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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

AUGUST 1962

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OAK RIDGE NATIONAL LABORATORY

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

STATUS AND PROGRESS REPORT

AUGUST 1962

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

REACTOR DEVELOPMENT PROGRAM

GAS-COOLED REACTOR PROGRAM

EGCR: Component Fabrication and Testing. — Fabrication work on the casings and seal housings for the EGCR main and vessel cooling blowers continued. Assembly and testing are now expected in October and November. Hot tests of the EGCR control-rod testing facility were completed; the tests resulted in improvements to reduce heat losses. Helium in the test environment is being sampled to determine adequacy of purity control. Tests of the EGCR prototype top fuel dummy indicated that the design was not adequate for the EGCR application. Circumferential grooves tested previously with a dummy mockup were recommended to correct the deficiency. A "linear" plug recommended as a design change for the bottom dummy adjustable orifice is being tested to assure appropriate flow characteristics at reactor operating conditions. Continuation of mechanical performance tests of the prototype bottom dummy at the vendor's plant has delayed its delivery.

EGCR: Resistance-Heated-Tube Heat-Transfer Experiment. — An examination of the influence of the relative rotational displacement between successive EGCR-type clusters on the surface-temperature distributions within the rod bundles was completed. (The reference or 0° orientation corresponds to the situation in which both the tubes and the diametrical ribs of the end spiders are in line.) Rotations of 15, 30, 60, and 90° were examined; at the 60° orientation, the tubes are again in line, while the cross ribs are displaced by 60°. It was found, in comparison with the 0° data, that displacement from the complete in-line arrangement resulted in significant increases in the maximum circumferential surface-temperature differences for the inlet half of the downstream cluster. This variation was most pronounced at the 15° orientation, for which it was observed that these temperature differences were as high as 18°F at 2 diameters from the inlet and 24°F at 20 diameters. In the in-line experiments, the corresponding differences were about 9°F at 2 diameters and 2°F at 20 diameters. Accompanying this effect were a reduction in the mean surface temperature and an increase in the mean heat-transfer coefficient (and Nusselt modulus) over approximately the first 10 diameters of the cluster.

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PBRE: Hazards Studies. – Methods of preventing or minimizing oxidation of graphite and accumulation of explosive gas mixtures in the event of a depressurization accident in the Pebble-Bed Reactor Experiment are being investigated. Various types and degrees of secondary containment to provide an inert atmosphere around the primary reactor system are being evaluated with regard to difficulty of fabrication, space requirements, compatibility with auxiliary equipment, maintenance problems, and cost. The use of a single-pressure (500 psia) fuel-handling system for the PBRE is being evaluated as an alternative to the dual-pressure (500 psia and atmospheric pressure) system originally proposed. The single-pressure system would require that the fuel inspection and storage systems be designed for full system pressure but would avoid use of gas locks when recycling exposed fuel.

PBRE: Circulator Design. – A study was made of the feasibility of installing a gas-turbine-driven circulator in the PBRE after a period of operation with a motor-driven unit. The PBRE is suitable for a turbocirculator, since the relatively low ratio of pumping power to heat removal permits the use of single-stage compressor and turbine rotors, and the low-horsepower requirement (~100) permits the use of a compact unit equipped with gas-lubricated bearings. The preferred approach is to provide space in the shield for future replacement of the initial steam generator with one incorporating a turbocirculator unit.

PBRE: Core Model. – A full-scale model of the PBRE core region was constructed; it utilizes air rather than helium flow and contains appropriate mechanisms for sphere injection and withdrawal. This facility will be utilized in a study of the void fraction, pressure drop, levitation limit, velocity distribution, gas mixing, sphere movement, etc., of a packed-sphere bed having the specific PBRE boundary geometry. In initial experiments, it was determined that (1) the overall bed void fraction (averaged over three loadings) was 0.401 ± 0.002 and (2) the axial distribution of the void fraction (averaged over 10-cm-thick increments) showed a maximum value (0.43) in the lower 10 cm of the core, a minimum value (0.39) in the succeeding 10 cm, and an essentially constant value (0.40) over the remaining cylindrical portion.

PBRE: Mass-Transfer Studies. – The first phase of a study of the heat-transfer characteristics of packed-sphere beds by mass-transfer analogy was completed. In this initial investigation only the limiting situations of the loosest (cubic) and densest (rhombohedral) regular packings were considered. A single active sphere of benzoic acid was located at the center of an array of inert spheres and exposed to flowing 25°C water at Reynolds moduli (based on sphere diameter) ranging from 160 to 2500. The extent of mass removal was determined by measuring local changes in the sphere radius. The data showed that the convection-transfer coefficient is essentially zero at the points of contact and that the extent of this low-coefficient region varies with the orientation of the contact zone with respect to the mean flow direction. A comparison of the mass-transfer data at the forward stagnation point (in terms of the Colburn j factor) with the limited available heat-transfer data indicated reasonable agreement over the Reynolds modulus range of the experiments. Local mass-removal profiles for a single sphere displayed characteristics consistent with the hydrodynamics of boundary-layer flow along a sphere. In like

fashion, preliminary results for the local variation in mass transfer on the surface of a single active sphere located at the center of a cubic array of inert spheres can be qualitatively correlated with the general aspects of flow in cubic arrays.

PBRE: Fission Product Transport and Deposition Studies. – The transport and deposition of fission products from gas streams to the walls of a conduit were investigated analytically. A heat-transfer analogy was used to describe the diffusion of fission products from the gas stream to the wall surface. Only the steady-state conditions were considered. The analytical equations were derived for the deposition of a precursor, defined as a fission product that enters the gas stream directly from the fuel element, and its first and second daughter products. Deposition of molecular iodine and of larger-size particles from air streams to the walls of a circular tube was calculated, and these calculated values were compared with the available experimental data. Reasonably good correlations were obtained. A parametric study was performed to investigate the effects of gas velocity and passage diameter on the deposition of fission products on the wall surface.

PBRE: Component Development. – A test rig for a 30-in. Grayloc mechanical joint was designed, and the test equipment is being assembled. All items are being fabricated for the rotary assembly of the PBRE blower cold-test unit. The design of the remainder of the test unit is 90% complete.

GCR-3: Plant Design. – The plant layout for a 750-Mw (electrical) gas-cooled clad-fuel reactor power station was completed, and the cost of construction was estimated. The reactor is designed to generate 1908 Mw of heat, which is removed by helium at 400 psia. The helium enters the reactor at 577°F and leaves at 1150°F. Steam is generated in four once-through-type steam generators at 2490 psia and 950°F; after passing through a high-pressure turbine, it is reheated to 1000°F in reheat sections of the same steam generating units. Gas is circulated by four axial-flow compressors driven by condensing steam turbines. The work of compression returns 92 Mw of energy to the gas; so the total energy available in the steam generators is 2000 Mw. Feedwater is heated to 450°F by six stages of regenerative heating. The total electric power generated is 763 Mw, none of which is used for driving gas circulators or boiler feed pumps, since these are all turbine-driven.

The containment for the reactor and primary coolant system, which is reinforced concrete with a steel membrane lining, also serves as the biological shield. The reactor vessel has an inside diameter of 52-1/2 ft, and it is 4 in. thick, except where reinforcement is added for penetrations. The estimated power cost for an REA-owned plant, based on USAEC report TID-7025, is 3.60 mills/kwhr; for a municipality-owned plant, 4.19 mills/kwhr; and for an investor-owned plant, 6.42 mills/kwhr.

GCR-3: Fuel Element Design. – A preliminary design of the fuel elements for the GCR-3 was completed. The assembly consists of a seven-element cluster of UO_2 pellets clad with 0.015-in.-thick type 304 stainless steel. The UO_2 pellets are 0.97 in. in outside diameter, 0.74 in. in inside diameter, and 1 in. long. The surfaces of the fuel elements have low-height circumferential ribs that serve as turbulence promoters. The

element cluster is supported within a 6.5-in.-OD, 5-in.-ID graphite sleeve. The overall length of each assembly is 10-1/2 ft. The maximum design heat flux for the elements is 310,000 Btu hr^{-1} ft^{-2}, with a maximum linear heat rating of 80,000 Btu/hr per foot of length of element or 560,000 Btu/hr per foot of channel.

GCR-3: Component Development. – Design studies are in progress on the shaft seal for the GCR-3 main blowers at the containment penetration. It appears feasible to incorporate a labyrinth arrangement, with water as the buffering fluid.

GCR-ORR Loop No. 1. – Irradiation of a new test element (No. 9) was started August 3 at a measured heat rate of ~46,000 Btu hr^{-1} ft^{-1}. This element, although similar in construction to EGCR elements, is to serve as a control for later tests to evaluate roughened surface elements for improved heat transfer. All thermocouples inside the fuel can are functioning properly and further indicate the validity of instrumentation for EGCR instrumented fuel assemblies. The measured fuel center-line temperature at the ORR midplane is ~2400°F, with a measured cladding temperature of ~1250°F, the maximum fuel element cladding temperature being limited to 1575°F for this test.

GCR-ORR Loop No. 2. – Thirty test runs were completed in GCR-ORR loop No. 2 to determine flow characteristics as a function of compressor speed and throttle-valve position. Auxiliary systems are undergoing final leak checks before attachment to the main system. The 24-in. shielding-plug cavity successfully passed the required hydrostatic test. Nine temperature cycles were imposed on the main 18-in. plug in a laboratory component test stand. Wear at the slip joint on the dummy fuel element indicated need for minor redesign.

One of the three Bristol Siddeley compressors purchased for GCR-ORR loop No. 2 was operated at design conditions and subjected to a series of stop-start tests. Further tests were conducted to verify the manufacturer's performance characteristic curves for the blower.

A conceptual design was developed for equipment for irradiation of pebble-bed fuel balls in loop No. 2 under test conditions that would simulate the fuel temperature and power density, coolant velocity and temperature, and contact loading anticipated in the PBRE core. A specially designed and instrumented section is provided in the fuel-loading tube downstream of the fuel to study the deposition behavior of fission products. Provision will be made for separate temperature control of this section, independent of the loop operating conditions. The deposition surfaces can be removed for inspection and analysis following each fuel irradiation.

Release of Fission Products by In-Pile Burning of Uranium Carbide–Graphite Fuel. – A uranium carbide–graphite fuel specimen was exposed to air during high-temperature operation in the ORR and partially burned in order to study the release of fission products that would occur in a reactor accident in which air was admixed with the helium coolant.

The fuel specimen consisted of pyrolytic-carbon-coated uranium carbide particles in a graphite matrix made by the Minnesota Mining and Manufacturing Company. The specimen was in the form of a bushing 0.6 in. in diameter and 0.5 in. high with a 0.25-in.-diam hollow center. It contained 8 to 10 wt % natural uranium. Air at 400 cm^3/min was passed over

the specimen, which was heated by fission and gamma radiation to an initial temperature of 890°C. The specimen had been irradiated in helium at 890°C for 200 hr to build up trace quantities of fission products. Approximately half the specimen was consumed in the 15-min period of burning, during which the temperature reached 1400°C. The experimental assembly has been dismantled and examined in the hot cells, and metallographic examination and radiochemical analyses are being conducted to determine the fate of the fission products.

Postirradiation Examination of Swaged and Tamped-Packed EGCR-Type Fuel Elements. — Four stainless-steel-clad swaged and tamped-packed UO_2 fuel elements were irradiated to burnups of between 1200 and 2500 Mwd per metric ton of uranium and heat ratings of 8000 and 15,000 Btu hr^{-1} ft^{-1} to evaluate fission-gas release from various types of UO_2 under gas-cooled-reactor operating conditions. The examination is almost complete. None of the fuel elements failed during reactor operation, and the three elements that were hot-swaged at 800°C showed even burnup along the length of the capsule. No changes in cladding dimensions greater than 0.005 in. were observed. Metallographic examination revealed some evidence of grain growth of the UO_2 in the center but none in the edges of two of the capsules, and one capsule had a central void. The third swaged element was tested at a lower heat rating and showed no evidence of sintering; some sigma phase was observed in the cladding.

Examination of the element that contained hand-tamped UO_2 revealed discontinuous burnup along the length of the element. This has been attributed to a flux variation caused by a cadmium shutter during operation. The cladding collapse of 0.040 in. that occurred during the test was predicted from theoretical considerations. Metallographic examination showed a fine precipitate in the cladding and no evidence of sintering.

Electrical Resistivity of UO_2 During Irradiation. — Specimens of thin-plate UO_2 are being irradiated in the ORR C-1 facility to study the fundamental mechanisms of fission-gas release. A secondary objective was to measure the electrical resistivity of the same UO_2 specimens before and during irradiation. The before-irradiation measurements were made by placing an electric heater around the capsule containing the specimens. A major difficulty encountered in the in-pile measurements that was not encountered in out-of-pile measurements was the extreme and rapid fluctuations of both the potential and the current. The system seems to attain an equilibrium if maintained under constant temperature and flux conditions.

The resistivity of a sintered fine-grained specimen changed from 2.0 ohm-cm at 700°C to 0.8 ohm-cm after irradiation to a dose of 10^{18} neutrons/cm^2, and the activation energy changed from 0.65 to 0.50 ev. For a single-crystal specimen, the resistivity changed from ~500 ohm-cm at 700°C to 2.5 ohm-cm after similar irradiation; the activation energy changed from 11.3 to 0.4 ev. From these data it can be concluded that irradiation lowers the UO_2 resistivity by providing carriers for the electrical current. The activation energy is decreased because of irradiation-induced disorder in the UO_2 structure. This effect was most pronounced with the highly ordered UO_2 structure of the single crystal.

Evaluation of Coated Particles by Microradiography. — A sample of pyrolytic-carbon-coated uranium carbide particles from batch 3M-SP-2 was

examined by radiography after irradiation in the LITR in the L-CP-2b capsule. Dosimetry measurements indicated that a single particle was emitting beta radiation at a rate greater than 3000 r/hr and gamma radiation at ~120 r/hr. Because of the required contact between specimen and film, this quantity of radiation blackened the film during the normal 1.5-hr exposure. By increasing the x-ray energy from 10 to 50 kvp, the exposure time was reduced to 70 sec, and a usable radiograph of three particles was obtained. The quality of the radiograph was somewhat reduced, as expected, but useful magnifications of 200× were possible.

The coatings on two of the particles appeared to be sound, but the coating on the third was cracked and the fuel was missing from the core. Fuel migration through 30 to 50% of the pyrolytic-carbon coating had occurred in all three particles but was most pronounced in the sound particles. The migrating fuel assumed a ringlike concentration gradient around the original fuel particle. A microradiograph of a 3M-SP-2 sample prior to irradiation showed only superficial fuel migration into the coating.

LITR High-Temperature Irradiation Experiments. — The high-temperature capsule L-HT1, described previously (ORNL-3331, p 4), continued to operate satisfactorily and was withdrawn after a scheduled five weeks of irradiation. The indicated irradiation temperature of ~4000°F was stable throughout the irradiation.

MARITIME REACTORS PROGRAM

Reactor Compartment Filter Tests. — A second series of in-place tests was conducted on board the NS "Savannah" to determine the particulate and iodine-removal efficiencies of the filter-adsorber assemblies in the reactor-compartment ventilation systems. Approximately 90 days had elapsed since the previous tests.

The particulate-removal efficiency was measured by the DOP aerosol method. Both the normal-ventilation-system filter and the emergency-ventilation-system filter attained efficiencies that compare favorably with results of previous tests, although changes in the emergency-system filter unit were required because of damage incurred during a modification of the system. The measured efficiencies for filtration of the DOP aerosol were in excess of 99.97% for the normal system and 99.98% for the emergency system.

The iodine-removal efficiency was measured by the I^{131} tracer method developed for this purpose and first used in the previously reported "Savannah" tests. The observed iodine-removal efficiency of the normal system unit, which contains silver-plated copper mesh, was 90 to 95%, based on the I^{131} activity found in the two downstream samplers. This result is consistent with the previous test and with laboratory tests on silver-plated copper mesh in air at room temperature. The observed iodine-removal efficiency of the emergency-system unit, which contains activated charcoal as well as silver-plated copper mesh, was 99.7%. This value is slightly lower than that obtained in the previous test, in which the radioiodine downstream from the adsorber was below the limit of detection, but is appreciably higher than the value of 99% currently assumed for

accident analysis. The distribution of the I^{131} activity on the components of the downstream samples suggests strongly that the iodine penetrating the adsorber was predominantly associated with particulate matter.

Shielding Survey. – Further analysis of the data from the detailed survey of the radiation from the NS "Savannah" reactor shield shows that in all areas where passenger access is permitted the dose rates are below the specified limit of 0.5 rem/yr or 0.057 mrem/hr, assuming continuous occupancy. In the areas restricted to crew access, the design dose rate of 5 rems/yr or 0.57 mrem/hr is nowhere exceeded, except in a small region on D-deck in a room to which entry can be readily controlled. The specified maximum dose rate in cargo holds, 0.5 rem/yr at one-fifth full power, is also satisfactorily met. Comparison of measured dose rates at a number of special points with dose rates predicted at these points by the shield design calculations of Babcock and Wilcox Company showed that, in general, the actual dose rates are considerably lower than the predicted dose rates, reflecting the intended conservatism in the design. At a number of points the comparisons show overestimates of the gamma-ray dose rate and underestimates of the neutron dose rate.

Safety Analysis. – In connection with planning for the safe operation of the NS "Savannah" in port areas, a study was carried out for determining the influence of reactor power history, fission product decay, and the delay in release and transport of activity through the containment system on the rate at which activity could be released to the environment in the event of the maximum credible accident. Consideration of these factors significantly reduced the predicted activity release rates over those based on simplified treatments that neglect the release mechanisms involved, particularly during the first 1 to 2 hr following the accident. The time required for fuel element failure after loss of coolant and holdup time in the reactor compartment are important factors in limiting and delaying release during this period. At longer times, decay of fission product activity is the more important effect. By exercising some control over the reactor operating power level prior to port entry, the release rate can be further reduced so that it appears feasible to meet exposure criteria in practically any port of interest.

FUNDAMENTAL HEAT TRANSFER AND FLUID DYNAMICS

Reynolds Stress Measurements. – Efforts to measure turbulent Reynolds stresses of water flowing in a pipe were continued. Although a stable hot-wire anemometer reading had previously been achieved with 0.00025-in. platinum wire as the heated element, it had not previously been possible to obtain a satisfactory directional calibration. That is, when the power required to maintain the wire at constant temperature is known as a function of velocity, the power required to maintain a constant wire temperature as a function of wire orientation (at constant velocity) should be in accord with hot-wire anemometer theory (cosine law). An improved method of calibration (with 0.00022-in. nickel wire being used for increased sensitivity) yielded satisfactory results up to wire orientations of 45° to the mean flow.

Thermal Transient Studies. – Deterioration of the thermal bond between the stainless steel pipe and the cast aluminum jacket resulted in termination of experiments with the original thermal-transient test section. A new test section that eliminates the thermal bond problem was designed and is being fabricated, with delivery promised by September 1, 1962. The new test section is a type 321 stainless steel tube 6 ft long with a 2-in. inside diameter and a 5-in. outside diameter. Heat will be supplied by 18 Chromalox heaters brazed to the exterior of the pipe along its length. Inside surface temperatures will be measured at various points along the test section by means of stainless steel vs constantan gunbarrel thermocouples, as used previously. In addition, special surface thermocouples, both single- and double-junction Chromel vs constantan, will be evaluated by comparison with results obtained from the gunbarrel thermocouples. These new thermocouples will generate emf's up to five times that of the gunbarrel couples and hence should significantly improve the signal-to-noise ratio.

A vacuum system for deaerating water was purchased, with shipment scheduled for September 15, 1962. This system will provide up to 200 gpm of cold water with a maximum dissolved-gas concentration of 0.05 cm^3/liter.

Assembly and preliminary checkout are essentially completed for an integrated instrumentation system for recording and analyzing the complex transient signals generated by the temperature and velocity (hot-film anemometer) probes. This system will enable direct multichannel recording of signals as low as 10 μv peak-to-peak in the frequency range 0 to 2000 cps. The readout system consists of a low-frequency spectrum analyzer with provision for direct amplitude vs frequency, true rms amplitude vs frequency, or power spectral density vs frequency scanning. This instrument will analyze signals in the frequency range from about 0.5 to 2000 cps directly, with resolution as low as 0.3 cps. With an FM carrier-type recording and reproducing system for frequency multiplication, the system will analyze signals with frequencies as low as 0.05 cps. The relatively low carrier frequency employed in the FM converter limits the upper frequency of the tape recording and reproducing system to about 500 cps.

POWER REACTOR FUEL PROCESSING

Shear and Leach Process. – Particle size measurements on 8.8-kg batches of an ORNL Mark I fuel element (stainless-steel-clad UO_2 pellets) sheared into 0.5-, 1-, and 1.5-in. lengths showed that 84.5, 35.4, and 17.7 wt % of the UO_2 dislodged is < 9520 μ; and 31.9, 11.7, and 6.3 wt % is < 74 μ. Stainless steel and braze metal particles < 2000 μ were 1.6, 0.6, and 0.3 wt % and 0.09, 0.05, and 0.07 wt % respectively.

Stainless-steel-clad UO_2 multitube assemblies sheared to 1-in. lengths were successfully leached. The sheared fuel was fed to the leacher at 1-hr intervals, and visual inspection indicated that uranium leaching was complete after 4 hr. Earlier shakedown runs were unsuccessful owing to solids plugging the feed lines to the conveyor and leacher during transfer. Means for acid spray and rodding-out were placed in the line to eliminate this problem.

The leach curve relating uranium concentration to time indicated that steady state was approached after 3 hr. The highest uranium concentration

of the leachate was 580 g/liter. The overall material balance of the system was within 2%. The uranium inventory as steady state was approached, with a feed rate of 24.6 moles (one batch) per hour, was equal to about one batch. The composite product and wash-water uranium concentrations were 402 and 2.1 g/liter respectively. Some stainless steel fines were caught in the separators of the leachate and drain liquor streams.

Protactinium Studies. – In studies on recovery of protactinium, solutions containing up to 100 ppm Pa^{231} in 40-g/liter Th–5 M HNO_3 showed no indication of instability one week after preparation. Batch adsorption experiments showed that the capacity of unfired Vycor glass for protactinium from 6 M HNO_3–0.1 M $Al(NO_3)_3$ is > 360 μg of Pa^{231} per gram of glass.

Corrosion. – Types 347 and 304L stainless steels exposed to refluxing 22 M HNO_3–1 M HF containing 40 g of uranium per liter as $UO_2(NO_3)_2$ and 20 g of solid graphite per liter were corroded at maximum rates of 4.6 and 3.9 mils/month respectively.

The corrosion rate of INOR-8 in N_2-CCl_4 increased from 0.7 mil/month at 485°C to 870 mils/month at 746°C in 24 hr exposure; that in similar exposures for "A" nickel increased from 1.1 to 1.98 mils/month in going from a temperature of 480 to 700°C.

In single-cycle 5-hr exposures in O_2 at 765 to 800°C followed by 5 hr in Cl_2-CCl_4 at 495 to 500°C, corrosion rates of Haynes alloy No. 25 varied from 3.1 to 5.2 mils/month. In similar tests on "A" nickel the maximum corrosion rate was 0.5 mil/month.

Uranium Metal and UO_2 Pellet Dissolution. – The instantaneous dissolution rate of uranium metal in boiling 1.5 M $Th(NO_3)_4$–nitric acid increased from 0.31 to 15.9 mg cm^{-2} min^{-1} as the acid concentration increased from 0.05 to 4.2 M HNO_3. The rate was increased further by passing air through the solution during dissolution.

Times for complete dissolution of UO_2 pellets in 10 and 14 M HNO_3 were calculated from instantaneous dissolution rates, assuming uniform dissolution of all pellet surfaces, and were 1.5 times the observed times. The actual pellet surface area, recalculated from the observed dissolution rate, increased to a maximum twice the initial area when 35% of the pellet had dissolved.

The dissolution rate of UO_2 pellets did not increase appreciably when as much as 0.01 M HF complexed with aluminum (M Al/M F = 3) was added to 2, 6, 10, or 14 M HNO_3.

Solvent Extraction. – Countercurrent batch extractions were made under conditions simulating those of startup and shutdown in the recovery of U^{233} for use in the Kilorod Program. The product met specifications (decontamination factor from Th^{228} of > 100) until the uranium concentration in it decreased to 1% of the equilibrium value. The uranium concentration in the organic product stream from the extraction-scrub column during shutdown was expressed by $C = C_0 e^{-1.31V}$, where C_0 is the initial uranium concentration and V is the number of displacement volumes of the solvent in the scrub section.

Chemical Analysis of Advanced Reactor Fuels. – Since the direct coulometric titration of uranium(VI) in dissolver solutions that contain uranium, niobium, nitric acid, and hydrofluoric acid has been found to be

inaccurate, two procedures for the analysis of that type of sample have been studied. The first method involves the evaporation of the solution to fumes with H_2SO_4 in order to remove HNO_3 and HF, followed by the addition of a solution of oxalic acid to prevent the hydrolysis of niobium salts, after which the coulometric titration of U(VI) is carried out on the resultant solutions. This procedure can be used when the weight ratio of Nb:U does not exceed 3. The relative standard deviation is 0.2% when samples containing 5 mg of uranium are titrated.

The second procedure involves the extraction of uranium into 0.1 M tri-n-octyl phosphine oxide in cyclohexane from an aqueous solution of 0.1 M Al, 1 M in HNO_3 and 0.2 M in lactic acid, followed by extraction from the organic phase with 3.5 M $(NH_4)_2SO_4$. The titration is then carried out on the final aqueous extract. The standard deviation of this procedure is 0.2% when applied to solutions containing 5 mg of uranium. The maximum amount of niobium that can be tolerated in this procedure has not yet been established.

Fluoride Volatility Processing. — A study of AlF_3 phase behavior in four systems, $LiF-BeF_2-AlF_3$, $NaF-BeF_2-AlF_3$, $KF-ZrF_4-AlF_3$, and $LiF-NaF-ZrF_4-AlF_3$, was initiated in prospect of locating solvents having a high capacity for containing AlF_3 in the molten state below 600°C. Preliminary phase data indicate that, as a solvent for AlF_3, the compound $2LiF \cdot BeF_2$ can contain as much as 52 wt % (30 mole %) AlF_3 in the liquid state below 600°C. Comparably high solubility of AlF_3 was not observed within the systems $NaF-BeF_2-AlF_3$ or $LiF-NaF-ZrF_4-AlF_3$. However, mixtures of $KF-ZrF_4$ containing between 33 and 42 mole % ZrF_4 appear to provide useful solvents for the dissolution of aluminum-based fuel elements by HF, with solubility of AlF_3 at 600°C of approximately 25 mole %.

THORIUM UTILIZATION PROGRAM

Thorium Materials Development. — A study was initiated on fabrication variables for the production of very fine thorium hydride powders to be used in the development of dispersion-hardening thorium metals with improved elevated-temperature properties. Present studies involve grinding ThH_4 in rubber-lined ball mills, both dry and in ethyl alcohol, for one, three, and six days. Use of the organic grinding fluid resulted in larger particle sizes, probably due to the dissolving of the finer particles. Increasing the grinding time one to three days also increased particle size, indicating that agglomeration had occurred.

Thorium oxide powders prepared by attritioning sol-gel ThO_2 and by steam denitration of thorium nitrate were found to have sizes of 7.2 and 10.1 μ, respectively — too large to be used as dispersion-hardening agents.

Thoria powders prepared by arc vaporization were found to have an average particle size of 0.04 μ, considered to be in the proper range for dispersion hardening of thorium.

Fuel Cycle Development: Fuel Preparation. — Studies of the behavior of spherical ThO_2 pellets prepared by the sol-gel process indicated that the addition of 0.13 at. % of carbon, palladium, or chromium to ThO_2 sols decreased the hourly attrition rate in a standard spouted-bed test from 0.36%/hr for pure ThO_2 to < 0.1%/hr. Postcalcination polishing of 1200°C-fired sol-gel ThO_2 pebbles by tumbling with 600-mesh carborundum and then

with 4-μ 1200°C-fired ThO_2 decreased attrition rates of ThO_2 spheres by factors of 2.5 to 6.5; values were as low as 0.04%/hr. Approximately 1 kg of thoria and 0.5 kg of 3% uranium-thorium oxide pebbles, ranging from 0.15 to 0.21 in. in diameter, were prepared by the best sol-gel techniques available. Attrition rates of samples in the standard spouted-bed test were 0.049%/hr for the 0.2-in.-diam ThO_2 pebbles, 0.03 for the 0.15-in. ThO_2, and 0.02 for the 0.2-in. uranium-thorium oxide.

The problem of obtaining a uniform uranium distribution in mixed ThO_2-UO_2 prepared by the sol-gel process is being studied further. The tendency for uranium to concentrate in the fine gel particles when sols are evaporated was increased by both incomplete dispersion of the ThO_2 and excess nitric acid in the sol. The optimum NO_3^-/ThO_2 mole ratio for avoiding these conditions, as shown by conductimetric titration of ThO_2 with HNO_3, was found to be dependent on the specific surface area of the ThO_2. For ThO_2 prepared by steam denitration at 475°C, the optimum ratio was 0.08 to 0.09. In four tests the excess uranium in the fine particles, which composed ~3% of the total weight, was decreased from 25 to 2.6% by agitating and digesting ThO_2 in uranyl nitrate solution containing 30% excess nitrate, followed by addition of ammonia equivalent to the excess nitrate.

The presence of organic impurities in the uranyl nitrate solution, as a result of the solvent extraction process, caused no operational difficulties and did not affect the final product. Evaporation and steam denitration of thorium nitrate solution in the rotary calciner produced a satisfactorily dispersible ThO_2 product. A 3 mole % uranyl nitrate—97 mole % thorium nitrate mixture was steam-denitrated to give a product which was satisfactorily dispersed to a uranium-thorium oxide sol.

Fuel Cycle Development: Fuel Fabrication Studies. — An experimental study of the causes of density variations within vibratorily compacted fuel rods was continued. Seventeen fuel rods similar to those required for the Kilorod Program were fabricated with the Branford variable-impact vibrator coupled to a revised loading mechanism. The fuel was sol-gel-derived ThO_2—3 wt % UO_2. Fabrication variables included compaction time, static load on the free oxide surface, particle size distribution, and chamber pressure.

These studies indicate that bulk fuel densities uniform to within ±2% of the average bulk density can be obtained by a proper choice of the fabrication conditions. Chamber pressure and compaction time were found to be important factors in controlling the axial uniformity of the compacted bulk density. It was determined that high and acceptably uniform densities result when a static load of 1.2 kg is applied for 4 to 6 min after 2 min of operation without load. In a group of eight rods fabricated under these conditions, the average density varied from 8.96 to 9.09 g/cc, and in all but one rod the axial density variation was held to ±2%.

Postirradiation examination of the two 11-in.-long × 5/16-in.-diam specimens is nearly completed. Mass spectrographic analyses indicated that the burnups for specimens U-1 and Z-5 were 11,300 and 13,000 Mwd per metric ton of metal respectively. Twelve additional specimens, irradiated in the NRX Reactor, have been submitted to the hot cells for detailed examination.

Thorium-U^{233} Fuel Rod Fabrication Facility. — Construction of the Kilorod fabrication facility is now approximately 65% complete and appears to be on schedule. Phase I is listed at 100% complete, phase II at 86% complete, and phase III at 0% complete.

All the major pieces of the rod fabrication equipment, with the exception of the gamma scanning device, have been received and are in different stages of being tested under mockup conditions. Construction drawings of the gamma scanner were completed in August. The evaluation and modification of all process equipment are estimated to be 40% complete.

MOLTEN-SALT REACTOR PROGRAM

Molten-Salt Reactor Experiment. — Layout drawings for auxiliary piping in the reactor cell are finished. Drawings of the jigs for out-of-cell preassembly of the salt system are complete. Containment-cell designs and vapor-condensing-system drawings are finished. Between-cell piping layouts, cable trays, and electrical conduit drawings are 75% finished. Design changes for the 480-v switchgear are complete. Cell electrical-heater schematics are 75% complete. All drain-tank furnaces are 60% complete. Two types of salt-pipe heater designs have been made; when tests on these are evaluated, one will be chosen for use.

A sufficient quantity of INOR-8 tubing for the MSRE radiator and heat exchanger has been received to avoid shop delays. The rest of the material is expected by early September. Fabrication of the components in the Y-12 shops continues to be on schedule. The fabrication of the thermal shield by the Paducah shops is approximately 75% complete.

The extension to the reactor containment cell in Building 7503 was completed, and stress-relieving operations were performed. Work was started on the high-bay liner and the maintenance control room. Installation of the cooling tower and the off-gas stack was completed. The blowers and the ducting are being installed.

Reactor Analysis. — EQUIPOISE-3A was used to compute fluxes, adjoint fluxes, and power densities in a 19-region model of the MSRE. Axial distributions were closely approximated by curves of sin $(\pi z/H)$, with an effective H between 77 and 85 in. This compares with a length of 62 in. for the fuel channels, a length of 69 in. for the longest graphite stringers, and an effective length of 63 to 66 in. assumed in earlier "bare-reactor" approximations of the core.

Results of the EQUIPOISE calculations were used to compute average nuclear importance and heat production in 18 regions of fuel and 9 regions of graphite in the core. These quantities were incorporated in an analog simulation of the core for studying regulation and control systems.

The ZORCH code for the kinetics of the MSRE was extended to include CALCOMP plotting of axial temperature profiles in the fuel and the graphite along the hottest channel at specified times during transients.

A system of equations describing the behavior of iodine and xenon in the reactor was written, in preparation for the on-line computation of xenon poisoning during MSRE operation.

Development of Components and Systems. — The engineering test loop was shut down for installation of approximately 60 kg of graphite. To

remove any oxygen which may have been present, the graphite was evacuated in situ at room temperature and then purged with helium at 1300°F. At the same time, the equivalent of 175 ppm of oxygen was removed from the flush salt by treatment with a mixture of HF and H_2 in the drain tank. According to chemical analysis of salt samples during the treatment, the rate of chromium removal from the exposed Inconel tank surface was approximately 0.01 mil/hr. The loop is now operating with the treated salt and graphite.

Thermal-shock cycling of the drain-tank cooler test was resumed after heater repairs and installation of reactor-grade thermocouples. All previous efforts to keep thermocouples attached in this test have failed.

The flexible portion of the control-rod test equipment was in excellent condition after 25,000 cycles at 1200°F. All bronze bushings of the drive system were replaced with shrouded ball bearings, and testing was resumed.

The foamed, fused-silica, pipe-heater insulation was tested, and the heat loss was excessive. Because the mechanical and irradiation properties of this material are excellent, an effort is being made to combine it with other insulators to reduce this heat loss.

The freeze-valve test loop was modified to permit evaluation of a mockup of the core-drain-line valve, including the complete instrumentation and controls. A prototype, overflow-line mechanical disconnect was also included for simultaneous evaluation.

An INOR-8 freeze-flange joint has been subjected to 44 thermal cycles from room temperature to 1200°F. The flange was opened after 36 cycles, at which time the maximum helium leak rate was below 2×10^{-4} cc/sec at the lower temperature and 4×10^{-7} cc/sec at 1200°F. A leak of 1.7×10^{-2} cc/sec on a new ring was traced to foreign material on the sealing surface. Another new ring was installed and cycling was resumed. A second flange joint, installed in the prototype pump test, performed as expected, with leakage of less than 5×10^{-5} std cc/sec.

The maintenance tools and in-cell equipment for handling the freeze flanges are on hand. Preliminary testing began on the tools for (1) clamp operation, (2) clamp stowing, (3) gasket handling, and (4) cover handling. Preparations are being made for a realistic demonstration in the maintenance mockup.

The design of a portable shield for use in working through openings in the cell roof is approximately 75% complete. All special items for the shield are being procured.

MSRE Pump Program. – Acceptable INOR-8 castings have been obtained for the impellers and volutes of the MSRE fuel and coolant pumps. A spare volute and impeller casting for each pump is being repaired by welding.

Fabrication of the components for the rotary elements of the reactor pumps was completed, except for two bearing housings which are expected to be delivered in September. Fabrication of the fuel- and coolant-pump tanks is approximately 30% complete. The lubrication stands are about 40% complete.

The manufacturer's procedures were approved for brazing and leak-testing containment vessels for the drive motors. Fabrication of the vessels is being delayed by difficulties in obtaining proper plate materials.

Shakedown of the prototype fuel pump was completed, and hydraulic performance data were obtained with the 13-in.-diam impeller in MSRE fuel

salt at 1200°F, at several pump speeds and with three flow-resistance lines. After 335 hr of operation, the pump shaft seized and welded in the lower 4 in. of the radiation shield plug. The seizure was caused by rubbing of the hot (~1000°F), clean and dry surfaces when the running clearance between the shaft and the stationary shield plug was reduced to zero as the shaft was deflected by the radial hydraulic force on the impeller. The pump was operating on a flow-resistance line well removed from the balance line and in the region of reduced pump capacity. The shaft and shield plug are being replaced; dimensions have been adjusted to provide adequate running clearance during off-design operation of the pump.

The Inconel centrifugal pump (PKP type) has run 5260 hr in an endurance test in molten $LiF-BeF_2-ThF_4-UF_4$ salt, circulating 510 gpm at 1225°F and 1950 rpm. The test pump having a molten-salt-lubricated hydrodynamic journal bearing was assembled and installed in a test stand. During checkout of the system, it was found that the hot, wetted end of a thermocouple well in the pump tank had dissolved. The remainder of the well is being examined metallurgically, and the salt is being analyzed for oxide contamination.

Instrumentation Development. — A prototype model of a conductivity level probe, developed for use in single-point detection of level in the MSRE storage tank, was fabricated and is now being tested. Initial results indicate that the design concept is correct. Signals of 100-mv amplitude were received when the probe contacted the salt. Excitation current used in the test was 15 amp at 1000 cps.

Long-term testing began for the differential scan-alarm system being developed for use in monitoring temperatures in the MSRE during heatup. In this test the system is being operated under simulated MSRE conditions and is connected to 100 thermocouples on an operating molten-salt test facility. Approximately 15 days of operating time have elapsed so far. Except for a component failure in the oscilloscope used for visual display of the scanned temperatures, operation of the system has been satisfactory.

Thermocouples were installed on a freeze-valve test and on a bayonet-cooler test, by use of installation methods proposed for the MSRE, to determine whether the thermocouples would withstand the thermal shocks and differential expansions produced by the severe temperature transients inherent in these applications. No failures have been experienced to date.

A six-circuit radiation-resistant thermocouple disconnect assembly was fabricated and was tested in a remote-maintenance facility. The disconnect is simpler in construction than the assembly previously reported and is more compatible with MSRE requirements. The complete assembly can be obtained from a commercial supplier, with only slight modifications being required for the MSRE installations.

NUCLEAR SAFETY

Release of Fission Products on Out-of-Pile Melting of Reactor Fuels. — Efforts to design experiments for simulating nuclear reactor fuel meltdown have led to development of the concept of a cored UO_2 rod heated with a central tungsten electrical resistor. The principal advantages of the

resistor technique are the ease of obtaining center melting, the close simulation of nuclear heating, and the possibility of surrounding molten fuel with rods of incompletely melted fuel.

Heating single UO_2 rods in helium at atmospheric pressure with a central tungsten resistor resulted in melting up to 80% of the UO_2 before the tungsten itself melted. The melting process was characterized by extrusions of molten UO_2 through cracks in the unmelted outer surface, due to internal gas pressure, and some pouring of UO_2 through larger openings. Upon analysis of the helium in the vessel, it was found that approximately 1.5 cc (STP) of gas was released during melting of a 2-1/2-in.-long UO_2 rod weighing about 52 g. This gas, analyzed with a mass spectrometer, was found to contain 50% H_2 and 50% N_2 + CO. However, a similar gas release was shown to occur when a bare tungsten rod was heated to about the same temperature after having been subjected to rigorous degassing treatment.

It is concluded that no significant fraction of the released gas has its origin in the UO_2, and therefore the gas could not indicate an additional hazard to UO_2-fueled reactors. In future experiments with irradiated fuel, a previously outgassed tungsten rod will be used to minimize sweeping by the released gases.

Release of Fission Products on In-Pile Melting of Reactor Fuels. — Experimental assembly 6 was melted and was examined in the hot cells. Radioassay is completed, and calculations of the results are essentially complete.

The distributions of the various fission products in the exit gas systems of experiments 2–5 are being examined for the purpose of determining the physical forms of the fission products which escaped from the furnace. This system consists of a diffusion channel, three particulate filters, and a charcoal adsorber. Analysis of diffusion-channel data indicates that significant fractions of the iodine, strontium, and barium activity emerging from the furnace have diffusion coefficients of approximately 0.03 cm^2/sec in helium, which corresponds to a very small particle size. A small fraction of the uranium and of the zirconium activity exhibits a diffusion coefficient of approximately 0.016 cm^2/sec, corresponding to somewhat larger particles in experiments 3, 4, and 5, but not in experiment 2, which had been irradiated with melted cladding and was kept molten longer. Ruthenium and cerium activities did not exhibit diffusion coefficients in this range, indicating that they appear only in larger particles. The analysis of the distributions of activity in the exit gas systems is being continued in order to obtain additional information about the physical forms of fission product activity released during meltdown incidents. Experiment 7 was assembled and was melted and removed from the reactor the week of August 15.

Characterization and Control of Accident-Released Fission Products. — Investigation of the efficiency of conventional filtration media for very fine particles was continued, by use of the previously described particle and vapor characterization technique which is based on diffusion measurements. The filter materials studied were activated carbon and a high-efficiency particulate filter medium in conjunction with I^{131}-labeled aluminum oxide particles having diameters of approximately 0.004 μ. The results obtained indicated that neither material removed such particles effectively, since ≧10% of those impinging appeared to penetrate either media under the experimental conditions.

Consequently, attention has now been directed toward evaluating some less-conventional methods which might be useful for disposing of ultrafine particles, although much remains to be done in extending the previous studies. In experiments now in progress, the objective is to increase the efficiency of a filter for 0.004-μ particles by condensation of water vapor on them with an attendant increase in their effective diameter. Also, investigation of other methods, not involving filters, is planned.

Nuclear Safety Pilot Plant. – Design and procurement for the Nuclear Safety Pilot Plant are on schedule. The model containment vessel was ordered, along with components of the gas-sampling train. Instrumentation and pumps that were to be salvaged from existing HRE-2 material were assembled, and reworking was started on some items. Design work was started on remote-handling procedures, tools, and carriers, as well as instrumentation and irradiation equipment.

A laminar-flame plasma torch was procured, and a furnace development program is under way. Melts were successfully accomplished in a 3-in.-diam water-jacketed stainless-steel-tube furnace with a drive mechanism which provides 6-in. linear movement of the fuel container. Assembly of materials for tests of decontamination solutions and air samplers was started. A store of long-cooled irradiated UO_2 was set aside for meltdown. Steps were taken to comply with Laboratory health physics and safety review requirements.

Reactor Containment Handbook. – Chapter IV, "Energy Sources," was reviewed by ORNL personnel, and the comments received are being incorporated into the draft. The draft will be edited and reproduced and then sent to the AEC for final review. Work on other chapters is progressing. A contract agreement with Bechtel Corporation was reached for the writing of chapters on "Design Details," "Containment Proof Tests," "Materials Properties," and "Economics." First drafts will be submitted by January 1, 1963, and final copies by July 1, 1963.

WASTE DISPOSAL DEVELOPMENT

Clinch River Study. – Undisturbed cores of bottom sediments at 14 cross sections on the Clinch River, 2 cross sections on the Emory River, and 2 cross sections on Poplar Creek were obtained by use of the Swedish Foil Sampler. A basket-type core retainer was required at some sampling points to obtain satisfactory core recovery. The size distribution, mineralogy, chemical composition, and radionuclide content of the river sediment will be determined when sampling is completed.

Frequency curves for minimum dilution factors of 1, 3, 7, 15, and 30 days' duration were prepared. From these curves it is found that the minimum 30-day dilution factor is 130 for a 2-year recurrence interval and 78 for a 10-year recurrence interval. The minimum dilution factor for a 2-year recurrence interval varies from 130 for a 30-day duration to about 20 for a 1-day duration.

Mineral Exchange Studies. – When crystalline gibbsite, an aluminum hydroxide, was heated above its decomposition temperature, a highly selective sorbent for strontium was produced. The sorption capacities for cesium ions and strontium ions of a sample which had been heated to 400°C for 3 hr were measured. When cesium was used, the heat-treated gibbsite sorbed

4.4 meq per 100 g; the sorbed cesium was easily desorbed by equal concentration of sodium ions. When strontium was used, the material sorbed approximately 12 meq per 100 g at pH 8.0. Desorbing the strontium was found to be difficult; after passing sodium ions equal to 90 times the concentration of strontium on the sorbent, 50% of the strontium still remained on the sorbent.

More sorbents showing selective properties for strontium were produced when diaspore ($HAlO_2$), goethite ($HFeO_2$), and limonite ($Fe_2O_3 \cdot xH_2O$) were heated to 500°C for 3 hr. The minerals all increased in surface area following the heat treatment; limonite showed the largest increase – from 21 to 93 m^2/g.

Disposal in Deep Wells. – Sorptions of both calcium and strontium by columns of Richfield sand are reduced by the same relative amounts as the influent pH is lowered. At an influent pH of 2, dissolution of minerals from the column causes interference with ethylenediaminetetraacetic acid titration of calcium in the effluent and a reduction in exchange capacity from 6.21 to 2.67 meq per 100 g.

Calcium-strontium exchange from 0.005 M Ca^{2+} (calcium chloride saturated with calcium carbonate at pH 7) by mixtures of Richfield sand and calcium carbonate indicated that the calcium carbonate sorbed 1.91 meq Ca^{2+} per 100 g with a K_{Ca}^{Sr} of 0.31 and the Richfield sand sorbed 2.91 meq Ca^{2+} per 100 g with a K_{Ca}^{Sr} of 1.50.

Disposal in Natural Salt Formations. – Tests of an array of cylinders in the floor and of single cylinders in the wall and floor of the Carey Salt Company mine at Hutchinson, Kansas, were started in July. The cylinders simulate the pot-calciner solids waste. Operation of the tests is proceeding normally, but the six peripheral heaters in the array have failed due to breakage of the heater lead wires. The cause of the failure is being investigated.

In both the wall and floor tests, there has been some shattering of the salt, beginning at a salt temperature of about 280°C, but the heat transfer properties of the salt do not appear to have been significantly affected.

Engineering, Economic, and Safety Evaluation. – The effect of fission product removal on the cost of high-activity-waste management was investigated through interim liquid storage, pot calcination, and shipment to salt mines for permanent disposal, and it does not appear that fission product removal will significantly decrease waste management costs. The costs of separation and handling of the separated fission product concentrates were borne by their sale. The costs of interim liquid storage were decreased about 30% over those of untreated wastes because of decreases in cooling system requirements, but pot-calcination costs were unaffected, except that all calcinations could be performed immediately in the least expensive 24-in.-diam pots. Shipping costs for the wastes after 90 and 99% fission product removal were about 25 and 50% less, respectively, than for reacidified Purex waste because of the permissible thinner shipping-cask shielding. Minimum total costs (less costs for disposal in salt) were about 0.141 mill/kwhr (electrical) for 99% removal, and 0.147 mill/kwhr for 90% removal, compared with 0.147 mill/kwhr for management of acidic Purex waste from which fission products had not been removed.

PHYSICAL RESEARCH PROGRAM

PHYSICS AND MATHEMATICS RESEARCH

High-Energy Physics. — A program has been written for the IBM 7090 to reconstruct spatial geometrical data and calculate momenta of single tracks from coordinate information measured on stereophotographs. The program is based in part on existing similar programs, but incorporates features peculiar to analysis of events in the Northwestern University helium bubble chamber measured with the ORNL Hermes precision film reader. Special features of the program include efficient detection and correction of errors in the Hermes output, automatic best stereo view selection, least-squares fitting of measured track coordinates to polynomials of adjustable order, and flexibility of output. Auxiliary programs are provided which accept punched-card output of preselected information from the main program. For example, a histogram of momentum and angular distributions for a given type of track may be directly plotted as the events are processed. The program, as well as the operation of the Hermes, has been tested in several ways and found to be extremely satisfactory.

High-Energy Electronuclear Machines: Cyclotron Analogue II. — Additional studies of the performance of the 450-kev eight-sector electron cyclotron were made to determine the cause of a gradual diminution of observed beam beyond an electron energy of 300 kev. The influences of multiple scattering were examined with targets of C, Al, Cu, Cd, and Ta. At low energies, where the range of the electron is small compared with the radial width of the beam, the metered current varies according to the published back-scattering ratios for the several elements. In the energy range 300 to 500 kev the metered current is relatively independent of energy for heavy-element targets, decreasing less than 10%; for an aluminum target it decreases 30%. It is concluded that the attenuation observed is a result of multiple scattering from the edge of the target, an effect which is accentuated in low-density elements. At 450 kev the ratio of electron range in aluminum to the radial width of the beam is approximately 5, while for tantalum the ratio is about 1.

Basic Studies of Cryogenic Electromagnets. — A consistent pattern is emerging from the fabrication and testing of a series of small Nb-Zr superconducting magnets. Magnets simply wound with insulated 0.010-in. wire carry 18 amp up to the maximum field, 70 to 80 kilogauss; magnets wound with copper secondaries carry between 18 and 24 amp; magnets wound with copper secondaries and cast in epoxy carry 29 to 34 amp. During field collapse, when the conductor goes normal, all the field energy is dumped either in the Nb-Zr circuit or in the available secondary circuits. When the coil goes normal without the protection provided by secondary circuits, the Nb-Zr is damaged by a combination of high voltages and overheating. Heating occurs at the initial superconducting-to-normal transition spot during the total time required for the dissipation of the field energy.

The history of the latest magnet constructed in this series of six small magnets illustrates almost all the pertinent facts so far learned. A 0.25-henry 1/2-in.-ID magnet was wound bifilarly with copper wire on an epoxy form and cast in epoxy. With the secondary always connected, it carried 30 amp and survived several hundred transitions. In the first three tests after the secondary was disconnected, the magnet carried 30, 24, and 16 amp, and thereafter was always a 16-amp magnet. Apparently, sufficient damage was done to the superconductor during these three tests, in which the field energy was all dissipated in the Nb-Zr circuit, that it became permanently unable to carry more current. At 30 and 16 amp, the field energies are about 120 and 30 joules respectively. An approximate calculation shows that annealing temperatures were reached when 120 joules was deposited in the Nb-Zr circuit, but no further annealing was possible with 30 joules.

Extrapolation to megajoule magnets requires that protection be provided and, because of the longer time for field collapse, that additional external circuitry in the form of spark gaps or large switch resistors in the primary Nb-Zr circuit be provided. It should be pointed out that where the damage is localized at the point of transition, the amount of energy required to damage the superconductor is independent of magnet size; a much larger magnet would also be damaged by 120 joules. It is clear, however, that the use of the copper secondary and epoxy casting doubles the current capacity of a magnet and should result in reduced cost.

Multiparticle Medium-Energy Nuclear Physics: The 86-Inch Cyclotron. — Improvements have been made on the scattering chamber to allow completely remote operation from the counting room. Two of the computer programs used to analyze the experimental data were rewritten to facilitate faster and more flexible analysis of the data. Several new programs were written to aid in the analysis of experimental data. The assembly of the magnetic analysis system is nearing completion; preliminary tests of the system are being initiated. This system will be used to study nuclear states of specific interest that are poorly resolved with the present counter equipment.

Energy spectra of protons scattered by Ni^{64} and Zn^{64} were measured at incident energies of 9.6 and 11.7 Mev in collaboration with members of the Livermore Cyclotron staff. The maxima and minima of the elastic scattering angular distribution of Ni^{64} occur at angles ~4° smaller than the corresponding features of the Zn^{64} angular distribution. This is consistent with a nuclear symmetry dependence of the real nuclear potential-well depth. The inelastic-scattering measurements yielded data for excitation energies in Ni^{64} at ten levels below 4.40 Mev; eight of these levels below 4.70 Mev were measured for Zn^{64}, five not previously reported. The relative cross sections for exciting the first 2^+ levels of the two isobars are in approximate agreement with an interaction based on the collective model of the nucleus.

Multiparticle Medium-Energy Nuclear Physics: Heavy-Particle Physics. — With O^{4+} ions accelerated by the tandem Van de Graaff, the excitation function for the reaction $C^{12}(O^{16},\alpha)Mg^{24}$ was measured for the first five states in Mg^{24}. The overall resolution was 45 kev (center of mass), and

strong fluctuations in the excitation function were observed throughout the investigated energy region, from 25.10 to 26.10 Mev excitation in the compound nucleus Si^{28}. The width of the resonances varies from 100 to 200 kev. If the resonances are due to the interference of randomly distributed levels in the compound nucleus, one may conclude that the lifetime of the compound nucleus is no shorter than 0.7×10^{-20} sec. The 63-Inch Cyclotron was reactivated for nitrogen bombardment of P^{31} and S^{32}. With these targets the ratio of production of Sc^{44}/Sc^{44m} is being investigated as a function of nitrogen energy.

Scintillation Spectrometry and Instrument Development. — A Mössbauer apparatus has been constructed and is being used to investigate both nuclear and solid-state physics problems. The equipment was designed so as to incorporate a multichannel analyzer as a data storage unit. The apparatus is being used to investigate the Mössbauer nucleus Fe^{57} in an Fe-Rh alloy. The alloy changes from a nonmagnetic state to a ferromagnetic state near room temperature, but this transition temperature depends critically upon the rhodium concentration. Preliminary measurements show that there are at least two phases present in the sample, one with approximately zero magnetic field at the iron nucleus and one which exhibits a magnetic hyperfine splitting. The magnetic field responsible for the hyperfine splitting is about 230 kilogauss, compared with the 330-kilogauss field in pure iron. The temperature dependence of the hyperfine splitting is being determined.

High-Voltage Experimental Program: Coulomb Excitation. — Coulomb excitation measurements have been made by proton and alpha-particle bombardment of metallic targets enriched in the different isotopes of osmium. The B(E2)'s for excitation of the first 2^+ state in Os^{188}, Os^{190}, and Os^{192} are larger than the single-particle estimate by factors ranging from 70 to 100. The B(E2) for excitation of the second 2^+ state is about 0.1 of that for excitation of the first 2^+ state. The sign of $\delta = (E2/M1)^{1/2}$ in the $2 \rightarrow 2$ transition is negative, and the $B(M1, 2 \rightarrow 2)$'s are exceedingly small, being about 10^{-3} times the single-particle estimate.

States in Os^{187} at 74, 75, and 187 kev and in Os^{189} at 69.5, 95, and 219 kev are directly Coulomb-excited. The predictions of the symmetric rotator model of Bohr-Mottelson with rotation-particle coupling included do not agree with the experimental results for Os^{187}.

High-Voltage Experimental Program: Neutron Capture at Low Energies. — It has been recognized for several years that "direct" neutron capture processes can be important at low energies. Lane and Lynn have shown that an appreciable fraction of certain thermal cross sections may be due to this process. Neutron capture gamma-ray spectra have been measured in the resonance region ($\overline{E}_n$ = 30 kev) and compared with corresponding thermal capture spectra. Major differences occur for many nuclei. In particular, isotopes of nickel, copper, and lead show many gamma rays which would be expected following compound nucleus formation, but which are weak or absent in thermal capture. Such results support the conclusion that these mass regions are important in the consideration of direct capture.

Electronuclear Machines: The Isochronous Cyclotron. — The preliminary stage of test operation of the ORIC, which began March 18 with the

first full-radius beam, was completed, and the machine is being readied for full-power operation. During the preliminary stage a limited rf power supply was used; resonance at 7.79 Mc and 5.1 kilogauss gave a proton beam of 8 Mev at full radius. Extensive tests were made at this energy to confirm the validity of the design, the extensive computer calculations, and the unique construction. Isochronous acceleration of protons to maximum radius is achieved with a potential of less than 10 kv on the dee. The ions can be held in phase for at least 500 orbits.

Adjustment of the many magnet coil currents used to provide the isochronous field proved less difficult than had been anticipated. Suitable field configurations are obtained by computation, by beam-phase monitoring, or simply by systematic manual search. These settings are stable and fully reproducible. Orbit calculations indicate that a magnet "bump" suitable for deflection can be introduced with the existing coils.

Radioautographs and patterns burned in foils by the beam after it has passed through the electrostatic deflector channel show beam dimensions of about 0.75 in. radially and 0.5 in. axially. It is computed that a 6-kilogauss magnet channel now being designed will bring this beam to the desired beam port. The final power amplifier is now being installed in the rf system.

Stable Isotopes Development. — The research effort on high-output ion sources is being accelerated. Efforts are directed toward the construction of a model to explain the mechanism by which the ion is released from the arc ribbon. Magnetic-field calculations are being made preliminary to the design of a sector instrument.

Special Separations. — Approximately 52 g of uranium-233 oxide has been recovered from an acetate solution of uranium and purified. One batch each of U^{235} and U^{238} was converted to uranium metal. A total of 3.6 kg of depleted uranium-238 oxide has been pressed and broken into lumps to serve as charge material for high-purity U^{238} separations.

Electrodeposited sources of U^{235}, Am^{241}, and Np^{237} were fabricated.

CHEMISTRY RESEARCH

Thorium Oxide Studies. — A 12-month irradiation of arc-fused thorium oxide, sintered thoria compacts, fired sol-gel material, and a 1600°C-fired thoria powder at full reactor power in the LITR (14 months in the reactor) and a laboratory control experiment were completed. Metallographs of the original arc-fused materials, although of theoretical density, showed etched pits at former grain boundaries, some cracks, and an occasional large pore. Metallographs of the fired sol-gel material showed a considerable number of micropores and an absence of grain structure. The sol-gel material from the control experiment had a pycnometric density of 10.04 g/cm^3. The sintered thoria compacts showed a pronounced grain structure, micron-size pores, and, for the materials removed from the control experiment, densities less than theoretical (i.e., 9.83 g/cm^3 for one preparation and 9.62 g/cm^3 for a different preparation).

Equipment Decontamination. – The fission products Zr-Nb^{95}, Ce-Pr^{144}, Ba-La^{140}, and Ru-Rh^{106}, which had been baked onto stainless steel at 500°C in oxygen-free helium, were removed by decontamination factors of < 5 in 20 min in low-corrosion solutions such as oxalate-peroxide. Such solutions, therefore, are not adequate for decontaminating such equipment as the stainless steel blowers of the Pebble-Bed Reactor. Aluminum decontamination was satisfactory: 10^3 for Zr-Nb^{95} and Ba-La^{140}, and 100 for Ce-Pr^{144} and Ru-Rh^{106}. Decontamination of carbon steel was better than that for stainless steel, the decontamination factors in 20 min at 95°C in oxalate-peroxide being 20 to 40 for Zr-Nb^{95}, 10 to 38 for Ba-La^{140}, 17 for Ce-Pr^{144}, and 3 for Ru-Rh^{106}. Acetate buffer addition to oxalate-citrate-peroxide made it necessary to use more peroxide in order to keep the solution noncorrosive to carbon steel.

An attempt to volatilize Ce^{144} metal from cerium chloride and calcium at 1100°C in helium was unsuccessful.

Radiation Chemistry of Organic Materials: Moderator-Coolants. – Calibration factors for the areas under the gas chromatographic peaks have been determined for many of the compounds produced during the pyrolysis of pure biphenyl. These factors were used in quantitative analysis of the products formed during the pyrolysis of 3 g of biphenyl at 425°C for 16 hr. Following is the total amount of each product formed: 6.1 mg of benzene, 2.9 mg of m-terphenyl, 3.5 mg of p-terphenyl, 2.5 mg of 1,3,5-triphenylbenzene, and 2.4 mg of m,p-quaterphenyl. The amount of o-terphenyl present was below the limit of quantitative analysis, although it was shown qualitatively to be present. These results indicate approximately 0.7% decomposition of the biphenyl.

Properties of Aqueous Solutions: EMF and Solubility Studies. – The second dissociation constant of deuterosulfuric acid was computed from 25 to 225°C by using data on the solubility of Ag_2SO_4 in D_2SO_4 solutions. In addition, the thermodynamic constants $\Delta F°$, $\Delta H°$, and $\Delta S°$ for the reaction

$$DSO_4^- = D^+ + SO_4^{2-}$$

were calculated. As in previous work on the bisulfate acid constant, K_2, the entropy of dissociation is negative and attains a higher negative value, the higher the temperature. The K_2 for D_2SO_4 is a factor of 2.3 lower than the value for H_2SO_4 at 25°C. The isotope effect decreases as the temperature increases, and it reverses above 200°C.

Properties of Aqueous Solutions: Species and Thermodynamic Properties. – In normal practice, refractive index patterns obtained when a solute has attained an equilibrium distribution in a centrifugal field are interpreted in terms of the molecular weight of the solute. In principle, an alternate procedure should be possible in which experimental refractive index patterns are compared with those computed for an assumed model; such a course might be particularly attractive in connection with a complex polydisperse distribution of species having different refractive index increments and charges per monomer unit (as is frequently the case in hydrolysis). This procedure was evaluated in a study of aqueous bismuth perchlorate solutions, in which the predominant hydrolyzed

species is $[Bi(OH)_2]_6^{6+}$ (apparently the hexamer also complexes two perchlorate ions). The results indicate that there must be a small contribution of another hydrolyzed species to explain ultracentrifugations of all Bi(III) concentrations and degrees of hydrolysis. If $BiOH^{2+}$ is postulated, satisfactory agreement over all conditions is obtained, with an estimated formation constant of 0.26 for the hexamer (from $6Bi^{3+}$ and water, at 25°C, 1 M perchlorate) and a ΔH of about 40 kcal.

Nuclear Chemistry: Spectroscopy. — A cerium nuclide with a half-life of about 20 sec was discovered. The new nuclide was shown to be an isomer of Ce^{135} by measurement of the yields obtained from 14-Mev neutron bombardments of CeO_2 samples which had different isotopic compositions. Five gamma rays have been detected in the decay of the ~20-sec isomeric state to the 18-hr ground state. Three of the gamma rays have the same energies as gamma rays emitted in the decay of Pr^{135}, which is consistent with the assignment of the ~20-sec period to Ce^{135}.

Radiation Chemistry: Radiolysis of Alkali-Metal Bromates. — Measurements of the radiolysis of bromate ions in the alkali-metal bromates by nuclear reactor radiations were made in a continuing basic study of the Szilard-Chalmers reaction for the production of high-specific-activity radioisotopes. The radiation stability of BrO_3^- ion was found to decrease progressively from Li^7BrO_3 to $CsBrO_3$; this sequence was the same as had been observed previously with Co^{60} gamma rays. The stabilities relative to $KBrO_3$, however, generally differed, and this could be attributed to the production of internal radiation sources by neutron capture in the cations in addition to that in bromine, or by the creation of high linear energy transfer recoil fragments, as in the fission of Li^6.

Specific decompositions by thermal neutrons, or by reactor gamma rays, were estimated from irradiations conducted in a thermal column or with thick lithium or bismuth metal shielding respectively. Approximately one-half the total radiation damage appeared to be caused by the consequences of thermal-neutron capture, and about one-half was caused by reactor gamma rays. Decomposition by fast neutrons was relatively much less important, except possibly with Li^7BrO_3.

Bromine oxidation states intermediate between bromate and bromide were formed in the crystals. Their yields were dependent on the nature of the cation and appeared to approach saturation with increasing dose. The amounts of bromide ion produced followed a similar dependence on the cation, but, in contrast, the increase in yield with dose showed an induction period. These data have suggested that the radiolytic decomposition of BrO_3^- ion may occur in a stepwise manner.

Radiation Chemistry: Water Radiolysis. — An important parameter in the diffusion-kinetics model of water radiolysis is linear energy transfer. Yields were measured for oxidation of ferrous sulfate, and for reduction of ceric sulfate both with and without added thallous ion, by protons of various energies in the range 11 to 23 Mev. From these measurements, derived yields of intermediates G_H, G_{OH}, G_{H_2}, $G_{H_2O_2}$, and G_{-H_2O} were evaluated. The measurements extend the range previously covered (to 10 Mev at both Argonne and Brookhaven) into the lower LET range.

Methods were devised for accurately measuring both the proton energy and the proton beam current. The 100-ev yield for oxidation of ferrous sulfate decreased from 12.8 for 23-Mev protons to 11.3 for 11-Mev protons. The yield for reduction of ceric sulfate remained constant at 2.95 over this range of proton energies, while the yield for reduction of ceric sulfate in the presence of thallous ion decreased from 6.78 for 23-Mev protons to 6.01 for 11-Mev protons.

The derived molecular yields, G_{H_2} and $G_{H_2O_2}$, were essentially constant at 0.38 and 0.93, respectively, over this range of LET, while G_H decreased from 3.00 to 2.66 and G_{OH} decreased from 1.90 to 1.53 as the LET increased from 0.2 to 0.4. The net yield of water decomposition, G_{-H_2O}, decreased from 3.77 to 3.38 over this range of LET. Both the measured and derived yields extrapolate smoothly to the values reported for particles of LET > 0.4 ev/A. The results are consistent with quantitative predictions of the diffusion-kinetics model.

High-Temperature and Structural Chemistry. – The electrical conductivity of solutions of rare-earth metals in their molten triiodides was found to reflect the stability of Nd^{2+} and the instability or nonexistence of La^{2+} and Ce^{2+}, as first indicated by phase diagrams, with Pr^{2+} exhibiting intermediate stability. The entropies of fusion of the trihalides were determined calorimetrically and yielded, in conjunction with the phase diagrams, a cryoscopic number of $n \approx 3$ for the dissolution of the metals in the trihalides, corresponding either to the reaction $M + 2M^{3+} \rightarrow 3M^{2+}$, as for Nd, or to the ionization $M \rightarrow M^{3+} + 3e^-$, as for La and Ce. In Pr systems both reactions occur simultaneously.

Large differences in the electronic conductance of pairs of systems such as K-KX and La-LaX_3, involving salts of different stoichiometry, are explained by the assumption that the electronic conductance is proportional not only to the concentration of mobile electrons but also to the concentration of the metal ions between which the electrons are being exchanged.

Heat capacities over limited temperature ranges and heats of fusion were determined by means of a drop calorimeter for a number of rare-earth and alkaline-earth halides. The salts $SrBr_2$ and $BaCl_2$ undergo phase changes just below their melting points with fairly large heats of transition. Their high-temperature forms are believed to have the fluorite type of structure characterized as in CaF_2 and $SrCl_2$ by an unusually low entropy of fusion, probably because a high degree of disorder occurs in that structure at elevated temperatures.

The alleged existence, in molten $CdCl_2$-KCl mixtures, of a minimum in electrical conductance at the composition $KCl:CdCl_2 = 1:1$ attributed to the formation of $CdCl_3^-$ ions, was ruled out by measurements at 460, 500, and 570°C. The data are in agreement with higher-temperature data of the literature and with the assumption of $CdCl_4^{2-}$ rather than $CdCl_3^-$ ions. An analysis of emf measurements by Russian investigators leads to the same result.

Transuranium Element Processing: The Transuranium Facility. – The Transuranium Facility for separating and isolating the transuranium

isotopes from the target rods irradiated in the High Flux Isotope Reactor will have nine process cells, shielded by 54 in. of magnetite concrete, and eight laboratories. The cells will be served by master-slave manipulators and will have removable top plugs for access. The tops and backs will be served by a bridge crane located in the limited-access area of the building, where shielded space for off-gas filters will also be provided. Four of the cells will contain chemical processing equipment for dissolution, solvent extraction, and precipitation processes; three will contain equipment for remote preparation and inspection of recycle targets; and two will be for remote analytical operations. Preliminary (title I) engineering of the building structure was completed. Detailed (title II) design was started, with completion scheduled for January 1, 1963, start of construction for June 1963, and completion of construction for January 1965. With 11 months for installation of equipment and shakedown runs, full-scale operation should start in December 1965. Initial engineering equipment flowsheets were completed, and layout designs of process equipment, cubicle equipment racks, and shielded storage tanks were made. The remote-maintenance concept adopted depends on development of remotely operated process line disconnects, and an initial order for an experimental design that uses investment casting has been placed. Design, development, and fabrication of process equipment were analyzed in detail by the critical-path-schedule technique, and this detailed arrow diagram was combined with a similar one for construction of the building and shielded cells to form a master schedule. The master diagram was programmed, and the critical path of the project was determined.

The initial installation of the processing facility mockup in Building 9204-1 was completed. The intercell conveyor complex and the associated cubicle port closures are ready for testing, and fabrication of the equipment transfer caisson was started. The feasibility of using a pulsed column as a contactor in separating americium and curium from transcurium elements was partially demonstrated. The flow capacity ranged from 50 to 200 gal hr^{-1} ft^{-2} at 25°C over a pulse frequency range of 80 to 200 cpm for the system: 2-ethylhexylphenylphosphonic acid in diethylbenzene vs 1.5 M HCl, which has a density difference of 0.07 g/cc.

Transuranium Element Processing: Process Development. — In laboratory-scale mixer-settler studies on the Tramex process for actinide purification by tertiary amine extraction from lithium chloride solutions, americium was 99.9% recovered from feed containing 1 mg of irradiated Am^{241} (10 w/liter), with a gross gamma decontamination factor of 5×10^3. Ruthenium and silver were the principal fission product contaminants in the product, Ru^{4+} being extracted with the actinides. In stripping of the actinides with 6 to 8 M HCl, Ru^{3+}, which forms by slow reduction of the extracted ruthenium, is also stripped, thus limiting the ruthenium decontamination factor that can be obtained. The use of nitrite to reoxidize the ruthenium resulted in a decontamination factor of 10^4, but H_2O_2 could not be used, since its half-life in 8 M HCl at 60°C is only about 1 min and the solution residence time in the mixer-settler is about 20 min. In a small-scale batch run, separation was more rapid and distribution coefficients were the same as in the experiments with tracer Am^{241}.

The extraction of barium by 30% Alamine 336 in diethylbenzene from 11 M LiCl solution was increased by the presence of $AlCl_3$. At 0.0025 M $AlCl_3$ the barium distribution coefficient was 0.1; at 0.06 M $AlCl_3$ it was about 2.

The process will be demonstrated in equipment being installed in cells 3 and 4 of Building 4507. Hastelloy C storage tanks were installed in a pit beneath cell 4. The equipment is designed for remote maintenance by means of specially designed process line disconnects. Contaminated equipment will be renewed and replaced through an air-lock transfer box, now being fabricated, over the top access port of cells 3 and 4. Process equipment, tanks, mixer-settlers, and valves will be constructed largely of Hastelloy C, tantalum, and, where visibility is important, of Homalite plastic. Completion of this installation is scheduled for November of this year.

Uranium-232 Preparation. – A total of 1.04 g of high-purity U^{232} was recovered from the second irradiation of Pa^{231}. Isotopic analysis of this product showed 99.24% U^{232}, 0.72% U^{233}, 0.0014% U^{235}, and 0.024% U^{238}. Radiochemical analysis indicated < 0.1% Pa in the uranium product.

This uranium was prepared by irradiating ~45 g of Pa^{231} to a total of 1.25×10^{20} neutrons/cm^2. The irradiated protactinium was allowed to decay seven days and was then processed through two anion exchange cycles from mixed HCl-HF feed to separate the uranium from the protactinium. Tributyl phosphate extraction from 6 M HNO_3 was used for final purification of the uranium. No further preparation of U^{232} is planned. After the protactinium has been stored for about one year to allow Pa^{233} to decay, it will be purified and returned to the United Kingdom.

Corrosion Tests for the TRU Facility. – Two types of acrylic-butadiene-styrene plastics were found to be incompatible with mono-2-ethylhexylphenylphosphonic acid and 30% Alamine 336 chloride at temperatures of 43 and 80°C. After 200-hr exposure periods, specimens exhibited considerable swelling and weight increase. In the same solutions at 80°C, Bakelite, Havegs 41 and 43 (all phenolic-resin types), and Kynar (vinylidene fluoride resin) showed promising behavior after 500 hr.

Hydrogen pickup in niobium occurred during a 1000-hr exposure in oxygenated 6 M HCl solution at 43°C. Cracking of the specimen took place during a bend test after exposure. The hydrogen content of the specimen was 87 ppm, compared with 4 ppm in the unexposed material. Neither tantalum nor Zircaloy-2 was subject to hydrogen pickup in similar tests.

Target Preparation. – Hydrides of Li^6 and Li^7 were successfully evaporated onto 25-μg/cm^2 carbon films. Evaluation of these targets in the tandem Van de Graaff accelerator indicated uniform LiH for film thicknesses of 100 μg/cm^2. Also prepared on carbon substrates were target films of tellurium and silicon (100 μg/cm^2 thick). Developments in self-supported targets include the elemental forms of Cd, Ag, Si, and Cu isotopes; minimum thicknesses for these target materials are between 150 and 500 μg/cm^2.

Metallurgical techniques for the fabrication of WO_2 and WO_3 in pressed form have been developed by using 60 wt % copper as a matrix. Foils of this material show resistance to damage, and x-ray examination

proved the dispersed tungsten oxides to be uniform. Developmental work is progressing on hot-rolling techniques suitable for the alloy UFe_2, a highly refractory and pyrophoric material.

Electrodeposition of ~100 $\mu g/cm^2$ of nickel or chromium on copper has been studied. Foils prepared by annealing these plated copper sheets at ~600°C and removing the copper backing with trichloroacetic acid are ductile and uniform in thickness.

METALLURGY AND MATERIALS RESEARCH

Preparation of Pure Materials. — A third LiF crystal (98.06% Li^7), weighing 278 g, was produced and loaned to the Materials Research Center, Cornell University. Portions of the second crystal (ORNL-3321, p 29) were analyzed by emission spectroscopy at ORNL. The results are tabulated below:

Element	Amount (ppm)	
	Top	Bottom
Al	< 10–300[a]	nd[b]– < 100
B	nd–500	nd
Ca	30	< 10–20
K	20	20
Mg	20–50	10
Mn	< 100–300	nd
Na	30	10
Si	nd–200	nd–300[c]
Ti	nd	100

[a]Eleven analyses were performed. The ranges of the results are shown in this table.

[b]Not detected.

[c]Of the eleven analyses, eight did not show Si, one gave < 100 ppm, one 100 ppm, and one 300 ppm.

Infrared absorption spectra of the first two crystals (ORNL-3269 and -3321) show no OH^- contamination. A 20-g portion of the second crystal was supplied to the Metals and Ceramics Division for high-temperature thermal conductivity studies. Approximately 900 g of high-purity LiF (99.99% Li^7) has been produced for the growth of new crystals.

Reactions at Metal Surfaces. — A study was made of the surface stresses generated in tantalum specimens during oxidation. Stress values were obtained from an analysis of measured bending stresses occasioned by the oxidation of one side only of flat tantalum specimens. A stress distribution model was proposed in which it was assumed that the lattice expansion accompanying oxygen solution in the specimen was the principal source of stress. The stress gradient in the specimen was assumed to be proportional to the oxygen concentration gradient. The model proved to be consistent with the experimental data, which indicated that a stress of the order of 50,000 psi was developed at the specimen surface within the first 5 min of oxidation and remained approximately constant during subsequent oxidation.

Fundamental Investigation of Radiation Effects in Solids: X-Ray Observations of Nearly Perfect Copper Single Crystals. — Initial x-ray diffraction studies of nearly perfect copper single crystals have been made with both Lang and rocking-curve techniques. The Lang topographs clearly resolved individual dislocation lines lying in or very close to a (110) surface. It was also seen in these topographs that the strain field surrounding dislocation cores in copper can be as high as 50 μ. Rocking-curve measurements with a large (111) surface gave a width at half-maximum intensity of 34 sec as an upper limit on the absolute half-width of a (111) $K\alpha_1$ reflection, with Ag $K\alpha$ radiation being used. Correlations of etch-pit determinations with x-ray measurements give good agreement of dislocation density estimates and reveal densities as low as $\sim 3 \times 10^2$ dislocations/cm^3 in some of these crystals.

Fundamental Investigation of Radiation Effects in Solids: Etch-Pit Studies of Dislocations in Copper Crystals Deformed by Bending. — Annealed and irradiated copper crystals of low initial dislocation density were deformed by bending, and dislocation multiplication and motion were studied by use of an etch-pit technique for observing the dislocations. For the annealed crystals, there was dislocation motion and multiplication prior to macroscopic yielding, and the percentage of grown-in dislocations moved by the stress increased with the stress. The dislocations were hindered in the motion by subboundaries and by interaction with other dislocations. Relaxation effects were observed and were much greater for stresses less than the yield stress than for higher stresses. For the neutron-irradiated crystals, there was no motion or multiplication of dislocations prior to yielding. The slip traces were long, with dislocations closely spaced in the trace. Although not conclusive, the evidence apparently was best interpreted in terms of source hardening. A cube-root dependence of the yield stress on neutron dose was observed. No hardening resulted from irradiation with cobalt gamma rays at an intensity of 10^{18}/cm^2.

CONTROLLED THERMONUCLEAR RESEARCH

Plasma Physics and Arc Research. — The study of the decay of a deuterium plasma formed by injection of ions random in energy and direction into a mirror magnetic geometry has continued. The apparatus was modified

to include an air-driven shutter which, in 2 msec, closed the plasma region to the gas feed and the ionizing electron stream and removed the cathode potential. With the modified apparatus, the ion-collecting electrodes of the plasma sensing device (the plasma sweeper, used to determine the presence of the plasma and its density) were operated at bias voltages from 0 to a potential at which their own breakdown current was observed (about -400 v). In addition, a switching device for applying and removing the bias potential several times during a single decay was used. With these modifications on the apparatus and within the range of the bias potentials used, the decay constant was about the same (15 msec) as that previously reported.

DCX-1 Facility. — Until recently, gas dissociation runs with high molecular beam currents and long proton containment times (low operating pressures) have always produced plasmas that occupy a steady-state volume much larger than that calculated on the basis of single-particle interactions. The previous report indicated that a set of operating conditions had been found such that these volumes, though still larger than the calculated, could be reduced by factors of ~2 to 5. It now appears that the necessary conditions for reducing the spread are associated with operation at a magnetic field strength higher than that which produces the 3.25-in. stable orbit radius for trapped 300-kev protons. About 5 to 10% increase in field seems to be required. A reduction in the repetition rate of the coherent rf bursts accompanies the reduction in spread, and there is indirect evidence that the energy distributions of the circulating protons are less broad; so the present observations are consistent with arguments that charge clumping is responsible for the spreading.

The currents to insulated end walls just outside the throats of the mirror coils have been measured as functions of bias voltage and operating parameters (injected molecular ion current, pressure, and magnetic field). The dc levels of these currents indicate that the source is ionization of background gas by the trapped protons. Two types of fluctuations occur simultaneously with bursts of rf. At pressures of about 10^{-9} torr, a fluctuation in electron current to the plates dominates. As the pressure is raised to about 10^{-8} torr, equal and in-phase variations in the flows of ion and electron currents appear and sometimes dominate. Experiments are planned to determine the origins of these fluctuations.

DCX-2 Facility. — When the DCX-2 system was shut down in June for cleaning and to install bakeout equipment, the magnetic field was rescanned. These measurements showed the field shape to be unsatisfactory and led to the discovery of several coil shorts. In addition, the shimming shunts on the inboard coils were found to be unstable and had to be modified.

The DCX-2 was operated in mid-July, still at high (10^{-5} mm Hg) pressure with ion currents up to 100 ma. Microwave phase-shift measurements indicated an electron density of about $2 \times 10^{10}/cm^3$. Considerable change had to be made in the various field currents to maximize the density and the energetic neutral flux, indicating that the field shape still was not satisfactory. Later magnetic measurements confirmed this indication. Intermittent shorts were found in several of the coils and were corrected.

Finally in late August, injection into the flat field region appeared to be successful. Data from this run are being analyzed while the machine is being prepared for bakeout.

Vacuum. — Ion-gage studies on nude gages were extended to systems pumped by a mercury diffusion pump. The nude gage as calibrated against an enveloped gage of similar electrode geometry showed no decrease in sensitivity over 50 hr of operation. For three oils studied previously, a steady decrease of sensitivity had been noted.

Apparatus was constructed which should allow a separate study to be made of various pumping mechanisms which have been suggested as being involved in diffusion-pump operation.

The large titanium getter-pump facility has been used to obtain the sticking probability of water vapor, hydrogen, and other gases on titanium film prepared in high vacuum on baked substrates. The base pressures during film preparation were between 2×10^{-7} and 2×10^{-8} torr for films deposited on water-cooled substrates and between 7×10^{-9} and 2×10^{-9} torr for films deposited on liquid-nitrogen-cooled substrates. Films prepared on water-cooled substrates gave initial sticking factors in the baked system as follows (the numbers in parentheses were obtained previously in the unbaked system); water vapor, 0.25 (0.20); deuterium, 0.27 (0.05 for hydrogen); nitrogen, 0.15 (0.08); carbon monoxide, 0.38 (0.38); carbon dioxide, 0.6 (> 0.4). Films prepared on liquid-nitrogen-cooled substrates in the based system gave values as follows: hydrogen, 0.82 (0.24); deuterium, 0.75 (no data); nitrogen, 0.85 (0.90); carbon monoxide, 0.95 (0.98); oxygen, 0.98 (no data). The generally higher values obtained in the baked system are not completely understood, but are probably due to less contamination of the films during their formation, since the pressures during deposition were more than a factor of 10 lower in the baked system.

BIOLOGY AND MEDICINE PROGRAM

TERRESTRIAL AND FRESH-WATER ECOLOGY

Evaluation of Fission Product Distribution and Movement in White Oak Drainage System. — A sampling train that separates suspended solids directly from creek water is being used to study the transport of suspended solids and their associated activity in White Oak Creek. Results from eight operating runs show that (1) the amount of activity transported downstream by suspended solids greater than 9 μ is small during low creek flow rates and/or low suspended-solid loads, but during high stream flow and/or high suspended-solid loads significant quantities of some radionuclides move downstream with particles greater than 9 μ in size; and (2) considerable variations occur in the concentrations and total amounts of activity associated with the various particle-size groups studied.

ISOTOPE DEVELOPMENT PROGRAM

Neutron Activation Analysis Research and Development: Oceanographic Studies. – Neutron activation analysis has been demonstrated to be an important method for acquiring systematic knowledge of the abundance of trace elements in samples of materials collected in oceanographic studies. Equipment is now available and procedures have been developed for applying these methods to the determination of microgram and submicrogram quantities of zinc and copper in sea water and also of uranium, scandium, indium, and iridium in deep-sea sediments and similar materials.

Neutron Activation Analysis Research and Development: Enforcement of the Narcotic Laws. – The feasibility of applying the methods of neutron activation analysis to the problem of identifying the sources of certain drugs as an aid to law-enforcement officials has been demonstrated. Commercially available samples of phenobarbital and meperidine hydrochloride have been examined, and the sources of manufacture have been identified. In effect, identifications have been made of certain seizures of meperidine hydrochloride, and efforts are being made to correlate these findings with those of the U.S. Bureau of Narcotics. The information obtained from these preliminary studies is indicative of the potential of these methods of analysis in controlling the manufacture and distribution of drugs, particularly as an aid in prosecuting those persons responsible for illegal traffic in these materials.

Neutron Activation Analysis Research and Development: Identification and Comparison of Physical Evidence for Law-Enforcement Purposes. – A feasibility study has been conducted on the applicability of activation analysis to forensic chemistry. Test portions of automobile paint finishes and also soot and soil samples were irradiated in the ORNL Graphite Reactor, after which the induced gamma radioactivity of each specimen was measured by means of a gamma scintillation spectrometer. The spectral decay curves of the radionuclides in the various specimens were then utilized for classifying the materials as to origin. This nondestructive technique is particularly suitable for the analysis of samples that must be maintained in an unaltered state, since such samples must be used subsequently as evidence in law-enforcement work.

Neutron Activation Analysis Research and Development: Applications of 14.3-Mev Neutrons in the Solution of Analytical Problems. – Neutron activation analysis, utilizing 14.3-Mev neutrons produced by a 150-kev Cockcroft-Walton neutron generator, has been used for the determination of trace amounts of stable oxygen in graphite and beryllium by the $O^{16}(n,p)N^{16}$ reaction. Nitrogen-16 decays with a half-life of 7.35 sec and gamma radiation greater than 6 Mev. Studies were carried out for the purpose of perfecting irradiation and counting techniques, utilizing an automated system of irradiation, transfer, and counting to analyze test samples of benzoic acid and SiO_2. It is possible to increase the effective sample size and thus improve the sensitivity by using a multiple 10-sec irradiation and 18-sec counting sequence in carrying out the analysis. At present, utilizing a five-cycle sequence, the limit of detection

for oxygen in graphite is 30 ppm. By using Ti-H^3 targets of higher tritium loading in the neutron generator, it should be possible to lower the limit of detection by at least a factor of 5.

As the sensitivity is increased, it has become obvious that special facilities will be required to prevent contamination of the sample by air or moisture. Erratic results were obtained for graphite samples prepared under helium; the extent of the error was dependent on the amount of air that had diffused into the sealed rabbit. The oxygen content of a dry rabbit, cleaned and filled with helium, was found to be approximately 0.7 mg (apparently the natural polyethylene background), but, after standing in air for three days, the rabbit was observed to contain 1.1 mg of oxygen. Methods of eliminating this problem are being studied. Each container will be loaded and stored in a glove box containing an inert gas until it is analyzed.

Preliminary results have also been obtained for the determination of lead and fluorine which reveal that neutron activation analysis is a useful, rapid, nondestructive method for the determination of these particular elements. This program will be extended to almost all the elements in the periodic table in order to evaluate the sensitivity of each to activation methods based on (n,p), (n,2n), and (n,α) reactions.

Radioisotope Research and Development. — Design and testing of a second model of an air-pulsed mixer-settler for aqueous-organic systems were completed. The stage efficiency as measured by $Eu^{152-154}$ in a nitric acid–di(2-ethylhexyl)phosphoric acid system was 95% for all stages except the first (85%). This device was developed for remote operations with highly radioactive solutions. Only pneumatic lines are needed for the mixer-settler operation, thus eliminating in-cell mechanical agitation.

The preparation and fabrication of cesium glasses for Cs^{137} gamma-ray and heat sources are being studied. Glasses of the type $0.55Cs_2O \cdot 0.15Li_2O \cdot 0.3RO \cdot 2.5SiO_2$, where RO is ZnO, BaO, SrO, PbO, and CdO, have been prepared. These glasses, fabricated in the form of right cylinders, rectangular rods, and slabs, are resistant to dissolution in fresh and sea water and contain ~40 wt % cesium, equivalent to ~42 curies/cm^3.

Americium-241 samples irradiated in the ORR were examined to determine the neutron cross section for Cm^{242} production and to determine the allied fission cross sections. Analytical results indicate that the cross section of Am^{241} for Cm^{242} production is ~10 to 20% less than the generally accepted values and that the fission product yields exceed calculated yields by a factor of 2. Calorimetric measurement of an irradiated 100-mg sample of Am^{241} substantiated the probability that the cross section for Cm^{242} production was less than reported values.

OPEN LITERATURE PUBLICATIONS

Alexeff, I., and R. V. Neidigh, "Experimental Observation of Plasma Electron Pressure," Phys. Rev. 127, 1 (1962).

Alvarez-Funes, A., J. Braunstein, and M. Blander, "Thermodynamic Association Constants of Silver Ions with Bromide or Iodide Ions in Molten Potassium Nitrate and Their Comparison with the Quasi-Lattice Theory," J. Am. Chem. Soc. 84, 1539 (1962).

Bennett, R. L., and W. T. Rainey, Jr., "Drift Studies on Chromel-P–Alumel Thermocouples in Helium Atmospheres," Temperature – Its Measurement and Control in Science and Industry, vol 3, part 2, Reinhold, New York, 1962.

Boston, C. R., and G. P. Smith, "Spectra of Dilute Solutions of Bismuth Metal in Molten Bismuth Trihalides. I. Evidence for Two Solute Species in the System Bismuth–Bismuth Trichloride," J. Phys. Chem. 66, 1178 (1962).

Braunstein, J., M. Blander, and R. M. Lindgren, "The Evaluation of Thermodynamic Association Constants in Solutions with an Application to Molten Salt Solutions," J. Am. Chem. Soc. 84, 1529 (1962).

Brosi, A. R., A. I. Galonsky, B. H. Ketelle, and H. B. Willard, "A Precision Measurement of the Longitudinal Polarization of Betas Following P^{32} Decay," Nucl. Phys. 33, 353 (1962).

Charles, G. W., "Optical Doublets, Regular and Irregular, Laws of," pp 212–13 in Encyclopaedic Dictionary of Physics, vol 5 (ed. by J. Thewlis), Pergamon, London, 1962.

Curtis, O. L., Jr., "Effect of a Phase Transformation on the Vapor Growth of Single-Crystal HgS," J. Appl. Phys. 33, 2461 (1962).

Dabbs, J. W. T., "Nuclear Alignment, Orientation, and Polarization," pp 79–80 in Encyclopaedic Dictionary of Physics, vol 5 (ed. by J. Thewlis), Pergamon, London, 1962.

Davis, F. J., and P. W. Reinhardt, "Radiation Measurements over Simulated Plane Sources," Health Phys. 8, 233 (1962).

Dworkin, A. S., H. R. Bronstein, and M. A. Bredig, "The Electrical Conductivity of Solutions of Metals in Their Molten Halides. V. Praseodymium–Praseodymium Trichloride," J. Phys. Chem. 66, 1201 (1962).

Eichler, E., G. D. O'Kelley, R. L. Robinson, J. A. Marinsky, and N. R. Johnson, "Nuclear Levels of Ge^{74}," Nucl. Phys. 35, 625 (1962).

Fettweis, P., and E. C. Campbell, "Study of Some Nuclear Isomers Produced by Reactor Neutrons," Nucl. Phys. 33, 272 (1962).

Frank, A. L., E. T. Arakawa, and R. D. Birkhoff, "Optical Emission from Irradiated Foils II," Phys. Rev. 126, 1935 (1962).

Gwin, R., and R. B. Murray, "Studies of the Scintillation Process in CsI(Tl)," IRE Trans. Nucl. Sci. NS-9, 28 (1962).

Hochanadel, C. J., "A Simple Device for Determining Slopes Using the Glass Rod Method," J. Chem. Educ. 39, 299 (1962).

Holmes, D. K., and D. O. Thompson, "The Investigation of Radiation Damage Using Mechanical Vibrations," p IX-1 in Resonance and Relaxation in Metals, ASM, 1962.

Hurst, G. S., L. B. O'Kelly, and J. A. Stockdale, "Quasi-Trapping of Low Energy Electrons in Water Vapor," Nature 195, 66 (1962).

Kelly, M. J., W. W. Johnston, and C. D. Baumann, "The Effects of Nuclear Radiation on Thermocouples," Temperature — Its Measurement and Control in Science and Industry, vol 3, part 2, Reinhold, New York, 1962.

Kohn, H. W., "Deuterium Exchange on Silica Gel Initiated by Cobalt-60 Irradiation," J. Phys. Chem. 66, 1017 (1962).

Kohn, H. W., "Surface Carbonium Ions Produced by Irradiating Silica Gel," J. Phys. Chem. 66, 1185 (1962).

Lidsky, L. M., S. D. Rothleder, D. J. Rose, S. Yoshikawa, C. Michelson, and R. J. Mackin, Jr., "Highly Ionized Hollow Cathode Discharge," J. Appl. Phys. 33, 2490 (1962).

Macklin, R. L., T. Inada, and J. H. Gibbons, "Neutron Capture in Tin Isotopes at Stellar Temperatures," Nature 194, 1272 (1962).

McClung, R. W., "Techniques for Low-Voltage Radiography," Nondestructive Testing 20, 248 (1962).

Moore, G. E., H. A. Smith, and E. H. Taylor, "Catalytic Reactions on Semiconductors: Hydrogen-Deuterium Exchange and Formic Acid Decomposition on Chemically Doped Germanium," J. Phys. Chem. 66, 1241 (1962).

Murray, R. B., and A. Meyer, "Effect of Delta Rays on the Response of Inorganic Scintillators to Heavy Particles," IRE Trans. Nucl. Sci. NS-9, 33 (1962).

Neiler, J. H., "Neutron Capture Cross Sections for Energies Above a Few Hundred ev," pp 95–109 in Proceedings of Conference on Physics of Fast and Intermediate Reactors (Vienna, Austria, August 1961), IAEA, Vienna, 1962.

Nelson, D. J., "Clams as Indicators of Strontium-90," Science 137, 38 (1962).

Plummer, G. L., "Growth Responses of Helianthus Annuus to Internal Calcium-45," Botan. Gaz. 123, 272 (1962).

Ritchie, R. H., and H. B. Eldridge, "Optical Emission from Irradiated Foils I," Phys. Rev. 126, 1947 (1962).

Sanders, F. W., and J. A. Auxier, "Neutron Activation of Sodium in Anthropomorphous Phantoms," Health Phys. 8, 371 (1962).

Schmid, Erich, "A Monte Carlo Method for Nuclear Many Body Problems," Nucl. Phys. 32, 82 (1962).

Stiegler, J. O., and T. S. Noggle, "Nitrogen Ion Bombardment of Thin Pt Films," J. Appl. Phys. 33, 1894 (1962).

Van der Spuy, E., "A Fundamental Particle Model II," Nucl. Phys. 34, 341 (1962).

Welton, T. A., "Nuclear Reactor Period," pp 136–38 in Encyclopaedic Dictionary of Physics, vol 5 (ed. by J. Thewlis), Pergamon, London, 1962.

Williams, R. O., "Stored Energy and Release Kinetics in Lead, Aluminum, Silver, Nickel, Iron, and Zirconium After Deformation," Trans. AIME 224, 719 (1962).

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