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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

MAY 1962

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OAK RIDGE NATIONAL LABORATORY
STATUS AND PROGRESS REPORT
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Oak Ridge, Tennessee
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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

MAY 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 Control-Rod-Drive Test Facility. — Installation of test facility components continues. The test vessel, which includes the heater and graphite assembly, was completed. The electrical control panels for the heaters were installed and wired. Except for testing, the loop piping is essentially complete. The loop instrumentation is being installed.

EGCR Core Top and Bottom Dummy Flow Distribution Test. — Flow tests with the Allis-Chalmers plug design and a modified orifice for the bottom dummy of the EGCR core were performed with 0.010- and 0.020-in. radial clearances between the orifice and the adjustable plug. With the 0.010-in. radial clearance and the plug fully closed, the flow was too low to be read without making changes in the test setup. The eccentricity between the plug and the orifice was greater than 0.010 in., since the plug was scored during the last test run when inserted to the fully closed position.

The orifice was machined to be concentric with the adjustable plug, and the radial clearance was increased to 0.020 in. The range of flow control that can be obtained with a 0.020-in. radial clearance is from 360 to 2550 lb/hr for a total pressure drop of 9.6 psi. The flow is approximately linear from the 3-in.-open plug position to the 0-in. (fully closed) position; however, plug travel from the fully open (5-in.) position to the 3-in.-open position has little effect on the flow.

The top dummy was machined to increase the clearance between the machined grooves and the fuel extension channel and thus increase the flow for the same pressure differential. This modified test piece is being installed in the test rig.

Pebble-Bed Reactor Experiment. — A conceptual design of the ball-bed bottom-support grate was developed for evaluation testing in the full-scale core mockup. The grate is to be made of removable slotted sections placed on top of the bottom reflector.

Teledeltos paper models were made to simulate the graphite reflector to determine the temperature distribution around a control-rod channel

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and generally throughout the side reflector. The model is set up to simulate an axial temperature gradient at the core wall as well as at the outer boundary. Temperature gradients through the "reflector" were mapped, and the direction for model refinement was indicated. Preliminary results indicate that the assumptions previously used in estimating the core heat losses and pressure-vessel temperatures are conservative.

Calculations were performed to estimate the gas temperature profile at the core outlet by use of literature data for the gas velocity distribution. The maximum outlet gas temperature appears to occur between one and two ball diameters away from the wall, but it is only about 80°F above the average gas temperature. It appears that the velocity peaking which occurs near the wall is not sufficient to allow completely for the flux peaking caused by the reflector-moderation characteristics of this reactor. The value and the location of the maximum gas temperature vary as a function of control-rod position and are quite sensitive to the gas velocity profile, which is not well established.

GCR-3 Design Studies. — Preliminary design studies are in progress for the core graphite, peripheral restraint structure, and core support structure of GCR-3. A thickness of 0.75 in. was tentatively chosen for the graphite fuel-element sleeves. The outside diameter of the 4.94-in.-ID sleeve is therefore 6.44 in. The moderator blocks are hexagonal cylinders with central fuel channels. There are axial keys and slots on the outer surfaces to interlock adjacent units and impart structural unity to the core. The cylinders are 9.4 in. across flats and 10 ft 6 in. long. The arrangement of moderator cylinders in the core was designed to eliminate continuous horizontal cutting planes through the core in an effort to obtain maximum stability against seismic forces.

The reflector regions are made of monolithic columns approximately 1.5 ft in radial thickness and 2 ft wide. A row of solid hexagonal cylinders is inserted between the reflector pieces and the moderator blocks. These solid cylinders are subjected to the large fast-neutron flux gradients at the edge of the core and serve to protect the outer reflector columns from induced-bowing deformations. Peripheral restraint bands around the graphite stack are designed to permit graphite removal and changes in the positions of elements at room temperature. At higher temperatures the band must exert inward forces on the stack. Several concepts for the restraint bands were examined, and two promising ones were found. Both utilize the differences in thermal expansion between Invar and type 304 stainless steel to control the expansion of the ring.

The graphite stack rests on a segmented flat plate 2 in. thick, which is mounted on a grid structure. Three sets of parallel beams are used for this grid structure, since they must form a triangular pattern with openings matching the channels through the core. The grid members tentatively selected are made of A212, grade B, carbon steel plates. The beams are 1.5 in. thick and 36 in. deep, and they are supported at the circular outer boundary of the structure by a short cylindrical skirt 170 in. in radius. The 1.5-in.-thick, 24-in.-high skirt transmits the weight of the core to the pressure vessel and supporting structure. This cylinder also serves as a separating membrane between the reactor inlet and outlet gases.

GCR-3 Fuel-Cycle Cost Analyses. — Core lifetime and fuel-cycle cost analyses were made for the GCR-3 with beryllium substituted for the stainless steel cladding on the fuel elements. The fuel fabrication cost, lattice pitch, and enrichment were chosen as variables. Lifetimes comparable to those for the steel-clad elements were obtained with fuel enrichments lower by ~1% (i.e., 1.5% instead of 2.5%). If there were no metallurgical limitation on the attainable exposure, the beryllium-clad elements could cost 3 or 4 times as much as steel-clad elements and yet have lower fuel-cycle costs. If the exposure were limited to 20,000 Mwd per metric ton of uranium, the fuel fabrication cost could not be as much as three times that of steel-clad elements.

Tests of Bristol Siddeley Experimental Gas-Bearing Compressor. — Vibration tests were made on the Bristol Siddeley experimental compressor by using a dc motor having an eccentric weight mounted on the shaft as a driving unit. No journal- or thrust-bearing touching was noted with vertical vibration amplutides as high as 0.0031 in. with the compressor operating at 6000 and 9000 rpm. Thrust-bearing touching was noted during an overspeed test at 17,300 to 17,400 rpm with loop pressures ranging from 50 to 250 psig. At loop pressures lower than 50 psig, thrust-bearing touching was noted at 16,000 rpm.

GCR-ORR Loop No. 1 Operation. — Instrumented EGCR prototype fuel element No. 7C is operating well in GCR-ORR loop No. 1 at an actual heat rate of 24,000 to 28,000 Btu hr^{-1} ft^{-1}, which is below the design heat rate of 35,000 Btu hr^{-1} ft^{-1}. All four thermocouples (0.0625-in.-OD type 304 stainless-steel-sheathed Chromel vs Alumel units with insulated junctions) attached to the inner surface of the fuel element cladding continue to function. After five weeks of operation, one of the thermocouples that measured the gas inlet temperature failed. The hydrogen content of the helium coolant remained at 60 ppm or less for the first four weeks of the cycle, but suddenly rose to a new level of 250 to 300 ppm, which approximates the level attained earlier in the previous cycle.

Studies are being made of the power generation of this type of element in loop No. 1, since some gamma scans taken of irradiated specimens show inconsistencies in power generation rates over the length of the element. The next test element (No. 9) is to operate at a power rating of 50,000 Btu hr^{-1} ft^{-1}. This experimental assembly will have two additional thermocouples attached to the lower end to measure the temperature of the exit gas. This is being done to check the possibility that the two existing thermocouples that measure gas exit temperature have been affected by the long exposure to the high flux in the reactor.

Preparation of Fueled BeO Particles for Irradiation Experiments. — Spheroidal fueled BeO particles to be used in irradiation experiments were prepared from 20%-enriched UO_2 powder by using a technique in which irregular granules were tumbled in a high-velocity air stream. The resulting particles were very regular in shape but were less spheroidal than particles prepared from depleted UO_2 in preliminary work. This technique is most effective in batches of limited particle-size ranges. An ultimate particle shape seems to be obtained after a certain tumbling time, and further tumbling, under the same conditions, results in a loss of material as fines without appreciable change in shape. Most of the

speroidized particles, after the ultimate shape is achieved, are in the same mesh-size fraction as the starting granules; for example, −65 +80 mesh spheroidized particles, obtained from −65 +80 mesh starting granules, represented 74 wt % of the starting granules, and −80 +100 mesh spheroidized particles, obtained from −80 +100 mesh starting granules, represented 62 wt % of the starting granules.

The sintering characteristics of a $BeO-UO_2$ mixture were determined by use of the forming die designed to fabricate specimens to the dimensions specified for the irradiation experiment. Based on these data, trial specimens were successfully fabricated by cold-pressing and sintering in hydrogen at 1750°C. Subsequently, 30 specimens were fabricated for use in the experiment. Nearly all these specimens failed to meet density and dimensional specifications (93% of theoretical density with a dimensional tolerance of +0.005 in.). Bulk densities for most specimens were 87 to 90% of theoretical. The cause of the lower density has not been determined.

High-Temperature Measurements for Gas-Cooled Reactors. — As mentioned previously (ORNL-3286, p 4), inhomogeneities developed in the wires when stainless-steel-sheathed Chromel-P–Alumel thermocouples were exposed to CO at 1000°C for six months. This damage did not result in emf drift because it occurred in a reasonably isothermal region. Long-term drift tests are now in progress, and after three months of exposure there has been no appreciable drift in emf output; no homogeneity tests have yet been made.

Exposures of tungsten and tungsten–26% rhenium alloy wires in pure flowing helium at 1700 to 1800°C have continued. The latest test showed that alloy wires from both vendors E and H were stable within ±10°C over a period of 950 hr. The previous indication that emf drifts occurred in 100 to 200 hr appears to have been caused by trace contaminants in the atmospheres. With extreme care to prevent contamination, it is apparent that the couples are stable within the limits of furnace control and optical temperature measurements.

THORIUM UTILIZATION PROGRAM

Planning and Evaluation Studies. — Preliminary equipment design and sizing of three competitive energy conversion systems for transferring reactor heat to the steam system were completed for the Molten-Salt Converter Reactor (MSCR) and were transmitted to Sargent and Lundy for comparative cost estimating. The three conversion systems are (1) generation of steam in a special boiler heated directly with fuel salt, (2) generation of mercury vapor in a boiler heated with fuel salt (binary cycle), and (3) transfer of heat from fuel salt to intermediate salt with steam generated in a Loeffler boiler.

Further work was done concerning the effect of processing assumptions on minimum MSCR materials cost and the associated conversion ratio. With noble gases adsorbed on the core graphite, with no sparging or cold-trapping of the fission products, and with no recycle of thorium or salt, the materials cost (fuel cost minus processing cost) was 0.80 mill/kwhr (electrical) and the conversion ratio was 0.84. With no gas adsorption and with

sparging of the noble gases (10% per pass), the materials cost was 0.61 mill/kwhr (electrical) and the conversion ratio was 0.92; with no gas adsorption, with sparging of the noble gases (100% per pass), removal of noble metals (5% per pass), and recycle of the thorium and salt, the materials cost was 0.40 mill/kwhr (electrical) and the conversion ratio was 0.96.

Costs were calculated for processing MSCR fuel in the AEC reference processing plant and were compared with preliminary estimates of processing costs associated with an on-site fluoride volatility plant. Based on thorium discard, the estimated processing cost for an on-site plant was about 0.27 mill/kwhr (electrical); for the AEC reference plant the corresponding processing cost was about 0.19 mill/kwhr (electrical).

Testing of Thoria-Pellet and -Suspension Fuels. — In-pile slurry loop 0-1-28S operated for 2036 hr in horizontal beam hole HN-1 of the ORR, accumulating a dose on the entire slurry equivalent to 1616 hr at an approximate flux of 1×10^{13} nv. The run was terminated on May 13, 1962, when water leakage into the region between the shield plug and the loop containment vessel shorted electrical leads to the loop circulating pump. Up to that time, the oxygenated heavy-water slurry of thoria had been circulated at 280°C for 2360 hr, including preirradiation testing.

Four samples were taken during the irradiation. The surface area of samples increased from levels of 0.5 to 1.8 m^2/g on unirradiated slurry to a value of 24 m^2/g on the third irradiated sample (1105 hr in-pile), but no reduction in particle size (as measured by sedimentation) was found. Subsequent to this latter sample, beginning about 400 hr before the end of the run, a gradual reduction was observed in the flow rate of the filtered pressurizer purge water (based on heat-balance measurements). No changes in loop operating parameters or slurry qualities were observed during the run which would have led to operating difficulties.

Analyses on the first three irradiated samples showed good agreement with inventory concentrations (99, 124, and 103% of inventory) at levels of 1266 to 1132 g of Th per kg of D_2O. This agreement, together with the constancy of pump power demand and loop temperature distributions, indicates the maintenance of a stable slurry suspension during the run.

Engineering of Thorium Reactor Systems. — When a slurry fertile fuel is used in a two-region reactor, there are usually moderately high heat fluxes from the structural material into the slurry. The burnout heat flux for a flocculated suspension flowing past a hot surface has not yet been established. To measure this parameter with aqueous thoria slurries, a test section was fabricated in which a $6 \times 1/2 \times 0.005$ in. resistance-heated stainless steel strip is mounted axially in a 1-1/2-in. stainless steel pipe. The strip acts as a resistance thermometer as well as a heater.

Preliminary measurements with water flowing past the test section at velocities of 6 to 15 fps confirmed commonly accepted boiling correlations. The section will be run with thoria slurries at varying pressures, velocities, and concentrations to establish a burnout correlation.

Homogeneous Reactor Experiment No. 2. — Processing of the HRE-2 fuel solution continued in the Fission Products Pilot Plant. Approximately 13 kg has been recovered, and approximately 4 kg remains to be shipped and processed when the schedule of operations at the Pilot Plant permits.

The blanket access port was removed from the pressure vessel to permit photographic and visual examination of corrosive attack on the stainless steel parts in the blanket region. Results of the examination will be reported later.

No further work is planned on HRE-2 except the removal of the remaining fuel and the cleanup of equipment.

MOLTEN-SALT REACTOR PROGRAM

MSRE Design. — Drawings showing all major piping and structural arrangements in the drain-tank cell were finished, as were drawings of coolant piping and all supporting structure.

Drawings of the thermal shield, charcoal bed, heat exchanger supports, and pump supports were approved and released for construction. Designs were approved for the drive mechanism of the radiator door. The reactor nozzle-insert drawings were released for construction.

Electrical heater circuits for the coolant system were finished. Work continues on circuit layout for the reactor cell and the drain cell. Heater design for the fuel pump and drain-tank furnaces is 50% complete.

Jigs for remote-handling fixtures were finished. Layout of the complete cell-piping jig is complete but has not been checked.

Nuclear control circuits are approximately 25% complete. Electrical interlock circuitry is 75% finished. Thermocouple routing between junction boxes and patch panels is 70% complete. Panel designs of instrumentation for the cover-gas system were finished.

MSRE Procurement and Construction. — Procurement of components and construction of the MSRE are progressing on schedule. The fabrication of components is approximately 25% complete, and the site preparation work is approximately 40% complete.

Machining of the heads for the reactor vessel and the drain tank is approximately 50% complete. Cylinders for the drain tanks have been rolled, and welding is in progress. The cylindrical shell which surrounds the graphite moderator blocks is complete, and the grid support for the moderator blocks is approximately 75% complete.

The heat exchanger shell was rolled and welded, and the heads were machined. The flow-baffle assembly for the heat exchanger was completed.

The radiator enclosure is approximately 85% complete. Headers for the radiator have been formed and are being welded.

The first pour of concrete in the drain-tank wall was made, and the reinforcing steel and stainless steel walls were completed for the second pour. The horizontal hold-down beams were installed in the drain-tank cell. This cell is approximately 70% complete.

Work was started on the modification of the 24-ft-diam containment vessel. Installation of the cell penetration sleeves was started.

Construction work outside the building was started. Excavation was completed for the filter pit and the stack and cooling-tower foundation. The concrete for the cooling-tower foundation was poured.

Chemical Development. — Recent experiments concerning oxide precipitation in MSRE-type fluoride melts that contain ZrF_4 as an oxide scavenger have involved low concentrations of fuel (e.g., 1 wt %) in flush salt ($LiF-BeF_2$, 66-34 mole %) — that is, simulated, used flush salt. The saturation limit for ZrO_2 has been sought by using Hf^{181} as a radioactive tracer and titrating with additions of oxide as BeO. Previous experiments had suggested that the oxide saturation limit for flush salt might be as high as 1000 ppm, in comparison with a tentatively established 500-ppm oxide solubility limit before precipitation of ZrO_2 from MSRE fuel or any similar melt containing 5 mole % ZrF_4; there was also a possibility that a minimum in the oxide solubility limit might occur at lower concentrations of ZrF_4. Preliminary indications from recent experiments are that the minimum does occur, probably in the vicinity of 1000 ppm ZrF_4 and perhaps at as low an oxide concentration as 200 or 300 ppm. Increasing oxide solubility with increasing Zr^{4+} ion concentration can possibly be attributed to complexing as ZrO^{2+} or related ions. As previously observed at other concentration ranges, the uranium was protected from precipitation until a substantial fraction of the zirconium had been removed from the solution. Thus the protective action of the zirconium persisted even when the fuel solution was greatly diluted by the flush salt.

Irradiation Tests. — Irradiation experiment ORNL-MTR-47-4 (see ORNL-3279, p 7), designed to determine if CF_4 exists in the cover gas over MSRE fuel in contact with submerged graphite, has been irradiated for ten weeks. It is scheduled for removal from the MTR on June 4, 1962. The maximum measured temperature among the four instrumented capsules was maintained at 1400 ± 50°F. The other three capsules were at mean temperatures of ~1380, ~1370, and ~1310°F. These temperatures, according to the design temperature distribution obtained by use of the TØSS code (see report K-1494) on the IBM 7090 computer, essentially indicate the graphite-to-salt interface temperatures. The INOR-8-to-salt interface temperatures indicated for the capsules are 1130, 1125, 1115, and 1100°F. The surface of the INOR-8 end cap in contact with the fuel salt, to maintain the graphite submerged, is at the graphite interface temperature. (Only about 12% of the 5.6 in.^{2} of metal surface is in contact with the salt at the higher temperature.)

The temperature history of the in-pile experiment is being duplicated with out-of-pile control capsules for comparison.

Experimental assembly ORNL-MTR-47-5 is being designed. In this experiment the formation of CF_4 over fissioning MSRE fuel which contains completely submerged graphite will be studied by intermittently collecting the cover gas from two capsules during irradiation. The collection system has been developed and demonstrated by full-scale bench tests. The cover-gas region will be purged with 200 cc/hr (maximum) of helium and the effluent collected in an evacuated 200-cc bulb. The system volumes, flow rates, and restrictions have been chosen to permit collections at (1) subatmospheric pressures and (2) constant cover-gas pressure.

Radiation Effects. — A preliminary study of the distillation of solvent from MSRE-type fuel into cooler graphite parts exposed to pools of 800 or 900°C fissioning fuel (200 w/cc, 10^{20} nvt) has been completed for the four capsules in experiment 47-3. Temperature gradients both in externally heated control capsules and in the MSRE do not favor distillation

into the graphite moderator, in contrast to the temperature gradients in the in-pile capsules.

Nevertheless, several curious aspects of the condensed-salt—graphite system were noted, even though the amount of salt (less than 2% of the graphite) was relatively quite small. Although the vapor can be considered to be mainly Li_2BeF_2, among the minor constituents ZrF_4 predominates, probably in the form of a complex or associated gas-phase molecule containing some LiF. Metallographs reveal that the condensed salt is aggregated in a few scattered larger pores rather than as a uniform frosting of all pores; autoradiographs support this picture. Vapor-liquid fractionation evidently occurred to a remarkable extent, since several of the voids were loaded, according to analyses with the petrographic microscope, with ZrF_4-rich phases, even pure ZrF_4. Trace and occasionally larger amounts of an oxygen-containing salt phase, previously characterized but never identified as to formula, were also ubiquitous under the petrographic microscope. Possibly the trace oxide was a residue carried by the graphite through the pretreatment in a 2000°C vacuum for oxide removal; the oxide phase was not noted in the fuel ingot, and thus appears to have remained fixed, even though converted to a salt compound, in the graphite pores.

STUDIES AND EVALUATIONS

Reactor Evaluation Studies. — A study was initiated regarding the economic production of Pu^{238} in fluid-fueled reactors. To facilitate this study, the SISYPHUS code, which calculates the time-dependent nuclide concentrations and fuel costs for single-region fluid reactors, was rewritten to include a secondary "target" loop and to provide continuous fuel processing in both the main loop and the target loop. Material can be removed from the main loop and fed to the target loop if this is desirable; a separate feed stream to the target loop can also be considered. The revised program is presently being checked out.

Evaluation of the fuel cycle of the 630A Maritime Reactor proposed by General Electric was begun. By use of information provided in report GEMP-108, cell geometries and dimensions and effective nuclide concentrations in various regions were specified. The Thermos program was obtained from BNL for calculating the spatial and energy variation of the thermal-neutron spectrum; the program was modified to conform to the K-25 monitor system and is being checked out.

ADVANCED REACTOR DEVELOPMENT

Advanced Test Reactor Corrosion Program

An aluminum corrosion test was completed which simulated the conditions expected to exist during operation of the ATR. In this 16-day test the heat flux was gradually decreased from 1.44×10^6 Btu hr^{-1} ft^{-2} at the beginning to 1.24×10^6 Btu hr^{-1} ft^{-2} at the end of the test. At the

start of the test the cooling water (pH = 5.0 with HNO_3) was adjusted to give a specimen-water interface temperature of 360°F at the axial midpoint of the specimen. During the test the water temperature was decreased 24°F. The coolant flow rate was constant at 45 fps throughout the run.

During the first 10 days the specimen temperature increased at a gradually decreasing rate to a value at the aluminum—aluminum oxide interface of about 460°F and remained at approximately the same value for the duration of the test. At the end of the test the specimen had an adherent, nearly transparent oxide film on the water-cooled surfaces; there was no sign of film stripping.

Specimens of QMV beryllium exposed to water (pH = 5.0; 4 ppm oxygen) at 100°C and at either 13 or 23 fps corroded at rates ranging from 2.1 to 2.8 mils/yr regardless of velocity during a 560-hr test. Other specimens exposed under the same conditions except at flow rates ranging from 22 to 81 fps also showed no velocity effect. In the latter test, which lasted 319 hr, all specimens corroded at rates of 1.3 to 2.1 mils/yr.

High Flux Isotope Reactor Design and Development

Metallurgy. — Blister formation in the outer-annulus fuel plates was significantly reduced. In the past, 16% of the plates were rejected for this cause. By lowering the fabrication temperatures from 550°C to 500°C, blister rejections were limited to 4%.

The fuel-element flow-test core for the mockup facility was completed, with the finishing of the inner-annulus fuel element. Although this element contained unfueled composites, experience gained in assembly and welding techniques was reflected in the results observed after measuring the plate spacings. All the individual measurements showed control within the ±10-mil allowable tolerance, and the average spacing was well within the (50 ± 6)-mil specification.

Fuel-plate procurement was initiated, with prebid meetings held individually with United Nuclear, Sylvania Electric Products, Westinghouse Atomic Fuels, Babcock and Wilcox, and the Martin Company. Their written comments were reviewed, and final specifications will be established soon.

Design and Analysis. — The convergence method employed in the fuel-element hot-spot analysis was modified to facilitate calculation of burnout power levels when there is touching of adjacent fuel plates. A study of the effects of loss of pressure and loss of flow on burnout power level was initiated.

The necessary input data were compiled for the analog kinetic calculations. These calculations are of a parametric nature and therefore will provide information that will be useful in supporting possible recommended design and/or criteria changes for the control system.

Heat generation rates for all-nickel control plates were computed and were used in estimating the rates in the silver and aluminum regions of the control rods. By use of these values, control-region coolant temperatures useful in analyzing the thermal deflection of the control plates were calculated.

A study of the effects of internal heat generation in the control-rod bearings indicates a definite need for forced-convection cooling of the

stainless steel bearing shaft in order to eliminate the possibility of boiling in the bearing water lubrication film. Results of the most recent heat generation calculation indicate that with forced-convection cooling of the bearing shafts, the bearings can be mounted near the fuel region.

All stress calculations for the primary heat exchangers were submitted and approved, except for stresses in the support lugs on the shell. All drawings and procedures were approved "as submitted" or "as noted." All tubes for the initial order of three heat exchangers were produced, and the final run of tubing is being bent.

Design drawings of the pressure vessel were reviewed. Except for a few drawings being held for further study, the drawings were approved "as submitted" or "as noted."

The vendor was instructed to proceed with the use of A350, grade LF-3 forgings for the HB-2 and HB-3 nozzles. An attempt will be made to qualify all pertinent welding procedures in the shop to avoid a costly development program and subsequent delays. The vendor satisfactorily completed the qualification of procedures for welding the longitudinal and circumferential seams of the main vessel, the hand overlay procedures, and the single-pass submerged-arc overlay procedures.

Engineering Development. — A full-scale mockup of the HFIR is being assembled in Building 9204-1, Y-12. This mockup utilizes a tank that duplicates the internal dimension of the reactor pressure vessel and uses reactor-design structural internals, control-rod drives, simulated control rods (identical except for omission of poison), a reflector made of aluminum, and a dummy fuel element made of aluminum plates. The tank is connected to pumps that will duplicate reactor primary-coolant flow rates.

The purpose of the mockup is to prove the reliability of the mechanical components of the HFIR; to measure flow rates through the various reactor regions; to establish whether the flow conditions lead to undesirable vibration, stress, or wear; and finally to develop the tools and techniques for remote servicing.

Assembly of the mockup is approximately 60% complete. All parts are on hand except the upper shrouds, which are scheduled for delivery during the week beginning May 28. The mockup is currently assembled up to the elevation of the top of the reflector. The control rods, which are on hand, will be installed after the shrouds are received. Instrumentation (flow pressure lines, strain-gage leads, control-rod drive-motor leads, etc.) is approximately 35% complete. The mockup is scheduled to go into flow service by July 1, 1962.

NUCLEAR TECHNOLOGY AND GENERAL SUPPORT

Basic Reactor Physics. — In the experiment to determine the decay constants of neutrons in various media by the pulsed-neutron method, data have been accumulated for ice blocks down to temperatures of −85°C, and the measurements for this medium are approximately 60% complete. One difficulty in the use of ice was the fabrication of large ice blocks which were of uniform composition and free of bubbles. A method was finally developed, and large cylindrical blocks up to 12 in. in diameter and 15 in. high are now being used.

Basic Reactor Shielding. — The model 4 spectrometer was used to measure the spectrum of gamma rays emitted by the stainless steel Bulk Shielding Reactor II for energies up to 10 Mev at distances from 1 to 60 cm from the reactor surface. In addition, the angular distribution of gamma rays has been measured about two points located 10 and 25 cm from the reactor. The spectrometer is now being calibrated; afterwards the data will be analyzed.

Nondestructive Test Development. — Recent emphasis in low-voltage radiographic studies has been directed toward elementary microradiographic techniques for the nondestructive evaluation of items such as graphite-coated uranium carbide particles. Several different photosensitive emulsions have been used as detectors to produce the contact radiographs. These are then viewed at high magnifications to observe the core and coatings of the carbide particles. Type M radiographic film has been successfully viewed at magnifications up to about 60×. At this stage, the grain size of the emulsion becomes very evident. Nuclear-track plates which seem to have about the same exposure speed as M film will allow magnifications up to approximately 200× before the grain size becomes excessive. The highest magnification has been possible with very-fine-grained emulsions on high-resolution plates having an effective grain size of about 0.1 μ. These have been viewed at magnifications up to 500× with little difficulty from grain size, and the particle and coating images are very sharp. The original purpose of the study of coated particles was to develop techniques which would allow the measurement of coating thickness and particle size. This capability has been observed, but, in addition, the excellent detail which can be obtained at high magnification has allowed the detection of a number of other conditions such as low-density core reactions, unfueled particles, and high-density material in the coating.

Materials Compatibility Studies. — A method for determining the oxygen concentration of potassium by first gettering the nonmetal from the potassium with an active metal such as zirconium and then analyzing the zirconium by vacuum fusion is being investigated. Since the use of this procedure depends on (1) the accuracy of the vacuum-fusion technique in analyzing oxygen in zirconium and (2) the accurate determination of the distribution coefficient for oxygen between zirconium and potassium, tests have been continued to evaluate these variables. Analyses of zirconium samples containing measured additions of oxygen have shown an average deviation of ±10% in the range 1000 to 6000 ppm. The data thus far indicate a distribution coefficient $\underline{K}_{815°C} = 7 \pm 2$, where $\underline{K} = C_{O \text{ in Zr}}/C_{O \text{ in K}}$.

Studies were also continued to determine the role of oxygen in the corrosion of some of the refractory metals by lithium. In general, it was found that Cb, Ta, V, Ti, and Zr are resistant to dissolution type of attack by lithium even at temperatures in excess of 1000°C. However, the presence of small quantities of oxygen in tantalum and columbium can result in the rapid penetration of these metals by lithium over a wide range of temperatures. No such effect has been observed when comparable oxygen concentrations are present in V, Ti, and Zr. A redistribution of oxygen was observed in all the systems, probably according to Nernst's law: $\underline{K} = C_{O \text{ in solid metal}}/C_{O \text{ in K}}$, where $\underline{K}$ is the distribution coefficient referred to above. This suggests that lithium penetration is not

related to the gettering of oxygen that occurs according to the thermodynamics of the particular system involved.

Power Reactor Fuel Processing: Corrosion. — Specimens of 1100 and 6061 aluminum and type 309SCb stainless steel were corroded at overall maximum rates of 0, 0.1, and 0.3 mil/month, respectively, in exposures of 192, 312, and 312 hr in refluxing 23 M HNO_3–1 M HF. The addition of 50 g of uranium and 20 g of graphite per liter of solution increased the corrosion of the 309SCb stainless steel to 24.7 mils/month in 96 hr exposure but had no detectable effect on the corrosion of either type of aluminum.

Unwelded specimens of Corronel 230 were corroded at maximum overall rates of 2.1, 62.8, 60.3, and 172.9 mils/month in exposures of 257, 103, 103, and 89 hr, respectively, in refluxing 4 M HNO_3–0.3 M HF, 4 M HNO_3–5 M HF, 10 M HNO_3–1 M HF, and 10 M HNO_3–5 M HF. The attack was an acid etch in all cases.

Titanium-45A was corroded at maximum rates of 82.5 and 62.3 mils/month in 48-hr exposures in initial Darex solutions at 87°C to which 0.005 M $Na_2B_4O_7$–0.01 M HBF_4–0.01 M $ZrO(NO_3)_2$ and 0.005 M $Na_2B_4O_7$–0.01 M HBF_4–0.04 M $Al(NO_3)_3$, respectively, had been added. When the additives were 0.0025 M $Na_2B_4O_7$–0.01 M HBF_4–0.04 M $Al(NO_3)_3$, maximum rates were 15.6 and 11.6 mils/month for 72- and 168-hr exposures respectively.

Power Reactor Fuel Processing: Shear-Leach Process. — The shear lubrication piping was modified to a system consisting of three manifold sections for more efficient operation. The fourth and last porcelain-filled Yankee prototype fuel assembly containing external ferrules was sheared into 1/4-in. sections without difficulty.

Further particle size measurements on sheared pieces of procelain-filled ORNL Mark I prototype fuel assemblies showed that < 9520-μ (~3/8-in.) fractions from 1/4-, 5/8-, and 1.5-in. sheared lengths constituted 69, 21, and 6.6%, respectively, of the total particles, and fractions < 44 μ were 5.2, 3.0, and 0.9% of the total particles produced. Stainless steel and braze metal particles in the fractions < 9520 μ were 33.3 and 2.6% of the total metal from 1/4- and 5/8-in. sheared lengths, respectively, with stainless steel comprising 33.1 and 2.57% of the total metal. The amount of procelain in the < 9520-μ fractions was 93, 46, and 12% of the original amount from the 1/4-, 5/8-, and 1.5-in. cuts respectively; procelain constituted > 99% of the material in the < 590-μ fractions from all sizes sheared. Visual comparison of the sheared pieces > 9520 μ indicated that a sheared length of ~9/16 in. would probably be optimum.

Power Reactor Fuel Processing: Solvent Extraction. — The distribution coefficient of uranium between 0.6 M $Al(NO_3)_3$ and 2.5% tributyl phosphate in diethylbenzene decreased from ~0.4 with undegraded solvent to ~0.2 with solvent boiled 4 hr in 2 M HNO_3 and washed with carbonate. The degraded solvent contained materials that reacted as ~0.1 M acid in titration with caustic. Stirring the solvent 16 hr with feed solution containing 350 g of Th and 5 g of U per liter, 0.8 M Al, and 0.1 N acid deficient did not noticeably decrease uranium extraction.

A countercurrent batch extraction of uranium with 2.5% di-sec-butyl phenyl phosphonate in diethylbenzene from aqueous solution containing 5 g

of U and 10 g of Th per liter, 1.0 M $Al(NO_3)_3$, and 0.1 N acid deficient resulted in a decontamination factor from thorium of $> 2 \times 10^4$ and a 0.03% uranium loss. A similar experiment with 2.5% TBP in diethylbenzene as extractant and 1.5 M $Al(NO_3)_3$ in the feed resulted in a decontamination factor from thorium of 2.5×10^3 and a uranium loss < 0.01%.

Power Reactor Fuel Processing: Thorium Dicarbide Hydrolysis. — Hydrolysis of thorium dicarbide in water at 80°C yielded, per gram of sample, 68 ml (STP) of gas consisting of 78% free hydrogen, 1.5% methane, 6% ethane, 1.4% ethylene, 5% acetylene, 1.8% butenes, 3.5% of unidentified compounds in the C_4 region of the spectrum, and small quantities of saturated C_2-C_8 compounds. Of the 7.55 mg-atoms of total carbon (0.4 to 0.9 mg-atom of free carbon) in each gram of the original carbide, 1.56 mg-atoms were found as gaseous hydrocarbons and 3.41 mg-atoms were in a water-insoluble wax; the remaining carbon presumably goes to nonvolatile, water-soluble compounds, which have not yet been isolated. Thorium dicarbide, like uranium dicarbide, appears to yield predominantly nonvolatile carbon products.

PHYSICAL RESEARCH PROGRAM

Reactor Operations. – During the first 18 weeks of 1962, the ORR operated 81.5% of the time. Several new facilities have been added to the ORR, including a hydraulic-tube irradiation facility comprising five tubes in which samples can be inserted and removed while the reactor is operating. Practically all available core positions in both the ORR and the LITR are being used.

All reactor operators and shift foremen have completed the first phase of retraining started during the latter part of 1961.

Waste Disposal. – Design is continuing on a new intermediate-level waste trench to replace the open pits and trench No. 6, which was taken out of service because of a breakthrough of activity. The new trench will be excavated in three sections, each approximately 100 ft long, so that the entire trench will not have to be taken out of service if a leak should develop.

Except for a small circular section approximately 20 ft in diameter, the filling of pit No. 4 has been completed. The completion of the job is being delayed until the level of the liquid in the unfilled section is lowered.

Hot-Cell Operations. – Operations in the hot cells were routine. Examination of six NaK capsules containing APPR miniature plates irradiated in the ETR was essentially completed. Components of two UO_2 meltdown experiments were disassembled and examined. Examination of ORR and LITR capsules, mainly UO_2 and pyrolytic-carbon-coated UC_2, was continued in the alpha-gamma cell. A Kollmorgen periscope was installed in the ORR south hot cell which provides for better visual examination and photography of experiments.

PHYSICS AND MATHEMATICS RESEARCH

Charge Spectrometry. – The fragment and charge spectra, produced as the result of nuclear decay, have been measured for $C_2H_5I^{131}$, $C_2H_5I^{125}$, and CH_3I^{125}. This was done by allowing the radioactive gas to decay in a specially designed mass spectrometer. Two of the more significant generalizations which arise from the analyses are as follows: (1) The ethyl xenon ion, which results as a direct consequence of the beta decay of $C_2H_5I^{131}$, remains intact in only 1.4% of the decays. This is in contrast to an earlier study on CH_3I^{131}, in which the CH_3Xe^+ remained stable in 70% of the decays. (2) The effect of the internal conversion of I^{125}, with its subsequent Auger processes, is, in most cases, to completely dehydrogenate the adjacent organic fragment, leaving only the singly and multiply charged carbon ions.

Neutron Diffraction. – Single-crystal neutron diffraction data were obtained for metallic erbium to determine its magnetic form factor. Below 20°K the erbium moments assume a ferromagnetic spiral configuration with a ferromagnetic c-axis component of 8 μ_B per atom. The contribution of this component to the neutron scattering was measured for all (h00), (hh0),

and (hk0) reflections out to $(\sin \theta)/\lambda = 0.81$ and for some of the (h0ℓ) and (hhℓ) reflections. At the larger $(\sin \theta)/\lambda$ values those reflections with scattering vectors normal to the c-axis ($\ell = 0$) have higher form-factor values than those with scattering vectors at small angles to the c-axis (hkℓ's). This is associated with the asymmetric magnetic moment distribution of the Er^{3+} ion, and the observed effect is comparable in magnitude to that calculated by Odiot and Saint-James [J. Phys. and Chem. Solids 17, 117 (1960)]. However, at large $(\sin \theta)/\lambda$ the experimental form-factor curves are appreciably higher than those calculated.

Theoretical Physics. – The inelastic scattering of medium-energy alpha particles was analyzed in terms of a direct interaction model, by use of the distorted-waves theory. A deformed potential-well interaction based on the collective model of the nucleus was found to give results in good agreement with experiment. The parameters of the potential well are determined by fitting the elastic scattering, and the multipole deformations obtained from the magnitudes of the inelastic cross sections agree reasonably well with those obtained by other techniques. The effects on the theoretical predictions of variations in the parameters have been studied. Some preliminary study of the effects of including Coulomb excitation has also been made.

Fast-Chopper Time-of-Flight Spectrometer. – The ORNL 1.25-m-diam liquid-scintillator capture detector was installed at the Rensselaer Polytechnic Institute electron linear accelerator laboratory. This apparatus was placed at the 25-m flight station, and the electron accelerator was operated at an energy of ~66 Mev, 2 amp of peak electron current, a pulse duration of 100 nanoseconds, and a repetition rate of 60 pulses/sec (the latter limited by the duty cycle of the time-of-flight analyzer). A resolution of 6 nanoseconds/m was observed in capture with this equipment at a neutron energy of ~1 kev. Capture data have been obtained on samples of Fe, Zr, Ag, In, Sn, W, Pt, and Au from ~10 kev to 4 ev. A strong but very narrow resonance was observed in iron at 1154 ± 5 ev; this resonance was predominantly a capture resonance and was in agreement with the lower-resolution measurements of Isakov, Papov, and Shapiro [J. Exptl. Theoret. Phys. (U.S.S.R.) 38, 989 (1960)]. The tungsten data have been partially analyzed, and tentative spin assignments have been made for the following resonances occurring in the target nucleus W^{183}: J = 1 for the resonances at 157.6 and 174.6 ev, and J = 0 for the resonances at 144.8 and 154.8 ev.

Low-Temperature, Nuclear and Solid State Physics. – Preliminary measurements of the isomer shift of pure gold and of a 1% Au–Ni alloy relative to a Pt^{197} source were previously reported. More recently, this isomer shift, I, has been measured as a function of the atomic percentage, C, of gold in nickel for nine additional alloys containing 10, 20, 30, ..., 90% Au. The isomer shift is found to be a linear function of composition with $I = (4.38 \pm 0.2) - (5.96 \pm 0.3)C$ mm/sec. For the 1% Au alloy the line has a width at half height of 5.3 ± 0.5 mm/sec and shows a slight splitting into two components previously unresolved. In a preliminary analysis, this is equivalent to a $|\mu_e H|$ of $(1 \pm 0.3) \times 10^5$, where μ_e is the magnetic moment of the nuclear excited state of Au^{197} at 77 kev, and H is the effective magnetic field at the nucleus.

As previously reported, $|\mu_e H|$ has been measured for the first excited state of Au^{197} for 1% Au–Fe and 1% Au–Co alloys and is reported here for the Ni alloy, where μ_e is the magnetic moment of this first excited state, and H is the effective field at the nucleus. The values are $(4.5 \pm 0.3) \times 10^5$, $(3.3 \pm 0.3) \times 10^5$, and $(1.0 \pm 0.3) \times 10^5$ respectively. Within experimental error these values are proportional to the magnetic moments per atom of the host materials, which are 2.22, 1.72, and 0.61. Also, the ratio of $|\mu_e H|$ for the iron and nickel alloys from these measurements is in agreement with this ratio as calculated from recent results by Samoilov et al. They give the effective field at the gold nucleus in the iron alloy as 1.0×10^6 gauss, from which $\mu_e = 0.45$ nuclear magnetic moment. This is a remarkably small moment for an odd-proton, spin-1/2 nucleus.

High-Voltage Experimental Program: Differential Neutron Cross Sections. – In order to assign quantum parameters to neutron resonances of light and heavy nuclei near closed shells, it is often necessary to measure differential cross sections with an energy spread of a few kev. Apparatus utilizing a stilbene crystal as an efficient neutron detector was set up for measuring such neutron angular distributions. $Li^7(p,n)$ neutrons are collimated by a doubly tapered slot through a 50-cm-thick lithium-loaded paraffin shield. The throat of the slot is 1.2 cm wide and 4.6 cm long. The cylindrical sample, which can be moved remotely, is supported in the neutron beam in the center of a shielded space approximately 1 m square and 60 cm deep. The 2.5-cm-diam neutron-detecting crystal, from which pulses due to gamma rays are suppressed by pulse shape discrimination, is rotated about the sample by remote control also. Signal-to-background ratio is considerably improved over that obtained with shadow shielding often used in such experiments. Differential measurements made at the 723- and 820-kev resonances in the neutron cross section of Pb^{208} indicate that these are d-wave resonances.

High-Voltage Experimental Program: Coulomb Excitation with Ne^{20} Ions. – Neon ions with energies ranging from 8 to 15 Mev were obtained by the acceleration of doubly and triply charged ions in a 5.5-Mv Van de Graaff. These projectiles were used to study Coulomb excitation in 18 nuclei ranging from Li^7 to Th^{232}. In particular, the levels of Ti^{47}, V^{51}, Fe^{57}, Ni^{61}, Zn^{67}, Ge^{73}, and As^{75} were investigated. New spin assignments were obtained for the 93- and 184-kev states in Zn^{67}. A unique spin assignment is obtained for the 320-kev state of V^{51}, and the multipolarity mixture of the gamma ray is established.

Spectroscopy Research Laboratory. – Studies of the infrared spectra of the metaborate ion, BO_2^-, in solid solution in alkali halide crystals, have shown that the selection rules for the unperturbed ion are rigorously observed, and thus that the ionic environment has a high symmetry. Observation of absorptions from higher vibrational states has shown that there is no rotation in the crystal. The fundamental absorptions have a half-width of 0.95 cm^{-1} at 300°K, and the intense asymmetric stretch absorption (ν_3) has been observed at concentrations near 1 part per billion. Spectra were studied at 77°K, and many combination and overtone bands were observed. The interaction of BO_2^- with other ions was investigated, and evidence was found for the reaction with the ions of the alkaline-earth metals.

CHEMISTRY RESEARCH

Effects of Radiation on Analytical Methods. — The study of the effect of gamma radiation on the reaction of diphenylcarbazide (DPC) with dichromate was continued. The rate of degradation of a pure potassium dichromate solution was found to be entirely different from that of a solution in which the dichromate had been reacted with DPC. The dichromate is reduced in approximately one-tenth of the radiation time required to destroy all the color in a dichromate-DPC solution. The rate at which gamma radiation degrades DPC itself has been studied in an attempt to correlate the sensitivity of the Cr-DPC color to the degradation of the DPC. In this work it was necessary to look into the basic chemistry involved in the reaction of dichromate with DPC. With Cr^{51} as a tracer, it was discovered that after formation of the Cr-DPC color and extraction with isoamyl alcohol, the Cr remained in the aqueous phase, whereas the color migrated to the organic phase. This proves that the Cr is not a constituent of the compound responsible for the color. It appears probable that the color is an oxidation product of the DPC itself. Further studies revealed that the addition of excess Cr(VI) also destroys the Cr-DPC color, apparently by oxidation of the colored intermediate. Since it was suspected that the reaction is purely an oxidation process, an attempt was made to produce a color by reacting DPC with Tc(VII). It was found that Tc(VII) does indeed form a color with DPC and that this reaction provides a very sensitive method for the spectrophotometric determination of Tc. The necessary conditions for using this reaction in the determination of Tc were established.

An infrared study of the colored Cr-DPC intermediate has been made; however, the results have not been correlated.

Mechanisms of Separations Processes: Foam Separation. — Concentrations of calcium, which interferes with removal of strontium from low-activity wastes, and magnesium were decreased to 1–2 ppm (as calcium), corresponding to 96% removal, in a gently agitated sludge chamber. Precipitation was with 5×10^{-3} M each of NaOH and Na_2CO_3 and coagulation with 1 or 2 ppm of Fe^{3+}; retention times in the sludge bed were 35 min and flow rates were ~8 gal hr^{-1} ft^{-2}. The resulting solution contained only 0.2 ppm of calcium plus magnesium as solids. Waste decontamination factors from strontium were 20 to 200 and from cesium were 10 to 40. Addition of grundite clay to the alkali chamber in ~0.5-g amounts at ~12-hr intervals over a two-day run, to an average of ~0.5 lb per 1000 gal, gave a further decontamination factor from cesium of > 10. Passage of 4000 column volumes of the solution plus contained solids from the sludge column through a column of the cheap ion exchange mineral Decalso did not improve the decontamination factor from cesium but increased that from strontium by a factor of ~50. Cesium broke through to 1% at ~5000 column volumes and to 10% at ~6500 column volumes.

A 0.4-in.-diam cyclone tested as a foam breaker had a feed capacity of 14 liters/min for an inlet/outlet pressure ratio of 4. The uncondensed foam volume varied from < 0.2% for dry foam to 4% of the feed foam volume for wet foam. Foam densities initially were as much as six times the steady-state values for the same conditions with recycle of the condensed foam. Bubble sizes from the spinnerette gas distributor showed little

variation for gas velocities of up to 500 cm/sec in the 50- or 80-μ-diam holes, but increased as the gas velocities in the holes increased above this value. The bubble size distribution from the spinnerette with 50-μ-diam holes was well represented by normal distributions (average diameter = 0.53 mm, σ = 0.08 mm) for hole gas velocities below 500 cm/sec. The spinnerettes at higher velocities and porous-metal or fritted-glass gas spargers at all velocities gave size distributions with a tail of large bubbles which did not fit a normal curve. Heights of transfer units at higher column throughputs were 0.8 to 1.1 in. at 120 gal hr^{-1} ft^{-2} and 1.4 in. for one run at 160 gal hr^{-1} ft^{-2} for stripping of Sr^{89} with 7×10^{-4} M dodecylbenzene sulfonate.

Mechanisms of Separations Processes: Thermodynamics of Solvent Extraction. – Vapor pressures of nitric acid in water were measured by a transpiration technique at 25°C over the concentration range 2 to 16 M. Activity coefficients calculated from these data were combined with literature data on partial pressures of this acid over aqueous solutions measured in the concentration range 10 to 23.867 M (100% HNO_3) and with literature data on freezing points of solutions containing 0 to 3 M acid. From this combination a consistent set of activity coefficients of HNO_3 from 0 to 100% acid were calculated, and the thermodynamic constant K for dissociation reaction $HNO_3 \rightleftharpoons H^+ + NO_3^-$ was calculated for two standard states: (1) $K = 1000\rho/63.016 = 23.867$ in molar units when the stoichiometric activity coefficient $y_{s,o} = 1$ for the pure acid. In this standard state, the stoichiometric activity coefficient for nitric acid infinitely dilute in water is 0.00925; ρ is the density of pure HNO_3 (1.504 g/ml), and 63.016 is its molecular weight. (2) If the activity coefficient of the acid infinitely dilute in water is defined as unity, then $K = 1.169 \times 10^4$ and the activity coefficient of pure acid $y_{s,o} = 22.1$.

Ion Exchange Studies. – Ten to twenty percent of Dowex 50W resin samples decomposed and dissolved or became suspended in water when irradiated to $0.75–0.77 \times 10^9$ r (2.0–2.1 whr per gram of dry resin). Both the specific wet resin volume (i.e., ml of wet resin per g of dry resin) and the moisture content increased 10 to 15%. The resin lost 40 to 50% of its original strong-acid capacity but gained ~5% weak-acid capacity. The radiolytic loss of sulfur was calculated to be 1.0 to 1.2 atoms/100 ev. A comparison of the titrated strong-acid capacity and actual sulfur determination of the exposed resin showed that only 75 to 80% of the sulfur remained on the polymer as the active sulfonate (HSO_3^-) group. Partially completed analyses of the collected effluents indicated that degradation products included sulfate, sulfonate, and oxalate in the acid form. Effluents concentrated by vacuum distillation showed evidence of an increasing quantity of suspended solids < 10 μ as the resin exposure time increased.

For these studies, hydrogen-form Dowex 50W-X8, -X12, -X16, and -X20 were exposed in a system of flowing demineralized water (< 1 μmho/cm) in a 10,000-curie Co^{60} source. The resin column effluent was passed through (1) a series of cells that continuously monitored the pH and electrical conductivity and (2) a strong-base anion exchange resin column that concentrated the sorbable cation exchange resin degradation products. In order to obtain a solution concentrated enough to analyze for radiation

degradation products, this stream was collected and its volume decreased 100-fold by vacuum distillation at room temperature.

Chemical Engineering Research. – The flow capacity of nozzle-plate pulsed columns (organic, continuous) for a modified Purex flowsheet, with first-cycle uranium product as feed without intercycle evaporation, was lower than with standard Purex, probably because of the higher ratio of dispersed to continuous phase flow (aqueous/organic ratio of 1.5 vs 0.45) and lower density of the aqueous phase at the feed point where flooding occurred. The uranium production capacity was only 40% of that of standard Purex because of the lower flow capacity and lower uranium concentration in the feed (65 vs 320 g/liter).

Volatility Studies: Niobium. – Niobium, a possible constituent of reactor fuels, forms a volatile fluoride, NbF_5 (bp 229°C). Niobium metal was hydrofluorinated in $LiF-NaF-ZrF_4$ (31-24-45 mole %) at rates of 4 to 6 mg cm^{-2} min^{-1}. Observations indicated that an intermediate fluoride, possibly NbF_3, formed in the presence of excess metal or in the presence of undissolved uranium or zirconium. The material was bluish and had a low solubility in the fused salt. On prolonged hydrofluorination, the blue material disappeared and volatilized as NbF_5.

In two tests the product NbF_5 was trapped from an HF stream on NaF at 350°C. This temperature was chosen to minimize the formation of NaF-HF complex. In one case, 11.4 g of NbF_5 was absorbed on 92 g of 1/8-in. NaF pellets, with a trapping efficiency of 95.4%. In the second test, with 88 g of 12 to 20 mesh NaF, the trapping efficiency was 100%, 97.3% being collected on the first half of the bed and 2.7% on the second half. The results may indicate formation of the complexes $NaNbF_6$ and Na_2NbF_7 reported in the literature.

Volatility Studies: Corrosion. – In the highly corrosive 50.5-37.0-12.5 mole % $NaF-LiF-BeF_2$ melt at 650°C, alloy 79-4 (79% Ni, 4% Mo, bal Fe) was more resistant to HF than either INOR-8 or several other experimental alloys of nickel and various combinations of Mo, Fe, V, and/or Al:

Alloy	Maximum Penetration Rate (mils/month)	
	Weight Loss Data	Micrometer Measurements
Alloy 79-4	4.08, 8.02*	23, 23*
INOR-8	23.23, 12.85*	81, 107*
90% Ni–10% Mo	23.68, 2.19*	75, 15*
85% Ni–10% Mo–5% Fe	17.16, 11.45*	70, 38*
86% Ni–5% Mo–4% Fe–5% V	16.28, 17.90	171, 111
82% Ni–8% Fe–10% V	17.18, 22.62	46, 61
86% Ni–14% Al	Specimen completely severed	
84% Ni–13% Al–3% Si	Section nearly dissolved	

*First number from test with fresh salt and second number from repeat test with same salt; others were duplicate tests.

The HF flow rate in the 93-hr test averaged 9.3 g/hr. The melt composition and temperature combination was chosen for its high corrosivity to provide accelerated test conditions.

Solvent Extraction Research. – In further study of the stability of sulfuric-acid-treated Amsco 125-82, some of the solvent was scrubbed with concentrated acid at room temperature, made 1 M with tributyl phosphate, and then boiled 24 hr under total reflux with an equal volume of 2 M nitric acid. The Zr-Nb extraction ability of this material was approximately the same as that of fresh, undegraded 1 M TBP–Amsco.

Extraction of a number of metals from 0.5 to 10 M HCl and LiCl–0.2 M HCl (0.5 to 10 M total Cl) was surveyed with typical primary, secondary, tertiary, and quaternary amines in diethylbenzene diluent. In general, extractions increased with increase in chloride concentration and were higher for the quaternary (Aliquat 336) than for the other amines. The maximum coefficients (0.1 M amine) were ~10,000 for iron(III), ~100 for vanadium(V) and vanadium(IV), 0.35 for scandium, and 0.6 for chromium(III).

Process Chemistry of Uranium and Thorium. – Effluents from uranium mills normally contain certain radioisotopes (e.g., Ra^{226}) at concentrations too high to legally permit their direct discharge to the environment. Radium was removed from simulated lime-neutralized acid waste by adsorption on some natural and synthetic zeolites, including clinoptilolite, Decalso, and Linde molecular sieves 13X9X and AW-500. In a column test with clinoptilolite, the effluent activity was still less than 5% of that of the head solution after passage of 2200 column volumes of solution. The radium was almost completely eluted with ~10 column volumes of 1.8 M NH_4Cl–0.2 M HCl.

Nuclear Methods of Chemical Analysis. – It was demonstrated that an Am^{241} source of gamma radiation can be used successfully for the radiographic determination of the distribution of uranium in thin sections of graphite-uranium fuel elements. Ten segments of fuel elements were analyzed simultaneously, utilizing a 10-mg Am^{241} gamma source, standard medical x-ray film, a film distance of 40 cm, and a 62-hr exposure period. Variations were noted in the distribution of the uranium. It is anticipated that this gamma radiographic method can be applied to studies concerned with the distribution of uranium in most types of reactor fuels.

Thermochemistry and Calorimetry. – The molar enthalpy of mixing, ΔH^M, for the liquid LiF-KF system at 875°C was determined as a function of composition with the Bunsen ice calorimeter. The data can be expressed by the following equation:

$$\Delta H^M = X(1 - X)[-3886 - 1059X - 1469X(1 - X)] ,$$

where X = mole fraction of LiF.

The system exhibits energetic asymmetry as shown by the following limiting heats of solution:

for KF in LiF, $$-\left(\frac{\partial \Delta H^M}{\partial X}\right)_{X \to 1} = -4945 \text{ cal/mole} ;$$

for LiF in KF, $\left(\frac{\partial \Delta H^M}{\partial X}\right)_{X \to 0} = -3886$ cal/mole .

The relative partial molal heat contents of the components are

$$\bar{L}_{LiF} = -X^2_{LiF}(1358 + 7994X_{LiF} - 4407X^2_{LiF}) ,$$

$$\bar{L}_{KF} = -X^2_{KF}(4535 + 3758X_{KF} - 4407X^2_{KF}) .$$

Nuclear Chemistry: Characterization of Short-Lived Fission Products. — The radiations from 2.7-hr Pm^{150}, produced by using the $Nd^{150}(p,n)$ reaction, were studied by single-crystal and coincidence scintillation spectrometry. Beta groups were observed with end points (and relative intensities) at 1.4 (10), 1.8 (24), 2.28 (46), 2.77 (weak), and 3.16 ± 0.08 (20) Mev. Gamma rays were found with energies (and relative intensities) of 0.333 (100), 0.41 (10), 0.59 (5), 0.72 (11), 0.84 (30), 0.88 (12), 1.02 (4), 1.18 (32), 1.23 (7), 1.330 (31), 1.625 (2.6), 1.75 (14), 1.96 (3.5), 2.07 (1.7), 2.2 (0.8), 2.41 (0.35), 2.53 (1.3), 2.75 (0.4), 2.91 (0.5), and 3.08 (0.16) Mev. These data, together with the results of beta-gamma and gamma-gamma coincidence studies, were used to formulate a decay scheme with excited states in Sm^{150} at 0.333, 0.743, 1.18, 1.66, 1.96, 2.08 Mev, and others. The disintegration energy for Pm^{150} is 3.50 ± 0.08 Mev, which is about 1.5 Mev lower than the literature value. The present disintegration energy is in accord with beta-decay systematics.

Chemical Physics: Microwave and Radio-Frequency Spectroscopy. — Recent electron spin resonance studies of gamma-irradiated single crystals of KNO_3 at 77°K had suggested a relationship between the production of NO_2 and the presence of NO_2^- in the crystal. Irradiation of KNO_3 which had been doped with KNO_2 produced an easily detected concentration of NO_2 which disappeared irreversibly on warming to room temperature. No NO_2 was detected in similarly irradiated pure KNO_3. However, when irradiated pure KNO_3 was warmed to room temperature and then cooled to 77°K and again irradiated, NO_2 was easily detected.

To elucidate further the role of NO_2^- in the formation of NO_2 by irradiation, crystals of KNO_3 containing a small amount of $N^{15}O_2^-$ were grown. Upon irradiation and examination at 77°K, the spectrum characteristic of $N^{15}O_2$ was observed, and it was apparent that essentially all the NO_2 must have come directly from the cocrystallized NO_2^- and little or none from NO_3^-. It was further shown with a new, more sensitive spectrometer that the yield of NO_2 from irradiated KNO_3 at 77°K was at least two orders of magnitude smaller than that from similar crystals containing small amounts of NO_2^-. These results verify that the NO_2 formed from crystals of KNO_3 containing NO_2^- comes solely from the NO_2^-, that no NO_2^- in substitutional sites is formed from KNO_3 when irradiated and maintained at 77°K, but that when such a crystal has been warmed to room temperature after irradiation, a species capable of giving NO_2 on reirradiation, presumably NO_2^-, does form.

High-Temperature Aqueous Solution Chemistry: High-Temperature Acidity Measurements. — For the continuing studies of the hydrolysis of Th(IV) at

elevated temperatures, a hydrogen-electrode concentration cell, analogous to the glass-electrode concentration cell used previously (ORNL-3120, p 27), has been developed:

$$Pt \mid H_2 \mid \text{solution A} \mid\mid \text{solution B} \mid H_2 \mid Pt$$

The hydrogen electrode, which under the proper conditions is capable of high stability and reproducibility, is considered the primary standard for potentiometric acidity measurements, and its usefulness has been demonstrated at temperatures from 0 to 275°C. It has, nonetheless, two serious limitations. It cannot be used in the presence of solutes which are reduced by hydrogen. In the present Th(IV) hydrolysis study, and in some others which are planned, no such reduction is expected. The second limitation is that, since H_2 saturation of the solutions being measured must be attained, the H_2 electrode may be relatively slow in coming to equilibrium. To overcome this difficulty the platinum electrodes used in the present cell consist of capillaries crimped at the end immersed in the solutions. When these capillaries are pressurized with hydrogen, slow streams of bubbles emerge from the capillary tips and pass continuously through both solutions. This provides relatively short equilibration times (a few minutes), permitting emf titrations to be performed conveniently. Since both half cells are exposed to the same hydrogen atmosphere, the measured emf is independent of the hydrogen pressure; it is determined only by the hydrogen ion activities in the two solutions and by the liquid-junction potential.

Acidity measurements with the new hydrogen-electrode concentration cell have proven to be in reasonably good agreement with those obtained in the previous study at 94°C (ORNL-3237, p 20) with the use of the glass-electrode cell. These hydrogen-electrode measurements are being continued and will soon be extended to higher temperatures.

High-Temperature Aqueous Solution Chemistry: High-Temperature Isopiestic Studies. — The investigation of the dependence of osmotic behavior on concentrations and temperature of a set of representative aqueous electrolytes (LiCl, KCl, CsCl, $BaCl_2$, $MgSO_4$, UO_2SO_4) has been extended with the completion of studies at 140°C in the concentration range from ~0.65 m to the limit of the salt solubilities. These data, in conjunction with those previously reported at 121, 100, and 25°C, permit a more intensive examination of aqueous solution behavior over an extended temperature as well as concentration range. Two distinct trends in the data are now apparent. At arbitrary concentration levels (about 2 m) the osmotic ratios of many salts, when normalized to NaCl, appear to show a linear temperature dependence with slopes which are charge dependent. This is a typical trend for temperatures ranging from ~25 to 150°C. Secondly, the extension of the osmotic investigations at 140°C to the more dilute salt concentrations, about 0.65 m, indicates that a more thorough examination of salt behavior at 140°C, especially in the concentration range from 0.1 to 1 m, may prove profitable. For example, when the concentration of $MgSO_4$ is decreased from 2 m to 1 m, the osmotic coefficients fall only slightly from a value of $\Phi \cong 0.43$ at 2 m to a value of 0.40 at 1 m. When, however, this system is diluted to 0.65 m $MgSO_4$, the osmotic coefficient rises rapidly to a value of 0.64. This rate of ascent is far in excess of that

required to reach the limiting osmotic coefficient of unity as the molality approaches zero. Preliminary investigations of this and other multivalent systems indicate that at 140°C, experimental evidence for three well-known solution effects (Debye-Hückel, strong ion hydration, and ion-pair formation) can be obtained on the same salt system by means of concentration vs osmotic coefficient measurements in the 0.1 to 1 m concentration range.

Physical Chemistry of Molten Salts. — Over a period of years, measurements of equilibrium concentrations for the reaction $NiF_2 + H_2 \rightleftharpoons 2HF + Ni$ in several molten fluoride solvents were made to determine the variation with temperature and with solvent composition. The activity coefficient, γ_{NiF_2}, was independent of NiF_2 concentration in these solutions. Detailed calculations and deductions based on the measurements were completed.

Among the solvents studied, an $LiF-BeF_2$ mixture with 62 mole % LiF is unique in that pure NiF_2 is the phase in equilibrium with saturated solutions. For this system, therefore, activity coefficients, $\gamma_{NiF_2(c)}$, with crystalline solid as the reference state, are obtained directly from solubility data. Combination of the appropriate activity coefficients with measured equilibrium quotients and with pertinent thermodynamic data in third-law calculations permits an evaluation of the standard free-energy function for the reaction; a value of ΔH^0_{298} of 26.777 kcal is obtained, in comparison with 28.2 kcal from earlier data of Jellinek and Rudat; also, for example, $\Delta(F^0_T - H^0_{298})/T$ is 40.289 at 1073°K. The revised values correspond to a revision of the standard free energy of formation of NiF_2 to a value 3.5 kcal/mole more negative than that formerly accepted.

Typical values of activity coefficients based on both crystalline and supercooled liquid NiF_2 are tabulated, for all cases where equilibrium constants, K_N, are available:

Solvent	Temperature (°C)	K_N (atm)	$\gamma_{NiF_2(c)}$	$\gamma_{NiF_2(\ell)}$
		$\times 10^3$		
$LiF-BeF_2$ (62% LiF)	500	5.04	240	0.29
	550	9.90	160	0.39
	600	17.3	120	0.48
$NaF-ZrF_4$ (60% NaF)	575	19.2	200	0.64
	600	25.9	175	0.72
	625	37.2	166	0.91
$NaF-ZrF_4$ (53% NaF)	550	7.57	125	0.30
	575	11.0	115	0.36
	600	15.3	103	0.43
	625	21.9	107	0.54
$NaF-ZrF_4$ (43% NaF)	600	4.55	31	0.13

Chemical Separation of Isotopes. — Ion exchange studies of alkali-metal ions in nonaqueous solutions were made with the cation exchanger Amberlite 200. The exchange rates were found to be an order of magnitude faster than comparable systems utilizing Dowex 50. The rate of exchange of the Amberlite 200 systems increased as the water content of the resin decreased from one molecule per active site to completely anhydrous resin. The effective diffusion coefficients (D^i) and selectivity coefficients (K_K^{Cs}) for K^+ Amberlite 200 containing Cs^{134} tracer equilibrated with 0.1 N KCNS in an amide solution are presented below:

Amide	D^i (cm^2/sec)	K_K^{Cs}
	$\times 10^{-8}$	
$HCONH_2$	2.03	1.09
$HCON(CH_3)_2$	2.02	5.45
$CH_3CON(CH_3)_2$	2.05	7.21

Other nonaqueous solvents studied were primary alcohols, ethylenediamine, glycol, and propylene carbonate.

Chemical Applications of Nuclear Explosions. — Deuterium exchange with hydrogen of water was near statistical at plasma jet temperatures of 10,000 to 12,000°K for 40 to 100 msec residence time of the gaseous mixture. Three determinations were made with a D_2/H_2O mole ratio of 1.3 and deuterium enrichments of 49.1, 59.0, and 51.7 at. % D.

The stoichiometry of the reaction of $CaSO_4$ with H_2 varied slightly with the mass of $CaSO_4$ used in fixed-bed tests, indicating diffusion-controlled side reactions. At 885°C, the mole percentages of sulfate decomposing to form H_2S with 2.5- and 5.0-g samples of $CaSO_4$ were 4.1 and 2.0 respectively. The bulk of the sulfate was converted to CaS (> 95%). Increasing the reduction temperature from 885 to 915°C increased the conversion of sulfate to H_2S from 2.0 to 2.5 mole % and decreased the conversion to SO_2 from 1.5 to 1.1 mole %. Thermodynamic calculations of the species formed by reduction of $CaSO_4$ and $MgSO_4$ by hydrogen agreed with the experimentally observed products of the reductions.

METALLURGY AND MATERIALS RESEARCH

Ceramics Research: Sintering Studies. — Densification rates during initial, rapid sintering of ThO_2 give a definitive indication of the mechanism of material transport. Powder compacts of ThO_2 held 10 min at 1450°C had a density of 7.36 g/cc, while other ThO_2 compacts held 11 min 10 sec at 1450°C had a density of 7.38 g/cc. Compacts held 10 min at 1450°C and heated to 1600°C in 1 min 10 sec had a density of 7.57 g/cc. The densification rate after 10 min at 1450°C was ten times greater for compacts taken to 1600°C than for those remaining at 1450°C, while the ratio of the diffusion coefficient of thorium in ThO_2 between 1450 and 1525°C (halfway to 1600°C) is approximately 1.6. This indicates that volume diffusion is

not the dominant material transport mechanism, as the densification rate by volume diffusion should be approximately linear with the diffusion coefficient of the slower species. Rate data are compatible with plastic flow, which is the only other known mechanism of material transport expected to promote densification.

Physical Property Studies. – Two of the twelve measuring thermocouples used in the radial heat flow apparatus were calibrated to 850°C. Only small negative deviations were noted, and this serves to increase the validity of the previously noted large increase in the thermal conductivity of UO_2 below 600°C which was caused by a change of O/U ratio from 2.012 to 2.006. The radial heat flow apparatus is being reassembled with UO_2 (93.4% of theoretical density) as the specimen. The apparatus temperature control systems were reworked, and the reassembled apparatus will incorporate new thermocouple wire and insulation and a new means of thermocouple exit from the stack assembly.

CONTROLLED THERMONUCLEAR RESEARCH

DCX-1 Facility. – A low-density arc plasma, developed by the DCX-EPA Group as a possible dissociation mechanism for use in high-energy injection devices, has been installed and is now being operated in DCX-1. The plasma is generated by a discharge between a resistance-heated cathode and a gas-fed ring anode. The electrodes are located in close proximity near the midplane of one of the DCX-1 outboard field coils, and a well-collimated plasma streams along magnetic field lines down the length of the apparatus. This plasma column traverses the central innermost vacuum region and passes on to a target plate mounted in the intermediate vacuum system. The target can be floated or grounded, and can be operated as a "plasma sweeper" in order to determine the density of the column.

As expected from the performance at the EPA facility, the arc operates stably in DCX-1 and appears to contribute a negligible gas load to the innermost vacuum region. By way of example, with a base (ion-gage) pressure of 3.9×10^{-9} torr in the innermost region, a hydrogen gas bleed of 1 atm cc/min to the arc anode produced a pressure of 4.0×10^{-9} torr, heating the cathode produced no further increases, and application of the arc voltage raised the pressure to no more than 4.1×10^{-9} torr.

Several investigations have been made comparing neutral-particle detector, energy analyzer, and coherent cyclotron signals from the high-energy trapped proton plasma measured with and without the arc in operation, but at the same indicated pressure in the innermost vacuum region (the plasma region). These pressures were usually near 10^{-9} torr, and the arc parameters were as follows: hydrogen gas feed rates of 1 to 7 atm cc/min, anode to cathode potentials of about 300 v, anode current drains of 0.3 to 1 amp, and target currents of about 10 to 50 ma. The investigations are not yet complete, but the present data indicate that (1) the proton containment times measured during use of the arc are reduced to 25 to 50% of the values measured without the arc; (2) the arc does contribute to the dissociation of the H_2^+ beam, but not enough to compensate for this reduction in containment time, so that there is a net reduction in fast-proton density when the arc is used; (3) the arc column density is in the

range of 10^9 to 10^{10} ions/cm^3; (4) the energy distributions of the fast protons measured when the arc is used are less diffuse, having full width at half maximum about 75% of those without the arc; (5) the spatial extent of the fast-proton plasma is also less, with neutral-particle detector signal profiles having full width at half maximum about 75% of those without the arc; (6) the coherent rf signals are reduced in amplitude and are more sporadic with the arc; (7) strong correlations are observed between fluctuations in the rf and the neutral-particle detector signals with the arc, but no correlations are observed without the arc.

The implications of these data are being explored, and further experiments are planned.

High-Current Injection. — The new accelerator tube with external epoxy skirts has been completed and is under test. It holds 620 kv for extended periods with a freon-nitrogen atmosphere retained by close-fitting bags from skirt to skirt. The arrangement is considerably more convenient than the previous tube. Further improvement seems likely.

Equipment for measuring emittance at high current has been completed and is being installed.

Theory. — An identification has been made between thermodynamic stability criteria and the criterion, discussed previously, that it is sufficient for stability that the linear operator in phase space defined by the linearized Vlasov equation be anti-Hermitian in some representation. The latter implies the existence of a positive definite constant of motion quadratic in perturbations. For a Maxwell-Boltzmann distribution, this constant proves to be the perturbation in the total free energy of the plasma. Free energy is constant here because collisions are neglected, but it would damp monotonically if collisions were admitted. That every perturbation of the free energy is positive ensures that the free energy itself is minimal at equilibrium, and stability is assured with and without collisions.

A numerical program has been inaugurated to study surface effects in the stability of plasma cylinders in a uniform magnetic field, a model of the DCX-2 configuration.

Radio-Frequency Heating. — Analysis of the most recent diamagnetic measurements on the ECP (electron cyclotron plasma) in the PTF magnetic mirror geometry indicates a 10- to 30-kev (T_e) plasma surrounded by a much-higher-temperature plasma (greater than 100 kev, T_e). The higher-temperature electrons are nearer the walls of the microwave cavity, and groups of these electrons driven to the walls are probably responsible for the short (2.5×10^{-7} sec) intense x-ray bursts previously reported.

Modifications of the PTF to permit higher microwave power (5 kw) and directed neutral gas feed are near completion.

Preliminary experiments with the magnetic folded-cusp configuration (ELMO) indicate favorable containment. These studies, to be made meaningful, depend on temperature and density diagnostics. These diagnostic devices for ELMO are still under preparation.

BIOLOGY AND MEDICINE PROGRAM

SOMATIC EFFECTS OF RADIATION

Pathology and Physiology: Genetic Control of Protein Synthesis. — Electrophoretic analyses reveal that the hemoglobin of some strains of mice acts as a single, homogeneous protein and that a heterogeneous mixture of three or four respiratory pigments exists in other strains of mice. Genetic tests showed that the above two groups of mice have different alleles at the Hb locus [J. Heredity 51, 141 (1960)]. Another major physicochemical difference among mouse hemoglobins, that is, their solubility properties, is controlled by allelomorphs at a second locus, Sol, which segregates independently from Hb. Two alleles at Hb and three alleles at Sol have been identified. Hemoglobins of 25 strains of mice are being examined for the possible presence of additional alleles. Tryptic digestion of mouse hemoglobins and a combination of paper chromatography and electrophoresis (fingerprinting) show that the variant mouse hemoglobins differ by one or more tryptic peptides. The α- and β-polypeptide chains of mouse globin can be separated by column chromatography with the system described by Wilson and Smith [Can. J. Biochem. Physiol. 37, 405 (1959)]. Genetic substitutions at Hb and Sol that correspond with differences among tryptic peptides of the β and α chains, respectively, of mouse hemoglobins have been noted.

COMBATING DETRIMENTAL EFFECTS OF RADIATION

Mammalian Recovery: General. — Recent investigations in other laboratories indicate that the thymus is the embryological organ from which the immune system develops. This idea immediately suggests that embryonic thymus cells might be used to get a tolerant immune system in lethally irradiated mice kept alive with foreign bone marrow. A tolerant immune system is needed to avoid the lethal immunologic disorders that come from foreign bone marrow transplants.

Many experiments were set up with thymus cells taken from mice just before birth. No effect on the lethal immunologic disorder was observed, but the experiments did reveal a marked difference in the transplantation behavior of adult versus embryonic thymus cells. In evaluating the largely negative results of these thymus experiments, it was clear that future experiments should consider the problem of the dose of thymus cells injected and the timing of the injection.

Radiation Immunology. — Previous experiments have shown that the length of the induction period preceding appearance of titratable antibody is a function of the number of competent spleen cells, the dosage of antigen to which they are exposed, and the interval between transfer of spleen cells and stimulation with antigen. Recent investigations here have dealt with the question of whether or not there is an effect of response to one antigen on the response and histological organization of cells acting against a second, non-cross-reacting antigen. The data indicate that response to one antigen does not shorten the induction period

during response to a second antigen. On the contrary, the data suggest that there is either no effect of the response to one antigen upon the other or that there is competition between the two types of cells producing the antibodies for "organizational space."

Further studies were made on homograft reactions performed by culturing incompatible cells in diffusion chambers. In experiments employing tritiated-thymidine labeling techniques, it has been found that the increased rate of proliferation of spleen cells ("active cells") taken from animals exposed to a primary dose of antigen ("target") cells begins within 24 hr after the immunization and continues for at least five days thereafter. Earlier it was shown that when active and H^3-thymidine-labeled target cells are mixed together in chambers, there is a rapid loss (killing) of target cells. By use of the same technique it has now been shown that when active and target cells are separated by a 150-μ-thick porous membrane (through which cells cannot pass), the killing of target cells still occurs. This strongly indicates that in homograft reactions humoral factors capable of acting over at least short distances are present.

In developing chick embryos the bursa of Fabricius has been shown to be a primary site of origin of cells involved in titratable antibody formation. There is little evidence to show whether or not the bursa is also a site of origin for cells responsible for homograft reactions. This question is being investigated by studying the effects of bursectomy on the reaction of splenomegaly following chorioallantoic (CAM) grafting of adult chicken spleen (a homograft phenomenon). Removal of the bursa by hormonal treatment of the embryo does not eliminate, although it may slightly reduce, splenomegaly resulting from CAM grafts. Experiments are in progress to clarify the reasons for splenomegaly under these conditions.

MOLECULAR- AND CELLULAR-LEVEL STUDIES

Biophysics. — Experiments involving polychromatic ultraviolet microbeam irradiation of starved and flattened cells of *Amoeba proteus* are continuing. Daughter cells are now being used, so that the population is fairly synchronous. Previous results showed that irradiation of the nucleus alone causes division delay and that this effect is photoreactivable. Irradiation of cytoplasm alone also causes division delay, and preliminary experiments indicate that this, too, is photoreactivable. Irradiation of the nucleus alone with a nonlethal dose that produces a large division delay causes complete cessation of RNA synthesis for 24 hr, as measured by radioautography. Preliminary experiments indicate that this effect on RNA synthesis is not photoreactivable. If this finding holds up, it may mean that cessation of RNA synthesis reflects a more basic effect that causes division delay and that is also photoreactivable.

RADIOLOGICAL PHYSICS, HEALTH PHYSICS, AND INSTRUMENTATION

Radiation Physics and Dosimetry. — Methods for calculation of first-collision doses (both absorbed dose in rads and RBE dose in rems) per unit flux of fast neutrons have been worked out for five classes of neutron

spectra other than monochromatic. A number of specific examples have been calculated for standard wet tissue, several hydrogenous materials, and a bone composition. The method arises from the observation that the ratio (F) of dose to flux can be well approximated over the energy range 0.01 to 10 Mev by a relation of the form

$$F = A + B\sqrt{E} + CE ,$$

where A, B, and C are empirically determined constants, and E is the energy.

Basic Instrumentation. — A preliminary test was made to determine the feasibility of doping silicon by irradiation with neutrons. The reactions are $Si^{30} \xrightarrow{n,\gamma} Si^{31} \xrightarrow[2.62\ hr]{\beta} P^{31}$. The phosphorus that results is a donor.

One-gram specimens of high-resistivity silicon, both n and p type, were exposed to the fast-neutron flux of the ORR for a total dose of $\approx 10^{17}$ nvt. Three days after the irradiation, the residual beta and gamma activities were found to be negligible. Therefore, detectors could be fabricated from such material without any special handling facilities.

TRAINING, EDUCATION, AND INFORMATION PROGRAM

International Programs in Reactor Technology. — Thirty-one students currently enrolled in Reactor School programs have completed 33 weeks of school since the beginning of classes in September 1961.

Plans have been made for a fifth session of international programs, starting in September 1962. Brochures and applications were distributed to industrial and governmental agencies in 43 countries. The deadline for receipt of applications is June 15, 1962.

Three hazards evaluation reports and three technical specification reports, compiled by students of the 1960–61 session, have recently been published. These reports summarize the results of study projects following class work and student laboratory assignments.

ASEE-AEC Summer Institute. — Reactor School experiments in physics, radiochemistry, and instrumentation will be demonstrated for, or conducted by, participants of the 1962 ASEE Basic Summer Institute conducted by North Carolina State College during the week of August 6–10, 1962.

A similar program will be conducted for participants of the ORINS Institute for Physics Teachers during the week of August 13, 1962.

ISOTOPE DEVELOPMENT PROGRAM

Application of Radioisotopes in Analytical Chemistry. — Studies have been initiated on the possibility of utilizing isotope-exchange reactions in liquid-liquid systems for analytical purposes. The exchange of a metal between an organic phase containing a metal-reagent ion-association compound and an aqueous phase containing the metal is under study. In carrying out this study, it is necessary to prepare the ion-association compound

in a high degree of purity and to determine the distribution of the compound between the aqueous and organic phases. Tetraphenylarsonium chloride was chosen because it forms extractable ion-association compounds with anionic species of many types. So far, work has been carried out on reactions of fluo-anions with this reagent, an area which has not been previously investigated. Tantalum, in H_2SO_4-HF solutions, reacts with tetraphenylarsonium chloride to form a precipitate which has not yet been characterized but which is believed to be $[(C_6H_5)_4As]_2TaF_7$. Small amounts of this precipitate are soluble in chloroform. The extraction of tantalum has been studied in detail, utilizing Ta^{182} as a tracer. Tantalum can be extracted quantitatively with chloroform from solutions which are at least 0.2 N in HF, 0.4 to 6 N in H_2SO_4, and not less than 10^{-3} M in tetraphenylarsonium chloride. Work is planned to characterize the precipitate and to study the exchange of tantalum between chloroform solutions of $[(C_6H_5)_4As]_2TaF_7$ and aqueous solutions containing TaF_7^{2-}. In addition, the reaction of tetraphenylarsonium chloride with other fluo-anions will be investigated.

OPEN LITERATURE PUBLICATIONS

Asano, Masahide, T. P. McDonald, and T. T. Odell, Jr., "Effects of Nitrogen Mustard on Mouse Tissue and Modification with AET," Intern. J. Radiation Biol. 4, 591 (1962).

Barnett, W. E., and H. E. Brockman, "Induced Phenotypic Reversion by 8-Azaguanine and 5-Fluorouracil," Biochem. Biophys. Research Communs. 7, 199 (1962).

Begun, G. M., and L. Landau, "Metastable Transitions in N_2O^+," J. Chem. Phys. 36, 1083 (1962).

Bender, M. A, and P. Carolyn Gooch, "Types and Rates of X-Ray-Induced Chromosome Aberrations in Human Blood Irradiated in Vitro," Proc. Natl. Acad. Sci. U.S. 48, 522 (1962).

Betterton, J. O., Jr., and D. S. Easton, "Nb-Nb_3Sn and Nb-Zr Superconducting Coils on an Iron-Core Magnet," pp 348–57 in Proceedings of the International Conference on High Magnetic Fields, Cambridge, Nov. 4–7, 1961, Massachusetts Institute of Technology Press, Cambridge, and Wiley, New York, 1962.

Bezkorovainy, Anatoly, and D. G. Doherty, "Isolation and Characterization of an Acidic Glycoprotein from Normal Bovine Plasma," Arch. Biochem. Biophys. 96, 491 (1962).

Bezkorovainy, Anatoly, and D. G. Doherty, "Thyroxine-Binding Properties of Bovine M-2 Glycoprotein," Biochim. et Biophys. Acta 58, 124 (1962).

Blewitt, T. H., R. R. Coltman, C. E. Klabunde, and D. L. McDonald, "Low Temperature Resistivity of Sodium and the Effects of Nuclear Irradiation," J. Appl. Phys. 33, 1612 (1962).

Block, R. C., G. G. Slaughter, N. J. Pattenden, and J. A. Harvey, "The ORNL Fast Chopper Time-of-Flight Neutron Spectrometer," pp 535–47 in Proc. IAEA Symposium – Pile Neutron Research and Physics, Vienna, Austria, October 1960.

Cable, J. W., H. R. Child, W. C. Koehler, M. K. Wilkinson, and E. O. Wollan, "Neutron Diffraction Studies of Rare Earth Metals and Compounds," pp 379–90 in Proc. IAEA Symposium – Pile Neutron Research and Physics, Vienna, Austria, October 1960.

Cable, J. W., E. O. Wollan, W. C. Koehler, and M. K. Wilkinson, "Neutron Diffraction Investigations of Ferromagnetic Palladium and Iron Group Alloys," Proc. Conf. Magnetism and Magnetic Materials, Phoenix, Arizona, November 1961 [J. Appl. Phys. Suppl. 33, 1340 (1962)].

Campbell, E. C., and P. Fettweis, "Rapid Pneumatic Transfer Device for the Irradiation of Samples in a Reactor," Nuclear Instr. & Methods 14, 272 (1962).

Celada, Franco, and W. J. Welshons, "Demonstration of F_1 Hybrid Anti-Parent Immunological Reaction," Proc. Natl. Acad. Sci. U.S. 48, 326 (1962).

Clayton, R. K., "High-Catalase Mutant Rhodopseudomonas spheroides. Characterization of the Catalase," Biochim. et Biophys. Acta 58, 360 (1962).

Coleman, C. F., C. A. Blake, Jr., and K. B. Brown, "Analytical Potential of Separations by Liquid Ion Exchange," Talanta 9, 297 (1962).

Congdon, C. C., and Joan W. Goodman, "Changes in Lymphatic Tissues During Foreign Tissues Transplantation," p 181 in Proceedings of the International Symposium on Tissue Transplantation (ed. by A. P. Cristoffanini and Gustavo Hoecker), University of Chile Press, Santiago, 1962.

Cosgrove, G. E., A. C. Upton, and C. C. Congdon, "A Histologic Study of the Foreign Spleen Reaction in Sublethally Irradiated F_1 Hybrid Mice," Am. J. Pathol. 40, 455 (1962).

Donnelly, R. G., and G. M. Slaughter, "The Brazing of Graphite," Welding J. 41, 46 (1962).

Drury, J. S., "Application of Chemical Exchange Methods to Isotopic Separations," Reactor Technol. 3, 120 (1962).

Dunlap, L. B., and W. D. Shults, "Controlled-Potential Coulometric Titration of Antimony," Anal. Chem. 34, 499 (1962).

Eisenstadt, J. M., Tadanori Kameyama, and G. D. Novelli, "A Requirement for Gene-Specific Deoxyribonucleic Acid for the Cell-Free Synthesis of β-Galactosidase," Proc. Natl. Acad. Sci. U.S. 48, 652 (1962).

Fowler, T. K., "Theoretically Stable and Confined Plasma," Phys. Fluids 5, 249 (1962).

Friedberg, Wallace, V. K. Jenkins, and O. V. Muderrisoglu, "Albumin Loss and Faecal Excretion of Polyvinylpyrrolidone in X-Irradiated Mice with Implanted Rat Bone Marrow," Intern. J. Radiation Biol. 4, 465 (1962).

Gengozian, Nazareth, Takashi Makinodan, and Rachel R. Carter, "Analysis of Immune Precipitates by Serum-Agar Diffusion," J. Immunol. 88, 426 (1962).

Grell, Rhoda F., "The Chromosome," J. Tenn. Acad. Sci. 37, 43 (1962).

Grimm, F. C., and D. G. Doherty, "Nature of the Coenzyme Binding Site of Bovine Malate Dehydrogenase," Biochim. et Biophys. Acta 57, 381 (1962).

Haste, G. R., and C. F. Barnett, "Plasma Potential Measurements Using an Ion Beam Probe," J. Appl. Phys. 33, 1397 (1962).

Hodgson, G. S., "Erythrocyte Fe^{59} Uptake as a Function of Bone Marrow Dose Injected in Lethally Irradiated Mice," Blood 19, 460 (1962).

Hollaender, Alexander, "Initial Steps in Radiation Damage to Chromosomes and Means of Preventing This Effect," p 201 in The Initial Effects of Ionizing Radiations on Cells (ed. by R. J. C. Harris), Academic Press, London, 1961.

Hollaender, Alexander, "Recent Developments in the Border Fields of Basic Biology," p 17 in Proceedings of the International Symposium on Tissue Transplantation (ed. by A. P. Cristoffanini and Gustavo Hoecker), University of Chile Press, Santiago, 1962.

Kameyama, Tadanori, and G. D. Novelli, "The Synthesis of β-Galactosidase by a Cell-Free Preparation from Escherichia coli," Proc. Natl. Acad. Sci. U.S. 48, 659 (1962).

Kimball, R. F., and D. M. Prescott, "Deoxyribonucleic Acid Synthesis and Distribution During Growth and Amitosis of the Macronucleus of Euplotes," J. Protozool. 9, 88 (1962).

Kneip, G. D., Jr., J. O. Betterton, Jr., D. S. Easton, and J. O. Scarbrough, "Increased Critical Currents in Nb-Zr Superconductors from Precipitation Defects," pp 603–8 in Proceedings of the International Conference on High Magnetic Fields, Cambridge, Nov. 4–7, 1961, Massachusetts Institute of Technology Press, Cambridge, and Wiley, New York, 1962.

Koehler, W. C., J. W. Cable, E. O. Wollan, and M. K. Wilkinson, "Neutron Diffraction Study of Magnetic Ordering in Thulium," Proc. Conf. Magnetism and Magnetic Materials, Phoenix, Arizona, November 1961 [J. Appl. Phys. Suppl. 33, 1124 (1962)].

Leonard, W. J., "Root-Pass Procedures for Inert-Arc Field Welding of Titanium," Welding J. 40, 1246 (1961).

Lyon, W. S., S. A. Reynolds, and J. S. Eldridge, "Radiochemistry Can Help Analyze Nuclear Accidents," Nucleonics 20(5), 92 (1962).

Makinodan, Takashi, "Bone Marrow Transplantation, A Problem in Immunology," Acta Haematol. Japon. 24, 724 (1962).

Makinodan, Takashi, E. E. Capalbo, Paul Urso, Franco Celada, E. H. Perkins, and J. F. Albright, "Studies on Immune Reactions in in Vivo Cultures," p 73 in Proceedings of the International Symposium on Tissue Transplantation (ed. by A. P. Cristoffanini and Gustavo Hoecker), University of Chile Press, Santiago, 1962.

McGowan, F. K., and P. H. Stelson, "Coulomb Excitation of Second 2+ States in Ge^{74}, Ge^{76}, Se^{76}, Se^{78}, and Se^{80}," Phys. Rev. 126, 257 (1962).

Novelli, G. D., Tadanori Kameyama, and J. M. Eisenstadt, "The Nature of the System Catalyzing the Synthesis of Induced β-Galactosidase," Cold Spring Harbor Symp. Quant. Biol. 26, 133 (1961).

Odell, T. T., Jr., and R. M. Kniseley, "The Origin, Life Span, Regulation, and Fate of Blood Platelets," p 203 in Progress in Hematology, vol III (ed. by L. M. Tocantins), Grune and Stratton, New York, 1962.

Odell, T. T., Jr., T. P. McDonald, and Masahide Asano, "Response of Rat Megakaryocytes and Platelets to Bleeding," Acta Haematol. 27, 171 (1962).

O'Kelley, G. D., "Detection and Measurement of Nuclear Radiation," Radiochemical Techniques Monograph NAS – NS 3105, National Academy of Sciences – National Research Council, Washington, D.C., 1962.

Peck, H. D., Jr., "Comparative Metabolism of Inorganic Sulfur Compounds in Microorganisms," Bacteriol. Rev. 26, 67 (1962).

Prescott, D. M., "RNA Synthesis in the Nucleus and RNA Transfer to the Cytoplasm in Tetrahymena pyriformis," p 527 in Proceedings of the

First IUB/IUBS International Symposium, Stockholm, vol II, Biological Structure and Function (ed. by T. W. Goodwin and O. Lindberg), Academic Press, London, 1961.

Prescott, D. M., "Symposium: Synthetic Processes in the Cell Nucleus. II. Nucleic Acid and Protein Metabolism in the Macronuclei of Two Ciliated Protozoa," J. Histochem. Cytochem. 10, 145 (1962).

Prescott, D. M., and M. A Bender, "Synthesis of RNA and Protein During Mitosis in Mammalian Tissue Culture Cells," Exptl. Cell Research 26, 260 (1962).

Prescott, D. M., F. J. Bollum, and B. C. Kluss, "Is DNA Polymerase a Cytoplasmic Enzyme?" J. Cell Biol. 13, 172 (1962).

Prescott, D. M., R. F. Kimball, and R. F. Carrier, "Comparison Between the Timing of Micronuclear and Macronuclear DNA Synthesis in Euplotes eurystomus," J. Cell Biol. 13, 175 (1962).

Robinson, Charlotte L., and G. D. Novelli, "Binding Sites as a Limiting Factor in Amino Acid Incorporation," Arch. Biochem. Biophys. 96, 459 (1962).

Stelson, P. H. (Editor), Electromagnetic Lifetimes and Properties of Nuclear States (Proceedings of a Conference, Gatlinburg, Tennessee, October 1961), National Academy of Science — National Research Council, Nuclear Science Series Report No. 37, Publication No. 974 (1962).

Stephenson, R. L., and H. E. McCoy, Jr., "Recording Equipment for Internal Friction Measurements," J. Sci. Instr. 39(2), 54 (1962).

von Borstel, R. C., and A. A. Buzzati-Traverso, "On the Role of Lethal Mutants in the Control of Populations," p 273 in Proceedings of Colloquium on Radioisotopes and Radiation in Entomology, IAEA, Kaerntnerring, Vienna, Austria, 1962.

Yee, W. C., G. H. Jenks, and E. E. Stansbury, "Fission Fragment Recoil Effects on Zirconium Oxidation," J. Electrochem. Soc. 109, 198 (1962).

Young, F. W., Jr., "On the Formation of Dislocations Around Precipitate Particles of Cu_2O in Cu," p 103 in Direct Observations of Imperfections in Crystals (ed. by J. B. Newkirk and J. H. Wernick), Interscience, New York, 1962.

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