thermocouples originally installed in the fuel element are operating, and these

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are the 0.069-in.-diam units at the top and midplane of the cladding interior walls. The midplane thermocouple is being held at 1345°F (1300°F true outer cladding temperature), and the top thermocouple gives readings that vary from 1325 to 1375°F. The leakage rate of the container around the compressor cubicle has been reduced to 12 cfm at 0.85 psig. This containment vessel is now adequate for the largest element scheduled to go into the loop.

Experimental assembly LM-1 was removed from the LITR. The fuel pellets irradiated in this assembly consisted of 30 vol % UO_2 and 70 vol % BeO. The UO_2 was enriched 20% in U^{235}. The pellets had been irradiated for 10,549 hr to an estimated burnup of 3.8 at. % of the total uranium. The central thermocouple of specimen "a" indicated 1100°F initially but had drifted to 1000°F before removal. The central thermocouple of specimen "b" failed during irradiation after indicating a temperature of approximately 1400°F for several months.

Preliminary visual examination of capsules 03-4 and 06-4, which consist of hot-swaged UO_2 powder in stainless steel tubes, showed that the cladding was clean and had no depressions or ridges. The diameters and profiles of each capsule were measured and were compared with similar preirradiation measurements. In all cases the postirradiation dimensions were within ±0.002 in. of the preirradiation measurements. Gamma scans were run on both capsules. On capsule 03-4 the burnup was constant over the length of the fuel element, with the exception of two dips that indicated fuel separation approximately in the middle and upper quarter of the fuel column. From the gamma scan on capsule 06-4, a variation in activity indicated that some fuel had broken off the bottom of the fuel column and had fallen into the void volume in the bottom end cap. The gamma activity also showed that there was about a 10% higher burnup at the top of the capsule than at the bottom. The variation in activity between the two ends was linear. In the preliminary disassembly of capsule 06-4 it was found that fuel had fallen into the bottom void volume, as indicated by the gamma scan. A central void indicative of UO_2 melting or vaporization was also found; however, the ends of the fuel column were closed. There was some orange-appearing compound on the top end of the UO_2 that may be hydrated UO_3.

Postirradiation examinations of irradiated tube-burst specimens of type 304 stainless steel were started. Observation of the specimen surfaces did not reveal surface cracks. In comparison with out-of-pile data, the rupture strain decreased by a factor of 2 to 3 as a result of irradiation.

Postirradiation measurements of the similar Inconel tube-burst specimen were completed. The strain vs time data obtained in the in-pile tests fall within the scatter band of data from tests on similar out-of-pile specimens. The data, while preliminary, indicate that the creep rate does not undergo a major change during irradiation at a fast-neutron (> 0.7 Mev) dose of 5×10^{13} neutrons cm^{-2} sec^{-1} for times up to 500 to 800 hr.

Samples of BeO recovered from the six capsules of the ORNL-41-6 experimental assembly were separated from the irradiated pellets and submitted for gas analysis of contained helium and tritium. Additional samples were prepared for metallography and electron microscopy. The irradiation of the similar ORNL-41-7 experimental assembly is continuing

for its fourth month in the ETR. No malfunction of the equipment was observed during the first three completed reactor cycles, and the assembly is expected to receive a fast-neutron (> 1 Mev) dose in excess of 10^{21} neutrons/cm^2.

Pebble-Bed Reactor Experiment. — Eight new layout drawings of the reactor building for the Pebble-Bed Reactor Experiment were prepared and issued. Despite reductions in both the height and the diameter of the containment vessel, approximately 6700 ft^3 of additional space was gained for auxiliary equipment. There appears to be ample space to perform all major reactor-system operations.

A new flow diagram was prepared for the ventilation system of the reactor containment vessel. This flow diagram depicts a system based on dividing the reactor building into two major ventilation zones: a "clean" zone that includes areas to which access is required for maintenance of components, electronic equipment, and control devices, and a "hot" zone that includes the primary high-pressure-system equipment cells and the service machine and hot-cell areas.

Materials Investigations. — Experiments are being performed to determine the thermal-cycling characteristics of UO_2 pellets clad with stainless steel of various thicknesses. The pellets have an outside diameter of 0.705 in., an inside diameter of 0.323 in., and a length of 0.750 in. The type 304 stainless steel tubing being used for cladding has a nominal inside diameter of 0.710 in. and was fabricated from a single heat. Three wall thicknesses will be investigated: 0.005, 0.010, and 0.015 in. In the two experiments completed thus far, capsules with 0.005- and 0.010-in.-thick cladding were thermal-cycled between 780 and 180°C with a 300-psi pressure differential. The 0.005-in.-thick cladding failed at the lower limit of the twelfth thermal cycle because of collapse into a gap between pellets. The 0.010-in.-thick cladding failed at the upper temperature limit on the eightieth thermal cycle because of strain introduced in the outer fibers at an axial ridge. These two tests clearly show that the diametral gap of 0.004 to 0.005 in. that existed in these capsules was too large to prevent the formation of the axial ridges that ultimately caused failure of the cladding. Collapse studies will be run for all three cladding thicknesses to determine the minimum diametral clearance needed to prevent axial wrinkling of the tubes.

Further examinations were made of graphite—type 304L stainless steel diffusion couples subjected to 1200-, 2400-, and 5100-psi contact pressures at 1100°F. Although there was no bonding of the couples, chemical analyses, hardness tests, and metallographic examinations established that carbon transfer occurred. Examination of the microstructure revealed scattered areas of heavy carburization extending to a depth of about 0.001 in., and one edge of a 0.005-in. specimen was found to be carburized across the entire thickness. Hardness tests produced values that were normal for type 304L stainless steel except in areas where metallographic evidence of carburization was found. Values in these areas ran as high as 32 on the Rockwell C scale. To study further the extent of carbon transfer, the carbon gradient across the thickness of one of the 0.050-in. specimens was determined. This was done by machining 0.001-in. cuts from the face of the specimen and analyzing the chips. The results indicate

that diffusion occurred to depths of about 0.012 in. and increased the carbon content to 0.12% at a depth of 0.006 in.

Techniques are being developed for fabricating $BeO-UO_2$ specimens for irradiation in the ORR poolside facility. Spheroidal oxide fuel particles 147 to 208 μ in diameter were prepared, and several means were tried for shrinking them to 110- to 156-μ particles of 95% theoretical density when sintered at 1750°C. A vibration technique was completely unsatisfactory, in that the particle sizes were apparently reduced by severe breakage of the particles rather than by attrition. Granules subjected to a tumbling process became smoother and tended to become spheroidal for particle sizes of about 60 mesh (> 246 μ), but with further reduction became irregular in shape. In the technique presently being studied, particles are gravity-fed from a chamber into a glass tube formed into a circle. The particles are tumbled around the tubular track by a high-velocity air stream. In preliminary trials the particles tended to become spheroidal, particularly in the +60-mesh particle size. Particles of smaller size were more uniform than the same-size particles subjected to the rolling techniques but appeared to be formed more by the breakup of larger particles than by attrition.

Several metallographic sections were taken of finned beryllium tubing in which suspicious indications were detected during eddy-current examination. Preliminary examination of the mounted specimens revealed a number of large inner surface cracks, some of which are approximately 0.040 in. deep. The presence of some of these cracks immediately under fins (thickest portion of tube wall) had prevented complete wall penetration. In one section, several cracks were noted that were not normal to the inner surface. Some of the cracks were deeper than had been predicted by the tentative eddy-current technique. Several metallographic sections were also taken of tubing which had been measured for minimum wall thickness by the prototype through-transmission eddy-current system. The variations in thickness along any valley between adjacent fins were as much as about 0.003 in., but they were generally less than 0.002 in.

A second attempt was made to thermally cycle a fuel element clad with finned beryllium tubing and subjected to a 300-psi pressure differential; however, a leak developed at the beryllium—stainless steel joint on the initial cycle. The experiment was designed for determining the number of cycles to failure for the beryllium cladding on a tube that was freestanding at room temperature but not at the test temperature. The as-assembled diametral gap was 0.001 in. Despite the leak and the consequent loss of pressure differential, the capsule was cycled between 650 and 250°C for 112 cycles. Posttest examination of the strain-recording device and the capsule revealed no axial growth of the beryllium cladding. The element completely fractured circumferentially on the sixty-seventh cycle, at the lower temperature limit of the cycle. Two possible causes of the failure are bending stresses and axial stresses resulting from differential thermal expansion. The nature of the failure indicates that the bending stresses were probably responsible. A radial crack 4 in. long in the beryllium cladding at the root of a fin is attributed to strains introduced by differential radial thermal expansion of cladding and fuel.

A third corrosion test was run on the Be—0.5 wt % Ba alloy. The test temperature was 750°C, the CO_2 pressure was approximately 570 mm Hg, and

the duration of the test was approximately 300 hr. In this case the weight-gain data indicated protective-film formation for 80 to 100 hr, in contrast with 10 to 20 hr for the previous test at a CO_2 pressure of 50 mm Hg and 0 to 10 hr for the test at a CO_2 pressure of 6 mm Hg. The weight-gain data from these tests indicate that the duration of protective film formation is pressure-dependent. In addition, the nature of the film formed appears to change as a function of CO_2 pressure, since spalling occurred only in the test at a CO_2 pressure of 50 mm Hg.

GCR-ORR Loop No. 2 Fabrication. – The main loop piping and components and the Marmon Conoseal flanges of GCR-ORR loop No. 2 were helium-leak-checked. Valve seat leakages were detected that were caused by particles lodged in the soft seat materials. The valves were removed, new seats were installed, and micron particulate filters are being inserted in the lines upstream of the valves.

A return bend on the main stream piping is being fabricated. This connection is required for the out-of-pile system checkout. Reworking of the cell penetration sleeves and remote-actuating mechanisms was started.

Fabrication of the 18-in. plug was delayed while a test was run on the water flow in the 1/8-in. cooling annulus. As a result of this test, modifications are being made to provide more flow area at the 5-in. nose. The dummy fuel element was completed, and work has continued on the cold finger and low-power nuclear test assembly. The cold-finger shield design was completed.

Additional beam-hole shielding was designed and will be installed during the April reactor shutdown. Changes to the plug cooling-water system are also scheduled during the shutdown.

THORIUM UTILIZATION PROGRAM

Planning and Evaluation Studies. – Further studies were made of a 1000-Mw (electrical) molten-salt converter reactor (MSCR). Design specifications and criteria were written for most major items of equipment (such as reactor vessel and core, fuel and coolant pumps, primary heat exchangers, superheaters, reheaters, and some piping). Preliminary equipment layouts showing the reactor, pumps, primary heat exchangers, reheaters, and superheaters were made; also a detailed steam-cycle flowsheet was developed.

A combined machine program was developed which obtains reactor criticality (from MODRIC) and equilibrium concentrations simultaneously. This code was used in obtaining MSCR fuel costs for various parameter values. The fuel-cycle costs obtained ranged from 1.1 to 1.6 mills/kwhr; associated with the lower value was an 18-ft-diam core, a C/Th ratio of 300, 9 mole % ThF_4 in the salt, a Th/U ratio of 23, and a conversion ratio of 0.83.

Testing of Thoria-Pellet and -Suspension Fuels. – In-pile slurry loop 0-1-28S has been operated under irradiation since February 19 in horizontal beam hole HN-1 of the ORR. In this second pump-loop experiment, an oxygenated heavy-water slurry of pure thoria is being circulated at 280°C. The circulating concentration when irradiation began was 1228 g of Th per

kg of D_2O. Two small samples of irradiated slurry have been successfully taken. A total of 652 hr of full-irradiation equivalent had been accumulated on March 22, and slurry had been circulated in the loop for a total of 1210 hr including preirradiation testing.

Loop operation has been satisfactory. Overall corrosion of the internal loop surfaces has been slight, as indicated by oxygen consumption. No radiolytic gas has been detected. Maximum flux, determined in the hydraulic rabbit facility of the adjacent HN-3 beam hole by cobalt activation, was 8×10^{13} neutrons cm^{-2} sec^{-1}, leading to an estimated overall loop flux of 2×10^{13} neutrons cm^{-2} sec^{-1}. The effective capture cross section of thorium in this neutron spectrum was found to be 9.6 barns.

Engineering of Thorium Reactor Systems. — Velocity profiles and friction pressure drops in 1.6-in.-ID smooth brass pipe were measured for a flocculated thoria suspension of 1600°C-fired 1.9-μ particles in the concentration range 0.09 to 0.20 volume fraction of solids, and at Reynolds numbers between 50,000 and 150,000. Rheological curves also were obtained for these slurries by use of a small vertical-tube capillary viscometer.

The resulting velocity profiles were Newtonian at all concentrations and velocities when plotted as u/u_{mean} vs y/R for the appropriate friction factor. It thus appears likely that deviations from the Newtonian friction-factor—Reynolds number plots previously obtained are due to an inappropriate choice of the viscosity term, rather than a gross distortion of the velocity profile. Such an inappropriate choice of viscosity may be related to a wall effect which tends to create a water-rich region next to the wall when very concentrated flocculated slurries are circulated.

Homogeneous Reactor Experiment No. 2. — Approximately one-third of the HRT core was cut into small pieces for metallurgical examination. A remotely operated Heliarc torch was used for the cutting operation. Approximately 56 pieces, out of a total of 78, were removed and were transferred to the Metals and Ceramics Division hot cell. No problems with excessive radiation levels or spread of contamination were experienced during this difficult remote-cutting operation.

Processing of the fuel solution in the Fission Product Pilot Plant was begun and will continue through next month.

MOLTEN-SALT REACTOR PROGRAM

MSRE Design. — Heat-exchanger-mounting drawings were issued. Drain-tank-mounting drawings are being revised to incorporate the few suggestions received on the comment prints.

Heater drawings for radiator heaters and coolant-pipe heater layout drawings were issued. Additional power-distribution drawings and heater circuit diagrams were completed. Pipe-support drawings for the primary cell are still being prepared. Support drawings for coolant pump, pipe, and drain tank were started.

A revision was incorporated in the drain-tank-cell salt piping to provide more flexibility in handling of salt for processing.

Design-package drawings for exterior site modification were signed, and specifications for this package were issued. Numerous contractor working drawings for site modification were reviewed and approved.

MSRE Procurement and Construction. – Fabrication of the dished heads for the drain tanks was completed by the Phoenix Steel Company, and the heads are now being inspected prior to heat treating.

Dies were completed for fabricating the reactor-vessel heads in the Paducah Machine Shops.

The radiator enclosure is approximately 50% complete. Work was started on the heat exchanger and the reactor in the Y-12 Machine Shops.

The contractor for the Building 7503 modifications completed the drain-tank floor and installed the reinforcing steel in the walls.

Critical-path schedules were completed for the major components for the MSRE. These are being checked on the IBM 7090 computer to determine man-power schedules and priorities for the activities involved in fabricating the components.

Chemical Development. – At 600°C, CF_4 does not react with either reduced or normal MSRE fuel, according to results from mass spectrometry of a 40:60 helium-CF_4 mixture recirculated through fuel for 200 hr. Also, procedures capable of detecting gas solubilities in the fuel as low as 10^{-8} mole/cc do not detect a measurable solubility of CF_4 at either 600 or 800°C.

Sulfate ion in MSRE-type fluoride melts decomposes at a rate which was easily discernible over a period of days and which probably increases with increasing acidity of the melt.

A small "mockup" to demonstrate the effect of mixing molten fuel (650°C) with water at room temperature apparently gave HF at 2% yield when fuel (6 g) was jetted into an approximately stoichiometric amount of water (2 g).

Irradiation Tests. – An irradiation experiment (designated ORNL-MTR-47-4) designed to determine if CF_4 exists in the cover gas over MSRE fuel in contact with submerged graphite was inserted into the HB-3 beam hole facility of the MTR during the shutdown of March 12. The MTR reached 40 Mw on March 15, beginning the scheduled 12-week irradiation of the experiment.

After adjustment of the experiment, the maximum capsule temperature was 1400°F, with the other three capsules at operating temperatures of 1380, 1370, and 1310°F. Instructions call for maintaining the maximum capsule temperature within ±25°F of the 1400°F set point. The minimum sodium-bath temperature was set at 960°F. These temperatures, consistent with the design temperature distribution obtained by use of TØSS (see report K-1494) on the IBM 7090 computer, indicate temperature ranges at the interface between graphite surface and salt of 1410 ± 25°F, 1385 ± 20°F, 1375 ± 20°F, and 1315 ± 15°F. The capsule-body INOR-8–salt interface temperature range indicated for each capsule is 1130 ± 50°F, 1125 ± 50°F, 1115 ± 50°F, and 1100 ± 50°F. The INOR-8 in contact with the salt to keep the graphite submerged is at the graphite temperature. Only about 12% of the 5.6 in.^{2} of metal surface in contact with the salt is at the higher temperature.

The preliminary design of experiment ORNL-MTR-47-5 was started. This experiment will be similar to 47-4 but will be equipped so that the capsules can be purged to permit measurement of the formation of CF_4 during operation. The effect of power density and salt-graphite interface temperature will be studied in this experiment. Components are being procured for the out-of-pile bench tests needed to develop the purge system.

Radiation Effects. – The R-0025 graphite irradiated in contact with MSRE fuel in test 47-3 increased in Rockwell hardness from 94 to 108. The AGOT graphite boats increased from about 56 to about 80 as a result of preimpregnation with fuel, and no subsequent increase as a result of irradiation was found. In neither case were there any differences in hardness between regions that had been in contact with the pool of fissioning fuel and regions that had not.

The principal gamma activity in the graphite (frequently 10^6 dis min^{-1} mg^{-1}) was due to the Zr^{95}-Nb^{95} chain. No Cs^{134} or Cs^{137} activity, expected as a consequence of xenon diffusion, was found; separations are being made to establish whether cesium activity was merely swamped.

Reactor Processing. – Methods are being investigated for disposal of excess fluorine from the fluorination of MSRE fuel salt for uranium recovery. Eight runs were made in which fluorine was reacted with charcoal. The combustion reaction was nonexplosive, and unreacted fluorine in the off-gas was consistently < 100 ppm. The off-gas is approximately 50% CF_4, a relatively inert gas. Of concern are the solids (0.01 g per gram of charcoal) and the liquid (0.1 g per gram of charcoal) carried over in the off-gas. These are mainly higher-boiling fluorocarbons, HF, and H_2O, and would constitute a radioactive disposal problem.

STUDIES AND EVALUATIONS

Reactor Evaluation Studies. – A study was made to determine the effect of changes in fuel-inventory charges and in uranium costs on fuel-cycle costs in Dresden-type BWR and Yankee-type PWR power plants. A summary of the parameter values associated with two of the price schedules is given in the following table:

Cost Sched	Natural Uranium Cost ($/kg)	Separations Work Cost ($/kg U)	Tails Composition (weight fraction U^{235})	U^{235} Price ($/g)	Pu Price ($/g)	U^{233} Price ($/g)
A	23.5	37.29	0.00277	13.70	8.0	15.0
B	15.0	30.0	0.0030	10.25	6.0	11.2

With enriched uranium as the fuel material, the fuel cost increase of ~0.5 mill/kwhr due to changing the inventory charge from 4-3/4% to 12% would be almost exactly compensated if the uranium price were reduced from present bases (schedule A) to those of schedule B. With thorium fuel, changing from schedule A and 4-3/4% fuel-inventory charge to schedule B and 12% inventory charge increased net fuel costs about 0.5 mill/kwhr.

At the 4-3/4% inventory charge, thorium had a 0.1 to 0.2 mill/kwhr advantage over uranium in the PWR-type reactors; in the BWR reactors the fuel costs were about the same for both thorium and uranium, with uranium

having a slight advantage. At the 12% inventory charge, uranium was a more economic fuel than was thorium with respect to the first cycle.

ADVANCED REACTOR DEVELOPMENT

High Flux Isotope Reactor Design and Development

Metallurgy. — Blistering of the HFIR inner-annulus plates while they were being fabricated and heat-treated at 500°C has been alleviated by vacuum heat treatment at 550°C of the cold-pressed as well as the forged fuel core and filler pieces. Of 60 plates rolled and tested at 500°C, 93.3% were acceptable.

Experiments have indicated that to produce an acceptable fuel element, local deviations in the involute shape of the composite plate must be controlled to ±4 mils. Fabrication studies of the outer-annulus plates have shown that by controlling plate thickness variations to within ±0.4 mil and exercising greater control of the annealing treatment, 51% of the plates could be marformed at low pressure to the tolerances needed. Further improvement is anticipated by closer control of the metallurgical properties of the composite plate and by alternative forming techniques such as high-energy forming and high-pressure marforming.

An alternative assembly design being examined consists of two grooved tubular side plates in which all the involute-shaped plates are slipped into position and fixed by circumferential welds spaced at 1-in. intervals along the length of the element. Welding parameters have now been established, and full-scale assembly experiments are being initiated.

Corrosion Studies. — Isothermal corrosion tests have been conducted to determine the corrosion resistance of a number of different alloys necessary in specific components of the HFIR and to determine the effect of coupling certain alloys. The following metals and alloys corroded at rates less than 1 mil/yr in flowing water acidified to a pH of 5 with nitric acid at 100°C: 18-8 austenitic stainless steels; hardened types 416, 420, 440C, and 17-4PH(H1125) stainless steel; Stellites 3 and 98M2; Kentanium 165; Inconel; nickel; and beryllium.

The coupling of aluminum to stainless steel resulted in random deep pitting of the aluminum on the surfaces contacting the stainless steel; aluminum in contact with either nickel or beryllium suffered no adverse effect. The coupling of beryllium to the 18-8 stainless steels produced heavy corrosion of the beryllium surface that contacted the stainless steel. In the HFIR the permanent aluminum members joined to stainless steel will be of appreciable thickness, and the pitting of the aluminum may not produce serious consequences. Beryllium will not be in contact with stainless steel in the HFIR.

Design. — The steady-state hot-spot analysis is now essentially complete. Results of these studies have been used to establish the fuel loading and fuel-element assembly tolerances indicated on the fuel-element drawings and in the plate procurement specifications. Some work is still in progress to improve the hot-spot machine program.

A preliminary hot-spot analysis of the HFIR target rod, by use of the same techniques and correlations employed for the fuel element, indicates that oxide buildup is the controlling factor in the target heat transfer requirements. Limiting the maximum oxide buildup to about 3 mils over a 2-yr rod irradiation period will require a target water velocity of about 40 fps. The calculated target-burnout power-level margin at this flow rate is about 4.0 at the time of maximum target heat production. Consideration has been given to the use of thermocouples to measure the power level of the target assembly. It appears that thermocouples attached to the target rods are impractical because of radiation damage, difficulty in replacement, and the large number required.

Drawings for the mockup control rods were completed, showing the details and assembly. The rods are mechanical prototypes; however, silver is not included in the initial rods for the mockup. Tolerance accumulations were investigated for the parts adjacent to the control region to determine the tolerance requirements for the control rods. The tolerances, along with prototype-material problems, precipitated a general review of the reactor control rods.

Following the determination of the heat generation rates, the heat transfer and thermal distortion of the control rods will be studied. Particular attention will be given to the mechanical joint between the gray and white regions of the control plate. Consideration is being given to control rods of materials such as stainless steel and europium oxide, in addition to the silver-nickel-aluminum rods presently being considered.

Drawings and specifications were completed for procurement of the HFIR beryllium.

NUCLEAR TECHNOLOGY AND GENERAL SUPPORT

Basic Reactor Physics. — A previous report (ORNL-3193, p 29) described in detail a method developed for the fitting of interpolation functions to scintillation-spectrometer pulse-height spectra. In the previous work the method — that of nonlinear least-squares estimation — was employed to calculate the response functions for the Compton and pair spectrometers used in observing the spectrum from 300 to 2300 kev of prompt gamma rays from the thermal fission of U^{235}. A like technique has now been used to compute response functions for the single-crystal spectrometer over the energy range 30 to 800 kev. Fits to experimental data have been as good as those obtained from the Compton spectrometer data.

Nondestructive Test Development. — Studies have begun toward the development of solid-state coupling materials to be used for "dry" coupling of ultrasonic vibrations into test materials. Silicone rubber has shown promise for such use, and a technique for forming thin sheets of it has been developed. This became necessary after commercial sheets of silicone rubber failed to transmit ultrasound into a test piece when a modified immersion technique was used.

The prototype sheets, which are made of RTV-731 silicone rubber, mold very closely to the surface of the test piece and allow ultrasound transmission. However, small pockets of air which reduce total transmission can be trapped between the rubber and the test piece. This problem may

be overcome by using pressure to remove the air pockets or by using very small amounts of liquid couplant. Different couplants are being investigated. Further work must be done before this technique can be applied to an actual evaluation; however, initial results are promising.

Use of this rubber couplant in Lamb-wave generation or similar techniques required fabrication of thicker sections and determination of some of its properties. For example, to establish the correct incident angle for Lamb-wave generation with the solid-couplant type of probe being used, the velocity of ultrasound in the solid (RTV-731 silicone rubber) was measured. This velocity, approximately 39,900 in./sec, was obtained by a through-transmission ultrasonic technique. An optimum theoretical angle for Lamb-wave generation has been calculated, and after the fabrication of rubber wedges of this angle, an attempt will be made to establish a Lamb wave in a thin metal sheet.

Mechanical Properties Research. — Instantaneous collapse testing of type 304 stainless steel at 1200°F has yielded results which can be correlated with stress-strain tensile properties. Inelastic collapse pressures for perfect tubes can be determined readily by a new graphical method of solution. The effects of the geometric imperfections of ovality and wall-thickness variation on reducing the critical pressure for collapse have also been related to the tensile properties. The effect of ovality is shown to be quite severe in affecting the loss in stability for resisting external pressures. However, the effect of wall-thickness variation within standard commercial tolerances is very minor and can be neglected. Thus, by knowing the expected minimum material properties and the expected maximum geometric imperfections, tubes can be designed to resist a given external pressure with any desired confidence factor.

Solid Reaction Studies. — Diffusion coefficients for self-diffusion in the body-centered cubic (beta) phase of iodide zirconium were determined at 900 to 1750°C. Zirconium-95 (65-day, 0.75-Mev gamma), purified of radioactive daughter Nb^{95} (35-day, 0.76-Mev gamma), was the isotope used in these experiments. All diffusion anneals were completed within 48 hr from the time of separation of niobium; therefore the activity due to Nb^{95} did not exceed 3.8% of the total activity. The diffusion coefficients obtained are best fitted on an Arrhenius-type plot [ln D vs (1/T°K)] by a curved line concave upward. Apparent activation energies calculated from the slope of the Arrhenius plot vary from 21,100 cal/mole at about 900°C to 45,900 cal/mole at about 1750°C.

Materials Compatibility Studies. — A reliable, accurate procedure for determining the oxygen concentration in potassium is necessary for the ORNL programs on purification, corrosion, and solubility studies involving this alkali metal. The mercury amalgamation and butyl bromide methods are widely used, although they were originally developed for sodium. Recent studies showed poor correlation when duplicate samples were analyzed by both methods.

To investigate the recovery of oxygen by the mercury amalgamation method, samples of potassium were spiked with KO_2 and equilibrated for 100 hr at 200 and 600°C. Chemical analyses of the total samples indicated recoveries of ~8 and ~45% respectively. This suggests that a portion of the oxygen in the potassium is lost during the amalgamation process and that changes occur in the oxide species according to prior thermal history.

Another method which may be useful for determining oxygen involves gettering of the nonmetal from potassium with an active metal such as zirconium and analyzing the zirconium by vacuum fusion. The distribution coefficient of oxygen between zirconium and potassium under the conditions of interest and the accuracy of the oxygen recovery from zirconium by vacuum fusion must be known in order to use this procedure. In one test, the coefficient was found to be 5–6 ($C_{O \text{ in } Zr}/C_{O \text{ in } K}$) at 815°C with highly contaminated potassium being used.

Vacuum fusion analyses on zirconium specimens contaminated to known oxygen levels showed deviations of −7 to +12% in the range 1000 to 6000 ppm.

Fuel Element Development. – In connection with the program designed to evaluate the potential of fueled BeO for use in all-ceramic power reactors, prototype specimens for an irradiation experiment were fabricated. These specimens contain 30 vol % of UO_2 as 110- to 156-μ particles and were sintered at 1750°C in hydrogen to a bulk density of 92% of theoretical. The purpose of the initial irradiation experiments is to investigate the effect of controlled porosity (voids) around the fuel particles on structural integrity and fission-gas release rates. Calculations based on linear shrinkage of the UOX-grade BeO matrix material used and the predetermined shrinkage characteristics of the fuel particles showed that a void gap of 2.0 to 2.5 μ would be produced between the fuel particle and the matrix in these specimens, and that the specimen density would be decreased accordingly from 96% to ~92% of theoretical. For the irradiation experiment, specimens of this type containing 20%-enriched fuel particles will be fabricated. A technique for forming spheroidal fuel particles by tumbling irregularly shaped green granules in a high-velocity air stream is being investigated.

Reactor Controls Development. – In a study of pickup noise in reactor pulse-counting instrumentation, laboratory tests duplicated successfully some aspects of observations made previously in various reactor installations. Study of relay systems as noise sources showed that shock excitation of the interconnecting wiring, which typically rings at frequencies in the 2- to 20-Mc range, is responsible for a substantial fraction of the pickup noise. The noise enters the counting equipment through the power feeder to the electronic components or signal cables, or both.

Tests using different types of signal cables revealed, as expected, widely different susceptibilities to induced electrical noise. RG-71A/U coaxial cable, because of its double shield, is a factor of 50 better than RG-62A/U, which is otherwise identical. A triaxial cable whose center conductor and inner shield are similar to RG-59A/U has twice the susceptibility of RG-71A/U. Tests on RG-108A/U, which is a balanced, shielded cable, showed a performance approximately equal to that of RG-71A/U for a simple termination network. The performance of the balanced system was improved by a factor of 3 when a better-balanced termination network was used, and a field test of this last system will soon take place.

Power Reactor Fuel Processing: Uranium Carbide. – Hydrolysis of a 158-g batch of uranium carbide at 80°C yielded 3.11 mg-atoms of carbon per gram of specimen as gaseous hydrocarbons, about 0.80 as a water-insoluble yellow liquid, and 2.12 in the water-insoluble uranium residue.

The sample contained 3.82 mg-atoms of uranium per gram of sample, 7.45 of total carbon, and 1.16 of free carbon. Gas chromatographic analysis of the yellow liquid showed the presence of C_6 to C_{11} hydrocarbons; about 60% of the carbon was in the form of C_8 hydrocarbons. The uranium residue, containing 1.82 g of combined carbon and 2.20 g of free carbon, yielded a dark-red solution and brown solids when reacted with 9 M HNO_3 at 80°C. Leaching of these solids with acetone yielded 0.36 g of free carbon and 2.44 g of dark-red acetone-soluble solids which were 50% carbon. Since the specimen originally contained 2.2 g of free carbon, it appears that the finely divided carbon dispersed throughout the carbide is attacked by HNO_3 under milder conditions than are required for the reaction of massive graphite with HNO_3.

Power Reactor Fuel Processing: Solvent Extraction. — The separation of uranium from thorium in aqueous solution by extraction with 2.5% tributyl phosphate is strongly dependent on the salting strength and the saturation of the solvent with uranium. Varying the aluminum nitrate content of the 0.01 N acid-deficient scrub from 0.6 to 1.5 M decreased the solvent saturation at the feed plate from 43% to 23% by decreasing the reflux. The fission product decontamination at the feed plate decreased from 100 to 30 and after three scrub stages, from 13,000 to 80.

Batch equilibration of 50 ml of a solution containing ~1.8 g of uranium per liter, 0.5 M HNO_3, 0.01 M $NaNO_2$, and 2.7×10^4 counts min^{-1} ml^{-1} of plutonium for 17 hr with 0.5 g of a zirconium silicon phosphate exchanger removed 99% of the plutonium from solution. Approximately 12% of the plutonium was removed from a similar solution containing 4 M HNO_3. The exchange material was prepared with a ratio of ZrO_2:SiO_2:P_2O_5 of 1:4.8:0.7.

Power Reactor Fuel Processing: Mechanical. — Particle-size measurements of the fines produced in the shearing of Kanigen and Nicrobraze 50 brazed assemblies to 1-in. lengths indicate that the stainless steel fines are larger, in general, than the porcelain fines. For all fines, 90% were > 9520 μ, 9% < 2000 μ, and only 1% < 44 μ. Of the last fraction 84% were < 10 μ and 50% < 3 μ.

Power Reactor Fuel Processing: Corrosion. — Unwelded Corronel 230 was corroded in boiling (~116°C) 10 M HNO_3–0.5 M HF at a maximum rate of 60 mils/month in 96 hr exposure. Under similar conditions, Hastelloy F (36 hr) and experimental alloys EB-4358 and EB-5459 (8 hr each) were corroded at respective rates of 212, > 500, and > 500 mils/month. At 60°C the maximum rate for Corronel was 2.83 mils/month in 312 hr exposure.

Unwelded Corronel 230 was corroded at a maximum rate of 5 mils/month in 312 hr exposure at 60°C in 1 M HNO_3–3 M HF vs 2700 mils/month in the boiling solution. Type 309SCb stainless steel, Hastelloy F, and Haynes experimental alloys EB-4358 and EB-5459 were corroded at maximum rates of 463 (20 hr), 123 (8 hr), 165 (8 hr), and 190 (8 hr) mils/month, respectively, in boiling 1 M HNO_3–3 M HF. All materials tested in the boiling solution suffered localized attack.

Ni-o-nel was corroded at maximum overall rates of 0.31, 0.43, and 0.59 mil/month vs 0.19, 0.27, and 0.42 mil/month for LCNA (a low-carbon nickel alloy with the same nominal composition as Ni-o-nel except that C = 0.005%) in the vapor phase above refluxing 4 M HNO_3 in exposures of 360, 516, and 676 hr respectively. Grain-boundary attack became visible

on specimens of both alloys between 192 and 360 hr exposure. Specimens exposed to the condensate showed negligible corrosion rates (< 0.01 mil/month) and no visible change in appearance.

Power Reactor Fuel Processing: Darex Process. – Methods of eliminating silica and other insolubles in a continuous Darex process for APPR fuel, which contains 2 wt % silicon, were investigated further. About 10% of the silica was solubilized by complexing with fluoboric acid at the standard fuel-solution content of 60 g of stainless steel per liter. A fluoride-stabilized silica precipitate that also formed was removed by filtration at an average rate of 0.5 ml cm^{-2} min^{-1} or passed directly through the chloride stripping column. About 87% of the total solids passed through the column, and those held up were easily washed through with hot nitric acid or water. During chloride stripping, 17% of the total fluoride appeared in the HNO_3-HCl condensate. Efforts to complex this free fluoride with aluminum or boric acid were unsuccessful. Hydrated silica was also stabilized by 24-hr boiling of the fuel solution at total reflux. Filtration of the resulting solution at 70°C at an average rate of 1.2 ml cm^{-2} min^{-1} removed 99% of the precipitate and insoluble stainless steel carbides and oxides.

Treatment of APPR fuel solution with gelatin or molybdates to coagulate or solubilize the hydrated silica was unsuccessful. However, molybdate treatment of solutions of fuel containing 0.5% silicon or less was encouraging.

Fluoride Volatility Pilot Plant. – In two runs, TU-11 and -12, with nonirradiated fully enriched zirconium-uranium alloy fuel, 40-kg charges were dissolved at 650 and 500°C, respectively, at an HF flow rate of 150 g/min. Dissolution rates in the NaF-LiF-ZrF_4 salt were 2.4 and 3.3 kg/hr, respectively, based on 90% completion. Corresponding HF utilization efficiencies were 17.5 and 24%. After the usual dissolution time, HF was passed in at 40 g/min to solubilize any dissolver metal remaining in the salt. The dissolver off-gas system performed well during both runs at a recycle HF flow rate of ~350 g/min.

A dual fluorine flow rate of 6 std liters/min (for 100 min) and 14 std liters/min (for 20 min) at 500°C decreased the residual uranium in the salt to < 10 ppm. A complete uranium balance was not made because of system holdup, but nonrecoverable uranium losses for runs TU-11 and -12 were 0.25 and 1.59 g respectively.

The off-gas filter was replaced with a new Yorkmesh cartridge in anticipation of irradiated-fuel processing. The discharged cartridge showed no increase in pressure drop for eight runs.

PHYSICAL RESEARCH PROGRAM

Reactor Operations. — During the first ten weeks of 1962, the ORR operated 83.1% of the time.

A successful preliminary irradiation of protactinium in the hydraulic tube was completed. A boiling experiment was installed to investigate the detection of boiling, and a thoria slurry loop was installed in hole HN-1 in February. The aluminum pool liner began leaking because of corrosion from the concrete side and had to be repaired.

At the LITR, a Biology Division experiment has been installed in beam hole HB-2.

Waste Disposal. — The installation of liquid and gaseous waste monitoring equipment in the Waste Control Center is expected to be complete next summer.

A number of proposals have been submitted for replacement of trench No. 6, which had developed a leak. The proposals included three temporary evaporator schemes and four alternate designs of trenches.

Hot-Cell Operations. — Operations in the hot cells were routine. Examination of six NaK-filled capsules containing APPR miniature plates was begun; these were irradiated in the ETR. Several ORR-GCR capsules and two specimens from ORR loop No. 1 were disassembled and examined. The uranium from the SRE elements disassembled in Building 3026D was shipped to Savannah.

PHYSICS AND MATHEMATICS RESEARCH

Charge Spectrometry. — Measurement of the charge spectrum of the K^+ ions formed from the decay of Ar^{41} completes a series of similar studies on the five rare gases from helium to xenon whose purpose has been to evaluate the atomic consequences of β^- decay. The experimental procedure consists in allowing the radioactive gas, formed by bombarding potassium aluminum silicate [$K^{41}(n,p)Ar^{41}$] in the core of the ORR, to decay in a specially designed mass spectrometer.

The analysis of the relative abundance of the K^+ ions formed from the β^- decay of argon is as follows: K^+, 82.3%; K^{2+}, (12.6 ± 0.8)%; K^{3+}, (3.0 ± 0.2)%; K^{4+}, (1.4 ± 0.1)%; K^{5+}, (0.44 ± 0.06)%; K^{6+}, (0.16 ± 0.04)%; K^{7+}, (0.06 ± 0.02)%; K^{8+}, (0.016 ± 0.009)%.

Neutron Diffraction. — Neutron diffraction studies have been made by means of the ORNL magnet diffractometer on single-crystal specimens of holmium in order to investigate the mechanism of magnetization in this substance. At each of the two temperatures, 64 and 4.2°K, magnetic fields up to 22.3 kilo-oersteds were applied to the specimens at angles of 0, 30, 60, and 90° to one or both of the principal directions a_1 and b_1 in the basal plane, and the distribution of magnetic reflections in the vicinity of important nuclear reflections was studied. At 4.2°K the conical arrangement of moments, which is characteristic of holmium

in the virgin state, was transformed in low fields to a ferromagnet in which the moments are parallel to a b-direction. The a-direction is a hard direction for magnetization. At 64°K the application of a magnetic field produced two or three distinct magnetic configurations, depending upon the strength and direction of the field. These configurations are similar to the model predicted by the theory, in which the magnetizations of the layers oscillate sinusoidally about the field direction.

Theoretical Physics. – The inelastic scattering of medium-energy alpha particles is interpreted as a direct interaction when the distorted-waves method is used. The optical potential which best fits the observed elastic scattering is found by using an automatic search routine and is then used to predict the shape of the inelastic angular distribution. The deformed-potential interaction [Phys. Rev. 120, 1375 (1960)] gives results in good agreement with experiment; the deformations obtained from the magnitudes of the cross sections agree reasonably well with those found by other techniques. Also, when the elastic data are consistent with more than one set of optical potential parameters, very similar inelastic cross sections are predicted. The α'-γ angular correlation was calculated, and it was found that the results may differ markedly from the predictions of the adiabatic theory [Phys. Rev. 115, 928 (1959)] when alpha particles are observed off the peaks of the angular distribution.

Fast-Chopper Time-of-Flight Spectrometer. – The ORNL fast chopper and associated equipment were utilized in measuring the transmissions of 1-in.-thick metal samples of $Sn^{116-120}$ (enrichment over 95%) and normal tin. Measurements were made from 30 to 10,000 ev with a time resolution of 10 nanoseconds/m by use of the 180-m-flight-path spectrometer. The transmission data have been analyzed to give the parameters of the resonances by use of an area analysis program (ORNL-3205) which includes the effects of resolution and Doppler broadening. The observed level spacings of the even isotopes, $Sn^{116,118,120}$ ($D_{obs} \sim 240$ ev), were found to be about four times those of the odd isotopes, $Sn^{117,119}$ ($D_{obs} \sim 60$ ev). Parameters of the resonances, the s-wave strength functions, and the nuclear radii of the isotopes have been obtained from the data.

High-Voltage Experimental Program. – The tandem Van de Graaff accelerator was accepted on March 8. For the following two weeks the machine was used to study proton elastic and inelastic scattering on zirconium and nickel isotopes. The data have not been analyzed completely as yet. At this time the machine is ready to be used for the acceleration of nitrogen ions.

A 9 × 12 in. NaI crystal has been used with the ORNL pulsed Van de Graaff to study the gamma-ray spectra from the capture of 30-kev neutrons. The technique was used previously [Proceedings of the Saclay Symposium on Neutron Time-of-Flight Methods, p 213 (1961)], but improved gamma-ray energy resolution (10% for 0.66 Mev) and sensitivity (3-mb cross sections observable) make it possible to obtain the strengths of individual transitions in many cases. Measurements have been made for F, Al, Ca, V, Cr, Fe, Cu, Ni, Y, and Pb (including separated isotopes of

Cu and Ni), and in most cases the results differ from those of thermal-neutron capture. The main factors causing the differences are (1) changes in relative capture cross sections of isotopes, (2) fluctuations in transition strengths from resonance to resonance, (3) the averaging of transition strengths over many resonances, and (4) the contribution from p-wave neutron capture for 30-kev neutrons.

CHEMISTRY RESEARCH

Effects of Radiation on Analytical Methods. — The study on the effects of gamma radiation on methods involving the use of ethylenediaminetetraacetic acid (EDTA) is essentially complete. The EDTA amperometric titration methods for determining thorium (using Fe^{2+} as an end-point indicator) and for thorium plus zirconium (using VO_2^+ as the end-point indicator) have been assayed for possible gamma radiation effects. In both methods, exposure can reach a level of more than 10^4 r of gamma radiation before any indication of bias is noted.

A study on the possible effects of radiation on the diphenyl carbazide method for determining chromium has been initiated. The rate of apparent damage caused by gamma radiation is totally different for solutions containing unreacted $K_2Cr_2O_7$, as compared with dichromate solutions which have reacted with diphenyl carbazide prior to irradiation. Since there is a lack of understanding of the chemistry involved in this reaction, a corollary study is also being made to seek out this information.

Mechanisms of Separations Processes: Foam Separation. — A continuous calcium and magnesium precipitator was built and was operated to produce an adequate feed to a foam column from simulated ORNL low-activity waste. Fast stirring and 30 min contact time in the mixer and a partially agitated sludge column produced a high-quality effluent. Coagulation of the sludge was greatly improved by the addition of 2 ppm of Fe^{3+}. Addition of NaOH (to 0.01 M) to the mixer removed 95% of the calcium and 80% of the tracer Sr^{85} present. Addition of a mixture of NaOH and Na_2CO_3 gave about the same calcium removal but increased the strontium removal to about 95%.

Partial agitation of the sludge decreased the total hardness of the effluent, without filtration, to 1.8 ppm as $CaCO_3$ and the solids, as calcium plus magnesium, to $\leq$0.1 ppm (as calcium).

Discontinuous addition of grundite clay to the flocculator (total 3 g to 48 liters) produced an effluent, after 48 hr of continuous operation, with a decontamination factor from strontium of 40 to 90 and from cesium of 10 to 40. The grundite was retained in the sludge column. The agitated sludge column, besides improving the hardness and clarity of the water, classified the $CaCO_3$ and strontium at the bottom of the column, thereby producing a concentrated sludge with ~12% solids, corresponding to a volume reduction of about 1000. These values may be compared with those obtained in the present low-activity-waste treatment plant, which gives a volume reduction of about 300 and an average decontamination factor from Sr^{90} of 4 and from Cs^{137} of 6.5.

The heights of transfer units in a 6-in.-ID foam-liquid column were 0.8 to 1.6 in. for stripping of Sr^{89} during eight runs with 4 to 11 in. of countercurrent length and liquid flow rates of 40 to 100 gal hr^{-1} ft^{-2}. The HTU values were increased as channeling increased. This increase was particularly noticeable for poor distribution of the liquid feed and was noticeable for increased liquid feed rates or decreased foam rates.

Mechanisms of Separations Processes: Thermodynamics of Solvent Extraction. – Vapor pressures and activity coefficients of nitric acid were determined by a transpiration method in the concentration range 1 to 16 M. The relation between the logarithm of the nitric acid partial pressure and the logarithm of its mole fraction was linear. The results correlate well with those obtained by freezing-point-depression methods. At constant nitric acid molarity, the partial pressure of the acid increased as the uranyl nitrate concentration increased. However, for a given mole fraction of nitric acid, addition of uranyl nitrate did not alter its activity.

Chemical Engineering Research. – Both the flow capacity and the stage efficiency of the Mark IV stacked-cone contactor increased with increasing temperature from 29 to 45°C in the extraction of uranyl nitrate from 1 M $NaNO_3$ by 15% tributyl phosphate in Amsco. The flow capacity was $3.\overline{3}$ liters/min at 41°C, compared with 2.4 liters/min at 29°C, and the average stage efficiency at about 80% of flooding was 70% at 41°C and 35% at 29°C. The improvement at higher temperature probably results from the decrease in viscosity.

HETS (height equivalent to a theoretical stage) values for extraction and stripping, with uranium as a stand-in for plutonium, were determined as part of the amine-extraction final-cycle plutonium flowsheet studies. The uranium-extraction HETS value for a sieve-plate column (0.125-in.-diam holes, 23% free area, aqueous continuous operation) decreased from 6.6 to 4.2 ft as the pulse frequency increased from 50 to 70 cpm, and for a nozzle-plate column (0.125-in.-diam nozzles, 10% free area, solvent continuous operation) was 4.2 ft at a pulse frequency of 70 cpm. The HETS value for uranium stripping decreased from 9.8 to 3.2 ft as the pulse frequency increased from 50 to 90 cpm for aqueous continuous operation of a sieve-plate column and was 3.0 ft for solvent continuous operation of a nozzle-plate column at 50 cpm pulse frequency.

Volatility Studies. – Studies made at Battelle Memorial Institute (under subcontract) indicated that alloy 79-4 (79 wt % Ni, 4% Mo, remainder Fe) is more resistant to fluorination conditions than either INOR-8 or L-nickel. The metal specimens were exposed at 500°C in both series; fluorine was passed through for 150 and 162 hr respectively. Uranium tetrafluoride was added to both salts periodically. In contrast to L-nickel, there was no significant intergranular attack of the INOR-8 or alloy 79-4. The presence of beryllium in the fuel salt increased its corrosiveness:

	Maximum Penetration Rate (mils/month)						
	27.5-27.5-45 Mole % $NaF-LiF-ZrF_4$				27.8-20.4-6.8-45 Mole % $NaF-LiF-BeF_2-ZrF_4$		
	INOR-8 (by wt loss)	Alloy 79-4 (by wt loss)	L-nickel (by wt loss)	L-nickel (metallographic)	INOR-8 (metallographic exam)	Alloy 79-4 (metallographic exam)	L-nickel (metallographic exam)
Vapor	3	1	0.2	8	9	7	11
Liquid	11	4	3.8	25	38	13	31
Interface	11	2	1.3	28	6	5	22

The oxidation resistance of alloy 79-4 in 2000 hr exposure to air at 700°C was equivalent to that of INOR-8 and L-nickel. The advantage of an adherent scale on L-nickel was offset by the extensive intergranular attack which occurred. The results showed that complete protection from oxidation could be provided by Chromallizing, a proprietary chromium-coating process.

Solvent Extraction Research. — Sulfuric acid was recovered from Sulfex decladding solution, for recycle with attendant waste-volume decrease, by amine extractants. Sterically hindered tertiary amines (alkyl branching close to the nitrogen) were the most useful, since they are readily stripped with water. With the more efficient amines, such as N-benzyl di(2-ethylhexyl)amine, 1 M H_2SO_4 was recovered.

Degradation of commercial aliphatic Amsco 125-82 by boiling nitric acid was decreased by treating with an equal volume of boiling 2 M H_2SO_4 for 2 hr under total reflux. The treated material, made to 1 M in tributyl phosphate (TBP) and boiled for 4 hr under total reflux with 2 M HNO_3 extracted no more Zr^{95}-Nb^{95} from another 2 M HNO_3 solution containing 10^4 counts sec^{-1} ml^{-1} of Zr^{95}-Nb^{95} tracer than did fresh TBP-Amsco, that is, < 100 counts sec^{-1} ml^{-1}. A 1 M TBP—Amsco solution so degraded without preliminary sulfuric acid treatment, after the usual sodium carbonate—calcium hydroxide scrubbing, extracted 4000 counts sec^{-1} ml^{-1}. No sulfur compounds remained in the Amsco after treatment.

In continued study of tracer strontium extraction (ORNL-3256) from 4 M $NaNO_3$ by di(2-ethylhexyl)phosphoric acid (D2EHPA) in benzene, the extraction coefficient went through a maximum in the pH region where $[NaD2EHP]/\Sigma[D2EHPA] = 0.25$ (pH from 4.5 to 5.5, depending on $\Sigma[D2EHPA]$). Such maxima were not shown in strontium extraction from systems containing only Sr^{2+} and H^+ as cations or in sodium extraction with or without Sr^{2+} present. These results indicate that the observed maxima in strontium extractions are associated with systems containing gross amounts of sodium and with a particular organic phase composition, that is, $[NaD2EHP]/\Sigma[D2EHPA] = 0.25$.

In Na^+-free systems the strontium extraction coefficient, E_{Sr}, was proportional to $[H^+]^{-2}$ up to loadings of ~1 mole of Sr per 8 moles of D2EHPA. In Sr^{2+}-free systems, E_{Na} was proportional to $[H^+]^{-1}$ to within 90% of stoichiometric (1 to 1) loading. In the presence of gross

quantities of strontium, E_{Na} was also proportional to $[H^+]^{-1}$, although only small amounts of sodium could be extracted under these conditions.

Reactor Neutron Cross Sections. – Two samples of approximately 10 mg of Ce^{140} were irradiated in the MTR to an integrated flux of 2.27×10^{21} and 6.66×10^{21} neutrons/cm^2 (monitored with Co^{59}). The Ce^{142} formed from the $Ce^{140}(n,\gamma)Ce^{141}(n,\gamma)Ce^{142}$ reaction was determined mass spectrographically and by neutron activation. A preliminary evaluation of the data yielded an effective cross section of 55 barns for the reaction $Ce^{141}(n,\gamma)Ce^{142}$.

Chemistry of the Heavy Elements. – The $DClO_4$-D_2O-H_2O system, as measured in a titanium, sapphire, and Teflon cell, was shown to be a spectrophotometrically stable solvent, at least to 1 f $DClO_4$, 250°C, and 600 psia in the wavelength range 0.33 to 1.8 μ. Solutions of 0.01, 0.1, 0.5, and 1.0 f $DClO_4$ were examined for periods up to several days at temperatures up to 250°C. However, neither the titanium nor the sapphire is inert in this aqueous system. Studies at 250°C were complicated by pitting of the synthetic sapphire windows. The onset and the progress of pitting were manifested by a very slowly rising base-line absorbance (0.001 to 0.002/hr) throughout the visible and near-infrared region while the cell was held at 250°C. Examination of the windows after exposure revealed hexagonal pyramid pits (6 to 10 μ across and 0.8 to 1.1 μ deep, covering 15 to 40% of the surface). The amount of titanium and aluminum appearing in cell samples increases with the time and temperature of exposure and is roughly proportional to the acid concentration.

The corrosion expressed in terms of mils per year per unit formality of $DClO_4$ is as follows:

	25°C	250°C
Titanium	0.005	0.08
Sapphire	< 0.001	340

Chemical Physics: Microwave and Radio-Frequency Spectroscopy. – In an earlier report (ORNL-3156, p 25) an electron-spin resonance spectrum measured in gamma-irradiated KNO_3 was interpreted to be that of NO_2 undergoing large amplitudes of torsional oscillation. This interpretation has been modified. It is clear that the NO_2 parameters have been modified by motional effects; however, further calculations indicate that the major effect does not arise from torsional oscillations, but from rapid reorientations of NO_2 in an anion vacancy between mirror-related positions in the vacancy.

Electrochemical Kinetics and Its Application to Corrosion. – Potentiostatic studies of the polarization characteristics of iron electrodes in hydrogen-saturated 0.10 f benzoic acid solutions, of pH 4.60 to 5.60, were continued. The goal of these studies was to elucidate the nature of the slow transient reactions found to accompany a shift in electrode potential and thereby to advance the mechanistic picture of iron corrosion and its inhibition.

At a new electrode potential E_2, the rates of the hydrogen evolution reaction and the iron dissolution reaction, at any time t, were found to be greater or less than their steady-state rates, depending on whether E_2 is more or less cathodic than the original steady-state potential E_1.

The results suggest that in shifting from a cathodic potential to a more cathodic potential, the concentration of adsorbed hydrogen atoms on the surface increases, and the equilibrium between the hydrogen atoms on the surface and those in the interior of the iron is disturbed. The slow transient then corresponds to the re-establishment of this equilibrium at the new potential and at higher concentration levels. In shifting to a less cathodic potential the situation is simply reversed; that is, the excess hydrogen in the metal is slowly removed. In shifting to an anodic potential the excess hydrogen in the interior of the metal serves as a source which feeds hydrogen atoms to the surface and thereby retards the rate at which the catalyst for the iron dissolution process, $(FeOH^+)_{ads}$, builds up. Experiments to show whether the rate of transfer of hydrogen atoms from the surface to the interior of the metal is determined by an activation barrier at the surface or by Fick's law of diffusion within the bulk of the metal are planned.

Physical Chemistry of Molten Salts: Cryoscopic Studies. — Measurements were made of the freezing-point depressions of NaF caused by the addition of up to 0.15 mole fraction of lanthanide trifluoride solutes. The purpose of this investigation was to correlate the excess partial molal free energies of mixing of NaF (evaluated from the freezing points) with structural parameters of the solutes. These free energies were found to be negative in sign. For fixed solute concentrations, the square root of the absolute magnitude of the free energy was a linear function of the reciprocal of the interionic distance of the solute. This particular dependence is suggested by the perturbation theory of Reiss [J. Chem. Phys. 36, 144 (1962)].

Physical Chemistry of Molten Salts: Theory of Molten-Salt Behavior. — The heat of solution of solid AgCl in molten KNO_3 has been estimated theoretically by means of a cycle first suggested by Flood, Førland, and Grjotheim. The cycle involved the evaluating of the sum of the heat changes for the processes

$$AgCl(s) + KNO_3(liq) \rightarrow KCl(liq) + AgNO_3(liq) ,$$

$$KCl(liq) \rightarrow KCl(\text{infinite dilution in } KNO_3) ,$$

$$AgNO_3(liq) \rightarrow AgNO_3(\text{infinite dilution in } KNO_3) .$$

A value of 19.6 ± 1.0 kcal/mole was obtained in this way. Since the published values of heats of solution of silver halides in molten nitrates were obtained by neglecting the known nonideal behavior of the solutions, a value of the heat of solution was obtained from emf and solubility measurements by use of rigorous thermodynamic methods. This value, 19.1 ± 0.6 kcal/mole, is in excellent agreement with the theoretical estimate.

Physical Chemistry of Molten Salts: Fluoride Phase Equilibria. — Single phases have been isolated from annealed mixtures at each of the compositions $NaF-ThF_4$ (77.8-22.2 mole %) and $NaF-UF_4$ (77.8-22.2 mole %), corresponding to the molecular formula $7NaF \cdot 2MF_4$. Crystalline materials having the properties of these compounds were previously thought to be low-temperature forms of $4NaF \cdot ThF_4$ and $3NaF \cdot UF_4$ respectively. Experiments have now shown that the two compounds $7NaF \cdot 2ThF_4$ and $7NaF \cdot 2UF_4$ are subsolidus at their compositions and stable only within the temperature ranges 558 to 610 and 497 to 546°C respectively. Above their upper limits of stability the $7NaF \cdot 2ThF_4$ disproportionates into $4NaF \cdot ThF_4$ and $2NaF \cdot ThF_4$, but the $7NaF \cdot 2UF_4$ disproportionates into NaF and $3NaF \cdot UF_4$; below their lower limits of stability both compounds disproportionate into NaF and $2NaF \cdot MF_4$.

Chemical Separation of Isotopes. — The isotopic equilibrium constants for the boron exchange between BF_3 gas and liquid $BF_3 \cdot O(CH_3)_2$ were calculated from recently obtained infrared and Raman spectra of the highly enriched B^{10} and B^{11} addition compounds. The calculated and experimentally observed values are presented below:

T(°C)	α	
	Calculated	Observed
−8	1.040	1.036
4	1.038	1.033
22	1.036	1.029

$$\alpha = \frac{[B^{10}F_3 \cdot O(CH_3)_2](liq)/[B^{11}F_3 \cdot O(CH_3)_2](liq)}{[B^{10}F_3](g)/[B^{11}F_3](g)}$$

Chemical Applications of Nuclear Explosions. — Magnesium sulfate reacted with hydrogen to form MgO, H_2O, H_2S, SO_2, and S at 734°C; the mole percentages of the original sulfate converted to H_2S, SO_2, and S were 43.4, 31.4, and 25.2 respectively. At 784°C the mole percentages of H_2, SO_2, and S were 14.7, 44.4, and 40.4 respectively. The apparent activation energy for the reaction was calculated to be 18 kcal/mole.

The stoichiometry of the reaction of $CaSO_4$ with hydrogen was reexamined by more accurate analytical techniques. At 900°C the mole percentages of the sulfate converted to H_2S and SO_2 were 2.0 and 1.9 respectively. The other reaction products were CaS, CaO, H_2O, and traces of S. Previous studies that had indicated that 6 to 20% of the sulfate was converted to H_2S and about 0.1% to SO_2 are suspected to be in error due to reaction of the SO_2 and H_2S in the H_2S absorption trap.

METALLURGY AND MATERIALS RESEARCH

Ceramics Research: Sintering Studies. — Measurement of densification rates during sintering of materials with the fluorite crystal

structure may give information regarding interaction of different material-transport mechanisms. Compacts of ThO_2 heated directly to 1600°C and held there for 1 min had higher densities (7.53 g/cc) than those heated at the same rate but held at 1000°C for 205 days before the 1-min treatment at 1600°C (7.31 g/cc). Compacts of CaF_2 also had lower densities if held at some temperature below the sintering temperature. Other studies will be carried out to determine what happens during the low-temperature anneal which causes less densification at the higher temperatures.

Physical Property Studies. – The measurement of thermal conductivity of UO_2 in the radial heat-flow apparatus was discontinued at 875°C because of difficulties encountered in the electrical circuits. Data taken during cooling gave the same value of k at 600°C as that obtained upon heating; however, the value of k obtained at 200°C was 4.5% higher than that obtained earlier. The oxygen-to-uranium ratio of the specimen was found to be 2.006 after returning to room temperature, whereas it was originally 2.012. The change in thermal conductivity apparently was due to this change in composition. Thus the variation in k with this change in composition appears to be more pronounced at lower temperatures and to be insignificant at 600°C or higher. Changes have been made in the apparatus which should correct the difficulties encountered, and the measurement of k for UO_2 to 1600°C will be resumed.

The calibration curve for the thermal comparator was obtained, and measurements were started on a series of specimens.

CONTROLLED THERMONUCLEAR RESEARCH

DCX-1 Facility. – More mass-spectrometer measurements have been made of the composition of the residual gas components in the plasma confinement region during various phases of the vacuum manipulations. With base pressures achieved by titanium pumping at liquid-nitrogen temperatures, the major constituent is hydrogen. The gases that evolve upon warming the walls of the confinement region to about 50° above liquid-nitrogen temperatures are primarily methane and ethane.

Fast-oscilloscope studies of rf probe signals have been made during periods of plasma accumulation following the injection of the molecular ion beam. These studies appear to confirm the previous conclusions that the initial radiation is due to the rotation of a single excess charge clump and that the more complicated signal patterns subsequently appearing represent the appearance of additional charge clumps.

Data are being accumulated on the energy distributions of hydrogen neutrals escaping the plasma region as a result of electron-capture collisions of the circulating protons with background gas. A silicon-barrier detector and a 256-channel analyzer are employed, and the measurements are being made as functions of pressure and injected H_2^+ beam current during steady-state operation and during the decay intervals.

The construction of a 12-unit neutral-particle detector designed to assess more accurately the extent of the plasma spread under steady-state conditions and the rate of spreading during periods of plasma accumulation is almost complete.

High-Current Injection. — The new accelerator tube planned for use in the accelerator-tube test facility is being assembled. Equipment for measurement of beam emittance is being designed.

A test at 600 kv with Lucite plates has shown that epoxy skirts will eliminate the need for a large-volume freon-nitrogen-filled bag.

Theory. — The "S-curve" relation between injection current into the DCX-2 and ion density achieved has been recalculated by using charge exchange and ionization cross sections properly averaged over ion and electron energy distributions. The distributions are obtained from the code, discussed previously, which solves Fokker-Planck equations. The principal effect is that I_{UC} and I_{LC}, the upper and lower critical currents marking the bends in the S-curve, are now almost coincident; while I_{UC}, itself, is little affected. Thus initial supplemental trapping on an arc, useful only between I_{UC} and I_{LC}, is of limited importance.

Radio-Frequency Heating. — Diagnostic activity on the plasma in the PTF (mirror geometry device) has centered around the diamagnetic measurements previously outlined. The gradient Hall probe has proved useful for following the decay of diamagnetism upon interruption of the microwave heating source. Instead of the decay being simple exponential and slow (0.3 sec) as previously thought, it was found to have two components, a 60-msec linear fall and a 300-msec exponential decay.

Measurements of ΔB_Z (plasma magnetism) on the axis of the machine as a function of Z show a normal diamagnetic signal in the far field and a reversed signal (i.e., a field aiding B_0) on the axis and in the midplane of the machine. A possible explanation can be constructed by employing two distinct plasma regions. The PTF is being modified, preparatory to the application of 5 kw, 3 cm of heating power, and further studies of plasma geometry are being deferred.

The components of the ELMO machine (microwave heating in a folded cusp geometry) have been tested, and plasma experiments are in progress.

BIOLOGY AND MEDICINE PROGRAM

SOMATIC EFFECTS OF RADIATION

Pathology and Physiology: General. — In the study of the comparative oncogenic effects of radiomimetic agents and x rays, ten-week-old female RF mice surviving midlethal doses of x rays (500 to 600 r whole-body), nitrogen mustard [HN2, methyl-bis(β-chloroethyl)-amine hydrochloride, 0.1 to 0.12 mg/mouse intravenously], and triethylenemelamine (TEM, 3.0 to 4.0 mg/kg intraperitoneally) were observed throughout life for effects on longevity and incidence of neoplasia. The mean survival time in months (number of survivors in parentheses) in the various groups was: x rays (242), 13.1; TEM (146), 16.8; HN2 (158), 18.6; and control (114), 21.1. Myeloid leukemia incidence (in %) was: x rays, 7.4; TEM, 6.3; HN2, 9.4; and control, 3.0. Thymic lymphoma incidence (in %) was: x rays, 26; TEM, 16; HN2, 5; and control, 5.0. Ovarian tumor incidence

(in %) was: x rays, 37; TEM, 58; HN2, 12; and control, 7.0. Pulmonary tumor incidence (in %) was: x rays, 8.3; TEM, 52; HN2, 59; and control, 20. Lens opacities were induced by TEM and HN2, but their severity was much less pronounced than those induced by x rays. These results indicate that TEM and HN2 are radiomimetic in the broad sense in induction of neoplasms and other late somatic effects but that they differ quantitatively, and possibly qualitatively, in their effects on different organs. The basis for these differences and the extent to which they may reflect variations in mode of action, as opposed to differences in organ uptake, remain to be determined.

Pathology and Physiology: Recovery from Somatic Effects of Radiation. — Further studies have been made on the inability of S,2-aminoethylisothiourea (AET) to protect immunologically competent cells. Earlier data showed that AET and APMT (S,3-aminopropyl-N'-methylisothiourea) were not effective in modifying the radiosensitivity of immune cells in adult mouse liver irradiated in vivo. In support of this finding, the following experiments carried out in vitro also show that AET does not protect immunologically competent cells in mouse spleen against radiation injury, as judged by the ability of such cells from inbred donors to induce wasting disease upon transplantation into sublethally irradiated F_1 hybrid recipients. That, however, hemopoietic cells in the same spleen preparations were protected by AET against radiation injury was demonstrated by transplantation of these cells into lethally irradiated isologous recipients, in which acute radiation death was thereby prevented. These results indicate that AET does not protect immune cells responsible for the wasting-disease syndrome against radiation injury, but does selectively protect hemopoietic cells present in the same cell suspension. This approach may thus constitute a procedure by which tissue immune cells in prospective grafts can be selectively destroyed by radiation.

Pathology and Physiology: Physiology of Blood Platelets. — Previous studies of platelet regulation showed that a solution of egg albumin or a suspension of ground glass injected subcutaneously into rats produced a 40 to 50% increase in the number of circulating platelets, with the peak number occurring five days after the initial injection. Because this finding raised the question as to whether the response was mediated by a humoral agent, serum from rats injected with these two materials was assayed in normal recipients for platelet-stimulating activity. Serum from both kinds of donors produced about a 40% increase in peripheral platelet counts on the fifth day, and the count returned to normal two days later. This response was comparable with that produced by serum of platelet-depleted donors. It suggests that the glass and the albumin stimulate the production and release into the blood stream of a humoral agent that is capable of stimulating platelet production in other hosts. Failure to elicit such a platelet response by injection of cortisone acetate into rats suggests that the release of an adrenal cortical agent in response to a stressful condition is probably not the common factor promoting this platelet response.

Medium(Low)-Level Long-Term Effects of Radiation. — Parental spleen cells injected into sublethally irradiated F_1 hybrid mice cause morbidity,

tissue changes, and mortality which vary in severity with the strain of the donor and the recipient. The threshold dose of radiation necessary for the appearance of this reaction has been studied in (101 × C3H)F_1 recipients of 101 or C3H spleen cells and in (C57 × 101)F_1 recipients of C57BL or 101 spleen cells. In irradiated (101 × C3H)F_1 recipients, parental spleen cells caused no mortality at 300 r or below, 10 to 20% mortality at 400 to 500 r, and 60 to 97% mortality at 600 to 900 r. The histocompatibility phenotype of both parental strains in this combination is H-2^k. In (C57 × 101)F_1 recipients, C57BL strain spleen cells produced 27% mortality at 0 r, 30% mortality at 50 to 100 r, and 80 to 100% mortality at 300 to 900 r; 101 strain spleen cells produced no mortality below 200 r, 15% mortality at 200 r, 50 to 60% mortality at 300 to 400 r, and 90 to 100% mortality at 500 to 900 r. The C57BL strain is H-2^b, while the 101 is H-2^k. From these results it is inferred that the possibility of the foreign-spleen reaction increased with increasing x-ray dose to the recipient and with the degree of histocompatibility difference between donor and recipient. In three of the four strain combinations studied, there was a radiation threshold dose below which no lethal reaction occurred.

RADIATION GENETICS

Genetic and Cytogenetic Effects of Radiation. — Through the use of a technique for the rapid isolation of clean preparations of *Vicia faba* nuclei, differences in rate and pattern of nuclear incorporation of tritiated lysine, arginine, and tryptophan in meristematic cells have been studied in autoradiographs. Lysine is incorporated rapidly into the nucleus, first becoming evident in the chromatin. The nucleoli rapidly become labeled, although the product synthesized is labile and readily washed out of the nucleoli in the presence of nonradioactive lysine. Chromatin label may be found, however, at the end of 48 hr, although the amount of label is decreased. Arginine and tryptophan incorporation are retarded.

Effects of Radiation on Paramecium. — Mutations induced in the Paramecium by nitrogen mustard show two of the major features of those induced by x rays: (1) The amount of mutation is a maximum when the mutagen is given just before chromosome duplication and is less when the mutagen is given some time before. This finding indicates that premutational damage induced by nitrogen mustard, like that induced by x rays, is reparable up to the time of chromosome duplication. (2) Just as with x rays, very little mutation can be induced after the chromosomes are doubled. This finding shows that the refractoriness of the doubled chromosomes to mutation induction can have nothing to do with the initial events that are peculiar to the absorption of radiation energy and probably involves some later step in the mutational process.

COMBATING DETRIMENTAL EFFECTS OF RADIATION

Mammalian Recovery: General. — A study of radiation sensitivity of mammalian cells has continued. A statistical analysis was completed of data obtained from experiments in which the sensitivity of mouse lymph-node cells irradiated in vitro was determined. The system is similar to the one used to measure radiosensitivity of mouse bone-marrow cells, in that the proliferative capacity of the cell is measured in vivo. The F_1 hybrid mice are exposed to an LD_{100} of x rays. After irradiation they are injected with both bone-marrow and lymph-node cells from one of the parent strains. Good 30-day survival is obtained with mice injected with bone marrow only. In those mice also given lymph-node cells, 30-day survival is reduced in proportion to the number of lymph-node cells injected. This killing effect of lymph-node cell injection can be reduced by irradiating the cells in vitro, and doses of 100, 200, 300, and 400 r were used. As the x-ray dose increased, the killing effect decreased, and only 1% of the lymph-node cells survived 400 r. By plotting x-ray dose against cell survival (log scale), an exponential reduction in surviving cells was observed with increasing x-ray dose. From this curve, the dose for 37% survival (D_{37}) was calculated to be about 70 r, with a 95% confidence interval of 50 to 91 r. The exponential portion of the curve extrapolates to about 2.8 at zero dose, which suggests a multihit system.

Mammalian Recovery: Mammalian Cytology and Genetics in Vitro. — In order to determine coefficients of chromosomal-aberration production in human peripheral leukocytes for use in the calculation of unknown human radiation exposures, studies of chromosome-aberration production by neutron irradiation of human blood have been initiated. The 14-Mev neutron exposures were completed, and the material was partially scored. Preparations are being made to perform 2.5-Mev irradiations.

Radiation Immunology. — It is well known that for cells to undergo stable differentiation in embryonic development an aggregate of cells, above a minimum size, acting in concert is required. Evidence that cellular association is a vital step in the establishment and maintenance of cellular antibody production, which may be considered a state of functional differentiation, has been obtained. Earlier it was found that the length of the induction period during secondary response is inversely related to the number of competent antibody-forming cells and the antigen dosage. It has now been found that when preimmunized cells are allowed sufficient time to organize before additional antigenic stimulation, the induction period preceding formation of secondary antibody can be greatly reduced. The induction period is believed to be the time involved in establishing specific cellular associations which are required for maintenance of the functional state of differentiation, that is, antibody production. Experiments designed for morphological confirmation of these results are in progress.

Histoincompatibility reactions are being studied at the cellular level by placing mixtures of incompatible cells in diffusion chambers and culturing in vivo in the irradiated animal. It has been found that proliferation of tritium-labeled "target" (rejected) cells is sharply

curtailed, either through inhibition of mitosis or cell death. The generation time of "active" (immunized) cells is reduced twofold, indicating that they are rapidly proliferating. Cytomorphological studies of the active cells indicate that they are migratory and actively seek out target cells which they destroy.

MOLECULAR- AND CELLULAR-LEVEL STUDIES

Biophysics. — It is known that ultraviolet light produces dimers between adjacent thymine residues in deoxyribonucleic acid (DNA) chains. Evidence has been obtained that such dimers are directly involved in the inactivation of the biological activity of DNA. The number of dimers formed by ultraviolet light approaches a constant value with large doses. This steady-state value depends on the incident wavelength:

$$\mathrm{T,T} \underset{2400\ \mathrm{A}}{\overset{2800\ \mathrm{A}}{\rightleftharpoons}} \widehat{\mathrm{TT}} \ .$$

At 2800 A the equilibrium is far to the right, but at 2400 A only ~15% of the T,T sequences are in the form of dimers. Irradiation of DNA at 2800 A produces large numbers of dimers (and other photochemical products). If this irradiated DNA is subsequently irradiated at 2400 A, the number of dimers decreases (and the number of other products remains approximately unchanged). Thus, if a loss in biological activity is associated with the production of dimers in DNA, DNA irradiated at 2800 A should have a lower biological activity than DNA irradiated at 2800 A followed by irradiation at 2400 A. Such is found to be the case. In these studies, the DNA irradiated was a transforming principle that transforms Hemophilus influenzae to streptomycin- and cathomycin-resistant cells. The quantitative analysis of the results indicates that thymine dimers account for 50 to 70% of the observed biological inactivation.

In studies on the modification of ultraviolet-induced chromosomal aberration frequencies in Tradescantia pollen (ORNL-3201, p 151), pretreatment with visible radiation in the 5000- to 6000-A range decreased the 2650-A ultraviolet-induced aberration frequencies, while irradiation at 7500 A resulted in an enhancement. These findings have been confirmed by using pollen grown under controlled conditions of light, temperature, and humidity. In addition, it has been observed that the effects of far-red (7500 A) and red (6000 A) radiation are reversible. Pretreatment with red or far-red + red results in fewer ultraviolet-induced aberrations; with far-red or red + far-red an increased number of aberrations were observed. The response observed is quite similar to that reported for seed germination and floral initiation and indicates that a photoreversible plant pigment is responsible for the sensitization of pollen to ultraviolet chromosomal damage and may be the same as that involved in other photobiological responses in plants.

RADIOLOGICAL PHYSICS, HEALTH PHYSICS, AND INSTRUMENTATION

Basic Instrumentation. – Lithium-drifted p^+-i-n^+ diode detectors with thin (< 7-μ) dead layers gave an energy resolution of 6.5 kev (full width at half maximum) for Cs^{137} conversion electrons (625 and 655 kev) and Pb^{207} x rays (74 and 90 kev). The detectors were cooled to 78–195°K to reduce diode noise to less than that contributed by the amplifier. The measured line width of a mercury-pulser constant-charge source was 3 kev. Diodes operated at room temperature gave a resolution of 20 to 30 kev, which was limited by diode noise. The best resolution was obtained with a bias of 150 to 200 v across the 2-mm sensitive thickness.

Silicon surface-barrier detectors with inverted edges and guard rings were operated in air at 1800 v (1.5-mm depletion depth) with a resolution of 15.5 kev (full width at half maximum) at room temperature for the 0.976-Mev k-conversion electrons of Bi^{207}.

For the same Bi^{207} transition, a similar detector operating at 1200 v and 273°K gave a resolution of 9.3 kev (full width at half maximum). The k- and l-conversion peaks were separated well, and the m-conversion peak was clearly seen.

At 1000 v bias and 285°K, the Cs^{137} conversion-electron peak showed a half-width of 7.5 kev.

ISOTOPE DEVELOPMENT PROGRAM

Application of Radioisotopes in Analytical Chemistry. – The experimental work performed during the last two months supports the idea proposed in the January report of the possibility of using a novel approach – a radioreagent – in an improved method for determining fluoride. The system Ta^{182}–sulfuric acid–diisobutylketone was selected for further evaluation. Initial results are promising and suggest that in many cases the new technique will eliminate the time-consuming steps of distillation and color development now involved in the most commonly used method for determining fluoride concentration.

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