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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

NOVEMBER 1961

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OAK RIDGE NATIONAL LABORATORY

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Oak Ridge, Tennessee
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U.S. ATOMIC ENERGY COMMISSION

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

NOVEMBER 1961

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 PROJECT

Physics. — The number of fully loaded fuel channels required to achieve criticality in the EGCR when the loading is symmetrical under control rod O was calculated. In addition, the reactivity effect on this configuration of fully inserting the control rods was calculated for several different rod patterns. This off-center loading of the core, which would reduce any perturbation effects of the two graphite-filled experimental holes near the center of the reactor, was compared with the same fuel loading configuration symmetrical about the center of the core. The comparison indicates that the proximity of the solid graphite reflector in the off-center loading produces a flux tilting of greater magnitude than the effect produced by the graphite-loaded experimental holes on the flux in the center-loading configuration. It appears that approximately 62 fully loaded fuel channels symmetrically loaded about the center will be required to achieve criticality with control rod N fully inserted.

Calculations were also made to determine the flux levels required in EGCR critical experiments to obtain sufficient activation of various foils, including copper, gold, and manganese, and to determine the dose rates relevant to handling the fuel elements to recover the activated foils. It was shown that if the reactor is operated at a maximum channel power of 1 w, adequate foil activities will be obtained, and the dose rates a few hours after shutdown will be of the order of 100 mr/hr at contact. It is concluded that the experiments can be carried out without difficulty.

EGCR Top and Bottom Dummy Mockup Test. — All parts for the top and bottom dummy mockup test were fabricated. The bottom dummy mockup was assembled, but some difficulties were encountered in sealing all the joints.

Instrumented Fuel Assemblies. — Work was completed on a mockup of a single instrumented fuel assembly for the EGCR instrumented fuel

[redacted]

stringer. This fuel assembly – the No. 3, or lowest, instrumented assembly in the stringer – was chosen because it is the most complicated. It has, in its seven fuel elements, three thermocouples for measuring cladding temperature and one central thermocouple for measuring the UO_2 temperature. In addition to these, there are one gas-stream thermocouple and five graphite-temperature thermocouples.

Welding of Dissimilar Metals. – The thermal-cycling tests on the dissimilar-metal pipes welded with BP-85 are being terminated. No cracks in the A212 steel–to–stainless steel joint were found by dye-penetrant examination after 145 thermal cycles. Also, no cracks were evident in the chromium-molybdenum steel–to–stainless steel joint after 130 thermal cycles. The welds will be examined metallographically for incipient cracks or microfissures.

Instantaneous Fission-Gas Release. – Irradiation of the single-crystal sample of UO_2 is continuing. Two additional runs of about ten days each have been made to measure equilibrium xenon and iodine release rates. A regular reactor shutdown, lasting ten days, also occurred during this time. The steady-state fractional release (ratio of release rate to production rate) from the UO_2 single crystal to date is summarized below:

Temperature (°C)	Steady-State Fractional Release			
	Xe^{133}	Xe^{135}	I^{133}	I^{135}
	$\times 10^{-4}$	$\times 10^{-4}$	$\times 10^{-4}$	$\times 10^{-4}$
765	9.1	1.2	10	7.1
850	13	2.9	7.3	8.5
912	16	3.9	14	17

The krypton releases reach equilibrium more rapidly. From a number of measurements of krypton at different temperatures, the activation energy of krypton in UO_2 has been established as 30 kcal/mole. Krypton releases are now being tabulated to give a diffusion coefficient formula.

During the process of studying the krypton releases it was found that apparently too much Kr^{85m}, as compared with Kr^{88}, was being released. This was true for previous samples also. The release of Kr^{87} was measured and was found to be in the proper ratio with Kr^{88}. It is not clear why a higher proportion of Kr^{85m} is being measured, but it is suspected that the fission yield is actually nearer to 2% than the 1% given in the literature [Nucleonics 18, 201 (1960)].

Heating bursts are produced when the single-crystal sample is heated rapidly, but as yet the cooling bursts are too small for analysis. Not all the xenon produced is released from the sample as xenon. From 40 to 50% of the Xe^{133} and approximately 80% of the Xe^{135} are born from iodine which has diffused from the single crystal and deposited on the walls of the sweep system. These are the same proportions of iodine to xenon as found in sintered samples.

GCR-ORR Loop No. 1. – An instrumented EGCR prototype fuel element was removed from GCR-ORR loop No. 1 following irradiation for a full seven-week cycle at a maximum external cladding temperature of 1450°F and a maximum external pressure on the cladding of 300 psia. The heat generation of this element was ~26,000 Btu hr^{-1} ft^{-1}. No reactor setbacks have been necessary since the loop was reinstalled in early May 1961. A duplicate EGCR prototype assembly is now being irradiated. A third fuel element having a heat rating of 35,000 Btu hr^{-1} ft^{-1} is being built for installation during the December 17, 1961, shutdown.

Both loop compressors were changed for routine scheduled lubrication and maintenance after having operated satisfactorily for 3300 hr. The set of compressors installed had previously operated satisfactorily more than 3000 hr. The bearings were changed as a precaution, but they were still in good condition, and the lubricity of the grease was satisfactory.

GCR-ORR Loop No. 2. – The 24-in. shielding plug was installed, and the second compressor for GCR-ORR loop No. 2 is being installed. Layouts and much of the detailing have been completed for the low-power fission-gas-source test, which will be the first nuclear test for the loop.

High-Temperature Measurements in Gas-Cooled Reactors. – Results of four drift tests currently in operation on stainless-steel-sheathed, magnesia-insulated, Chromel-P–Alumel thermocouples are summarized below:

Test Environment	Test Temperature (°C)	Test Time (days)	Thermocouple Drift (mv)	Temperature Error (°C)
7 psig CO	870	194	+0.28	+7.0
7 psig H_2	870	155	–3.84	–96.0
150 psig H_2	870	51	+0.00	0
Fresh graphite, 7 psig He	700	78	–0.05	–1.3

The expected acceleration of the drift in the higher-pressure hydrogen test did not occur. It is possible that the hydrogen diffused through the sheath so rapidly that the internal atmosphere became strongly reducing rather than selectively oxidizing.

The small drift of the low-temperature graphite-helium test is not entirely unexpected since, from previous experiments, this temperature (700°C) was known to be in the lower range of the selective reaction of chromium in Chromel-P.

The graphite-helix furnace for testing thermocouples is currently in operation at 1600°C with a W vs W–10% Re thermocouple in a pure helium atmosphere. The black body selected for use is made from 0.25-in. tungsten rod, 0.375 in. long, with a viewing cavity 0.063 by 0.34 in.

drilled in the center. In preliminary tests, agreement between optical pyrometer and Pt vs Pt–10% Rh thermocouple readings was excellent up to 1350°C.

Irradiation Tests of BeO. – The experimental samples for the ORNL-41-7 experiment have been assembled and will be inserted in the irradiation facility at the next ETR shutdown. The samples to be irradiated are the first of a series arranged to permit statistical analysis of the variables concerned in fabrication and irradiation, such as density, grain size, dimensions, temperature of irradiation, and integrated dose.

THORIUM UTILIZATION PROGRAM

Planning and Evaluation Studies. – Nuclear calculations were begun for a large one-region molten-salt converter reactor of 1000-Mw (electrical) capability. Preliminary cost bases and engineering design specifications are being used. A 15-ft core with 10 vol % molten-salt fuel (9% ThF_4) was considered; the external power-removal capability was 3.75 Mw (thermal) per cubic foot of salt, a 100-day cooling was allocated for protactinium decay, and the fuel-cycle processing time for protactinium removal and salt-carrier replacement was 1000 days. Based on equilibrium conditions and a capital-expenditure estimate of $1 million for the processing plant, the fuel-cycle cost was 1.52 mills/kwhr and the conversion ratio was about 0.42. Decreasing the protactinium-removal cycle time to 100 and 10 days, respectively, resulted in fuel costs of 1.64 and 2.35 mills/kwhr and corresponding conversion ratios of 0.45 and 0.57.

A survey of methods of processing fluoride salts has revealed that, other than recovery of uranium isotopes by fluoride volatility, no processes are being developed for the separation and recovery of components of thorium-bearing fluoride-salt mixtures.

The new equilibrium reactor code (ERC-8) is now operable with several modifications. Provision was made for the code to compute reaction rate coefficients from raw MODRIC output (absorptions and fissions by elements), to compute loss of delayed neutrons in circulating-fuel reactors, to average U^{238} concentration over some specified period of years (rather than using an equilibrium concentration), and to compute the equilibrium concentration of a carrier constituent (e.g., Li^6).

Testing of Thoria-Pellet and -Suspension Fuels. – Postrun sectioning of in-pile slurry loop L-2-27S and the opening of the slurry holdup (or dump) tank has permitted a satisfactory material balance of solids to be made. A total of 1590 g of solids was put into the loop; 1580 g has been recovered. This high recovery, plus the fact that no caking has yet been found, implies strongly that no appreciable loss of solids by deposition or caking occurred in the experiment.

The sectioning revealed that one end of the sintered stainless steel filter tube separating main-stream slurry from pressurizer water had broken loose and permitted 354 g of solids to enter the filter annulus and pressurizer. These solids showed low surface area and large crystallite size, implying that the break occurred prior to much irradiation.

Observations during operation indicate that effects of the break could be noted soon after shipment from Y-12 to X-10 and prior to irradiation. The filter tube still permits liquid flow, indicating that the obstruction to pressurizer water flow which occurred soon after beginning the irradiation developed elsewhere in the flow path.

Measurements of pore area distribution (calculated from pore volume determinations) on irradiated and unirradiated slurry samples from loop L-2-27S indicated good agreement between values of total surface based on the BET (nitrogen) monolayer and on the integrated pore area. Values were:

	Unirradiated	Fully Irradiated (7×10^{16} fissions per g of solids)
BET (N_2), m^2/g	3.1	34.7
Integrated pore area, m^2/g	4.8	37.6

Half the pore area of the irradiated sample occurred in pores less than 45 A in radius. In the pore volume determination the maximum was at 45 A, the median was at 270 A, and a secondary maximum was noted between 400 and 800 A. These measurements confirm the breakup observed in the irradiated thoria-urania slurry. The development of appreciable internal porosity is inferred.

Pure thoria and thoria–0.4% urania powders were bombarded by 24-Mev nitrogen atoms (range, 8.5 μ in solid ThO_2) in the 63-in. cyclotron to doses of 6×10^5 w-sec per g of solids. The bombardment was an attempt to simulate energy deposition by fission fragments as it occurred in in-pile slurry loop experiment L-2-27S, for which the energy deposition in particles was estimated to be 2.3×10^5 w-sec per g of solids. No change in crystallite size was observed on slip-cast targets which had been baked at 250°C; however, target areas became colored (robin's-egg blue). Earlier targets prepared by pressing showed only an x-ray line broadening as a result of pressing, which, if interpreted as crystallite size, would have implied a reduction from ~2500 A to 800–1200 A.

Engineering of Thorium Reactor Systems. – Friction factors were obtained for the 0.8-μ, 650°C-fired slurry at 600 g of ThO_2 per liter in the laminar-turbulent transition region at temperatures up to 280°C. When plotted against a Reynolds number based on the viscosity of a dispersed slurry, an apparent transition in friction factor occurred at values one-third to one-half the value of the transition friction factor for Newtonian fluids. It is not clear whether the transition is due to laminar flow (as assumed in a Hedstrom plot) or to a change in effective viscosity, with the flow remaining turbulent.

The loop was modified by addition of a heat meter to obtain values of the heat transfer coefficient in this region to delineate more clearly the turbulent-laminar transition.

Use of a pressure tap installed midway in the friction-factor test section demonstrated that the experimental pressure drops are linear with

distance and are thus free of entrance effects.

An experimental relationship was determined between the firing temperature and the particle bulk density of thoria slurries prepared from thorium oxalate. The bulk densities were found to vary between the theoretical minimum of 3.7 g/cc and the theoretical maximum of 9.7 g/cc in the firing range 650 to 1600°C. The correlation used involves a comparison of either the viscosity-concentration curves of dispersed samples of the slurry or the centrifuged-bed densities.

Homogeneous Reactor Experiment No. 2. – Processing of the HRE-2 fuel solution for heavy-water recovery was completed. Assay results showed the D_2O to be 97.4% pure and within the chemical specification set by Savannah River Operations. Approximately 10,000 lb is being returned for credit.

Plans are nearly complete for delivery of the concentrated fuel to the Fission Product Pilot Plant, where it will be processed for U^{235} recovery in December and January.

The development of torch-cutting equipment for dissection of the Zircaloy-2 core vessel is nearly complete. It appears that the core-cutting operations can be performed soon after January 1, 1962.

MOLTEN-SALT REACTOR PROGRAM

MSRE Design. – Process flowsheets and cell-penetration and attachment drawings were completed. Heat exchanger detailing is 75% complete, and the heat-exchanger-mounting drawings were issued. The cover-gas system is 90% complete. One-line installation drawings for primary piping were completed.

The rough draft of specifications for a digital data-handling and computing system is approximately 75% complete.

Instrument-application drawings and tabulations covering the instrumentation of the main systems were revised and were issued for approval.

A revised layout of the main control panel was completed and is ready for comment. Detail layouts of instrument panels located in the transmitter room, including the weigh system, the fuel-pump-bowl level-transmitter purge-gas system, freeze-valve coolant-air loading stations, and differential-pressure-cell signal transmitters, are also nearing completion.

Comments received on the equipment layout for the main control room, the auxiliary control room, and the transmitter room indicate that the proposed arrangement is acceptable.

Specifications were written for the thermocouple patch panel, the pneumatic weigh system, helium gas valves for cover- and off-gas service, and weld-sealed differential-pressure transmitters.

Drawings showing detailed design of the containment air-filter-pit instrumentation were issued for approval.

MSRE Procurement and Construction. – Two shipments of INOR-8 plate were received from Haynes Stellite Company, which is expected to complete all INOR-8 shipments by December.

Welders are being qualified in the Y-12 shops in preparation for fabrication of the major components for the MSRE. Procurement has been started for dished heads for these components. The UCNC shop at Paducah has produced a 9-in.-diam INOR-8 head which is well within MSRE specifications.

The Kaminer Construction Company has moved men and equipment into Building 7503, and modification of the building is in progress.

Chemical Development. – The reaction of CF_4 with regular MSRE fuel ($LiF-BeF_2-ZrF_4-ThF_4-UF_4$, 70-23-5-1-1 mole %) at 600°C appears to be too slight or too slow to be readily measured. However, MSRE fuel in which 10% of the UF_4 has been converted to UF_3 did react with CF_4 at a measurable rate at 600°C; three or four days were required for an essentially complete reaction when CF_4, recirculated and in excess, was bubbled through the melt. The standard free-energy change for the reaction $CF_4 + 4UF_3 \rightarrow 4UF_4 + C^0$ is about –230 kcal; hence the sluggishness of the reaction appears to be a matter of kinetics and not of driving force.

Irradiation Tests. – A fourth fueled irradiation experiment, designated ORNL-MTR-47-4, is being designed (1) to measure the amount of CF_4 present in cover gas over fissioning MSRE fuel containing submerged graphite, and, in so doing, (2) to investigate further the compatibility of the fuel–graphite–INOR-8 system under conditions at least as severe as those expected for MSRE operation.

Four capsules, each nominally 1 in. in diameter and 2 in. long, are being designed. Each capsule will contain a graphite core, nominally 1/2 in. in diameter and 1 in. long, submerged under ~0.2 in. of fuel contained in an INOR-8 can. Two capsules are being designed for ~1300°F fuel-to-graphite interface temperature and two for ~1650°F. The capsules will be contained in a sodium bath maintained at ~1050°F. The mole percentage of UF_4 in the fuel is selected to provide the temperatures desired.

Preliminary design of the capsules has been completed, and parts are being ordered for dummy capsules to be used in out-of-pile proof tests (i.e., hot-fuel filling and freeze-thaw cycling). All parts for the supporting equipment are on order and are scheduled for delivery on December 29, 1961.

The experiment is scheduled for a mid-March insertion at the MTR.

Radiation Effects. – The opening of four irradiated MSRE fuel-graphite compatibility test capsules (47-3) was completed. MSRE fuel, contained in graphite boats, under helium in sealed INOR-8 capsules, had generated 200 w/ml at temperatures of 800 to 900°C for 1600 hr (8.5% burnup) in the MTR. The results were reassuring in connection with the possible permeation of graphite by fuel; the fuel did not wet the graphite, even in boats that had been partially preimpregnated with fuel under pressure.

Due to the effects of a larger-than-anticipated amount of distillation of BeF_2, along with LiF, the composition of the fuel ingots was altered to the extent that LiF crystals were present in the fuel after freezing. The susceptibility of LiF to discoloration by beta emission from fission products was sufficient to cause the fuel to appear black when observed at room temperature. The blackening can be annealed out, but the discoloration gradually reappears.

Reactor Processing. — A conceptual design has been made of a uranium recovery system for installation in Building 7503. Spent fuel will be fluorinated in the fuel storage tank following a 90-day decay period. Uranium hexafluoride will pass through a 400°C sodium fluoride trap for niobium removal and then be absorbed in portable sodium fluoride absorbers at 100°C. Excess fluorine will be disposed of in a charcoal burner. Residual iodine activity will be removed in an activated charcoal trap. The absorbers will be desorbed and the uranium hexafluoride will be cold-trapped in the Volatility Pilot Plant. Waste salt will be stored in a tank at the reactor site.

PEBBLE-BED REACTOR

Reactor Physics. — A parametric study was made of the fuel-cycle costs for large power stations of the pebble-bed type in order to define better the fuel composition which should be specified for the PBRE. A U^{235}-Th feed and an equilibrium graded exposure were assumed. The minimum fuel-cycle costs were obtained with fuels containing from 3 to 7 wt % uranium plus thorium. On the basis of this finding, the fuel loading for the PBRE has been reduced from 10 wt % uranium plus thorium to 5%. The minimum fuel costs occurred with a burnup of about 3.1×10^{19} fissions per cubic centimeter of fuel, and this figure is to be used as the target burnup for PBRE fuel. A preliminary calculation indicates that the PBRE will have sufficient reactivity to obtain this amount of burnup on an equilibrium fuel cycle if the initial enrichment of the fuel (i.e., the ratio of U^{235} to total uranium plus thorium content) is 58%. Slightly different enrichments would be required for other types of fuel cycles to achieve the same burnup.

The control-rod worth calculations were repeated for the core containing the revised fuel loading. Four control rods on a 40-in.-diam circle gave a total worth of 0.25 $\delta k/k$. The requirements were 0.015 for temperature defect and 0.084 for burnup and fission product poisoning, leaving a shutdown margin of 0.15.

Design. — A calculation of the maximum temperature that would be attained by the bottom plate of the PBRE during a loss-of-coolant incident was made in order to aid in determining the need for using stainless steel (instead of carbon steel) for the bottom plate. In this case, it was assumed that there was no convective cooling and that the core afterheat was dissipated as component temperature rise and radiation to the concrete shielding. With no outside insulation on the side and bottom of the pressure vessel, the calculations indicated that ordinary steel would be satisfactory, since the plate temperature would not exceed 800°F.

The consequences of eliminating the pressure-vessel outside insulation are being investigated. Heat lost during normal operation at 5 Mw is estimated to be about 1.5%. This loss, corresponding to a pressure-vessel temperature of 550°F, is equivalent to the heat input of a 100-hp helium blower and thus increases the time required to heat the system from blower heat alone. Another consideration is that the

heat flux into the surrounding concrete would not cause the maximum allowable concrete temperature to be exceeded.

Pressure letdown rates are being calculated from the standpoint of afterheat removal by natural convection. Based on core inlet and outlet temperatures of 550 and 1250°F, calculations indicate that all the heat generated can still be removed with the system pressure reduced from 500 to 100 psia after about two days.

STUDIES AND EVALUATIONS

Reactor Evaluation Studies. – The effect of fuel density on the value of U^{233} was studied in a Dresden-type reactor fueled with thorium. A reduction in fuel density from theoretical to 0.8 of theoretical had little effect on U^{233} value in the U^{233}-Th cycle. The value of U^{233} recycled from a U^{235}-Th cycle increased by $0.25/g when the fuel density was reduced 10 to 20% from theoretical.

For a fuel density 20% higher than theoretical (corresponding physically to a tighter lattice), the value of U^{233} increased about $0.4/g due to the higher conversion ratio. Also, the value of U^{233} in the second U^{233}-Th cycle was higher than the value of pure U^{233} in the first cycle for effective densities from 0.8 to 1.2 theoretical. This was due to the increase in conversion ratio associated with the buildup of U^{234} in the reactor.

A two-dimensional, two-group reactor depletion code is being written for use in evaluating various fuel management schemes. This program is being developed in a form such that disadvantage factors can be applied to the cross sections, taking into consideration spatial variations in fuel concentration, cell dimensions, and coolant density. Control-rod movements are also considered. At present, a skeleton program is in operation in which the eigenvalue problem is solved with or without a criticality search.

ADVANCED REACTOR DEVELOPMENT

Advanced Test Reactor Corrosion Program

Three corrosion tests which simulated the conditions expected to exist during operation of the ATR were completed. In these tests, each of which lasted 17 days, the heat flux and the coolant temperature were gradually lowered in a manner similar to that expected during an ATR cycle. Two of the tests were conducted with X8001 aluminum specimens and one with a 6061 aluminum specimen. In all three cases the temperature of the specimen increased in an almost linear fashion during the first week and then remained nearly constant for the rest of the test. Maximum temperatures measured on the outside of the specimens were 536 and 593°F for the X8001 specimens and 608°F for the 6061 specimen. The

low value obtained on one of the X8001 specimens was apparently due to less severe test conditions than in the other two tests.

The major difference between the two alloys was that 6061 aluminum underwent "film-stripping" over most of its length and showed evidence of localized attack, whereas the X8001 specimens did not show evidence of either. Only uniform attack to a maximum depth of 2.5 mils was observed with the X8001 specimens.

High Flux Isotope Reactor Design and Development

Control and Instrumentation. — Accuracy tests were completed on both pneumatic and electric heat-power calculators. The tests indicate that both systems will provide the anticipated overall accuracy of ±1%. Environmental testing of these units is in progress.

Metallurgy. — Difficulty was experienced in marforming outer-annulus composite fuel plates for the flow-test element for the HFIR mockup. The out-of-tolerance deviations in the curvature would have resulted in an unacceptable fuel element. It has now been shown that composite fuel plates with only 6% cold reduction are not as completely softened in the annealing treatment which has been used (2 hr at 500°C) as plates with 22% cold work. Thus "springback" is greater in the former than in the latter. It is conceivable that variations in the degree of cold reduction in these outer-annulus composite fuel plates are at least partially responsible for the unacceptable variations in plate-to-plate curvatures.

An outer-annulus mockup of prototype dimensions was fabricated with unfueled plates of type 6061 aluminum. The purpose of this unit is to study forming and assembly problems. The inside edges of all but the last five plates were attached to the tubular side plate by peening. The last five plates were attached to the inner side plate by partial circumferential welding. At the periphery of the element, all plates were welded together by recently developed methods which combine banding and circumferential welding based on programming a series of overlapping short welds. All plate spacings were critically examined with respect to the average spacing specification of 0.050 ± 0.003 in. and the individual specification of 0.050 ± 0.010 in. Of the 7749 individual measurements taken, 99.91% met the specification. Of the 2543 average plate spacings recorded, 98.95% were within the desired specification. A clockwise rotation of all plates of about 0.140 in. from the original involute position occurred, apparently while the plates were being welded at the periphery of the element. A reduction of the overall average of the plate spacing from 0.0503 in. to 0.0481 in. was observed and is attributed to the change in the involute curvature of the plates caused by the rotation.

Design. — Detail drawings of essentially all the required HFIR hydraulic mockup components of the reactor core assembly, except the target assembly and control rods, were completed and issued for procurement.

A study has been undertaken to establish the effects of fuel-element mechanical tolerances on calculated burnout power level. The scope of this hot-spot study is being expanded over previous work to include the

effects of plate deflections due to pressure gradients across the plates and differential expansions between the fuel plates and side plates.

Calculations on the effects of 5-mil-diam U_3O_8 particles in the 10-mil-thick meat portion of the inner-annulus fuel plates indicate that three closely compacted particles would raise the local hot-spot heat flux by about 5%.

The maximum tensile thermal stress in the HFIR beryllium reflector following an electrical power outage, where the reactor power is reduced from 100 Mw to 10 Mw and when the coolant flow rate is reduced to the emergency level (10% of the normal flow rate), is 12,800 psi. No damage due to thermal stress should result to the beryllium.

Critical Experiments. – The outer control plate in HFIR critical experiment No. 2 has been replaced by a similar control in which 90° sectors of the poison sections have been replaced with aluminum. This configuration simulates an inoperative control rod in the reactor. Reactivities of the assembly have been determined for various control-plate positions, with and without the target assembly, with and without voids in the target region, and with and without boron in the moderator. These experiments were concerned with the safety of the reactor, whether or not there is enough negative reactivity in the control plates to shut down the reactor under many unfavorable conditions.

NUCLEAR TECHNOLOGY AND GENERAL SUPPORT

Nondestructive Test Development. – Recent eddy-current investigations have been directed toward the development of new techniques and instrumentation for making thickness measurements of various reactor components and materials. The system being studied uses a two-coil through-transmission principle. The phase of the received signal is monitored relative to the transmitted signal. This method is sensitive primarily to the amount of electrically conducting material through which the electromagnetic wave passes. As such, it is relatively insensitive to the coil-to-specimen spacing (within certain limitations) which generally plagues eddy-current testing. Therefore it is very applicable for thickness measurements in locations where limited access reduces the confidence that the inspection probe is in intimate contact with the specimen.

One of the more difficult instrument problems has been the measurement of small phase shifts in the presence of large amplitude variations due to changes in coil spacing. This has been largely overcome through the use of two new "zero crossover" trigger circuits which actuate a high-speed "flip-flop" circuit. The dc voltage output of the flip-flop is proportional to the phase shift and the specimen thickness. Transistors have been used throughout the instrument design.

It is anticipated that this system will prove applicable for the measurement of fillet thickness of finned beryllium tubing for the Gas-Cooled Reactor, for the measurement of spacer thicknesses in the Fermi core B fuel element, for wall-thickness measurements on graphite tubing for the GCR or other reactors, and numerous other difficult measuring problems.

Fuel Element Development. — Attempts have been made during the past year to braze ceramic materials to themselves and to metals. Ceramic-to-metal seals have been used for several years in the vacuum-tube industry and other similar manufacturing activities, but these seals are not generally adaptable to fuel element applications. The established processes involve highly complex multistep operations that usually include premetallizing of the ceramic. The object of this program is to develop brazing alloys and procedures for making ceramic braze joints for fuel element applications in a one-step operation.

Several brazing alloys have been developed for making such ceramic joints. To illustrate the potential usefulness of this technology, several mockup fuel elements were fabricated. One of these consisted of successfully brazing graphite tubes to a molybdenum hanger assembly with a 49 Ti–49 Cu–2 Be (wt %) developmental alloy. Also, a demonstration compartmented fuel plate assembly of Al_2O_3 was successfully brazed. This contained flat top and bottom cover plates and a segmented core plate, all of Al_2O_3.

The techniques developed have also been used to assist other research activities. Assistance was provided in the joining of Al_2O_3 to stainless steel, Al_2O_3 to zirconium, synthetic sapphire to molybdenum, and Al_2O_3 to titanium.

Reactor Controls Development. — An improved method of depositing boron onto ionization-chamber electrodes has been developed. A vacuum ($\sim 10^{-6}$ mm Hg) evaporation process is used, with 92%-enriched B^{10} powder as the raw material. Preliminary results with 0.003-in.-thick titanium foil as the electrode material show good adherence of the boron over the thickness range 14 to 350 $\mu g/cm^2$. Tests with a moderated neutron source indicate a sensitivity comparable to that obtained with the boron-in-oil dispersion previously used. The advantages of the new method are superior control over coating thickness, reproducibility of coating thickness, and increased adhesion of the coating to the electrode surface. In addition, the new method does not require heating the electrodes above annealing temperatures, which is undesirable for some electrode configurations and which was necessary for previously used coating methods.

A new task has been initiated to study the effects of externally generated noise on pulse-counting systems used for reactor control. Noisy counting channels have caused trouble in reactor systems at ORNL and elsewhere. In the past, the cause and cure of such disturbances have been studied sporadically at the different project sites. It is the object of the present study to reproduce the noise sources in the laboratory so that the instrument systems may be investigated systematically as regards their noise sensitivities. Results of this work should comprise a set of design and installation precepts for acceptably noise-free operation.

Power Reactor Fuel Processing: Darex Process. — The use of NO_2 for low-temperature stripping of chloride from HNO_3-HCl mixtures, as an alternative to distillation, was studied with solutions containing dissolved stainless steel. An apparatus consisting of a 2-in.-diam stripping column 36 in. long packed with 1/4-in. Berl saddles and a similar absorption column for aqua regia regeneration was assembled, and scouting runs were

made to determine the important variables. The chloride concentration was reduced to 0.084 M (3000 ppm) when feed solution (11.75 M HNO_3, 0.75 M Cl^-, 31 g of stainless steel per liter, 2.8 g of U per liter) was added at 27 gal hr^{-1} ft^{-2} countercurrent to 549% excess NO_2. Chloride removal was improved by lower solution feed rates (longer residence times), lower stainless steel concentrations, and higher NO_2 rates up to ~500% excess; above this rate, further increase in NO_2 excess produced only marginal improvement. The nitric and hydrochloric acid concentrations of the feed solution in the ranges studied (9–12 M HNO_3, 0.2–1 M HCl) were of secondary importance, since the HNO_3 in the stripped product, which may affect the final chloride concentration, approached a limiting value (~13.5 M) during NO_2 sparging. The stainless steel concentration, probably the iron alone, became the controlling factor at low chloride concentrations.

Power Reactor Fuel Processing: Mechanical. – Mechanical dejacketing of the SRE core I fuel, burned to ~675 Mwd/ton and decayed about two years, was completed. Decontamination and equipment removal from the segmenting cell are approximately 90% complete. Samples of cladding dissolved completely in both 2 M HCl–5 M HNO_3 and 3 M HCl–4 M HNO_3. Analysis of the solutions showed negligible uranium and plutonium: uranium from 0.001 to 0.0041 mg/ml (0.1 to 4.6 mg per mole of stainless steel) and plutonium from 108 to 1.1×10^3 counts min^{-1} ml^{-1}. A spectrophotometric scan of the dissolved jacket showed no fission products.

A satisfactory method of feeding and holding a fuel assembly during shearing was developed for use with the experimental hopper. A new gag (device for holding a fuel element while a cut is made) driving mechanism made possible the shearing of a porcelain-filled stainless steel prototype fuel bundle to within 1.5 in. of the end. Other shearing tests with mark I prototype fuel indicated that discrete pieces are produced when the flat side of a fuel assembly is sheared with a stepped blade. However, the sheared face of the bundle is not so compact as when shearing is across the diagonal, and drag-back of tubes occurs when the blade is retracted. The force required to shear a mark I assembly carburized to 1–2% carbon was ~25 tons as compared with ~50 tons for the ductile cladding.

Power Reactor Fuel Processing: Uranium and Thorium Carbides. – Heat treatment of arc-melted $UC_{1.5}$ specimens for 60 hr at 1600°C had a marked effect on the products of water hydrolysis. A non-heat-treated specimen upon hydrolysis yielded 1.29 millimoles of methane, 0.88 millimole of hydrogen, 0.44 millimole of ethane, and small quantities of higher hydrocarbons per gram of sample. In contrast, a heat-treated specimen yielded 0.05 millimole of methane, 1.47 millimoles of hydrogen, and 0.67 millimole of ethane as well as small quantities of higher hydrocarbons per gram.

Thorium monocarbide yielded about the same hydrolysis products as uranium monocarbide, principally methane (3.32 millimoles/g), with some hydrogen (0.64 millimole/g) and some higher hydrocarbons. Photomicrographs indicated that the thorium monocarbide was less pure than the uranium monocarbide, which probably explains the small decrease in methane concentration, while the hydrogen and higher hydrocarbons increased slightly.

Power Reactor Fuel Processing: Uranium-Graphite Fuels. — The reaction of uranium-free graphite with concentrated (60%) nitric acid is being studied. Reaction of 254 g of type GBF graphite for 211 hr with boiling HNO_3, the acid volume being maintained constant by daily addition of 90% HNO_3, yielded 33 g of water-soluble yellow solids. The solubility behavior of the solids indicated that they were a mixture of polycarboxylic acids. The mixture had a neutralization equivalent of 63 and contained 41.5% C, 2.0% H, and 0.5% N. It has not yet been determined whether the nitrogen is present as sorbed nitric acid or as organonitrogen compounds, but qualitative tests indicated that mellitic acid (benzene hexacarboxylic acid) is present.

In engineering-scale tests on semicontinuous leaching of graphite—2.6% U with 90% HNO_3, the uranium loss was 0.37%, corresponding to 100 ppm U in the graphite residue. The fuel was broken to −2 mesh and 73% was > 12 mesh. It was batch-contacted for 2 hr with 90% HNO_3, then continuously leached with 90% HNO_3 for 4 hr, and finally water-washed. Uranium loss for −4 mesh fuel, 27% of which was > 12 mesh, was 1.6% under identical treatment.

Power Reactor Fuel Processing: Solvent Extraction Studies. — The amount of protactinium removed by adsorption on unfired Vycor glass from hydrochloric acid solutions containing 7×10^5 counts min^{-1} ml^{-1} of Pa^{233} and ~0.05 M NO_3 was 81% from 0.1 M HCl, 65% from 1 M HCl, 75% from 4 M HCl, and 42% from 10 M HCl.

Preliminary experiments showed that Pa^{233} adsorbed on unfired Vycor from 6 M HNO_3 may be eluted with 0.1 to 0.5 M oxalic acid.

Power Reactor Fuel Processing: Beryllium- and BeO-Containing Fuels. — A simulated GCRE fuel element, containing 13 g of 66.5% UO_2—33.5% BeO pellets clad in 23.8 g of Hastelloy X, was digested in about 400 ml of boiling 2 M HNO_3—4 M HCl. During 10 hr reaction, 77% of the Hastelloy, 99.6% of the UO_2, and 28% of the BeO were dissolved. Most of the undissolved Hastelloy X was present as solid end caps.

Power Reactor Fuel Processing: Corrosion Studies. — Welded specimens of Haynes alloy No. 25 were corroded at a maximum rate of 0.36 mil/month for the last half of a 408-hr exposure in refluxing 2 M HCl—5 M HNO_3. Attack was of an intergranular nature.

Nichrome V exposed for 19 to 24 hr in N_2-CCl_4 was corroded at rates (mils/month) of 2.62 at 540°C, 5.1—5.3 at 570°C, 16.1 at 640°C, 41.6 at 670°C, and 14.9 at 685°C.

PHYSICAL RESEARCH PROGRAM

Reactor Operations. — Operating time at the ORR for September and October was 71.2%. The increase in downtime was due mostly to experiment installation and the open house on September 23 and 24. Less than 0.2% of the reactor downtime was caused by difficulties in reactor operation; experiments accounted for 2.1%. The last available top-access flanges are expected to be put into use during the December shutdown; the only unused experiment facilities will then be minor ones.

Waste Disposal. — Trench No. 6, put into operation in September, was found to be connected to porous strata which allowed radioactivity to leak to the surface of the ground. Use of the trench has been discontinued. As an interim measure, the open pits are being used along with trench No. 5 for disposal of intermediate-level liquid waste.

Discharges into the creek have been accounted for in a very satisfactory manner by the sampling stations located in the various branches. The October discharge of 1.2 curies from the Waste Treatment Plant was close to a record low in radioactivity release.

Hot-Cell Operations. — Examination of a 20%-enriched ORR fuel element is essentially complete except for metallography, and GCR capsule work is proceeding on a somewhat accelerated schedule in the 3025 hot cells. Clean-up, repair, and sample transfer on the evening shift have increased the effectiveness of the cells; eventually, metallography can also be done on shift when personnel become available. Dejacketing of fuel elements in the 3026-D hot cells was completed, and the cells are being cleaned and equipment is being changed in preparation for disassembly of loops.

PHYSICS AND MATHEMATICS RESEARCH

Charge Spectrometry. — As an extension of the work previously done on He^6 [Bull. Am. Phys. Soc. 6, 227 (1961)], measurements have been made with a mass spectrometer of both the charge and recoil spectra of the sodium ions resulting from the β^- decay of Ne^{23}. The recoil energy was measured from 0.2 to 0.9 of its maximum. Less than 1% deviation was noted from the expected theoretical shape based on the assumption that the beta-neutrino interaction for both the ground- and first-excited-state transitions is a pure axial vector. The charge spectrum is as follows (figures in percent): charge one, 79.1 ± 0.2; two, 17.5 ± 0.1; three, 2.85 ± 0.06; four, 0.49 ± 0.02; five, 0.076 ± 0.007; six, 0.006 ± 0.002; seven, 0.0007 ± 0.0007.

Neutron Diffraction. — Magnetic measurements on polycrystalline thulium have revealed the existence of a magnetic ordering transition, at a temperature variously reported as 51°K [Rhodes, Legvold, and Spedding, Phys. Rev. 109, 1547 (1958)] or 60°K [Davis and Bozorth, Phys. Rev. 118, 1543 (1960)], to what has been described as an antiferromagnetic state. At low temperatures, Rhodes, Legvold, and Spedding noted behavior of the magnetization suggestive of a tendency toward ferromagnetism, and Davis and Bozorth deduced a Curie point of 22°K from hysteresis measurements.

The highest moment reported was 0.5 Bohr magneton per atom. Henry [J. Appl. Phys. 31, 323S (1960)] has observed 3.4 Bohr magnetons per atom in fields of 70,000 oersteds.

Neutron diffraction measurements have been made on a single-crystal specimen of thulium, and the results of these measurements show that in the temperature range from approximately 38 to 56°K the substance is an antiferromagnet with the simple oscillating z-component type of structure which has previously been reported for the high-temperature structure in erbium [J. Appl. Phys. 32, 49S (1961)]. Below 38°K there are observed in the diffraction pattern additional satellite reflections which suggest that the sinusoidal modulation is modified below this temperature. At 4.2°K the normal lattice reflections show an increase in intensity in zero field which is consistent with a mean magnetic moment per thulium atom of approximately one Bohr magneton directed parallel to the c axis. The fundamental period of the modulation remains sensibly constant at a value corresponding to 3.5 a_3 spacings over the entire range of temperatures.

Fast-Chopper Time-of-Flight Spectrometer. — The ORNL fast chopper and associated equipment were utilized in measuring the transmissions of a sample of normal tungsten and a sample enriched in W^{184} (95%) from 100 to 2000 ev. The resolution was 10 nanoseconds/m, using the 180-m flight path. Data were analyzed on an IBM 7090 computer by means of an area analysis program (ORNL-3205) which computes the reduced neutron widths for the resonances for assumed total widths. Effects of resolution and Doppler broadening on the line shape were taken into account in computing the transmissions. Resonance parameters, the strength function, and the capture resonance integral of W^{184} will be obtained from the data.

High-Voltage Experimental Program: The Reactions $Li^7(He^3,n)B^9$ and $Be^9(He^3,n)C^{11}$. — Distorted-wave calculations have been made to fit previously reported measurements of the above reactions [Bull. Am. Phys. Soc. 6, 60 (1961)]. The IBM distorted-wave code of Satchler et al. [Bull. Am. Phys. Soc. 6, 66 (1961)] was used. For the reaction $Be^9(He^3,n)C^{11}$, neutron angular distributions have been calculated at E_{He^3} = 2.1 Mev for the 1.99-, 4.26-, and 6.50-Mev states of C^{11}, for which tentative assignments of $(1/2^- \rightarrow 7/2^-)$, $(1/2^- \rightarrow 7/2^-)$, and $(3/2^-)$ have been made. Excitation functions for these states have been calculated by using the optical-model parameters which fit the angular distributions. For the reaction $Li^7(He^3,n)B^9$, an angular distribution for the ground-state neutron group has been calculated at E_{He^3} = 2.1 Mev, and a tentative assignment of $(1/2^- \rightarrow 7/2^-)$ has been made. In addition, a phase-space analysis of the continuum neutrons for this reaction which are present for all neutron energies below that of the ground state has been attempted.

High-Voltage Experimental Program: Energy Levels in Highly Distorted Heavy Nuclei. — Interpretation of experimentally measured fission-fragment angular distributions can lead to assignment of K rotational bands of collective motion. The theory of A. Bohr predicts that fission angular distributions are determined by the relative availability of K bands in the highly distorted, relatively cold, compound nucleus near the barrier.

Measurements of fragment angular distributions from U^{234} plus a neutron have been made near threshold, where only a few K bands are available.

These measurements have been correlated with theory by means of the following relation:

$$\sigma(\theta)_K = \frac{\lambda\!\!\!^{-2}}{8} (-1)^{-K-1/2} \sum_{xI\ell} (-1)^{x/2} (2I + 1) T_{\ell I} \, C^{IIx}_{-KKO} \, Z(\ell I \ell I, 1/2x) P_x(\cos \theta) \; .$$

In actuality, $\sigma(\theta)$ is the distribution averaged over time of the axis of symmetry (major axis) of the fissioning nucleus. Compound-elastic and inelastic neutron scattering compete strongly with fission, especially near threshold. This competition is believed to be particularly strong for higher angular momenta, so that the coefficients of the Legendre polynomials of order greater than 2 in the normalized angular distribution represent upper limits.

Theory and experiment both indicate that fission occurs predominantly via a $K = 3/2^-$ band for 500-kev neutrons and that the next band is a $K = 1/2^-$, which is dominant for 850-kev neutron energy. At 850 kev a good fit to the data is obtained by assigning 68% of the fissions to the $1/2^-$ band and the rest to the $3/2^-$ band. It is not necessary to introduce the concept of a "wobbling K axis" to obtain a fit, although the possibility cannot be excluded. Such a wobbling would occur if K were not a good quantum number and would lead to an additional isotropic component in the fragment distribution.

Transmission factors, $T_{\ell I}$, were derived from the nonlocal potential model of Perey and Buck. The total reaction cross section at 850 kev is 3.9 barns, of which 1.26 barns is known to be fission. The remainder will be compound-elastic plus some inelastic neutron scattering.

CHEMISTRY RESEARCH

Effects of Radiation on Analytical Methods. — The effects of gamma radiation on aqueous solutions of sodium ethylenediaminetetraacetate (EDTA) of various concentrations have been studied by means of both spectrophotometric and electrometric measurements. It was found that the H_2O_2 formed by gamma radiation interferes with spectrophotometric measurements of EDTA, since H_2O_2 absorbs light in the same ultraviolet region as does EDTA. Consequently, upon gamma irradiation, there is an initial increase in absorbance which is partially compensated for by the breakdown of a portion of the EDTA. In fact, the absorbance of these solutions at 200 mμ was found to be essentially the same before and after a gamma radiation dosage of 1×10^6 r. However, an electrometric titration of the EDTA after the irradiation revealed that it no longer retained any capacity for complexation, indicating complete decomposition of the chelating bonds. From these measurements, it may be inferred that the disruptions of the EDTA molecule are not in the chromophoric groups but occur at other bonds. Studies are being continued to elucidate more completely this behavior and also to evaluate the effects of radiation on various dyes used as indicators in the titration of EDTA, such as alizarin S, xylenol orange, etc. From preliminary data obtained on xylenol orange, this dye is apparently more sensitive to radiation than is EDTA.

Mechanisms of Separations Processes. — The surface chemistry and foaming properties of dodecylbenzene sulfonate were studied with respect to the use of this surfactant in a foam process for decontaminating ORNL low-activity waste. With tap water as a substitute for the waste, the saturated surface concentration of the sulfonate by both static and single-stage foam column methods was found to be 3.1 to 3.4×10^{-10} mole/cm^2, the critical micelle concentration in the bulk phase was 2.2×10^{-3} mole/liter, and the foam was stable down to 0.08×10^{-3} mole/liter, that is, at < 4% of the critical micelle concentration. At calcium concentrations of 0 to 4 ppm, sodium hydroxide concentrations of 5 or 10×10^{-3} M, and sulfonate concentrations of 62 to 250 mg/liter, the strontium distribution coefficient, Γ/x (foam/bulk solution), ranged from 1 to 20×10^{-3} cm. On the basis of a practical value of $\Gamma/x = 2.5 \times 10^{-3}$ cm and a foam column of ~20 theoretical stages, the calculated decontamination factor is > 100 for a volume reduction of 100, a throughput of ~50 gal ft^{-2} hr^{-1}, and a bubble diameter of 0.5 mm.

Ion Exchange Studies. — Amberlite 200 resin, after being exposed to Co^{60} gammas for a total dose of 0.97×10^9 r, lost 34% of its original exchange capacity; Dowex 50W-X8 resin, after a dose of 0.85×10^9 r, lost 30%. The radiolytic loss of sulfur, G(−S), for Amberlite 200 was calculated to be 1.2 atoms per 100 ev of cobalt gamma radiation absorbed. The moisture content increased from its original 53% to 57%, median pore diameter from 250 A to 315 A, and surface area from 50 m^2 per g of dry resin to 60 m^2 per g of dry resin.

Volatility Studies. — In a nonradioactive evaluation run in the Volatility Pilot Plant, the newly installed dissolver off-gas system prevented solids from plugging the dissolver off-gas valve during dissolution of dummy Zircaloy-2 fuel elements. With HF feed rates of 162 and 350 to 370 gpm to the dissolver and the flash cooler, respectively, 54 kg of alloy was dissolved. The dissolution rate was 1.8 kg/hr, and the HF utilization efficiency was 18.3%. Fully enriched zirconium-uranium alloy fuel, 40 kg, was processed with HF at an average flow rate of 128 gpm. The dissolution rate, 4.0 kg/hr, and the HF utilization efficiency, 40.2%, were the highest of any run to date. No explanation is offered yet for the increase. Uranium was recovered as UF_6 by fluorination at rates of 6 and then 16 std liters/min for a total of 120 min. Nonrecoverable uranium losses were only 0.1 wt %. There was no difficulty with either the dissolver off-gas system or molten-salt transfer.

In laboratory studies, hydrofluorination rates in various molten-salt compositions were satisfactory with several types of fuel material. Zircaloy-2 dissolution rates were 4.3 to 13.5 mg cm^{-2} min^{-1} in 37-50.5-12.5 mole % LiF-NaF-BeF_2 at 650°C with different ZrF_4 concentrations, the rate decreasing with ZrF_4 concentration in the range of 0 to 28 mole %. Tubular fuel elements of UO_2-Y_2O_3-BeO dissolved in 40-49-11 mole % LiF-NaF-BeF_2 and in 63-37 mole % NaF-ZrF_4 at overall rates of 5 to 6 mils/hr at 650°C. Pellets of ThO_2-UO_2 (96-4 wt %) clad in Zircaloy-2 were dissolved in 34-26-40 mole % LiF-NaF-ZrF_4 at 600°C at an estimated rate of about 20 mils/hr to give a final thorium concentration of 5%. In subsequent fluorination, uranium volatilization was > 99.6%.

Solvent Extraction Research. — A tentative process has been developed for separating and recovering niobium and tantalum from alkaline ore leach

liquors by means of a quaternary ammonium extractant. From potassium carbonate solution, Aliquat 336 gave a separation factor of ~6 for Nb/Ta. Solutions of NaOH, Na_2CO_3, $(NH_4)_2CO_3$, K_2CO_3, KNO_3, and KCl were effective stripping agents.

A method has been developed for removing diluent nitration products from spent Purex or Thorex solvent, TBP, and Amsco. Scrubbing with low-molecular-weight alkanol amines (e.g., ethanolamine) converts the offending nitroparaffins to their amine salts, which are preferentially removed by the amine phase. This method is the best liquid-liquid system thus far devised.

Tertiary amines were shown to extract all the lanthanides preferentially to yttrium from concentrated chloride solutions. Relative extractabilities varied with composition of amine, diluent, and salting agent. Europium was always the most extractable of the series Ce, Eu, Tb, Ho, Tm, and Lu from 11 N LiCl–0.01 N HCl. The maximum separation factor obtained between europoim and yttrium was ~10. Differences between the elements were smaller in extractions from 8 N LiCl–2 N $AlCl_3$, with lutetium sometimes more extractable than europium.

Process Chemistry of Uranium and Thorium. – Rice University (under subcontract) made a field survey during the past summer of the Conway granite formations in New Hampshire. Over 500 field spectroradiometric determinations were made on an extensive portion of the 400 square miles of outcrop area with a portable, single-channel, transistorized, gamma-ray pulse-height analyzer. Preliminary analysis of the data indicated that the accessible surface of the Conway granite averages at least 40 ppm thorium.

Nuclear Methods of Chemical Analysis. – In order to improve the precision of measurements, modifications have been made on a device previously used to make a continuous scan of the radioactivity induced by irradiation into neutron-flux monitor wires. As modified, the device now functions by taking counts of about 1-cm segments of the wire at 1-in. intervals. The segments are counted through a tungsten radiation collimator. The detector is surrounded by lead, which shields it from that portion of the wire not over the collimation slit. The scanning device counts each segment automatically and sequentially for a preset interval of time and records the counts of each segment. The counts obtained for segments of a test wire are compared with those obtained with a comparator wire of known specific radioactivity in order to determine the specific radioactivity of the test wire as a function of distance along the wire. These radioactivity measurements are then used to calculate the average neutron flux to which the monitor was exposed.

To evaluate the precision of the scanning device, it was used to measure the specific radioactivity of segments of an irradiated cobalt wire, after which the segments were cut from the wire and, for the purpose of comparison, counted with a gamma ionization chamber. The average difference in specific radioactivities of 24 segments from an irradiated cobalt wire as measured by the two methods was found to be ±3%.

The scanning device is now used routinely for evaluating the specific radioactivity of wire, such as cobalt and nickel. About 400 in. of wire can be scanned per day.

High-Temperature Aqueous Solution Chemistry: Hydrogen Solubility. — Measurements have been made of the solubility of hydrogen from 40 to 140°C in water and in the following aqueous solutions: 1.0 M $HClO_4$, 1.0 M $HClO_4$–0.1 M $Cu(ClO_4)_2$, and 0.01 M $HClO_4$–0.1 M $Cu(ClO_4)_2$. The results indicate that perchloric acid lowers the solubility of hydrogen below 55°C and enhances its solubility above this temperature. Cupric perchlorate lowers the solubility of hydrogen over the entire temperature range studied, and the effect of the copper salt seems independent of acid concentration or temperature.

High-Temperature Aqueous Solution Chemistry: Thorium(IV) Hydrolysis. — A study of thorium(IV) hydrolysis in 1 M sodium perchlorate at 94°C, using the glass-electrode concentration cell described previously (ORNL-2874), is in progress. On comparison of the results obtained thus far with the extensive results of others at 25°C in the same medium, it was found that hydrolysis of Th^{4+} increases markedly with temperature. In general, a given value of the hydroxyl number $\bar{n}$ (the average number of bound OH^- ions per Th^{4+} ion) occurs about one pH unit lower at 94°C than at 25°C. In the hydrolysis of stoichiometric $Th(ClO_4)_4$ solutions at the two temperatures the comparative results were as follows:

Molality	25°C		94°C	
	$\bar{n}$	pH	$\bar{n}$	pH
0.001	0.45	3.35	~1.5	2.5
0.005	0.22	2.96	1.1	2.2
0.02	0.11	2.66	0.7	1.9

Hydrolytic precipitation begins at $\bar{n}$ values in the range 1.5 to 2 at 94°C, compared with 2.5 to 2.8 at 25°C.

At the higher $\bar{n}$ values, the dependence of $\bar{n}$ on acidity and on thorium concentration at 94°C is similar to that at 25°C, suggesting the formation of polynuclear hydrolysis products. In the early stages of hydrolysis (i.e., at lower $\bar{n}$ values), however, mononuclear hydrolysis products appear more stable at 94°C than at 25°C. Analogous behavior was found in a study of uranium(VI) hydrolysis (ORNL-3120).

High-Temperature Aqueous Solution Chemistry: Thorium and Protactinium Precipitation. — Studies on the system $Th(NO_3)_4$-HNO_3-H_2O-H_2O_2 indicate that the precipitate formed by the addition of peroxide is a chain species with a composition approaching $Th_6(OO)_{10}(NO_3)_4 \cdot 10H_2O$. Its solubility is less than 0.2 g/liter at 25°C. The compound is stable at 20°C, and the peroxide decomposes slowly at 100°C. The material is noncrystalline.

The solubility of protactinium in 1.95 M HNO_3 was found to be 8.21 ± 0.9 μg/ml, in good agreement with the results of Thompson (TID-5223, p 294). No precipitation of protactinium peroxide was observed upon the addition of 1 ml of 30% H_2O_2 to 4.5 ml of such a solution. Solid protactinium peroxide, precipitated from a sulfuric acid solution of protactinium, was found to be soluble in 1.94 M HNO_3 to the extent of 2.29 ± 0.75 μg/ml.

These results emphasize, by contrast, the unusual nature of the previously reported high solubility (over 100 ppm) of protactinium in nitric acid solutions containing thorium nitrate as well as the ease of removal of protactinium upon the partial precipitation of thorium with peroxide.

Oxygen-17 Pilot Plant. – Experimental operation of the water distillation cascade continued during the month. The optimum steam pressure for the reboilers associated with distillation columns 5 and 6 proved to be considerably lower than for the reboilers of the other four columns. Changes are being made in the steam generation system to remedy this defect.

Chemical Applications of Nuclear Explosions. – Studies of the mechanism of the reduction of calcium sulfate by hydrogen showed that the following reactions were involved:

$$CaSO_4 + H_2 \rightarrow CaSO_3 + H_2O$$

$$CaSO_3 \rightarrow CaO + SO_2$$

$$7H_2 + 3SO_2 \rightarrow 6H_2O + H_2S + S_2$$

$$4CaO + 2S_2 \rightarrow CaS + CaSO_4$$

$$4CaO + 4SO_2 \rightarrow CaS + 3CaSO_4$$

$$CaS + 2SO_2 \rightarrow CaSO_4 + S_2$$

$$CaS + H_2O \rightarrow CaO + H_2S$$

The final products were CaS, CaO, H_2O, and H_2S; the solid reduction product contained 15 to 20 mole % CaO, the remainder being CaS; SO_2 and S_2 were not observed in the off-gas and are intermediates only.

Deuterium readily exchanged with water at 10,000°K in a plasma jet. After injection of mixtures of 92 mole % D_2 and 8% H_2O into the plasma jet, the water phase was found to contain 82.6 at. % D (0.775 g of D_2O per g of solution). The residence time for the mixture in the jet was approximately 40 msec. This result strongly suggests that tritium will exchange very rapidly with environmental water at nuclear explosion temperatures.

METALLURGY AND MATERIALS RESEARCH

Metallurgy of Superconducting Materials. – Niobium-zirconium binary alloys containing 25 to 50 at. % Zr are of interest for the construction of superconducting solenoid magnets for operation at fields of 50,000 gauss and higher. Little is known concerning the transformation structures present in alloys in this composition range or of their effects on the superconducting properties. It has been shown that, in a 75% Nb–25% Zr alloy, heat treatment can cause a tenfold increase in the critical current at a given magnetic field strength. A study of the kinetics and structures of transformation in niobium alloys containing from 25 to 50 at. % Zr is in progress.

Microstructural examination of specimens held at temperatures from 400 to 950°C for times of 2 hr to one week, with starting conditions of cold-worked or beta-quenched from 1100°C, has shown that the transformation rates are relatively slow, are increased appreciably by cold-working, and are decreased by decreasing zirconium content. The fastest rates were observed for cold-worked specimens of the 50% Nb–50% Zr alloy held at 600 and at 700°C, there being about 25% transformation in 2 hr and complete transformation in about 24 hr. The transformation rates decreased with increasing temperature difference from 600 to 700°C, increasing niobium content, and prior beta quenching. The only transformation product which could be clearly resolved at 1000X magnification was a fine lamellar structure formed at 800°C for all compositions and both starting conditions. No definite morphology could be ascribed to any structure formed above or below 800°C.

Ceramics Research: Sintering Studies. – Changes in the microstructure near a large pore during sintering have been investigated in CaF_2. The pore was simulated by drilling a 13.5-mil hole in a sintered pellet which had grains with average diameters of about 20 μ. Further sintering at temperatures approaching the melting point caused additional grain growth except in the area adjacent to the hole, where the grains became smaller. The behavior suggests that plastic flow is involved in the sintering process. The absence of geometric hindrance to grain growth around the hole is indicated by the fact that large grains grew there on lengthy annealing at lower temperatures. Annealing prior to high-temperature sintering did not prevent the appearance of small grains around the hole, suggesting that strains caused by drilling the hole were not the cause of recrystallization.

Physical Property Studies. – Thermal-conductivity measurements on 93.4% dense UO_2 in the radial heat flow apparatus were extended to 740°C. Prior to each thermal-conductivity measurement an isothermal intercomparison of all measuring thermocouples was made. This procedure has yielded data which are reproducible to ±1.5% and accurate to ±3%. The results to date may be fitted to ±1% by $K = \rho/(6.7414 + 0.020069T)$, where ρ is the fractional theoretical density, K is the thermal conductivity in w cm^{-1} $(°C)^{-1}$, and T is the temperature in °K.

The calibration curve for the thermal comparator apparatus continues to be an illusive entity. This calibration depends on measuring a quantity which depends only on the thermal conductivity of the specimen. It appears that gaseous conduction between the detector spheres and the specimen is causing a prohibitively large contribution to the heat flow from the specimen surface. Efforts to correct this by operating with a restricted contact area and using a gas with a lower conductivity are being attempted.

CONTROLLED THERMONUCLEAR RESEARCH

DCX-1 Facility. – Improvements in vacuum technique in the DCX-1 have resulted in lower base pressures and greater ease in producing these lower pressures. Deposits of evaporated molybdenum in conjunction with titanium

have resulted in a base pressure of 3.5×10^{-9} torr, with changes of 5×10^{-11} torr per ma of injected current. Decay times at this pressure were 11 sec and were consistent with previous measurements at higher pressures.

Spikes that complicated the measurement of buildup and decay rates were eliminated by clipping those neutral particles originating with the incoming beam and permitting only the neutral particles from the trapped plasma to enter the neutral-particle detectors. Decay times and rise times were roughly exponential, but the decay times were 50 to 75% longer than the rise times at 0.4 sec containment times for 4 ma of injected current.

Further measurements of the sharp increase of the number of slow ions exiting through the mirrors have been made with a slow-ion spectrometer, a Faraday cup, and an rf probe. Accompanying the 1000-fold increase in slow-ion current is a drop of 100-fold in the Faraday cup current located in the east mirror throat and a drop of 100-fold in rf signal amplitude. The dependence of the break upon the type of gas and injected beam current conforms to a theoretical prediction by Fowler and Shima. The strong modulation of the rf at these break points has not been explained.

Modifications to improve the vacuum were completed, and the accelerator tube has been replaced to allow injection of 10 ma of H_2^+ current.

High-Current Injection. – Hydrogen ion beams up to 50 ma at 600 kv have been obtained with the accelerator tube operating within the transverse magnetic field of the DCX-2. The tube has new mild-steel electrodes for shielding the beam from the transverse magnetic field and has lead within the electrodes for x-ray shielding. Since the injection snout was not ready, the beam was stopped at a temporary target placed below the accelerator-tube vacuum manifold. This target is the limiting factor on the amount of current that can be extracted at present. A detailed evaluation of the beam will be conducted as soon as the injection snout and the rotating probes are installed.

Theory. – The recent proof that plasmas in which both ions and electrons are confined in potential wells are stable against electrostatic disturbances has been extended to show stability against magnetic disturbances as well. Examples are stellar plasmas confined gravitationally. The proof employs the newly developed method, reported previously, allowing the study of stability of spatially inhomogeneous solutions of the Vlasov-Boltzmann equation. Stability is implied by the existence of a nonzero quadratic form over perturbations which is constant in time.

The Harris instability arising from a resonance of cyclotron motion of ions and plasma oscillation of electrons has been calculated with negative effective mass for ions approximating the effect of a negative radial gradient in a magnetic mirror field. The negative mass effect was found to govern stability if the electric field perturbation is perpendicular to the magnetic field. The resonance mechanism dominates if $\vec{E}$ strongly couples to the electron motion parallel to the magnetic field.

Radio-Frequency Heating. – Energy densities greater than 10^{16} ev/cc have been observed in the plasma created by electrons heated at the cyclotron frequency via microwave power sources. Hall probes were employed to make the diamagnetic measurements (from which energy density is calculated), and the signal-to-noise figure of the probe and instrumentation was just adequate to observe time decay of energy density upon interrupting

the microwave power feed. The energy-density decay times were well correlated with the observed decay of temperature. The temperature observations were made with a microwave noise receiver at a frequency 2.5 times higher than the heating frequency. Energy densities of 3×10^{16} ev/cc were observed to decay in 1/10 to 1/3 sec.

A microwave cavity incorporating ion cyclotron heating coils and more refined diagnostic facilities were recently installed in the Physics Test Facility. Testing of the heating components and the better diagnostic equipment is near completion.

BIOLOGY AND MEDICINE PROGRAM

SOMATIC EFFECTS OF RADIATION

Pathology and Physiology: General. — Preliminary evidence suggests that spontaneous and radiation-induced lymphoid and myeloid leukemias in the AKR and RF strains of mice are associated with filterable leukemogenic agents. In the search for evidence of common etiologic factors, the present study was undertaken to compare the incidence of such diseases in these two strains and their F_1 hybrids. Exposure of young adult mice to 300-r whole-body x irradiation decreased the incidence of leukemia in AKR mice but increased it in the other strains. In all strains, lymphoma induction was greater in females and myeloid leukemia induction greater in males, as noted earlier in RF mice. The incidence of both types of leukemias in F_1 hybrids was intermediate between that of the parental strains, lymphomas being higher in $(AK \times RF)F_1$ than in $(RF \times AK)F_1$ mice. The pattern of leukemia incidence in F_1 hybrids suggests that susceptibility factors are inherited from each parental strain, as might be anticipated in a simple Mendelian system. It would appear, however, that susceptibility to lymphomas is transmitted to a greater degree via AKR females than via AKR males.

Pathology and Physiology: Recovery from Somatic Effects of Radiation. — Published data suggest that S,2-aminoethylisothiourea (AET) is not as effective a radioprotective agent for antibody-forming cells as for other cell types. In support of this idea, the following experiments show that AET and S,3-aminopropyl-N′-methylisothiourea (APMT) do not modify the radiosensitivity of immunologically competent cells in adult parental-strain mice, as judged by the ability of such cells to induce wasting disease on transplantation into sublethally irradiated F_1 hybrid recipients. Young adult $(C57BL/Cum \times 101/Cum)F_1$ and $(101/Cum \times C3H\ Anf/Cum)F_1$ hybrid mice were exposed to 600-r total-body x irradiation (an $LD_{0/30}$ for these strains) and subsequently injected intraperitoneally with parental-strain liver cells. The C3H donor mice were preimmunized against 101 spleen cells before the liver-cell transfer. Donors of both strains were exposed to 50 to 400 r of whole-body x irradiation immediately before removal of their cells for transplantation, and AET or APMT was administered to some of them 30 min before irradiation in doses and routes proved to be effective for protection of the whole animal. Recipient mice were kept under observation for 90 days to record the occurrence of wasting

disease (ruffling of hair, weight loss, and diarrhea) and related mortality. It was assumed that any impairment by radiation of the viability of the donor antibody-forming cells would be detectable by a reduction in the incidence of wasting disease among recipients. The x-ray dose to the donor required to reduce mortality among F_1 hybrid recipients to 50% was 206 r (95% confidence limits, 183 to 229 r) for C57BL donors and 363 r (95% confidence limits, 330 to 402 r) for C3H donors. The strain difference in dose possibly reflects differences in the absolute numbers of cells involved in primary and secondary immunological responses, since the C3H donors had been preimmunized against the recipient. Under the conditions of these experiments, administration of AET or APMT to donor mice did not modify the incidence of wasting disease among recipients. Hence the survival of immunologically competent cells in the irradiated liver was not altered by chemical radioprotective treatment. This finding indicates a possible method by which radiation may be used selectively to destroy immune cells in prospective tissue grafts.

Pathology and Physiology: Physiology of Blood Platelets. — The in vivo aging of blood platelets has been studied by comparing the size, adenosine triphosphate (ATP) content, and ability to promote clot retraction in relation to the age of young, old, and normal populations of platelets. Young platelets were obtained from rats two days after platelet depletion with antiserum. Old platelets were obtained by incubating fresh platelets for two days in rats whose platelets had been depleted by whole-body x irradiation. There was a decrease with age in the size of platelets of about 25% between young and old ($P < 0.05$). There was no statistically significant age-related difference in ATP content when expressed as micromoles of ATP per 10^{11} platelets or micromoles of ATP per ml of packed platelets. The clot-retracting ability of old platelets was about 10% less than that of young platelets ($P < 0.02$). Constancy of ATP on the basis of both platelet number and platelet volume is not consistent with a change in platelet size. There was probably a decrease in micromoles of ATP per platelet that was too small to be demonstrated statistically. The reduction in clot retraction may be due to a small decrease in the ATP pool or to an impairment of the platelet's ability to metabolize glucose for the production of the additional ATP necessary for clot retraction.

Medium(Low)-Level Long-Term Effects of Radiation. — In an effort to characterize the biology of the normal, aging RF mouse, it has been noted that the kidneys of such animals develop glomerulosclerosis, which increases in severity after the eighth month of life. Histological changes observed in early stages of the disease include thickening of the capillary wall and dilation of the capillary lumen. With advancing sclerosis there is pyknosis of intercapillary cell nuclei, capillary dilatation, hyalinization of the mesangium, and glomerular enlargement. Histochemical staining of glomerular hyalin suggests the presence of glycolipid, carbohydrate with 1-2 glycol linkage, collagen, and fibrin. There is no evidence of amyloidosis. The glomerular lesions are accompanied by reduction in the amount of acid mucopolysaccharides in the ground substance and the basement membrane of affected capillary tufts.

This lesion is similar in certain respects to age-dependent kidney changes which have been reported in mice of other strains and in other

species. Study of the influence of radiation on the course of the disease will be important in assessment of the delayed somatic effects of low-level irradiation.

RADIATION GENETICS

Genetic and Cytogenetic Effects of Radiation. – Part of the esterases in maize endosperm and seedling tissue have been shown to be particle-bound. With paper electrophoresis the particle-bound esterases do not migrate but remain at the point of application, while the free esterases in the crude extract migrate to both the anode and the cathode. The 100,000 × g supernatant contains only the free esterases, while the particle-bound esterases which do not migrate are found in the 100,000 × g pellet. The basic esterases whose genetic control is at present under investigation in this laboratory can be liberated from the washed pellets by treatment with a dilute solution of deoxycholate. Plants heterozygous for two alleles which specify electrophoretically separable basic esterases contain free esterases of both parental types as well as a hybrid esterase. Preliminary investigations on the basic esterases liberated from the particles of heterozygotes indicate that both the parental type and the hybrid esterases are associated with the particles. This finding would suggest that the hybrid enzymes are not dimers formed by two parental types after the enzymes have been synthesized on the particles.

Effects of Radiation on Paramecium. – Earlier studies had shown that fractionation of the dose has no influence on the number of recessive lethal mutations induced in *Paramecium aurelia* by ionizing radiation. The lack of a fractionation effect has been confirmed in recent work for two half doses of x rays given at 1500 r/min and separated by 2 to 6 hr. The same work showed the existence of an intensity effect, however, since a single exposure to x rays at 35 r/min produced appreciably less mutation than the same dose given as a single exposure at 1000 r/min. The existence of an intensity effect but lack of a fractionation effect under these conditions of exposure implies some form of rapid interaction between independent radiation events. This rapid process must be distinct from the relatively slow repair of premutational damage found in the earlier work.

COMBATING DETRIMENTAL EFFECTS OF RADIATION

Mammalian Recovery: General. – In vitro radiation sensitivity and protection of isologous mouse bone marrow cells can be estimated by measuring their ability to proliferate in lethally irradiated mice. Thirty-day survival of irradiated mice is a function of the number of normal cells injected. The number of normal cells to give 50% survival for 30 days appears to be the same (about 0.1×10^6 cells) for C57BL, $C3BF_1$, and LaF_1 mice. Modification of this in vitro system is being studied in an attempt to reduce the assay time. Ten spleen weights were found to be directly related to the number of marrow cells injected throughout the cell dose range of 0.05 to 1.6×10^6. Spleen nodule count did not prove to be a more accurate index of cell proliferation than spleen weights.

In addition to modifying the assay procedures, a re-evaluation of cell counting, cell injection, and cell preparation techniques is being made. It appears that the counting system presently used, the suspension medium, and the types of vessels used to contain the suspension can lead to errors in cell dosages of up to 50%.

A study was made of the development of transplantation antigenicity in hematopoietic tissues of mice. Antigenicity of the tissues was measured by their ability to induce homotransplantation immunity. The method used was based on the fact that lethally irradiated mice are able to reject homologous bone marrow if they have been immunized to tissues of the donor strain before irradiation. Tissues tested for antigenicity were adult spleen, neonatal liver, and fetal liver from embryos 13-1/2 or 15-1/2 days old. When the antigenicity of adult spleen was set at 100%, antigenicity of neonatal liver, 15-1/2-day fetal liver, and 13-1/2-day fetal liver was 20, 5, and 0% respectively.

Radiation Immunology. — Previous work has revealed that one-tenth of the total number of cells in the mouse spleen, when transferred to the irradiated, in vivo culture animal, is sufficient to give an antibody response equivalent to that of the intact mouse. This indicates that some mechanism sets a limit to the total antibody formation by the normal intact mouse which is considerably lower than its capabilities. Among a variety of possible limiting mechanisms, the regulation of antibody formation due to the quantitative level of circulating antibody has been investigated. It has been found that the introduction of preformed antibody alters quite significantly the nature of the production of new antibody by preimmunized spleen cells. There is a prolongation of the induction phase and a considerable delay in the time required for production of a given quantity of antibody. Further investigations are required to determine whether this feedback acts primarily upon release of antibody by cells or upon antibody synthetic processes.

A series of experiments, in which quantitative relationships between numbers of antibody-producing cells, antigen dosage, time of exposure to antigen, and circulating antibody titers were studied, have provided information about the kinetics of cellular antibody production. For example, in both primary and secondary antibody response there is a maximum rate at which cells can produce antibody, and increasing amounts of antigen do not increase this rate. Maximum antibody titers depend both upon this rate and upon the length of time to which cells are exposed to antigen. In the primary response this rate may be primarily that of the process of maturation of precursor cells to functional status. In the secondary response the rate may be determined principally by mitosis of competent antibody-producing cells.

MOLECULAR- AND CELLULAR-LEVEL STUDIES

Cell Growth and Reproduction. — The proteins of amoebae were labeled with an 18-hr incubation of growing cells in a medium containing tritiated amino acids. During the next ten days the amoebae were cultured on nonradioactive medium, but each day approximately half the cytoplasm was severed from each amoeba. This treatment prevents the cells from dividing,

but the cytoplasm grows back to its original mass between the operations. The experiment, in effect, allows a complete replacement of the original radioactive cytoplasm with nonradioactive cytoplasm. The radioactivity in proteins of the cell nucleus also declines during the treatment, but a substantial fraction of nuclear proteins is conserved in the nucleus. At the end of the experiment some cells were allowed to undergo division, and the radioactive proteins were localized in the two daughter nuclei with no detectable loss to the cytoplasm. The protein fraction involved here is believed to be a part of the chromosome, and it shows the same type of conservative behavior that is so well known for deoxyribonucleic acid.

Biophysics. — The irradiation of priming deoxyribonucleic acid (DNA) by ultraviolet light decreases the rate of priming activity. The shape of the dose-response curve is compatible with the idea that the decrease in rate arises, in major part, from the formation of dimers between adjacent thymine residues in the polynucleotide chain. DNA from *M. lysodeileticus* has a very low thymine content. Ultraviolet light produces very few dimers, as observed spectroscopically, and has a small effect on the ability of this DNA to act as a primer. Calf thymus DNA has five times as many dimers, and its priming activity is very sensitive to ultraviolet light. Experiments are in progress to determine the partial sequences of the DNA formed from irradiated primer to see how they differ from those formed from unirradiated primer.

The electron spin resonance (ESR) spectrometer has been converted from a transmission type of instrument to a reflection type using a new Varian cavity. This was done to permit ESR measurements of materials while being irradiated with ultraviolet and visible light, to permit work at temperatures down to liquid nitrogen, and probably to allow measurements on liquids at room temperature. Sensitivity and ease of operation are slightly less in the new configuration. Initial work has been done on natural and light-induced resonances in chloroplasts, chromatophores, and whole leaves, all at room temperature. No clear resonances have been seen on ultraviolet irradiation of aromatic and other amino acids at room temperature.

RADIOLOGICAL PHYSICS, HEALTH PHYSICS, AND INSTRUMENTATION

Basic Instrumentation. — Two circuit improvements, which are now being field-tested, were developed for the Personal Radiation Monitor, model Q-2041. The first increases the brightness of the flashing neon lamp by the use of separate lamps. One lamp, which is inside the instrument case, is used as a scaling element; a second lamp, outside the case, is driven directly from the high-voltage transformer winding. The second improvement increases the life of the battery to about one year when the instrument is subject only to normal background radiation. By use of a two-transistor timing circuit, all circuits are kept idle except for a low-duty-cycle recharging action in the power supply for the Geiger-Mueller tube.

Four transistorized nuclear instruments were developed and tested: a double-delay-line linear pulse amplifier having a scintillation counter

and semiconductor detector preamplifiers; a single-channel pulse-height analyzer that generates an output pulse when the input pulse crosses the base line; a fast-coincidence unit for use with the two previously mentioned units; and a biased-amplifier and linear-gate unit.

A simple hand-powered piezoelectric generator was constructed. Several millijoules at 2000 v can be produced by a single hand squeeze. The charge is retained with a time constant greater than 20 hr.

Silicon surface-barrier detectors with guard rings were assembled. At several hundred volts bias, the surface conductivity of the silicon was less than 2×10^{-5} micromho/square.

TRAINING, EDUCATION, AND INFORMATION PROGRAM

International Reactor Programs at ORSORT. — Thirty-one students representing seven countries have enrolled in the fourth session of international programs at ORSORT. The programs officially began November 6, 1961, following six weeks of preparatory mathematics and physics. The countries represented are Belgium, Brazil, Italy, Japan, Pakistan, South Africa, and the United States.

In addition to the programs in Hazards and Operations, ORSORT is again conducting a 12-month training program for seven newly hired AEC employees from various operations' offices throughout the country. Seven TVA and thirty-three Carbide employees are currently enrolled in courses at ORSORT.

Eighty-nine students completed courses at ORSORT during the 1960–61 session, which terminated on October 27, 1961. The enrollment was as follows:

Program	Number of Students
Reactor Hazards Evaluation	5
Reactor Operations Supervision	17
AEC trainee program	16
TVA trainee program	2
ORSORT for Carbide employees	
Full time	3
Part time	41
Special students	5
Total	89

Tentative plans have been made for starting a fifth session of international programs in the fall of 1962. Descriptive material for the program is being prepared for distribution.

ASEE-AEC Summer Institute. — Twenty-eight participants in the 1961 ASEE-AEC Summer Institute, conducted by North Carolina State University,

concluded the last week of their program with experiments at ORSORT. The ORSORT work consisted of seven experiments in radiochemistry and physics (including a criticality experiment at the PCA), tours, lectures, and the preparation of reports covering their experiments.

ISOTOPE DEVELOPMENT PROGRAM

Application of Radioisotopes in Analytical Chemistry. — A chemical method for the determination of 10 to 100 ppm of thorium in Conway granite has been studied by means of Th^{234} tracer. Test results by the chemical method were generally lower than those found by gamma spectrometry. Variable losses were found to occur in the chemical method, sometimes in the extractions with trioctylphosphine oxide and particularly in the back-extractions ("stripping") of thorium. When, however, corrections were made for losses during the extraction steps, based on tracer measurements, the amounts of thorium, determined spectrophotometrically, were found to be high, indicating the probability of unexpected positive interferences. This conjecture was confirmed by comparative tests made with thorium that had been repurified by thenoyltrifluoroacetone extractions. Typical test results in ppm were (chemical determination with tracer correction first; gamma spectrometric measurement second): (a) 76, 76; (b) 26, 25; (c) 29, 30. Modifications were made in the chemical methods, from which substantial improvements have been noted.

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