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HANFORD LABORATORIES MONTHLY ACTIVITIES REPORT

JUNE, 1963

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HANFORD ATOMIC PRODUCTS OPERATION

RICHLAND, WASHINGTON

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HANFORD LABORATORIES MONTHLY ACTIVITIES REPORT JUNE 1963

Compiled by
Section Managers

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By [illegible] 10/22/92
PM Eck 10-23-92

July 15, 1963

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

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PRELIMINARY REPORT

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TABLE I - HANFORD LABORATORIES FORCE REPORT

DATE: June 30, 1963

	At Beginning of Month		At Close of Month		
	Exempt	Salaried	Exempt	Salaried	Total
Chemical Laboratory	137	127	147	132	279
Reactor & Fuels Laboratory	186	178	193	185	378
Physics & Instruments Laboratory	104	77	107	82	189
Biology Laboratory	40	62	46	65	111
Applied Mathematics Operation	17	5	20	5	25
Radiation Protection Operation	43	90	47	94	141
Finance & Administration Oper.	98	112	127	113	240
Programming Operation	12	3	15	4	19
Test Reactor & Auxiliaries Oper.	58	306	59	308	367
General	3	4	3	4	7
TOTAL	698	964	764	992	1756

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BUDGET AND COST SUMMARY

Operating cost figures for June and for the completed fiscal year are not yet available and will therefore be included in the July report summary. It is believed these figures will reflect effective utilization of available funds within designated budgetary controls.

RESEARCH AND DEVELOPMENT

1. Reactor and Fuels

A test lot of NIE elements with self-brazed closures was completed for irradiation testing. Development work has been started for this closure on NOE fuel elements.

Development of the hot-headed projection welded closure has included evaluations of: (1) increasing the width of projection welds, (2) varying post-heat time and current, and (3) varying the amount of copper in the joint interface.

The performance of N-Reactor fuel components irradiated in the KER loops continues satisfactory, as shown by post-irradiation examinations.

Both bonded and unbonded N-inner fuel elements with tapered rather than flat end caps were satisfactorily irradiated to 1900 Mwd/T in KER Loop 2. No evidence of clad shearing at the cap-core interface was observed with this end cap design in either the bonded or unbonded condition.

Fluted N-Reactor size single-tube fuel elements continued to operate satisfactorily under N-Reactor conditions.

Precipitation of hydride platelets in the N-inner fuel supports during autoclaving has resulted in cracking of supports during sizing. A 300 C solution anneal followed by quenching will restore the normal ductility of the support.

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Irradiation of Zircaloy-2 clad lithium-aluminum target alloys in KER Loops 1 and 2 was started. These tests were designed to establish the performance of the target material under N-Reactor conditions.

The conditions resulting in recrystallization of cold and warm extruded aluminum-lithium material were determined.

Irradiated test specimens having intentional striations in the Zircaloy-2 cladding show a high incidence of localized clad thinning at an exposure of 1100 Mwd/T.

Initial study of sulfur impurity in uranium indicates some solubility of sulfur in the gamma uranium phase.

Uranium and uranium-zirconium alloys containing aluminum, iron, and phosphorus are being studied as dispersed phase fuel materials.

In tests up to 390 hours, Zircaloy-2 containing up to 1.0 wt % uranium exhibits corrosion behavior similar to Zircaloy-2 in 360 C water. Zirconium containing 250-2500 ppm uranium with 1, 2, 3, 4, and 5 wt % beryllium shows decreasing corrosion resistance with increasing beryllium after 100 hours in 360 C water; above 3 wt % Be the samples developed white oxide in these tests.

The major cause of N-fuel self-support flattening has been tentatively traced to using a charging machine magazine which is slightly larger in inside diameter than the process tube. In tests employing a process tube as the magazine, no significant support flattening occurred at column loads up to 1500 pounds, approximately twice the anticipated load at N-Reactor.

N-Reactor Zircaloy process tube material is remarkably resistant to brittle fracture originating from a 0.360-inch long crack introduced while the tube is at elevated pressure. At room temperature the tube must be stressed to the yield point (about 98% of ultimate) to cause such a crack to propagate in a brittle manner. At 150 C (302 F) the crack will not propagate even with the

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tube stressed to the yield point. High speed photographs of one of the room temperature crack propagation tests show that the moving crack tip travels at about 2500 ft/sec, or 1/6 the speed of sound in Zircaloy.

In 360 C, pH 10 (LiOH) deoxygenated water, pretransition corrosion product hydrogen pickup is greater for Zircaloy-2 samples quenched from the beta phase than for alpha heat treated samples. Corrosion rates are unaffected by these heat treatments.

The inhibition of gas phase hydriding of Zircaloy-2 at 375 and 425 C in 2% H_2, 1% CO_2, helium gas mixtures is apparently the result of water formation by the carbon dioxide-hydrogen reaction.

The effect of a 100-fold variation in the carbon monoxide concentration of a typical N-Reactor gas atmosphere was found to be very small in reducing the equilibrium water concentration.

Irradiations of N-Reactor graphite are proceeding satisfactorily in the GETR.

Two predefected target elements tested in an out-of-reactor loop at 520 F for 200 hours showed no swelling. The aluminum concentration in the coolant increased rapidly during the first 48 hours and then decreased, indicating plugging of the holes with corrosion product.

Tests to determine effects of residual decontaminants in crevices of stressed stainless steel samples showed no cracking after three months of exposure, but some intergranular attack was noted; pits were as deep as 8 mils.

Lithiated water at pH 10 and 530 F flashed across the face of a Zircaloy-2 specimen, to simulate a leak from the N-Reactor primary system, showed a white deposit after three weeks, but no accelerated corrosion or hydriding was noted.

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Irradiation of four I&E fuel elements to a maximum exposure above 3000 Mwd/T at high specific power has been completed to evaluate the susceptibility of this fuel to grain boundary tearing.

Examination of corrosometer probes placed in the inlet piping and storage tanks of present production reactors to measure corrosion rate of carbon steel in process water shows that at low velocities neither pH (6.6 or 7.0) nor dichromate concentration (1.0 or 1.8 ppm) affects the corrosion rate. At high velocity (8fps), an increase in corrosion rate was noted with low-pH, low-dichromate water.

An unautoclaved, Zircaloy-clad fuel element is being irradiated in the PRTR. The feasibility of eliminating preirradiation autoclaving on a routine basis is dependent on maintaining clean metal surfaces during fabrication, delivery, and charging of the fuel elements. Potential incentives include increased fuel element life resulting from reduced initial hydrogen concentration in the cladding, and approximately a 5% reduction in direct fuel fabrication costs.

Inspection of irradiated PRTR fuel elements continues to reveal excellent external appearance with the exception of an occasional damaged wire rod or bundle wrap. Remote repairs will be made before returning such elements to service.

Postirradiation examinations of four failed, vibrationally compacted PRTR fuel rods in one fuel assembly revealed internal cladding corrosion at end caps distant from the failures. Moisture and/or high chloride impurities in the archive specimen of the fuel used in three of the rods is currently suspected to be the cause of failure, rather than poor weld quality.

A maximum fuel thickness variation of 1.6 mils in the outer fuel annulus of a PRTR tubular element had no detrimental effect on the irradiation performance.

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After 106 days of exposure of an experimental PRTR Mark I fuel element in an out-of-reactor fretting corrosion test loop, only superficial wear was observed on the ring contact surface of the bottom end bracket.

Fuel for an In-Reactor Enrichment Test Element was fabricated. Controlled release of the UO_2 enrichment particles from the fuel reservoir was demonstrated with a mockup of the feed section.

Preliminary analyses of microdrill samples indicate that the plutonium distribution is relatively constant in a $(U, Pu)O_2$ pellet irradiated to 1.7×10^{20} f/cc. Of the fission products analyzed (Ce^{144}-Pr^{144}, Ru^{106}, Zr^{95}-Nb^{95}, and Cs^{137}) only Ru^{106} shows a very marked radial variation (10^3) in concentration.

Four short, prototypical EBWR fuel rods containing vibrationally-compacted, depleted UO_2-2.5 wt% PuO_2 were discharged from the ETR after reaching approximately 1850 Mwd/T_{fuel} at anticipated EBWR operating heat flux.

Preliminary examination of two irradiated specimens of vibrationally compacted, pneumatically impacted UO_2-PuO_2 revealed good irradiation performance at high heat ratings, similar to that of pneumatically impacted UO_2.

Analyses of microdrill samples of irradiated, high-heat rated MgO-PuO_2 pellets confirmed significant radial fission product concentration variations that resulted from migration of fission products or plutonium in an immiscible fuel system.

PuO_2 was densified to 95% of theoretical density by pneumatic impaction, and incorporated into pneumatically-impacted PuO_2-stainless steel cermets for irradiation tests. A novel die was designed in which six pellets can be simultaneously impacted.

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The PuO_2 concentration in UO_2-PuO_2 fuel clusters for the PRTR was increased from 0.48 wt% to 1.0 wt%. Four UO_2-PuO_2 and three unautoclaved Al-1.8 Pu test fuel clusters were completed in June for PRTR irradiation.

Loss of UO_2 during arc-melting of UO_2-PuO_2 mixtures was confirmed. The loss is apparently a preferential mechanical effect due to arc-blow.

A PRTR fuel element (vibrated for two weeks) with full-circle end brackets exposed in 530 F, pH 10 water in TF-7 showed fretting as deep as 15 mils at four locations on a rod wire wrap near the center of the fuel element. However, after 87 days of exposure there was no apparent fretting at the end brackets.

Analysis of data from experiments with an electrically heated 19-rod bundle test section revealed that the pressure drop was about what was expected from calculations, but surface temperatures during local boiling were somewhat higher than would be predicted using standard correlations.

The delay in the Doppler effect due to the lag time in transferring heat from PuO_2 to UO_2 in mixed oxide fuels is being investigated. Formulation of this problem has been completed in preparation for analog computer simulation.

Review of cyclic corrosion tests show that repeated use of APOX for decontamination should cause no serious corrosion problems.

Elevated temperature burst tests of pressurized irradiated PRTR pressure tubes show that increasing the test temperature 100 F decreases the ultimate strength by about 10%.

Three coextruded Zircaloy clad thorium-uranium fuel elements attained an exposure of 1680 Mwd/T. This irradiation will continue in the ETR Loop.

The corrosion of thoria dispersion hardened nickel in 600 to 1000 C oxygen fits an equation based on parabolic film growth plus a linear phase boundary reaction. Wrought alloys, 99.97 and 99.997% Ni, corrode more rapidly than TD nickel, by a generally parabolic process.

Increasing the ΔT in the nonisothermal loop from 8 C to 55 C increases aluminum corrosion rates by a factor of 1.5 to 2 at 330 C sample temperature. Increasing water pH from 5.4 to 6.4 also increases corrosion rates by a factor of 1.5 to 2.

Time-lapse photographic recording of tensile tests on irradiated molybdenum single crystals has revealed that for nearly all orientations tested, an offset occurs in the crystal after initial yielding. As plastic flow proceeds, the offset is gradually reduced, but rupture occurs at the point of the offset.

Time-temperature-transformation (T-T-T) curves have been obtained for high quality plutonium (less than 300 ppm total impurities). Compared with previous T-T-T curves, these are shifted in position due to the higher purity of the metal used.

The physical damage associated with the delta-to-gamma and gamma-to-beta thermal cycling of unalloyed plutonium was much less than the physical damage associated with beta-to-alpha thermal cycling. The density decreases were less than 0.01 g/cm^3 per cycle for the former two, whereas the density decrease for beta-to-alpha cycling varied with cycling rates from 0.03 to 0.4 g/cm^3 per cycle for metal of the same quality.

Direct experimental evidence that recovery processes are responsible for tearing in irradiated uranium has been obtained.

Tensile specimens of TZM molybdenum alloy, Cb - 1 Zr, and Cb 752 (Cb - 2.5 Zr - 10 W) alloys have been submitted for irradiation in the ETR. These specimens represent the first refractory alloys to be irradiated under the Irradiation Damage to Reactor Metals Program at Hanford.

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Investigation of the effect of loading rate on 23% cold-worked Zircaloy-2 has shown that Charpy specimens undergo a ductile to brittle transition at -175 C in slow bending as compared to 300 C in impact. A 30 C increase in the transition temperature is realized for a 40-fold increase in loading rate of fatigue-cracked notch beams. These are significant rate effects and are attributed to a deformation mode or a combination of interacting modes, which become operative in the high stress field in the immediate region of the notch.

High frequency induction heating and infrared radiation have both been successfully used as alternate heat sources for controlled-atmosphere tensile testing of refractory metal alloys at temperatures of 1000-1500 C.

Two additional in-reactor creep tests have been started, making three capsules in simultaneous operation. The two new tests are on 20% cold-worked Zircaloy-2 at stresses of 25,000 and 35,000 psi at 350 C (662 F) and 310 C (590 F), respectively. Initial creep rates in these tests are 1.5×10^{-5}/hr and 5.0×10^{-6}/hr.

There was no apparent reaction between molten stainless steel and UO_2 after 90 minutes at 1600 C.

A Pu^{90} vol% PuN cermet was heated for two hours at about 1000 C in vacuum and showed no indication of melting, vaporization, or reaction with the alumina crucible.

Specimens of tungsten carbide, zirconium carbide, tantalum carbide, hafnium carbide and a mixture of two parts hafnium carbide with one part tantalum carbide were densified by pneumatic impaction at 1200 C and 260,000 psi.

A sample of plutonium carbide being irradiated at the MTR has reached an estimated exposure of 6×10^{20} fissions/cc.

The melting points of polyphase PuB, PuB_2, PuB_4, and PuB_6 were determined to be 2030, 1825, 2050, and 2100 C, respectively.

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Square honeycomb cermet grids of good structural quality were fabricated by pneumatic impaction.

A fiber reinforced cermet disc was formed by pneumatic impaction of a mixed bed of tungsten fibers and tungsten-20 vol % UO_2 cermet powder.

Two strong infrared absorption bands, at 5.5 and 10 microns, were found in single crystal UO_2 and appear to be independent of oxygen-to-uranium ratio.

An apparatus to measure the electrical conductivity of UO_2 at temperatures up to 3000 C was put into operation. Electrolysis of liquid UO_2 was observed during the first run.

Vacuum insulated capsules containing Mo-UO_2 and Mo-UN cermets clad in Mo; W-UO_2 and W-UN cermets clad in W; and one UO_2 single crystal clad in W were successfully irradiated in the ETR. Cladding surface temperatures were calculated to be greater than 2000 C.

Vibrational compaction techniques utilizing a long horizontal beam for transmitting energy to multiple rods now permit EBWR-size fuel rods to be loaded routinely with arc fused material to required densities of 86 to 89%.

A study has been started to determine the feasibility of monitoring neutron fluxes by the optical determination of fission fragment tracks in natural mica.

The sixth EGCR graphite capsule has successfully completed two cycles of irradiation in the GETR.

Further analysis of irradiated boronated graphite samples disclosed migration of boron from one sample irradiated at 540 C, but no migration from graphite irradiated at 315 C. The migration is thought to be related to the presence of water vapor. Analyses for lithium, formed by slow neutrons in the reaction B(n, α)Li, agreed reasonably well with estimates based on neutron exposure.

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A second in-reactor aluminum corrosion test using nonfueled samples was completed in H-1 Loop using water at pH 4.5 with phosphoric acid. The in-reactor corrosion rates were lower than out-of-reactor rates and there appeared to be some difference in corrosion rates for different alloys.

Based on a revised core design for a 300 mw(e) Fast Supercritical Pressure Power Reactor, a fuel cycle cost is estimated at approximately 1.5 mills/kwh, which compares with an originally anticipated value of about 1 mill/kwh and a cost of 1.72 mills/kwh for the thermal SPPR.

2. Physics and Instruments

An improved measurement of the control strength of samarium balls is being conducted in the N-Reactor exponential pile mockup. The present mockup—more closely simulates the ball channels in N-Reactor than those of previous experiments.

Scheduled exponential pile experiments on the C Pile overbore program were completed this month. A final report is being prepared.

Using Zirconium process tubes, measurements continued on the reactor physics properties of the K-Reactor lattice. Measurements on poison spline samples were completed in this lattice.

Investigations continued on theoretical laws for the scattering of neutrons by graphite and water. Several computer codes have been modified and adopted for these studies.

One of twenty-four gamma energy spectrometers being built at APED for use in the N-Reactor Fuel Rupture Monitoring system was tested at the fabricator's plant; results were favorable. Fabrication of the other units is nearly completed; their shipment to Hanford is expected soon.

Progress on the PRTR experimental Fuel Testing Loop includes: ordering of flow controlling equipment; preparation of specifications for scintillation monitoring systems, line regulation equipment, and pulse generators; and placing of orders for relay rack cabinets and accessory equipment.

The multidecade N-Reactor kinetics startup model was used to study the reactor startup process and various transient conditions. The N-Reactor pressurizer model is now operational.

Subcritical neutron multiplication measurements continued in the Critical Mass Laboratory using plutonium oxide-polystyrene compacts to mock up a polymer which could form in chemical separations plants. The preliminary data indicate the critical mass to be about 34 kg of plutonium for a hydrogen-to-plutonium atomic ratio of 15. The experiments also showed that movement of fuel would be the best method for controlling reactivity in this experiment. Also evaluated were the reactivity effect of separating the table halves and the neutron reflecting properties of the support structure.

Nuclear safety consulting services were provided on four problems in Hanford Laboratories, on one problem in N-Reactor Department and on one off-site shipping problem.

Correction of an error in the method for calculating the buckling of partially filled spheres of fissionable material has increased the accuracy of this method. In other critical mass physics work, reflected cubic arrays of cylinders measured critical at Oak Ridge were analyzed yielding calculated results that agree with their experiment to within 0.2% in one case and 2% in another.

Studies of the scattering of slow neutrons by 95 C light water were resumed during the month. Measurements were made to improve the statistical accuracy of previous results and to provide direct comparison with results previously obtained with room temperature light water.

Fast neutron cross-section measurements were made on 22 elements this month. New data were obtained on Ce, Yb, and Pb^{206}. First Hanford measurements were made on six other elements. Repeat measurements were made on 13 elements.

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Studies of high exposure PuAl fueled graphite lattices continued with analysis of recently completed experiments which used 19-rod clusters having 20.6% Pu^{240}.

Isotopic analyses were made on 51 samples from three fuel elements which had been irradiated in the PRTR.

PRCF measurements continued in support of the startup of this facility. Control rod calibrations were performed. Transient response of the reactor was measured through kinetics experiments. Design started on a pile oscillator for use in the PRCF.

Design criteria for the HTLTR were approved by the Richland Operations Office of the AEC, and design work has been started. A formal report describing the HTLTR was written. Studies began on problems associated with the compatibility of the proposed nitrogen atmosphere with components of the HTLTR.

Investigations of control rod effectiveness in a plutonium reactor environment reported last month have been extended to include Hf rods of various thicknesses. Results indicate that effectiveness generally decreases with increased Pu^{240} content which is similar to the results obtained on a 1/v absorber. Work continued on evaluation of temperature coefficient of Phoenix-fueled cores. For the reactor analyzed, the coefficient was strongly negative as the temperature increases.

Analyses indicate that 100 gram samples of various plutonium composites are sufficient for measuring the reactivity coefficients in a fast spectrum critical facility. Negotiation for the performance of such measurements in a fast critical at Idaho Test Station will begin in July.

In "fuel re-use" studies, it was found that a Fermi blanket element placed in the PRTR would have a peak-to-average power ratio of 2.31, while a uniformly enriched rod would have a ratio of 1.55. If the blanket rod is cut in the center and both halves flipped (so that the middle of the old rod forms the ends of a new one) the peak-to-average power ratio is reduced to about 1.61.

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Extensive work continued on physics codes development. A series of cases which tests the various available options in CALX burnup code is being run for reference and checkout purposes. Cross section data for HRG are being obtained from the RBU library. This code should soon be ready for general use. A recipe for cross sections in program S-4 was determined which yields flux depression factors for program GROUSS that are in satisfactory agreement with the multigroup, multiregion program THERMOS. The one-dimensional, two-group survey burnup code, ALTHAEA, was used in burnup analysis of the NRX fuel element, and good agreement was obtained with experiment. The development of the RBU code continued. Plans to distribute off-site, a customer-oriented package consisting of the RBU basic cross section library, and supporting library processor programs and documentation, have been formulated.

New physics methods developed for analyzing plutonium-uranium oxide-fueled, light water moderated reactors have stimulated confidence as a result of comparisons with experimental data. Eleven critical experiments, six enriched uranium oxide (Yankee power plant fuel) and five Pu-Al, were analyzed using the GAM-THERMOS-HFN system of physics computer codes. The calculated multiplication factors for the critical assemblies differed from the experimental value of unity by less than 1.5% in all cases and less than 1.0% in seven cases.

Regenerative neutron flux detectors containing 28% Pu^{239} and 72% Pu^{240} have been fabricated and made ready for reactor irradiation. Arrangements are also being made to irradiate three Boron-11 detectors which have been checked out in the laboratory.

Experimental data have been obtained which suggest the multiparameter eddy-current nondestructive test instrument can separate three parameters when two of the parameters are changing simultaneously. One would not expect this from theoretical considerations, however, and the effect is receiving further study.

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Three-sixteenths-inch, spherically focused transducers have been selected for use in the ultrasonic tubing inspection station being developed under the AECL-USAEC cooperative program. Final transducer design will be made firm as development of a novel method of generating two beams simultaneously is completed. One beam will provide a signal to which electronic gating circuits can be accurately referenced. Fabrication of the electronic portions of the prototype station is about 90% complete.

A satisfactory method of molding Teflon center rods for use in recharging personnel dose meters has been developed. Detail planning for the purchase of 25 instruments is nearing completion.

The dependence of the peak exposure on the time of plume travel has been investigated for 363 atmsopheric physics field experiments. These experiments include ground source diffusion data collected at Hanford; Arco, Idaho; Dugway, Utah; Cape Canaveral, Florida; Vandenberg Air Force Base, California; and O'Neill, Nebraska. When the differences in emission time, stability, and horizontal growth are factored into the analysis, the data from the different locations compare favorably. Before this analysis, the differences in the diffusion measurements obtained at the sites had not been explained; this caused disagreement among investigators regarding the values of the diffusion parameters and their relation to the meteorological variables. The Hanford summarization has resolved many of these differences.

Personnel left for Alaska to begin the summer program of measuring radioactivity in Eskimos with the portable whole body counter. Other radiological physics work included the start of a study on use of spherical moderators for neutron dosimetry and development of more sensitive methods for calorimetry.

Capability for grinding and polishing laser rods to optically flat tolerance is being developed in the optical shop.

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3. Chemistry

The efficiency of 15 commercial agents for metal coating in reducing adsorption of reactor effluent radioisotopes was tested in 30-day exposures of coated aluminum coupons in reactor tubes downstream from the flux zone. The four superior agents (including two marking inks and two silicone resins) reduced radioisotope adsorption by factors of 1.4 to 2.6, 2.4 to 4.2, and 1.7 to 3.3 for As^{76}, P^{32}, and Np^{239}, respectively.

Operation of the experimental water treatment plant (feeding two KE tubes) with aluminum nitrate as the flocculent and zeta potential as the primary control index is yielding both water of lower turbidity and longer filter runs (8 hours versus 5 hours) than were obtained with the conventional water treatment.

Using effluent Na^{24}, Ni^{65} and Ga^{72} concentrations as indices of relative corrosion rates, half-reactor tests at F-Reactor disclosed no significant differences for high and low alum treatment. However, half-reactor tests at D-Reactor indicate a lower rate of corrosion at pH 6.6 than at pH 7.0.

Results of heating tests (500 C) of unirradiated aluminum-clad bismuth elements indicated that the integrity of the aluminum can was nearly lost in less than one hour. Thus, irradiated elements should be maintained below the melting point of bismuth (271 C) to prevent bismuth escape during shipment or storage.

Continued observation of the Sr^{90} loaded zeolite cartridge (which is releasing about 50 watts) showed no significant stable pressurization at 460 C. Some transient pressure excursions to ca. 30 psig are observed at 500 C and are not easily explained in terms of known properties of zeolites and radiolytic phenomena.

Use of immersion electrical heaters, instead of hot air, for the concentration and subsequent in-tank solidification of wastes appears promising.

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Studies with synthetic feeds showed that the previously-reported oxalate precipitation-caustic metathesis procedure (for extraction of rare earths from waste tank sludges) can be adapted, with minor modifications, to accommodate the high lead content found in Purex tank 106A sludge.

Radiochemical studies of promethium have shown the low abundance 0.121 Mev gamma (previously reported by other investigators, and inconsequential in terms of promethium shielding requirements) to be in identical ratio to Pm^{147} bremsstrahlung in promethium aged two and eight years. This implies that the 0.121 Mev gamma is emitted by Pm^{147} and not other promethium isotopes.

Pot calcination of wastes containing high concentrations of sodium nitrate are found to foster fission product cesium evolution during processing and pressure build-up during storage of the calcine.

A mixed bed of Dowex-1 and Dowex-50 resins showed promising results for ruthenium removal from Purex process acid recovery condensate. About 90% of the ruthenium was removed from 600 column volumes of condensate.

Repetitive laboratory-scale flowsheet cycles were made in order to demonstrate the integrity of Duolite C-3 resin during processing of Redox alkaline supernatant waste for cesium removal. Sorption properties did not change and less than 5% of the resin was lost during the test.

Based on laboratory-scale studies with synthetic CSREX 1BP solution, Linde 4A zeolite appears to be a satisfactory packaging material for the cesium and strontium products.

Cracks observed in the Inconel X, 18-inch, radiant-heat spray calciner are believed caused by mechanical stresses and lack of solution heat-treatment of welds. A new, versatile unit fabricated of Hastelloy X is now under test.

Ninety-seven percent recovery of cerium as CeO_2 at 85% purity was obtained on thermally decomposing $Ce(NO_3)_2$ in a $Mg(NO_3)_2 \cdot 6H_2O$ flux, a process under study for the separation of fission product cerium from promethium and other rare earth elements.

No evidence was obtained to support the postulate that spheroidized structure in the weld zone is responsible for the initiation of cracking in mild steel welds.

Solid state electromigration (a Process wherein impurities are depleted in heated solid metals by passage of direct current) has been tested for the first time in plutonium metal.

Molten salt electrochemical studies with the CsCl-LiCl eutectic (58 mol% LiCl) indicate that somewhat improved rare earth decontamination and increased co-deposition of PuO_2 with UO_2 are obtained in this melt than in equimolal LiCl-KCl. Co-deposition of PuO_2 and UO_2 is so favorable that it is doubtful that the two could be separated by electrolysis.

A field test of the sand-pack installation of piezometers in test wells was demonstrated to be superior to previous methods both in installation cost and time.

Field work on the seismic survey was completed on schedule with results appreciably exceeding expectations. In addition to the survey results, valuable information was gained on drilling and well logging techniques.

4. Biology

The Symposium on the Biology of Radioiodine was held on June 17, 18, and 19. It was the second in the series, the first one being held in May 1962. One hundred forty scientists from off-site registered along with 75 on-site registrants. From all reports, the meeting was highly successful.

There appear to be no significant effects on swimming ability of young chinook salmon raised in reactor effluent concentrations of 3 and 6% and in the presence of sodium dichromate and quachrome glucosate. Detailed statistical analysis of the data is not complete.

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Further studies with Vertan 690 (proposed for cleaning NPR pipes) indicate an LD_{10} of 1500 to 2000 ppm for trout and chinooks, respectively. Algae were affected at 10,000 ppm but not at 300. Bacteria (E. coli) were affected at 1000 ppm but not at 100.

A high incidence of columnaris infection was noted in fish taken from the Yakima River. At the same time, a very low incidence was noted in fish taken from the Columbia River, suggesting that this year, at least, the Yakima River is a primary source of this organism.

A markedly increased stable iodine intake in the dairy cow is followed, after cessation of iodine supplementation, by 6-to 8-fold increases in thyroid I^{131} uptake. Milk concentrations of I^{131} increased 50 to 75% in the 7days following cessation of stable iodine feeding.

Comparison of thyroid damage in sheep from I^{131} administration or external X ray indicated an approximately 20-fold greater effect from X ray, although damage from the two sources was not strictly comparable.

The ethyl ester of DTPA appears to be less effective than DTPA itself in removal of deposited Pu from rats, although certain differences in the pattern of removal (higher fecal Pu excretion with the ester) deserve further study.

Efforts to influence the translocation of subcutaneously injected Pu in swine by local injections of chymotrypsin or by application of cold packs or tourniquets were without sufficient beneficial effects.

A dog has died 1204 days following deposition of 6.29 μc of Pu^{239} in its lungs. About one-third of the initial deposit was retained in the body at death, with 49% of that retained being present in lung, 18% in bone, and 5% in liver. The highest Pu concentration was present in bronchial lymph nodes--500 times higher than the average concentration in lung and 5000 times higher than the average concentration in bone.

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Studies are in progress to determine the usefulness of the Physical Constants Test Reactor for neutron irradiation studies in rats.

Iodine-131 levels in deer and elk thyroids from California, Maryland, Montana, and New York were all below detectable limits (0.01 nc/g wet wt).

Preliminary data from one inland village in Alaska indicates an average increase, over last year, of 25% in the Cs^{137} body burden. The maximum value obtained in 1962 was 790 nc, and in 1963, 1230 nc. The Eskimos of this village utilize large amounts of caribou for food and had higher body burdens in 1962 than did members of other villages. Data from other villages and foods will indicate whether this is a general increase or specific for this village.

5. Programming

The computations for the study of Cm^{244} production in central station power reactors are being completed. All codes and data tapes were brought to final form. The balance of the effort has been in the direction of writing a code to organize, summarize, and plot the results. After examing the results of extensive efforts to establish equitable dollar values for Pu^{239}, Pu^{240}, Pu^{241}, Pu^{242}, and Am^{243}, a more limited definitive study was designed to complete this part of the program.

The conservation of fissile material in a variety of reactor types for both batch and graded irradiation was studied. The batch and the graded irradiation methods are idealized extremes that will bracket most practical methods. Using the batch cycle, it is presumed that the excess neutrons are absorbed in the control system while in the graded cycle no neutrons are lost to the control system.

Four different fuel conservation indices are computed in this analysis. Each is the ratio of the heat produced during the irradiation in megawatt days to some amount of fissile material in grams. They are quite strongly dependent on reactor type. This analysis technique is now being applied to plutonium recycle fueling systems which will include successive recycle.

It has been shown that the value of the plutonium bred in a thermal reactor is proportional to the price of fully-enriched uranium. The effect on the fuel cost of ignoring this finding was investigated for graded irradiation in a water-moderated- and heavy-water-moderated reactor simulation. The results show that neglecting to adjust the plutonium credit with an increase in the price of uranium can cause a significant difference in the fuel cost when the price of natural uranium is as low as $50 per kilogram.

The design criteria for the heating and cooling of the HTLTR were reviewed. A number of changes in the proposed equipment were recommended, including reduction of the core heating input, elimination of the saturable reactor for heating control, enlargement of the cooling system, and provision of a coolant backup for the gas system. These changes were, in general, favorably received in a June 27 discussion with members of HL and CE&UO, and should simplify the design task of the architect-engineer.

TECHNICAL AND OTHER SERVICES

One new plutonium deposition case was confirmed during this month. The body burden for this employee was estimated to be 4% of the maximum permissible body burden. There were two plutonium incidents involving 14 employees which required special bioassay sampling to determine if internal deposition had occurred. Pending bioassay results, the total number of individuals who have received internal plutonium deposition at Hanford is 318. With the resignation of one employee, the number of these deposition cases currently employed remains at 229.

The City of Richland began feeding filtered Columbia River water into the municipal water system. Columbia River water has been used since early May to recharge the North Richland well field.

A minor spread of particulate contamination occurred at the 100-K Area. The origin of the particles appeared to be one of the retention

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tank which had been allowed to dry. Surveys of ground surfaces showed above normal concentrations (3 particles per 100 square feet) up to four miles southeast of the 100-K Areas.

Calibration of the mobile whole body counter was completed. Orientation meetings and inspections of this mobile facility were held for members of the management staffs of the Chemical Processing and Irradiation Processing Departments.

A systematic sequential sampling plan was developed for inspection problems on N-Reactor facilities.

Analysis of diffusion data from hot-die-sizing end-bonding shows that the depth of the Al-Ni diffusion layer and the type of bond depend quite strongly on time and temperature. The reported results included prediction formulae from which the experimenter can determine the canning conditions which lead to the desired bonding characteristics.

Assistance was given in the interpretation of the operating characteristics of the present acceptance specifications for the percentage of U^{235} in natural and enriched uranium. It was determined that while the procedure gives very little chance of rejecting a good ingot it also has very little power to detect out-of-specification ingots under many conditions.

The use of cumulative sum control charts was recommended and adopted for controlling two variables associated with weapon component chemical specifications.

A new boundary value approach is being taken toward the solution of the nonlinear system of second order differential equations which express the mass transfer of uranium from organic to aqueous streams in the experimental pulse column. In connection with this same work further statistical analysis was done on the organic volume fraction profile data from a block of 48 experimental runs.

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A systematic design was constructed for an experimental program to investigate the chemistry of the hydrozine reduction of $[N_p^{+5}]$.

A computer program was written for the numerical inversion of a Laplace transform. Investigation to improve the accuracy of the inversion over a larger range of conditions is continuing.

A regression analysis is being done of plutonium homogeneous spherical critical mass experimental data to determine the relative merits of several reactor physics code systems which theoretically calculate k_∞ and critical mass. It is hoped that this study will show which of the systems does the best job of simulation for the plutonium homogeneous spherical system and that it will point up any inconsistencies in the physics and chemistry input data.

SUPPORTING FUNCTIONS

PRTR output for June was 1289 Mwd (a new monthly record) for an experimental time efficiency of 76.1% and a plant efficiency of 61.4%. There were nine operating periods during the month, of which seven were terminated manually and two were terminated by scrams. A summary of the fuel irradiation program as of June 30, 1963, follows:

	Al-Pu		UO_2		PuO_2-UO_2		Other		Program Totals	
	No.	Mwd	No.	Mwd	No.	Mwd	No.	Mwd	No.	Mwd
In-Core	15	1017.5	12	1652.4	58	3027.7			85	5697.5
Maximum		105.7		183.8		95.2				
Average		67.8		138.2		53.2				
In-Basin	28	1850.7	54	3724.7	12	464.2	1	7.3	95	6046.9
Chemical Processing	32	2309.3	1	78.0	—	—	—	—	33	2387.3
Program Totals	75	5177.5	67	5455.1	70	3491.9	1	7.3	213	14131.7

Note: (Mwd/Element) 20 Mwd/T_U for UO_2 and PuO_2-UO_2

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A total of 81 reactor outage hours were charged to repair work. Main items were:

Installation of new effluent activity monitors (DC 182)	- 16 hours
Helium compressor repairs	- 14 hours
Primary pump repairs	- 28 hours
Helium valve repairs	- 10 hours

June was an excellent achievement month in heavy water loss reduction performance. This was the lowest heavy water loss for an "operating month yet experienced. Losses for June were 555 pounds ($7700) and scrap generated was 1902 pounds ($1818). Heavy water accumulated through June 30 for return to SROO amounted to 9669 pounds valued at $121,629.

The PRCF was operated routinely for 20 days. Shutdown for irradiated fuel preparations and moderator heater tie-in consumed 10 days. The cadmium bullet experiment was accomplished without incident.

The installation of the Rupture Loop test section in B Cell is complete except for radiography of one weld repair.

Blower procurement for the Gas Cooled Loop Facility has been completed and the three blowers are installed in the loop. The project is 98.6% complete; the remaining work, test section installation, will not be done at this time.

Total Technical Shops Operation productive time for the month was 27,840 hours. Distribution of time was as follows:

	Manhours	Percent of Total
N Reactor Department	2,748	9.87
Irradiation Processing Department	5,482	19.69
Chemical Processing Department	311	1.11
Hanford Laboratories	19,289	69.29
Construction Engineering & Utilities	10	.04

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Total productive time for Laboratory Maintenance Operation was 17,100 hours of 19,400 hours potentially available. Of the total productive time, 88.5 was expended in support of Hanford Laboratories components with the remaining 11.5% used in providing service for other HAPO organizations.

Manpower utilization for June was as follows:

A.	Shop Work		2400 hours
B.	Maintenance		6500 hours
	1. Preventive Maintenance	1500 hours	
	2. Emergency or Unscheduled Maintenance	1800 hours	
	3. Normal Scheduled Maintenance	3200 hours	
	4. Overtime (included in above figures)	2300 hours	
C.	R&D Assistance		8200 hours

Visitor presentation activity figures show:

	Number of Visitors	
	In June	Since 6-13-62
Visitors Center	3718	47 780
Plant Tours	314	--

HAPO professional recruiting activity this month is given below:

	Plant Visits	Offers Extended	Acceptance Received	Rejections Received	Open Offers at Month End
Ph. D	13	12	8	5	11
BS/MS (Direct Placement)		12	11	7	3
BS/MS (Program)		2	5	27	4

Six technical graduates were placed on permanent assignment. Thirty-four additions to the program were effected and two terminations occurred. The total number of graduates on the program at month end was 60.

Authorized funds for ten active projects total $6,435,000. The total estimated cost of these projects is $10,680,000 of which $698,000 had been spent through May 31, 1963.

HM Parker

Manager, Hanford Laboratories

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REACTOR AND FUELS LABORATORY MONTHLY REPORT

JUNE 1963

TECHNICAL ACTIVITIES

A. FISSIONABLE MATERIALS - 02 PROGRAM

1. Metallic Fuel Development

Phosphorus Impurity in Uranium. Investigation was continued on the effects of phosphorus impurity on uranium structure, fabricability, properties, and fuel element quality.

Examination of NIE fuel containing 300 ppm phosphorus in the as-extruded, beta heat treated, and braze heat affected conditions was completed. No detrimental effects on bonding or core structure were observed. Tensile property data to 200 C are shown in the following table. Phosphorus lowers the room temperature ductility and ultimate strength. At temperatures of 100 C and higher no differences due to phosphorus are noted.

Attempts to prepare higher phosphorus contents by arc melting buttons of uranium with UP have resulted in structures composed of uranium, uranium-UP eutectic, and an additional compound that is apparently a uranium-oxygen-phosphorus phase. The complete eutectic structure has been observed in segregated sections of these melts but not in quantities satisfactory for analysis.

Sulfur Impurity in Uranium. An alternate uranium scrap recovery process at NLO will use uranyl ammonium sulfate (UAS) to replace the uranyl ammonium phosphate (UAP) feed to the Winlo process. The effects of sulfur addition to uranium are being studied. Arc melt buttons were prepared using uranium and US to yield approximately 5000 and 2500 ppm sulfur. Compound formation was observed that was confirmed as US by J. W. Colby at NLO by electron microprobe examination. Variable sulfur content in the compound was observed, indicating either "coring" or variable oxygen content in the US phase. Specimens were held four hours at 800 C and either water quenched or slowly cooled. Apparent eutectoid decomposition of either the gamma or beta structure was noted. The quenched sample appeared to retain the sulfur content of the eutectoid in solution.

Alternate Core Materials. The particle size and distribution of intermetallic compounds in standard N-fuel (150 Fe - 100 Si) is being

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EFFECT OF PHOSPHORUS CONTENT ON TENSILE PROPERTIES OF URANIUM*

Coextrusion No.	Phosphorus Content, ppm	Test Temp., °C	0.2 Yield Strength, 1000 psi	Ultimate Strength 1000 psi	Elongation, % in 1-inch gage
1151	< 50	Room temp.	56.1	132.2	17.5
		100	40.2	99.0	26.0
		200	43.4	72.3	27.0
1779	170	Room temp.	54.3	100.5	7.0
		100	44.0	97.8	23.0
		200	39.6	72.3	30.0
1861	296	Room temp.	47.0	110.1	13.0
		100	43.1	94.2	23.0
		200	40.8	75.9	26.0

*Samples prepared from NIE coextrusions in the beta heat treated condition.

All standard Fe and Si addition.

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determined for material in the single beta heat treated, braze heat affected and single beta heat treated, and the straightened and re-beta heat treated conditions. These data will serve as a basis for comparison of alternate compositions being studied as dispersed phase systems.

Material from arc cast buttons of (1) U - 1 w/o Zr - 200 ppm Fe - 350 ppm Al, (2) U - 1 w/o Zr - 350 ppm P, and (3) U - 400 ppm Fe - 700 ppm Al was treated three days at both 800 C and 1050 C, water quenched, and reheated 100 hours at 600 C. The resulting structures and distribution of intermetallic compounds are being studied by optical and electron microscopy.

Closure and Joining. Corrosion tests in 360 C water have continued on the alloy coupons of the zirconium + beryllium, zirconium + beryllium + uranium and Zircaloy-2 + uranium series. The following results have been obtained:

1. Zirconium containing 4, 4.5 and 5 w/o Be has turned white after 810 hours and the weight gains have increased sharply.

2. Zircaloy-2 containing 0.5 and 1.0 w/o uranium remains glossy black after a 390-hour exposure. This behavior should not be expected in the reactor but does clearly show that autoclave testing is not a suitable means of detecting uranium contamination in the Zircaloy-2 cladding.

3. Zirconium containing 250-2500 ppm uranium with 1, 2, 3, 4, and 5% beryllium shows a decreasing corrosion resistance with increasing beryllium after 100 hours in 360 C water. The coupons containing 1 and 2% Be with up to $\frac{1}{4}$ w/o uranium have the same appearance and weight gains as the 4 and 5% Be with no uranium additions. Above 3% Be with uranium the coupons turn white in the autoclave.

Light adsorption measurements of the corrosion film appears to be a valuable tool in studying the corrosion behavior of zirconium alloys. Slight, but consistent changes in the light adsorption appear before either a visual color change or a significant weight gain rate occurs. The light adsorption will increase sharply 10 to 50 hours prior to formation of a noticeable gray film.

Self-Brazed Closure. A test lot of N-Reactor inner tube specimens for irradiation under a production test utilizing the self-braze closure was completed. Work is proceeding with the adaptation of similar principles to the development of a satisfactory closure for

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N-Reactor outer tubes. This work involves: (1) selection of usable tube stock to make working material for test pieces, (2) applying nondestructive tests to this material to insure suitable quality, (3) cutting stock to working length, (4) recessing and shaping ends, (5) fabrication and fitting of cap rings, (6) plating and "tinning" cap rings, (7) assembling and welding closures, (8) modification of the Sciaky welder to accommodate specimens, (9) processing specimens in the welder, (10) evaluation of results, and (11) repetition of processing with modifications as indicated by results.

Hot-Headed Closure Studies. The procedures currently used to produce sound projection welds on hot-headed NIE type fuel elements utilize ring projections which are machined 0.030-inch wide at the base of the projection. After projection welding the weld widths are approximately 0.035-0.040-inch on the OD and 0.030-0.035-inch on the ID. By increasing the width of the machined projections from 0.030-inch to 0.040-inch the weld widths increased to approximately 0.045-0.050-inch. This increase in size would make the projection welds slightly larger than the cladding thickness. The quality of these welds was not as consistently sound as the narrower welds. This variation in quality is attributed to current limitations of the laboratory equipment. It is believed that welding equipment with greater current capacity would consistently produce the larger projection welds.

A series of samples were welded using different postheat time and current levels. It was demonstrated that a variety of postheat schedules can be used to obtain bonding of both the uranium-copper-Zircaloy and the Zircaloy-copper-Zircaloy joints. In general, it is evident that uranium-copper-Zircaloy bonds are accomplished before the Zircaloy-copper-Zircaloy joints are bonded. Apparently the uranium in the vicinity of the joint reaches the melting point during a successful closure weld.

A series of samples were made using different amounts of copper in the joint interface. The amount of copper was varied by controlling plating time. Although these studies are not complete, metallographic examination of single cross sections of each joint showed no apparent differences in the uranium-Zircaloy joints but did show improvement in joint geometry and thickness of the Zircaloy-Zircaloy joints as the amount of copper was reduced.

Detailed drawings were completed of tooling for Hanford tests employing the 1200 KVA welder at the Rocky Mountain Arsenal.

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Examination of Irradiated "N" Fuel Elements. The post-irradiation examination of two inner fuel element components irradiated at near prototypic conditions in KER is in progress. No unusual features or unsatisfactory performances have been revealed. The examination will continue with particular emphasis on the "buggy spring" type supports used on the inner component. Examination of three outer tubes from the same prototypic irradiation test has been completed with satisfactory performance and behavior being noted.

A charge of 14 NAE's was discharged from a KER loop after attaining an average exposure of 1800 MWD/T. The first two-thirds of the exposure was conducted at N prototypic conditions and the last one-third was conducted at reduced coolant temperatures. Analysis of the "weasel" data reveals a maximum assembly exposure of 2860 MWD/T. Post-irradiation weighing in the basin for swelling determinations shows a range of 0 to 1 v/o fuel swelling in the inner components and 0.3 to 2.5 v/o fuel swelling in the outer components. Initial basin examination indicates the components are free of any severe warp with no indication of crud deposition or corrosion. Ultrasonic nondestructive examination by Testing Methods indicated the fuel in the outer components was crack-free except for one component which had been dropped 10 feet during handling.

Five NIE's irradiated in KER Loop 1 to an average exposure of 1400 MWD/T were found to have experienced fuel swelling in the range of 0.7 to 1.3 v/o. These elements operated in ammonia pH controlled coolant and appear to have performed satisfactorily.

Tapered End Cap Irradiation Test. Eight N-inner fuel components with tapered end caps have been irradiated to 1900 MWD/T in KER Loop 2. Four of these elements have braze bonded and TIG welded caps, and the other four have unbonded electron beam welded caps. The calculated surface temperature ranged from 168-226 C. The elements operated at a specific power above that anticipated for N-Reactor conditions. Density measurements in the basin indicate the swelling to be 0.5-1% with no significant difference between the bonded and unbonded elements. Visual examination in both the basin and in air in Radiometallurgy showed no abnormalities in any element. Longitudinal sections of both ends of an unbonded and a bonded element were prepared and examined. They revealed some brittle-type cracking in the uranium between the tapered portion of the caps and the OD cladding on both elements. The cracks in the bonded element extended through the braze layer to the cap, but in neither element did the cracks extend into the cladding. No evidence of clad shearing, as experienced with flat, flush, unbonded caps, was observed.

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Fluted Fuel Element Irradiations. Two fluted, single-tube N-Reactor size fuel elements have completed four cycles of irradiation (800 MWD/T) in the ETR M-3 facility. These elements are being tested under conditions approximately equivalent to N-Reactor operating conditions.

Fuel Component Development. Irradiation of four Hanford I&E fuel elements was completed in the MTR GEH-4 loop facility to investigate the possible occurrence of large volume increases (grain boundary tearing) at intermediate irradiation temperatures. A calculated maximum exposure of 3100 MWD/T was achieved in this test with the maximum fuel temperature calculated to be approximately 700 C. These elements were discharged on June 17 and will be returned to Hanford for examination.

Cladding Deformation Studies. Thirty-six NaK capsules containing a total of 94 Zircaloy-2 clad uranium rods have been irradiated to provide data on cladding strain capabilities as a function of cladding thickness uniformity, temperature and exposure. Nine of these capsules were discharged at 1100 MWD/T and the remainder at approximately 1800 MWD/T. The low exposure capsules have been opened and initial visual examinations made on the 25 fuel samples. All seven samples which had intentionally extruded striations of a depth of 30% of the nominal 0.025-inch cladding thickness show necking on the external cladding surface. Five of the eight samples with striations of 15% of the cladding thickness show necking, and three of the eight samples with no intentional striations showed necking indications on the external cladding surface. The one sample with a nominal cladding thickness of 0.035-inch and an intentional extruded striation of 30% did not show any indications of necking. Diameter measurements are being made in order to correlate total strain with the onset of visible localized deformation. Examination of the remaining capsules which were discharged at an estimated exposure of 1800 MWD/T will start in July.

Irradiation of Thorium-Uranium Fuel Elements. Three Zircaloy-2 clad thorium-2.35 w/o U-235 - 1.0 a/o Zircaloy fuel elements completed their second cycle of irradiation in the ETR P-7 Loop. The maximum exposure after two cycles is 1680 MWD/T. The fuel elements will be weighed to determine the extent of swelling, and will be re-installed for a third cycle of irradiation.

N-Reactor Fuel Support Development. In the assembly of the inner and outer tubes which make up the N-fuel it is necessary to "size up" the inner supports to center the inner fuel and produce a specified spring constant in the inner fuel support system. The

sizing operation is done by mechanically deforming the support to decrease its length and increase its height after the inner fuel is in place. This operation is done after the fuel components have been autoclaved. Although the supports have more than adequate ductility to take the sizing deformation without damage in the as-fabricated condition, it was found that sizing would produce cracks in autoclaved supports. This susceptibility to cracking was found to result from the presence of hydride platelets which form in the Zircaloy-2 during slow cooling in the autoclave. The crystallographic orientation of the zirconium in the loops of the supports was such that the hydride platelets formed approximately normal to the inner surface of the bend. Since the sizing operation places this region of the part in tension, the hydrides act as crack initiators. It was found that a solution anneal at 300 C followed by rapid cooling will eliminate the large platelets and restore the ductility of the support.

Although the solution treating appears to provide an immediate solution to the problem, additional improvements such as reduction of hydrogen pickup during fabrication and changes in texturing of the strip are being studied.

Fuel Element Support Fabrication. Metal Fabrication Development is currently fabricating a second lot of 30,000 N-outer fuel element supports. Total parts produced for the period May 16 through May 31 was 30,000 parts. Improved delivery of strip from NRD has permitted fabrication of approximately 23,000 parts for the period June 17 through June 21.

Fuel Component Development. Laboratory tests to study possible damage to N-Reactor process tubes by charging N-fuel elements are proceeding. Tests are being conducted to determine to what extent the reactor process tube is damaged by the repeated corrosion of the bare Zircaloy-2 that is exposed as a result of scratching by the fuel element supports. The test cycle consists of passing steel support shoes 40 times over a single path on the process tube, then autoclaving the tube in 400 C, 1500 psi steam for 14 days to give the corrosion product buildup on the bare Zircaloy-2 equivalent to that expected to form in-reactor between the charge and discharge of the fuel elements.

The sixth autoclave cycle has been completed and 40 passes made on the process tube in the same damaged region as the previous tests. After the third, fourth, and fifth autoclave cycles, 50 passes with steel shoes were made with no sign of scratching the process tube

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and it was necessary to intentionally initiate scratching in order to continue with the original purpose of the tests. However, in this last cycle the scratching started immediately. The maximum total depth of the damaged region after the last 40 passes is 0.0025-inch and the average over the length of the tube is 0.0016-inch. From the data in these tests, the increase in scratch depth per cycle is 0.00035 to 0.00045-inch. This rate of wear extrapolates to 0.018 to 0.023-inch in 2000 passes as compared to a maximum of 0.003-inch wear in a test in which 2000 passes were made on a tube without intermediate autoclaving.

There may be two reasons for the difference. The removal of the autoclave film formed between each series of passes may result in deeper total scratch depth in the cyclic scratch-autoclave test, or the autoclaving cycle at 400 C may cause recovery of some of the cold-work induced in the surface of the tube during the scratching test. In-reactor the cold worked surface of the tube would not be annealed as in the autoclave, but there would be a corrosion film formed.

To determine how much of the damage is caused by removal of the corrosion film and what the possible annealing effects are in the autoclave tests, two new series of tests have been started. In the first test a section of process tube, designated as section B, is scratched with 50 passes of steel shoes and then is heated in vacuum at 400 C for 14 days. This is the same heating cycle as used in the autoclave tests. A second series of 50 passes made after one heating cycle increased the scratch depth 0.0002-inch. The test will be repeated on the same damaged section of the process tube for further comparison with the cyclic autoclave-scratching tests.

The second test being made on process tube section A consists of 50 passes with steel shoes followed by a heating cycle of 400 C for 14 days in a vacuum. The first 500 passes resulted in a maximum scratch depth of 0.0012-inch, and the second series of 500 passes after a heating cycle did not increase the scratch depth.

Analysis of Fuel Element End Caps. The difference in thermal expansion between fuel and end cap materials in metallic fuel elements is a potential cause of fuel element failures. A numerical method of stress analysis for shaped end closures with thickened or reenforced cladding near the end cap has been developed, programmed, and numerically evaluated. General case studies have been run for transitions with linear and power laws of thickening. These studies indicate that major reductions in bending stresses can be obtained

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with the use of transitions. The linear thickened cladding, when properly designed, will give the lowest bending stresses throughout the cladding region. The transitions described by power relationships have nearly the same bending stresses, have lower bending stresses near the end cap, and are less critical in regard to the length or height of the transition zone. Actual case studies have been run for "N" inner and "N" outer fuel elements.

A series of cases were run which represent the geometries encountered in the hot-headed closure technique. The case studies run on these geometries showed that the bending stresses for the closures presently being formed were from two to three times less than those encountered in closures without transitions. The general case studies and the designs for the N-Reactor closure are described in the document HW-77816.

Besides the mechanical analyses, a temperature distribution analysis based on a nodal point solution has been programmed and numerical results obtained on a representative case. This solution will analyze the temperature distribution within arbitrarily shaped end closures for cylindrical geometries which have axial symmetry.

Vibrational Studies. A theoretical study has been completed on the effect of process tube vibrations and their relation to fuel element support design. Two programs were developed: one is a two-component model for the vibration of a fuel assembly, and the second calculated the spring constants of various shaped supports. The spring constant program only applies to non-sized supports. The vibrational program can be used with either calculated or measured values for the support spring constants. A document describing these programs (HW-77415) has been published.

Fabrication of Crud Probe Stock. Two 3.8" diameter x 50 lb ingots of Th - 1½ w/o U - 1.0 w/o Zr have been double vacuum arc melted for the fabrication of a long life constant power heat source for heat transfer studies. One of the ingots is alloyed with natural uranium and will be used as pilot material for the other which is alloyed with 93% enriched uranium.

Coextrusion of the pilot stock has been completed. This was done at 760 C in the 700-ton press and produced a rod 1" diameter x 135" long with a 0.475" diameter Zircaloy-2 core piece and a 0.025" Zircaloy-2 cladding.

The reduction ratio of 15 to 1 required a peak force of 620 tons yielding an extrusion constant of 17.2 TSI. This extrusion constant

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is the lowest yet obtained on a thorium-uranium coextrusion. Previous constants on seven extrusions of 2.5 w/o U ranged from 19.0 to 21.3 TSI. The solid rather than tubular shape plus the lower uranium content probably accounts for the lower constant.

Lithium-Aluminum Target Elements. Irradiation testing of 16 experimental lithium-aluminum target elements, canned in aluminum and Zircaloy-4, was initiated in KER Loops 1 and 2 to investigate the performance of the target material under N-Reactor conditions. However, a leak in Loop 1 has limited the exit loop water temperature to 40 C, while insufficient heat generation in Loop 2 has limited the exit water to 250 C.

Two target elements were intentionally defected by drilling a 0.025-inch hole through the Zircaloy-4 cans. The elements were tested for approximately 200 hours in an ex-reactor loop with the loop coolant at 280 C and 1250 psi. The concentration of aluminum in the loop water was determined periodically. The concentration of aluminum in the coolant was detectable within 10 hours after startup, peaked after 20 hours and decayed to the background level after 40 hours of the test. At the end of the test a visual macroscopic examination of the target elements showed no evidence of gross corrosion in the vicinity of the defect. These elements are being sectioned for further examination. This test indicates that a target element rupture which occurs during irradiation can be detected by monitoring the irradiation test loop water for aluminum concentration.

Target Element Development. Metallographic examination has been completed on the extruded aluminum-lithium cores. The section extruded cold shows a much finer grain and a lower recrystallization temperature than the 300 C extruded section. Recrystallization begins at 350 C after only 30 minutes and is essentially complete at 400 C after 30 minutes. The 300 C extruded section begins to recrystallize after 30 minutes at 400 C, is essentially complete after one hour, and is completely recrystallized after 30 minutes at 450 C. Longer time and higher temperature results in grain growth. The final heat treatment chosen for both the cold and warm extruded billets was 450 C for 45 minutes.

High Temperature Induction Furnace. A 200 KW induction billet preheat furnace has been designed for heating extrusion billets up to a maximum temperature of 4000 F. This furnace will be powered by the 3000 cycle building supply and will be attached to the 200 KW mobile station. The furnace will be capable of handling extrusion billets up to 4" OD and 12" long. All items for this furnace are on order and the furnace should be operable by August 1963.

2. Corrosion and Water Quality Studies

Rotating Disk Corrosion of Aluminum. Accelerated corrosion tests are being conducted on aluminum alloys, using high rotational rates (~ 72 ft/sec at the periphery of a 4-inch disk). Pitting was observed at the outer edge of a 4-inch disk of 1245 aluminum alloy, rotated for 72 hr at 90-95 C (194-203 F) in 300 Area tap water. Due to water losses from the system the tank pH increased to 9.2 during the run. The sample was electrically insulated from the rotating shaft. The run was repeated using tap water with the pH adjusted to 6.7. During the run the pH increased to 8.7. However, no pitting was observed in a 72-hr run. A third disk was rotated in deionized water at pH 6.0 with 10 ppm chloride ion added. The sample showed no pitting attack.

Corrosion of Zircaloy-2 Containing Varying Amounts of Beryllium and Uranium. A joint investigation by Chemical Metallurgy and Metal Fabrication Development to determine the cause of oxide sloughing on N-Reactor fuel end closures has been initiated. Zircaloy-2 samples containing varying amounts of beryllium (1-5%) and uranium (200-1000 ppm) have been prepared. The various samples will be corrosion tested in 360 C (680 F) deoxygenated water for exposures up to six months. Following each exposure, the coupons will be weighed and amount of gray oxide will be determined by optical reflectivity of the sample. Additional samples containing 25 to 200 ppm uranium and 5% beryllium will be added to the test later.

Effect of Heat Treatment on the Corrosion and Hydriding of Zircaloy-2. The effect of heat treatment on the corrosion and hydriding of Zircaloy-2 exposed to 360 C (680 F) pH-10 (LiOH) deoxygenated water is under study. After 28 days of exposure virtually no effect is observed on corrosion. Weight gain for the α heat treated samples is 23.2 mg/dm^2 as compared to 24.5 mg/dm^2 for the β heat treated samples. Pretransition hydrogen pickup is higher for β than α heat treated samples. The corrosion product hydrogen pickup fraction is 32% for the α heat treated samples and 46% for the β heat treated samples. In 400 C (752 F) steam pretransition hydrogen pickup is independent of heat treatment.

Effluent Activity and In-Reactor Corrosion Testing. Measurements of aluminum corrosion in high (18 ppm) and low (7.5 ppm) alum content process water were obtained from samples in F-Reactor production channels during a half-plant test under PT-549. The corrosion of aluminum fuel cladding material (X-8001) was ~ 0.2 mil per month for coupon samples exposed in process water treated with either 18 or 7.5 (average) ppm alum. Process tube material (1100 aluminum alloy)

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samples corroded at a rate of 0.35 mil per month in water treated with 7.5 ppm alum, and 0.5 mil per month in the high-alum treated water. Initial penetration of 1100 alloy samples was also higher in the water treated with 18 ppm alum. Samples of aluminum alloy 6061 showed a pronounced effect of alum treatment, with corrosion rates of 0.43 mil per month in the low-alum water and 0.82 mil per month in the high-alum treated water.

Corrosion Monitoring in Production Reactor Coolant Piping Systems. Corrosometer probes have been installed in the tanks and feed lines of the reactor water supply system at C, D, KE and KW Reactors. Preliminary measurements indicate that pH 6.6 and pH 7.0 process waters, with either 1.0 or 1.8 ppm dichromate, are equally corrosive to carbon steel, with one significant exception. The exception is the case of low pH and high velocity. In a system with a pH of 6.6, dichromate dosage of 1.0 ppm, and flow velocity of about eight feet per second, the calculated corrosion rate was about 0.1 mil per month, while the rates in other systems at low flow were all in the range 0.01 to 0.04 mil per month.

Additional corrosometer probes will be installed in the sample room water lines of D-Reactor during the present outage. At the same time, corrosion samples will be placed in the process channels in the sample room water lines.

In-Flux Film Adsorption and Corrosion. Activation measurements were obtained from metal foils exposed with film and corrosion samples in 1706-KE Facility SP-1. These measurements were used to provide values for thermal neutron fluxes and fast neutron fluxes in the test channels. Preliminary measurements indicate that nickel, titanium, and iron provide accurate fast flux measurements, and that the cobalt content in nickel is equally as satisfactory as aluminum-cobalt alloy for measuring thermal flux. The nuclear reactions involved are: (1) Co-59(n, γ) Co-60, (2) Ni-58(n,p) Co-58, (3) Ti-46(n,p) Sc-46, and (4) Fe-54(n,p) Mn-54.

Measurements of thermal flux from cobalt present in the nickel foil may require correction, under certain conditions, due to formation of Co-60 by the reaction Ni-60(n,p) Co-60.

Evaluation of NH_4OH as Replacement for LiOH for pH Control. Operation of K-1 Loop was resumed in June using target elements in ammoniated coolant at pH 10. Initial operations were conducted at low temperature in the ex-reactor section to obtain a material balance for the ammonia. This objective was accomplished. Attempts to evaluate thermal decomposition effects were unsuccessful, however, since the temperature could not be raised above 80 C.

A few hours after in-reactor operation was initiated, a leak developed at the process tube inlet, necessitating operation at low temperature. Operation under these conditions will continue until the next reactor shutdown. Very little meaningful data on ammonia decomposition can be obtained while this type of operation continues.

In general, the coolant samples were slightly turbid during this period; however, the turbidity is attributed to the low-temperature operation rather than to the ammoniated coolant, since turbid coolant conditions are also encountered in lithiated systems at low temperature. Some crud deposition may be encountered on the fuel elements as the result of the turbidity.

To date, radiolysis of the coolant has not been significant, apparently since gross formation of oxygen and peroxide has not been observed. Appreciable radiolysis is a normal occurrence in lithiated systems under these conditions. It is possible that the presence of ammonia inhibits the radiolysis reactions that result in the formation of oxygen and peroxide.

Activity Monitoring in K Loops. A program to monitor the activity buildups at 33 designated points in the K-1 and K-2 loops was initiated this month and will continue through the next fiscal year. The measurements are part of the program to determine the feasibility of using NH_4OH in N-Reactor. The K-1 Loop will have ammoniated water as coolant while K-2 will have lithiated water. The data from the K-2 Loop will be used for comparison purposes.

Prior to reactor startup, both loops were decontaminated. Only the in-reactor portion of K-1 was decontaminated, while the full K-2 Loop was decontaminated. Radiation readings prior to startup indicated the levels in K-2 were 2 to 8 times higher than in K-1. After the startup of the reactor, the radiation levels in K-2 become very high. Apparently the loop was not adequately flushed after the decontamination, and the crud subsequently released was circulated through the flux zone and became very radioactive. Seventy-two hours after startup, the pump strainer and a blow-down valve were reading 3 r/hr. The same positions in K-1 were reading 29 mr/hr. In K-2 twelve of the thirty points were 1 r/hr or more - three points could not be monitored during reactor operation. The high radiation levels in K-2 demonstrate the necessity for proper flushing after cleaning or decontaminating.

Crud Formation on Fuel Elements. Fuel elements from the first in-reactor NH_4OH test in K-1 were discharged and examined in the KE viewing facility. The elements had been in the reactor for a period

of about two months (March 6 to May 12) with operation at 260-280 C for 43 days and at 70-80 C for 19 days. During the exposure there were three outages totalling six days. A brown crud film, 2-5 mils thick, was distributed over the surfaces of the elements. This crud has been removed for examination and will be analyzed for specific gamma activities, total iron, total cations, and chloride content. The coolant conditions during irradiation were not adequately controlled to determine whether this film is typical of operation with NH_4OH.

Ex-Reactor Testing of Target Elements. Two target elements predefected with a 25-mil hole near the end cap were dynamically tested in TF-7 under simulated KER conditions. Element A was tested for 202 hours at 530 F and Element B for 112 hours at 530 F. The purpose of the test was two-fold: (1) to determine whether a rupture could be detected by an increase in aluminum concentration in the water, and (2) to determine the rupture characteristics of the element.

No swelling was observed when the elements were discharged. There was sufficient release of aluminum to the coolant for detection purposes. The aluminum concentration increased very rapidly during the first 48 hours and then decreased to background level of the loop, indicating corrosion products were plugging the defects.

Decontamination Testing for N-Reactor. Stainless steel systems can be decontaminated by single-pass techniques using cyclic procedures. Single-pass procedures may be advantageous from a time and control standpoint. Preliminary evaluations were completed during the month of cyclic procedures using alkaline permanganate (10 min at 105 C), rinse, acid (10 min at 70 or 85 C), and rinse. Sulfamic or oxalic acid solutions were successful in removing films after six cycles; APACE was relatively ineffective, especially with aged films.

Cyclic corrosion tests have shown that commonly used decontaminating procedures (APACE, APOX, APSUL) properly controlled cause no serious problems with any of the materials usually found in water-cooled reactor systems. However, incomplete rinsing and subsequent high-temperature operation with trapped or residual decontaminant can lead to serious corrosion problems.

A test was recently completed in TF-7 to determine effects of trapped decontaminants in crevices. Stressed crevice samples of Zr-2, welded and non-welded 304 and 316 stainless steels,

were exposed in the laboratory for six hours in AP at 100 C, six hours in OX at 60 C, 24 hours at room temperature in AP, and 24 hours in OX at room temperature. The samples were placed in TF-7 without rinsing and exposed at 530 F for three months in lithiated water. Cracking in the crevices did not occur. On one of the thirteen 304 stainless steel stress coupons an intergranular pitting attack 0.008" deep had occurred.

Flashing Tests. Water at 530 F and conditioned to pH 10 with lithium hydroxide was flashed across the face of a Zircaloy-2 specimen to simulate a leak from a Zr-2 process tube. A thin white deposit, presumably Li_2CO_3, was found after three weeks; the quantity of material was insufficient to obtain a chemical analysis. Metallographic examination has not shown accelerated corrosion or hydriding. The test is continuing.

Evaluation of Materials for Cleaning Carbon Steel Pipe. Several proprietary compounds have been tested to determine relative efficiencies in removing lacquer and mill scale from carbon steel pipe. Practically all of the compounds remove the mill scale if used under recommended conditions. Some remove the lacquer only partially. One additive designed to remove the lacquer caused a heavy precipitate to form and film out on the iron surfaces.

3. Gas-Atmosphere Studies

Graphite Burnout Monitoring. Small graphite burnout monitors inserted January 20, 1963, were discharged from channels 1889 and 1960 at C-Reactor on June 3, 1963. Results showed the highest oxidation rates in channel 1960, where a very sharp peak of 21% per 1000 operating days (%/KOD) occurred at the usual location of 80 inches into the graphite. In channel 1889-C the rates were much lower. A peak of 6%/KOD appeared at 102 inches, and a smaller one of 1%/KOD at about 144 inches.

A new facility at KE-Reactor, channel 5080, was assigned to temporary monitoring service.

Graphite-Zirconium Compatibility in the N-Reactor. A kinetic expression and rate constants for the water-gas shift reaction (both forward and reverse)

$$CO + H_2O \rightleftharpoons CO_2 + H_2$$

have been obtained and put into the N-Reactor atmosphere computer program. The effect of a 100-fold variation in carbon monoxide

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inlet gas content on the removal of water by reaction with carbon monoxide was found to be very slight. For inlet helium gases containing respectively 0.50, 0.076 and 0.076 mm Hg of H_2O, H_2 and CO_2, and 0.076, 0.76 or 7.6 mm of CO, the outlet water contents were calculated to be 0.48, 0.47 and 0.45 mm Hg. Assumed flow was 400 ft^3/min; maximum graphite temperature, 820 C.

Increasing the frequency factor for the forward reaction by a factor of 10 resulted in the loss of about 0.02 mm more of the water. Although the above calculations indicate that carbon monoxide is probably not important to the compatibility problem, it must be emphasized that the possible effect of radiation was not included in the rate expressions. Experiments are planned to check the above calculations.

Hydriding of Zircaloy-2 with Thick Oxide Films. In March 1963, it was reported Zircaloy-2 samples with thick oxide films (250 mg/dm^2) hydrided at 425 and 375 C in a 3% H_2, 2% CO, 0.05% H_2O helium mixture, whereas samples with thin autoclave films had not hydrided during the 37-day exposure.

A second group of the samples has been exposed 83 days to the same atmosphere and the results agreed with the 37-day data. The thick film samples continued to hydride whereas the thin film samples still show only a small amount of corrosion product hydrogen absorption.

Effect of CO_2 as a Hydriding Inhibitor. Zircaloy-2 coupons with three surface pretreatments (etched, pre-autoclaved in 400 C (752 F) steam, vapor blasted) have been exposed for 40 days at 375 C (707 F) and 425 C (797 F) to a 2% H_2, 1% CO_2 helium mixture. No gas phase hydriding of the etched or preautoclaved samples has been observed. The vapor blasted samples all showed signs of gas phase hydriding; however, vapor blasted surfaces are unusually prone to hydriding. The fact that no hydriding of the etched or preautoclaved samples has occurred in 40 days establishes that the CO_2 is acting as a hydriding inhibitor at the 1% concentration. However, CO_2 still appears inferior to H_2O as an inhibitor since H_2O has successfully prevented hydriding of vapor blasted samples at H_2O concentrations of only 0.05%. This observed effectiveness of CO_2 is the result of water formation due to $CO_2 + H_2 \longrightarrow H_2O + C$. A moisture analysis of the gas showed the water content increased from 10 ppm to 200 ppm H_2O as the gas mixture and samples were heated to 425 C (797 F). This level of water vapor accounts for the observed inhibition.

4. Process Tube Development

Brittle Fracture Test of Reactor Pressure Tubes. Recent tests have shown N-Reactor process tube material to be remarkably resistant to brittle fracture originating from a 0.360-inch long crack introduced while the tube is at elevated pressure. It has proven necessary even at room temperature to stress the tube to the yield point (about 98% of ultimate) to cause such a crack to propagate in a brittle manner. At 150 C (302 F) and above, the crack will not propagate even with the tube stressed to the yield point. The G_c value (a measure of crack toughness) for this material calculated on the basis of these room temperature tests is about 700, a number that compares favorably with the 800-1000 range exhibited by the toughest turbine rotor steels.

In high speed photographs at 17,000 frames per second of one of the room temperature crack propagation tests the moving crack tip appears to travel at about 2100 ft/sec. This is about 15% of the speed of sound in Zircaloy.

5. Thermal Hydraulic Studies

N-Reactor Studies. An electrically heated test section was fabricated to represent the outer piece of the N-Reactor tube-in-tube fuel element situated eccentrically within the process tube. The test section was designed to obtain boiling burnout data for the case where the devices supporting an N-fuel piece in the process tube would fail, leaving only the weld tabs between the fuel and process tube.

The test section consisted of a 2.390-inch OD by 0.145-inch wall Hastelloy "C" heated tube housed in a 2.700-inch ID process tube in the horizontal position. A 23-inch length of the heated tube was eccentrically located in the process tube such that the minimum annulus, 0.040-inch thick, was oriented to the bottom of the process tube. A concentric 9-inch length of heated tube was located upstream of the eccentric piece. Copper rods attached to each end of the heated section passed through the process tube end seals to provide the electrical connections. Ceramic supports on the eccentric length, located 3 inches from each end, provided the 0.040-inch spacing.

During boiling burnout experiments the test section developed leaks when the eccentric portion bowed until an electrical short was developed between it and the process tube. Bowing of the eccentric section was the result of differential thermal expansion around the

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circumference of the tube arising from higher fluid temperatures in the minimum annulus region. The 17-inch length between supports permitted the bowing to accelerate until contact was made with the process tube about midway between the supports. A new eccentric section has been designed to alleviate this severe bowing.

In other experiments for N-Reactor, detailed plans were developed for the first group of experiments to determine pressure drop-flow relationships for an N-Reactor process tube and fuel elements with net steam generation. These experiments are designed for determination of off-standard conditions which would produce flow instability either in the tube or in any of the three fuel element flow channels. This information will be used in setting operating limits to prevent fuel damage from the substantial flow reductions which can result from flow instability.

The experimental apparatus for these tests is a full scale model of the downstream half of a process tube and fuel column, with typical outlet fittings and connectors. The model of the downstream half of the fuel column is an electrically heated test section, with stepped-cosine heat generation.

The first group of experiments will investigate relationships at pressures comparable to those provided by the emergency cooling system, and about equal to planned startup pressures.

6. Shielding Studies

MAC Code Development. Three computer codes were debugged for calculation of cross sections for MAC input. The BARNS code calculates isotopic neutron cross sections in the particular group structure desired and prepares cards for the new Elemental Cross Sections code. This code calculates cross sections in a form suitable for MAC input and punches the input cards. A new program called Inelastic Matrix calculates the MAC neutron inelastic matrix and punches cards for MAC input.

Shielding Experimentation. Equipment was inventoried and work began in the counting room at 1704-D to clean up, restore some of the apparatus to working order, and to calibrate it. Survey of available neutron spectral analysis instrumentation disclosed that three instruments might be suitable for shielding experimentation. These are: (1) the He^3 proportional or solid state spectrometer for the 0.1-0.8 Mev energy range, (2) the Li^6 solid state detector for the

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0.6-6.5 Mev range, and (3) the plastic or stilbene single crystal scintillation detector for the 1-12 Mev range. None of these instruments require collimation.

Combined use would enable experimental determination of neutron spectra over the energy range of major interest in shielding studies.

7. Reactor Technology

Fast Spectrum Processing Study. The tentative steam cycle conditions selected for the FSPR are 1500 psig pressure and 950 F temperature with one reheat to 950 F at 450 psig. A cursory calculation yields a minimum gross plant efficiency of about 42.5%.

Studies to optimize the primary and secondary sodium cycles have not been conducted. However, the results of such studies will have no effect on the expected steam cycle efficiency.

As the size of a fast reactor is increased, the neutron leakage from the core decreases causing the in-core breeding ratio to increase. The in-core breeding ratio is inversely proportional to the percent fissile enrichment for a given reactor. If the reactor is made large enough, the in-core breeding ratio may be substantially greater than unity. With this in mind, it appears that it is possible for a large fast plutonium breeder reactor to breed its own fuel in-core such that after the initial fuel loading the subsequent fuel loaded could be depleted or natural uranium on a graded fuel cycle.

Burnup calculations were performed for a 6000-liter sodium cooled fast reactor, in spherical geometry. The reactor consisted of 55 v/o fuel, 25 v/o sodium and 20 v/o steel. A fuel exposure limit of 100,000 MWD/T was assumed. A fueling scheme of depleted uranium charged into the blanket, allowed to build up plutonium, and then charged into the core was assumed.

A reactor multiplication of about unity was achieved when the plutonium density was integrated after the core fuel life.

It is anticipated that a fast reactor of this size may tend to have undesirable kinetic behavior. If the kinetics problem can be solved without adversely affecting the in-core breeding ratio, this type of fueling scheme may have merit for large fast reactors.

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8. Graphite Studies

N-Reactor Graphite Irradiations. Irradiations of N-Reactor graphite are proceeding satisfactorily in the GETR. The H-6-2 and H-4-3 capsules successfully completed another cycle of irradiation on June 9. Construction is under way on the second of the third-generation capsules, H-5-3. All of the samples in the H-5-3 capsule have been previously irradiated with 80% of them being high exposure samples from second-generation capsules.

B. WEAPONS - 03 PROGRAM

Research and development in the field of plutonium metallurgy continued in support of the Hanford 234-5 Building Operations and weapons development programs of the University of California Lawrence Radiation Laboratory (Project Whitney). Details of these activities are reported separately via distribution lists appropriate to weapons development work.

C. REACTOR DEVELOPMENT - 04 PROGRAM

1. Plutonium Recycle Program

Fuels Development

PRTR Fuel Element Development. The PuO_2 concentration in UO_2-PuO_2 fuel clusters for the PRTR was increased from 0.48 w/o to 1.0 w/o. This increase was made possible by (1) improved powder loading techniques resulting in better UO_2-PuO_2 homogeneity, (2) development of the capability to measure Pu concentration accurately in a fuel rod after fabrication, and (3) relaxation of fuel element heat transfer limits. Fabrication of these higher enrichment elements was initiated by both incremental loading/swage compaction and bottle loading/vibrational compaction.

Four UO_2-PuO_2 and three unautoclaved Al-1.8 Pu test fuel clusters were completed in June for PRTR irradiation.

Two UO_2-PuO_2 fuel rods with reject end cap welds (before swaging) were reclaimed. The end cap was removed with a tubing cutter, the weld joint was dressed with a file and reamer, and a new end cap was welded in place. Techniques are being developed to refurbish or reclaim other reject rods by appropriate techniques.

Fast Reactor-Thermal Reactor Exchange Element. A Fast Reactor-Thermal Reactor Exchange Element mockup was assembled to evaluate components and fabrication procedures. The completed stainless steel mock fuel element will be used for flow tests.

Fuel Element Design Studies. Tests of a UO_2 Mark-I PRTR fuel element having continuous ring contact surfaces on each end bracket is continuing in the ex-reactor TF-7 facility at PRTR coolant conditions. Superficial wear occurred on the contact surface of the bottom end bracket only after an accumulated exposure of 106 days. This performance is particularly encouraging because the test section was vibrated throughout the test period.

Incorporation of a trial eddy current coil in a vibrationally compacted UO_2 fuel rod was attempted as part of the development of an instrumented fuel element for fretting corrosion studies in the EDEL-1 loop and, eventually, in the PRTR. Assembly processes are being revised to eliminate damage to the quartz coil form by high energy vibration.

Preparation of High Density UO_2-PuO_2 Mixtures. Examinations were continued on high density (> 99% TD) UO_2-PuO_2 materials produced by arc-melting pressed pellets under one atmosphere of argon. Two portions were prepared initially by mixing powders to form UO_2-2.5 w/o PuO_2, and UO_2-97.5 w/o PuO_2 compositions. Pellets were pressed without binder to a green density of 60% TD. After arc-melting the materials were massive in form with densities greater than 99% TD. Replicate analyses confirm that the green pellet originally containing UO_2-2.5 w/o PuO_2 underwent an increase in PuO_2 concentration to 4.1 w/o during the densification by arc-melting. This increase is attributed to a larger mechanical loss (arc-blow) of the UO_2 during the melting process. The PuO_2 melts first and, hence, would not be expected to blow away as readily as the UO_2.

PRTR Fuel Element Inspection. A vibrationally compacted, UO_2-PuO_2, Mark-I-H physics test element (5176) which includes three pellet rods, was inspected in the reactor basin and in the Fuel Element Examination Facility (FEEF). The element appears to be in excellent condition. Four rods in this element have fabrication histories similar to the three fuel rods which failed in element 5174 after an exposure of only 106 MWD/ton. The examination did not reveal any abnormal external corrosion in the suspect regions of these rods. There is no visible, external evidence of poor weld quality.

A vibrationally compacted UO_2-Mark I with an accumulated exposure of approximately 1800 MWD/ton was inspected in the FEEF. With the exception of a broken rod spacing wire, the element appeared to be in very good condition. The wire, broken at the bend near the end cap, appears to have suffered mechanical damage. Irradiation of the element will be continued after it has been repaired.

Examination of PRTR Tubular Fuel Element 1501. A severe variation in the thickness of the outer fuel annulus of PRTR tubular element 1501 had no detrimental effect on the irradiation performance of the fuel element. A maximum fuel thickness ratio of 1.6 was measured near the midsection of the fuel element. The core temperatures in the area of maximum fuel thickness were high enough to cause sintering of approximately 1/3 the fuel.

Unautoclaved Fuel Element Irradiation in PRTR. Irradiation of an unautoclaved, Zircaloy-clad fuel element began in the PRTR on June 15, 1963. The test is being conducted to determine the feasibility of maintaining clean metal surfaces during fabrication,

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delivery, and charging of a fuel element, as well as to determine the in-reactor behavior. Elimination of pre-irradiation autoclaving will increase potential fuel element life by reducing the initial hydrogen concentration in the cladding. Direct fuel fabrication costs are reduced approximately 5%. Elimination of the autoclave step would be particularly desirable in remote fabrication of fuel elements containing partially decontaminated fuels, because of the difficulty of remotely manipulating high pressure autoclave equipment.

Post-Irradiation Examination of PRTR Fuel Elements. Examination of the bottom end cap of a vibrationally compacted UO_2-PuO_2 fuel rod (PRTR element 5113) that suffered cladding failure near the midpoint, revealed internal hydride deposits. A relatively uniform layer (0.008 to 0.025-inch thick) of massive zirconium hydride was observed on the inner surfaces of the cladding and end cap. The zirconium hydride in the bottom end cap region is approximately four feet distant from the point of cladding failure. Moisture initially in the fuel material or water which entered the fuel rod after cladding failure could have been the source of hydrogen. Similar hydride deposits were observed previously in long, deliberately defected UO_2 fuel rods.

Examination of three other failed, vibrationally compacted UO_2-PuO_2 fuel rods (PRTR element 5174) revealed severe corrosion in the crevice between the bottom end cap and cladding similar to that which caused original cladding failure in the top end cap weld areas. The corrosion was not as far advanced (cladding temperature at the bottom of the rod was approximately 50 F less than at the top). Samples of corroded cladding were removed for hydrogen analysis.

Although these fuel rods are from the first, experimental batch of vibrationally compacted UO_2-PuO_2 rods (processed early in 1962), poor weld quality is now considered to be a less likely cause of failure than impurities in the fuel. A sample of UO_2-PuO_2 from the same batch as used in the fuel rods contains 30 ppm fluoride and 350 ppm chloride. The source of the high chloride concentration in the fuel has not been determined. The effect of chloride on Zircaloy in this environment is not well known.

Remote Fabrication Studies. New counterweights were installed on the remote fabrication manipulators, providing greater and more efficient cell coverage. The carriage units are now capable of a vertical lift in excess of 600 pounds per unit. Data recently received from the

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manufacturer show the manipulator arms have been re-evaluated upwards in capacity. The manipulator arms can be adjusted so each will handle up to 100 pounds in any position (a 20-pound increase from the previous 80-pound rating).

MgO-PuO_2 and ZrO_2-PuO_2 Ceramic Spike Fuel Irradiations. A large variation in the gamma activity was observed among analytical samples obtained by microdrilling (0.020-inch diameter) in selected areas of irradiated $\frac{1}{2}$-inch diameter MgO-PuO_2 pellets. The radioactivity of samples taken near the edge of an MgO-13.5 w/o PuO_2 specimen, irradiated under conditions where extensive migration of PuO_2 and/or fission products has not been observed, was four times greater than of samples collected near the center of the same specimen. The high concentration of fission products near the fuel rod surface reflects self-shielding by the relatively highly concentrated plutonium. The activity of samples taken from selected regions of an MgO-3 w/o PuO_2 specimen, irradiated at temperatures which promote migration, differed by a factor of 50.

X-ray diffraction data show no crystallographic changes in two MgO-13.5 w/o PuO_2 specimens irradiated to approximately 0.5×10^{20} and 1.0×10^{20} fissions/cm^3. The calculated maximum fuel temperatures were approximately 1700 C.

Irradiation Testing of Injection-Cast Al-Pu-Ni Alloy Fuel Rods. A paper, "Irradiation Testing of Injection-Cast Al-Pu-Ni Alloy Fuel Rods," (HW-SA-2909), summarizing the development of an injection-casting process and the irradiation test results for Zircaloy clad, Al-Pu-Ni alloy fuel rods was presented at the Ninth Annual ANS Meeting.

Irradiation of Uranium-Plutonium Oxide. Preliminary evaluation of fission product distribution in an irradiated $(U,Pu)O_2$ pellet (GEH-14-86) was completed. Irradiation to 1.66×10^{20} fissions/cc produced extensive columnar grain growth and fission product migration. Microdrilled samples were removed from sharply-defined zones of markedly different radioactivity levels disclosed by autoradiography. Initial analyses indicate that the plutonium distribution is relatively constant throughout the sample. Of the fission products analyzed (Ce-144 - Pr-144, Ru-106, Zr-95 - Nb-95, and Cs-137), the only one that shows a marked variation of concentration as a function of radial position is Ru-106. The concentration of Ru-106 differs by three orders of magnitude between the central region of low radioactivity and the high radioactivity areas revealed by autoradiographs.

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delivery, and charging of a fuel element, as well as to determine the in-reactor behavior. Elimination of pre-irradiation autoclaving will increase potential fuel element life by reducing the initial hydrogen concentration in the cladding. Direct fuel fabrication costs are reduced approximately 5%. Elimination of the autoclave step would be particularly desirable in remote fabrication of fuel elements containing partially decontaminated fuels, because of the difficulty of remotely manipulating high pressure autoclave equipment.

Post-Irradiation Examination of PRTR Fuel Elements. Examination of the bottom end cap of a vibrationally compacted UO_2-PuO_2 fuel rod (PRTR element 5113) that suffered cladding failure near the midpoint, revealed internal hydride deposits. A relatively uniform layer (0.008 to 0.025-inch thick) of massive zirconium hydride was observed on the inner surfaces of the cladding and end cap. The zirconium hydride in the bottom end cap region is approximately four feet distant from the point of cladding failure. Moisture initially in the fuel material or water which entered the fuel rod after cladding failure could have been the source of hydrogen. Similar hydride deposits were observed previously in long, deliberately defected UO_2 fuel rods.

Examination of three other failed, vibrationally compacted UO_2-PuO_2 fuel rods (PRTR element 5174) revealed severe corrosion in the crevice between the bottom end cap and cladding similar to that which caused original cladding failure in the top end cap weld areas. The corrosion was not as far advanced (cladding temperature at the bottom of the rod was approximately 50 F less than at the top). Samples of corroded cladding were removed for hydrogen analysis.

Although these fuel rods are from the first, experimental batch of vibrationally compacted UO_2-PuO_2 rods (processed early in 1962), poor weld quality is now considered to be a less likely cause of failure than impurities in the fuel. A sample of UO_2-PuO_2 from the same batch as used in the fuel rods contains 30 ppm fluoride and 350 ppm chloride. The source of the high chloride concentration in the fuel has not been determined. The effect of chloride on Zircaloy in this environment is not well known.

Remote Fabrication Studies. New counterweights were installed on the remote fabrication manipulators, providing greater and more efficient cell coverage. The carriage units are now capable of a vertical lift in excess of 600 pounds per unit. Data recently received from the

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the fuel rod. The wire was bent back about three inches from the break, but appears to be repairable. This fuel element is the only remaining UO_2 Vipac element in the PRTR except for special physics test elements.

A proposal for refurbishing Moxtyl fuel element 5119 was submitted to the PRTR Experiment Scheduling Council. This element has a broken wire wrap. It is proposed that the broken wire be repaired and the element returned to the reactor as a special test element.

Fuel Element Rejuvenation. The rejuvenation fuel element was returned to the MTR for second cycle irradiation (GEH-4-84). The single rod was used in place of the four-rod cluster previously reported to improve reliability of the test element. A special aluminum liner was used to position the rod in a standard GEH-4 basket which will allow the irradiation to approximate as closely as possible the test conditions of previous irradiations.

The closure weld for this fuel element was made using a welding apparatus specifically designed for operation in a remote facility. The apparatus consisted of an inert gas chamber, a rotating chuck, the welding torch, and a device for placement and removal of a chill block. The unit was an integral, compact package, allowing quick and accurate positioning of the inert gas chamber and welding torch with respect to the fuel element.

Corrosion and Water Quality Studies

Radioactivity on PRTR Piping. Jumpers are being removed monthly from the PRTR as part of a program to study films, corrosion, and decontamination. One inlet jumper recently removed was sectioned and autoradiographed using the same exposure, same type of film, and the same development sequence that was employed in mid-1962 on another PRTR jumper. The recent autoradiographs showed that there was less adsorbed activity at present than there was prior to the PRTR decontamination. These results substantiate the primary system radiation readings taken during reactor shutdowns; i.e., there is currently less radiation associated with the PRTR primary system than there was before the $MgO-PuO_2$ fuel failure.

Corrosion by Decontamination Chemicals. Cyclic tests in TF-1 are continuing to determine possible latent corrosion effects on PRTR materials from use of decontamination chemicals. Successive treatments with alkaline permanganate and oxalic acid followed by high-temperature operation have had no detrimental effects after four temperature cycles.

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Fretting Studies in TF-7. A PRTR fuel element with 360° ring-type end-bracket supports exposed in 530 F, pH 10, flowing water with induced vibrations has experienced fretting of 5-15 mils at four locations on a rod wire wrap during this reporting period. The vibration frequency had been increased during this period from 30 cps to a frequency too high to measure with the present equipment (> 80 cps). Simultaneously, the deflection was reduced from 7 to 8 mils to less than 1 mil. All the fretted areas were on one wire wrapping and were near the center half of the fuel element. Apparently the flexibility of the element allows the fuel element to touch the pressure tube. The pressure tube was not examined. After a total exposure of 87 days in TF-7 under PRTR conditions with vibration, no sign of fretting was apparent on the end bracket.

PRTR Primary Coolant Zirconium Concentration. The program to monitor routinely the zirconium concentration in the PRTR primary coolant was continued, employing emission spectrographic techniques. The results indicate that the zirconium concentration was generally within the range considered "normal" for this system, that is, 0-1 ppb, during the past month. However, on two separate occasions the concentration increased rapidly to about 5 ppb. The first period of high concentration was experienced for two days following a reactor startup, while the second period occurred during normal operation at rated power and also lasted for about two days.

It is possible that either one or both of these periods may have represented some fretting attack in the system. In each case the concentration returned to normal within two days.

A continuous, colorimetric procedure for analyzing for ionic zirconium is being investigated.

Carbon Steel Pitting Corrosion. Pitting corrosion has been observed during inspection of carbon steel exposed to process waters in dead legs and other stagnant sections of the PRTR system. Selected piping has been examined by Radiography and, in some cases, piping has been removed for detailed examination. General agreement between radiography and visual examination has been found; however, the radiography has a tendency to underestimate pit depths by a few mils. Small pits with dense corrosion product buildup and less than 5 mils deep are usually not seen on the radiograph.

The pitting which has been found to date has been located in areas of stagnant water with the exception of a tank which displayed 1/8-inch deep pits below the water line. All the pitting observed has been of the variety common to carbon steel in impure waters containing oxygen. The study is continuing.

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Restricted Moderator Strainer. A sample of material from a moderator strainer which was removed because of a decreased flow condition has been analyzed. Microscopic examination of the material revealed a dark powder, ion exchange resin, and shiny magnetic particles or flakes. The gamma spectrum of the sample corresponded closely to a mixture of Co-60, Cr-51, W-187, and Ag-110. The emission spectrum showed Cr, Fe, Al, Co, Ni, Si, Ag, Cu, Mg, and Mn, in the order of decreasing concentration. Examination of a moderator pump throat bushing and sleeve revealed severe wear such that the thin Stellite facings were mostly removed. Presumably the metallic flakes in the moderator strainer originated from the pump bushing and sleeve. The source of the ion exchange resin was not determined. It was concluded that the restriction of the strainer was not related to a corrosion problem.

Absorption of Ions by Aluminum Corrosion Product. Redeposited aluminum corrosion products have been reported to absorb and concentrate chloride ions from very dilute solutions at temperatures where the aluminum oxide is a trihydrate. Analysis of a redeposited aluminum corrosion product at 300 C (572 F) shows this absorption for the higher temperature oxide (presumably Boehmite or diaspore) as well.

An all stainless steel autoclave system was cleaned and then operated at 300 C (572 F) - 2000 psi for 30 days with a throughput of 6480 gallons of high purity deionized water. The corrosion product oxide on the aluminum corrosion samples in the autoclave was partly dissolved and redeposited on the system walls during operation. An analysis of this redeposited oxide by a pyrohydrolysis technique showed a concentration of 60 and 200 ppm of chloride and 1500 and 1800 ppm of fluoride. Dehydration at 1300 C (2372 F) showed the oxide to be essentially a monohydrate. Analysis of the deionized water is in progress, but it is believed to be very low in chloride and fluorides. A stressed stainless steel coupon is being placed in this autoclave to see if this surface concentration of chloride will induce stress corrosion cracking.

Controlled Hydriding of Process Tube Sections. Six more hydrided N-Reactor process tube sections have been supplied to Testing Methods Operation as standards for development of nondestructive methods of hydrogen analysis. The tubes contain discrete patches of known hydrogen concentration ranging from 300 to 5000 ppm. The tubes were hydrided in the gas phase at 600 C (1112 F). Future work will be done at temperatures below 400 C (752 F) in order to retain the characteristic microstructure of the tube material.

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Reactor Components Development

PRTR Pressure Tubes. The fifth of a group of elevated temperature burst tests was performed. The purpose of testing this group was to obtain data to show how test temperature influences the mechanical properties of pressurized irradiated PRTR pressure tube segments. The ultimate strength data show that an increase of 100 F in test temperature will on the average decrease the ultimate strength by about 10%.

In order to obtain better utilization of discharged PRTR pressure tubes for metallurgical testing, Testing Methods of NRD was asked to apply their ultrasonic techniques to the problem of locating the transition from the cold worked end to the annealed end of the tubes. Ability to locate this transition accurately was demonstrated.

The classical equations of the strength of beams on an elastic foundation are applicable to the problem of measuring elastic strain of tubular burst test specimens. They show that the end fitting elastic strain influence distance is about two inches on PRTR pressure tubes. Since the end fitting takes about two inches, a 20-inch long burst test specimen has about 12 inches for uninfluenced elastic strain during a burst test. Using the value of the mean elastic strain within the influence region, an equation was written from which circumferential elastic strain can be calculated, knowing the change in volume and the longitudinal elastic strain during a burst test. Monitoring the change in volume and length of an irradiated burst test specimen is potentially a simple method of strain measurement.

Second Generation Mechanical Shim Rod for PRTR. Detailed design of the second generation shim rod (Mark II) is estimated to be 95% complete. Fabrication of components for both assemblies is estimated 80% complete.

Shim Rod Environmental Test Facility. Operation of the facility with a new first generation shim rod (Mark I-A) was continued during the month. Fabrication of two braking devices to prevent coasting of the control elements is being completed.

PRTR Fretting Corrosion Testing. Data from vibration pickups mounted on PRTR piping were obtained and are now being analyzed. The pickup mounts were not satisfactory as they charred and allowed the vibration pickups to slide out of position. Pressure transducers to measure flow oscillations will be installed.

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Rupture Loop. The stainless steel Grayloc outlet connector for the rupture loop developed a substantial leak at 37 cycles. This leakage occurred during the initial pressurization following the cooling portion of the previous cycle. Leakage was 700 cc within the first 2 to 3 minutes, at which time it dropped to approximately the values previously reported (0.53 lb H_2O/24 hr).

Analysis of dimensional data indicates that the short seal lips on the special seal ring have undergone permanent deformation. A second ring was tested and at the start of the ninth cycle, the same type of failure was observed. A permanent deformation of 0.008-inch was measured on the seal lips of this ring. The second test was terminated after 20 cycles. An experimental seal made of Inconel has been received from Gray Tool Company and will be tested as soon as the EDEL-II loop becomes available.

The problem of hub deformation found on the initial connectors has apparently been solved through improved dimensional control.

Plutonium Recycle Critical Facility

Safety Studies. Additional "four factor" calculations of PRCF loadings with UO_2-PuO_2 (0.9-2.5 w/o) fuel in H_2O moderator were completed as an independent check on previous 3-group diffusion theory results. The calculations were somewhat inexact because resonance neutron interaction with plutonium was entirely neglected. More precise multigroup calculations recently completed by Applied Physics Operation for EBWR loadings have shown substantially smaller critical loadings than predicted by the above method. Results of previous hazards analyses are not expected to be appreciably affected, however.

The delay in the Doppler effect in UO_2-PuO_2 mixed oxide fuels because of the finite heat transfer time from the heat generating particle to the U-238 is being investigated. Formulation of this problem has been completed except for averaging the temperature over the UO_2. This is complicated by a singularity in the temperature at the source point. It is anticipated that the proper average can be obtained by excluding the source point from the integration. The problem appears to be suitable for analog calculation if a satisfactory function for the average temperature can be developed.

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2. Plutonium Ceramic Fuels Research

Pneumatic Impaction of Refractory Materials. Specimens of tungsten carbide, zirconium carbide, tantalum carbide, hafnium carbide and a mixture of two parts hafnium carbide with one part tantalum carbide were densified by pneumatic impaction at 1200 C and 260,000 psi. The latter material is reportedly useful as an electrical resistance heating element material in the 4000 C range.

UO_2-Stainless Steel Reaction. Molten stainless steel and UO_2 did not react appreciably during 90 minutes at 1600 C. Compatibility was evaluated by heating a charge of initially powdered, 304 stainless steel in a $\frac{1}{4}$-inch diameter UO_2 crucible. The crucible successfully contained the molten steel, and the post-heating microstructure of the oxide-steel interface showed no significant interaction.

Electron Microscope for Plutonium Compounds. Laboratory facilities required for installation of the "plutonium" electron microscope column are completed. Instrument modifications in progress will permit use of two similar microscopes operating from a single power supply. The second column will be used particularly for study of plutonium ceramics and other toxic materials, and for advanced instrumentation development.

Plutonium Cermets. A Pu-90 v/o PuN cermet was heated in an alumina crucible for two hours at 1000 C in vacuum (approximately 2×10^{-5} mm Hg nitrogen pressure). Visual inspection of the heat treated specimen showed no indication of melting or reaction with the alumina crucible. Weight loss was very slight (0.06%).

Preparation of PuO_2-steel cermets for irradiation at NRTS is in progress. PuO_2, densified to 95% TD by pneumatic impaction, was crushed and sized to -60 +200 mesh. This PuO_2 was mixed with -325 mesh stainless steel powder in preparation for pneumatically impacting pellets approximately $\frac{1}{2}$-inch diameter by one inch long. A test of the compaction procedure was conducted in which a single pellet was impacted. Data on this pellet are not yet available.

Methods are being developed for more efficient pneumatic impaction of high density PuO_2 cermets. A steel die block was designed in which six pellets can be impacted at one time. Removal of the pellets from the die block presented an unusual problem. A successfully demonstrated method uses a hole saw to trepan the pellet from the die block. A second, more efficient method uses a die block made in sections. After the pellets have been impacted, the die block can be broken apart to expose the individual cermet pellets. Break-apart die blocks are being fabricated for further tests.

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Plutonium-Boron System. The melting points of polyphase plutonium borides were determined. The nominal compositions and their respective melting points (± 50 C) were as follows: PuB (2030 C), PuB_2 (1825 C), PuB_4 (2050 C), and PuB_6 (2100 C). Indications are that PuB_4 is the predominant phase when synthesis is performed by reacting mixtures of PuO_2, carbon, and boron at 1500-1650 C in vacuum.

Plutonium Sub-oxides. A 175-gram batch of composition $PuO_{1.56}$ has been prepared by carbon reduction of PuO_2 in vacuum. The material will be further reduced by carbon to $PuO_{1.50}$ to yield essentially single-phase β-Pu_2O_3.

Irradiation of Pure Plutonium Compounds. A sample of pure plutonium carbide being irradiated at the MTR has attained an estimated average exposure of 6×10^{20} fissions/cc (approximately 18,000 MWD/ton). Goal exposure is 100,000 MWD/ton.

3. Ceramic (Uranium) Fuels Research

UO_2 Specimens for Basic Research. UO_2 single crystals of 55 and 79 grams in weight were prepared, characterized, and sent to the National Bureau of Standards for fundamental studies on measurements of elastic constants.

Electrical Conductivity of UO_2. A four probe method for measuring electrical conductivity of tungsten-encapsulated UO_2 at temperatures to 3000 C was devised. The apparatus was constructed and initial experiments are in progress.

The ionic nature of liquid UO_2 was evidenced by the first experiment. The tungsten capsule (filled with UO_2) was resistance heated to 2850 C. The UO_2 melted and, because of the dc potential gradient, began to electrolyze. As the $O^{=}$ ions reached the positive end of the capsule they reacted with the tungsten, apparently formed a low melting W-U-O ternary alloy. The capsule eventually failed and extensive reaction was apparent from the microstructure.

Fiber-Reinforced Cermets. A fiber reinforced cermet disc was formed by pneumatic impaction of a mixed bed of tungsten fibers and tungsten-20 v/o UO_2 cermet powder. The tungsten fibers were prepared by cutting 0.005-inch diameter tungsten wire into $\frac{1}{2}$-inch lengths. Cracks which initiated in the cermet during impaction because of an unfavorable wrinkle in the impaction container did not propagate to the extent that would be expected for a cermet not containing reinforcing fibers.

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Pneumatic Impaction of Cermet Shapes. Square honeycomb cermet grids of good structural quality were fabricated by pneumatic impaction. Mild steel mandrel assemblies containing tungsten - 20 v/o UO_2 powder were impacted at 1200 C and 250,000 psi. The mandrels were subsequently dissolved chemically. During prolonged chemical dissolution of the steel with hydrochloric acid moderate chemical attack of the tungsten occurred. Surface oxidation of the steel mandrels permits the acid to penetrate the interface between cermet and steel, reducing by 75% the time required for removal of the mandrels.

Irradiation of Cermet Fuels. Seven vacuum insulated capsules were successfully irradiated one cycle in the ETR. These capsules included two Mo-UO_2 and two Mo-UN cermets clad in Mo; one W-UO_2 and one W-UN cermet clad in W; and one UO_2 single crystal clad in W. One Mo-UO_2 and one Mo-UN cermet capsule will be irradiated additional cycles. The five discharged capsules will be returned to HAPO for post-irradiation evaluation.

Irradiation of Large Grain UO_2. Post-irradiation examination of specimens of initially large grain UO_2 pellets and small grain UO_2 pellets that were irradiated in various geometrical combinations revealed no difference in thermal conductivity of the two types of material. This contradicts earlier experimental results using only large grain pellets. Radial limits of melting, columnar grain growth, and other structural features developed during irradiation appeared independent of type of material. The optical density of archive specimens of the large grain UO_2 used in the test was essentially the same as that of small grain UO_2 - considerably greater than that of previously measured large grain specimens. The cause is not yet established. The O/U ratio (2.005) and impurity content were normal.

Examination of Electrical Resistivity Element. Further examination of the electrical resistivity element (GEH-4-82) disclosed two unusual areas of columnar grain growth in the fuel. A macrograph of a longitudinal section shows unaffected fuel near the cladding, a narrow band of radially oriented large columnar grains and a second band of columnar grains sloping toward the bottom of the capsule. Photomicrographs of the inner columnar grain region revealed an eutectic type structure (probably UO_2 and Al_2O_3 supplied by an end spacer-insulator) extending from the center of the element through the region of sloping grains. The columnar grains of UO_2 are thought to have been formed first. Subsequent diffusion from the Al_2-UO_2 phase into the UO_2 grains to lower the softening temperature and allow slumping of the fuel is hypothesized.

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Optical Properties of UO_2. Infrared absorption data for UO_2 single crystals between 3 and 13 microns show two strong absorption bands at 5.5 and 10 microns. These bands appear to be independent of oxygen-to-uranium ratio.

Thermal Conductivity of UO_2. Warping of the heater element used for radial flow conductivity measurements has been one of the principal experimental difficulties. The problem was eliminated by a liquid metal electrical contact at one end of the heater. A gallium-indium eutectic (24 w/o In; 16 C melting temperature) was suitable under the experimental temperature-vacuum conditions and served to maintain a perfectly straight heater element.

4. Basic Swelling Program

Irradiation Program. Two general swelling capsules are continuing to be irradiated. One capsule is operating satisfactorily at 625 C (1157 F). The second capsule underwent a gradual increase in thermal conductivity until the pre-selected temperature could no longer be maintained with the power available to the experiment. This second capsule, therefore, is now operating at the low temperature of 180 C (356 F). This will provide very valuable data in a temperature range not yet explored with this series of experiments. Two other capsules are at the reactor available for charging and two additional capsules are completely assembled and are awaiting shipment to the reactor. Specimens are being prepared and components are being assembled for the construction of additional capsules for future irradiations.

Uranium samples similar to those included in recent capsules are being annealed in NaK filled Laboratory capsules at 525, 575, and 625 C (977, 1067, and 1157 F). These specimens will be examined after annealing to determine the extent of the changes that occur in density, hardness, second-phase morphology, and grain size. This information will be used in the evaluation of the data obtained from the irradiated specimens.

Post-Irradiation Examination. Optical metallography has been completed on specimens irradiated to 0.03 a/o B.U., in a general swelling capsule controlled at 525 C (977 F). The as-extruded specimens exhibited the expected longitudinal striations indicative of irradiation growth and the beta treated specimen exhibited severe bumping and warping. The metallography revealed a well-defined grain structure very similar to the pre-irradiation structure and crystallographically aligned micro tears. These findings correlate well with data from other specimens of this series.

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Replicas of the etched specimens were prepared and are being processed for electron microscopy. The density measurements on these specimens and on the specimens irradiated to 0.1 a/o B.U. in a general swelling capsule controlled at 625 C (1157 F) have been completed and are indicated in the following table.

VOLUME INCREASES IN TEST SPECIMENS IRRADIATED AT CONTROLLED TEMPERATURES

Spec. No.	a/o B.U.	Irradiation Temp., °C	Pre-Irradiation Treatment	Density* gm/cc	% Vol. Inc.
17A-2	0.1	580 (1076 F)	As-extruded	13.73	38
17B-2	0.1	625 (1157 F)	As-extruded	17.96	5
17C-2	0.1	585 (1085 F)	β quench	14.13	34
18A-	0.03	520 (968 F)	As-extruded	17.03	11
18B-	0.03	525 (977 F)	As-extruded	16.91	12
18C-	0.03	525 (977 F)	β quench	17.61	8

*Pre-irradiation density = 18.95 gm/cc.

These values agree qualitatively at least with the metallographic observations that have been made thus far. This is true for the samples from both capsules. It is interesting to note that the 525 C (977 F) specimens have rather large volume changes in spite of the relative low burnup (0.03%). The difference in the 580 C (1076 F) and 625 C (1157 F) specimens (0.1 a/o B.U.) is even more remarkable but is wholly consistent with metallographic observations.

Electron microscopy has been completed on the 625 C specimens and tends to corroborate the optical metallography described in the May 1963 monthly report. The crystallographic features observed with the light microscope in the 580 C specimen can be described as evenly spaced rows of micro cracks or tears within grains which are perpendicular to twin bands. Almost no twins are observed in regions of a grain where the rows of tears occur. This appearance is very similar to descriptions in the literature of the formation of emissary dislocations due to the receding of deformation twins. As the twins recede they give off dislocations which polygonize into walls perpendicular to the direction in which the twin is moving. In irradiated uranium this process could be complicated by the fission products (not necessarily gases) which may collect into the polygonized walls and give rise to tears as stresses develop. This observation strongly supports the concept that the recovery of fission

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event induced damage is in a large part responsible for tearing and it is highly probable that swelling is also very closely associated with this or some similar recovery process.

Restrained Irradiations. The influence of restraint on the swelling of uranium is being investigated with NaK capsule irradiations of Zr-2 clad rods of unalloyed uranium and uranium - 2 w/o Zr. Nine capsules irradiated to approximately 1100 MWD/T have been opened and the samples removed for examination. Diameter measurements and macro photographing have been completed on six of the 25 fuel samples and a cursory visual examination has been made on the remainder. Several of these specimens contained an intentional striation in the clad at the clad-uranium interface, and they therefore will yield information on the effect of cladding restraint on swelling. Average diameter increases ranged from 1.28% to 2.32%. There is no apparent correlation between the diameter increase and the amount of intentional thinning of the cladding. Measurements of diameter, density and burnup are being made on the remaining samples.

Thorium. The two thorium specimens (B-2 and S-3) irradiated to 0.18 and 0.92 a/o B.U., respectively, have been completely examined after a 100-hour anneal at 750 C (1382 F) and are now being reannealed at 950 C (1742 F) for 100 hours. No microstructural changes due to annealing at 750 C (1382 F) could be detected after examining replicas prepared of the surfaces of these specimens in the electron microscope. Observations of hardness, density and microstructure will be repeated at the completion of the 950 C anneal.

5. Irradiation Damage to Reactor Metals

Alloy Selection. Procurement of materials to be used as test specimens for the Irradiation Effects on Reactor Structural Materials Program is continuing. The rolling of 304 SS plate in 1/2, 1, and 2½-inch thickness at the Lukens Steel Company mill and final nondestructive testing of the Inconel X-750 and Inconel 600 alloys were witnessed during the month. These materials along with quantities of AM 350, AISI 406 SS, and A-286 plate, sheet, and bar stock are scheduled for shipment prior to July 1, 1963.

To evaluate several nickel and iron base hardenable alloys, tensile specimens of R-27, R-235, Inconel 702, Inconel 718, Hastelloy N, Inconel 625, Hastelloy X-280, and TD Nickel have been fabricated and irradiated in the ETR hot water loop. In addition, tensile

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specimens of R-235, R-27, Inconel 625, and Hastelloy N have been irradiated in the ETR G-6 cold water facility. Specimens of each of the above alloys have been sent to Radiometallurgy for testing. Results of these tests are presently being processed by Electronic Data Processing Operation. Additional specimens of these alloys have been fabricated to meet future program requirements.

To determine the resistance of several alloys to oxidizing environments, heated specimens have been exposed to flowing CO_2. During the past month specimens of Inconel 718 and Hastelloy N were subjected to CO_2 for 200 hours at a temperature of 1900 F (1038 C). Specimens have been submitted for metallographic examination to determine the type and depth of oxidation penetration and any changes in microstructure caused by the high temperature exposure.

In-Reactor Creep Measurements of Zircaloy-2. The in-reactor creep test on 20% cold worked Zircaloy-2 at 20,000 psi and 350 C (662 F) was terminated after 3000 hours. The average creep rate, including shutdown, was determined to be 1.07×10^{-6}/hr. This rate is greater than the rate determined for an ex-reactor creep test presently in progress under the same conditions in a standard creep machine. The ex-reactor rate is about 5×10^{-7}/hr.

Two additional in-reactor creep tests on 20% cold worked Zircaloy-2 were started this month. One of these tests has accumulated 340 hours at 25,000 psi and 350 C (662 F). The rate appeared to approach a steady state value of about 5×10^{-6}/hr after about 40 hours. The other test, run at 35,000 psi and 310 C (590 F), has accumulated about 360 hours. The steady state rate for this test is 1.5×10^{-5}/hr. Out-of-reactor data are not yet available for the new tests.

After completion of the 20,000 psi, 350 C (662 F) test, the capsule was used to determine a series of activation energies. Values found were 84,000 cal/mole at 354 C (669 F), 61,000 at 430 C (806 F), and 54,000 at 448 C (838 F). These values are in excellent agreement with previously reported data. Upon completion of the activation energy measurements, the specimen stress was adjusted to 30,000 psi at 330 C (626 F) in order to obtain information concerning creep rates during reactor outage at temperatures between 350 C (662 F) and 310 C (890 F).

Capsule Development. A tungsten resistance heater for use in a proposed high temperature in-reactor creep measurement capsule has been tested for 270 hours. During this time a 1/8" molybdenum rod was held at 1300 C (2472 F) under a partial pressure of helium. At 240 hours the test was stopped due to a scheduled building power outage.

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The test was resumed after the power was back to normal, and approximately 30 hours later the test was stopped due to failure of the tantalum heat shield.

Irradiation Effects in Structural Materials. The purpose of this program is to investigate the combined effects of irradiation and reactor environment on the mechanical properties of structural materials. Special attention will be given to the determination of mechanical property changes produced in metals by irradiation at elevated temperatures.

During the month a total of 92 room temperature tensile tests were performed on both irradiated and unirradiated program materials. The majority of these tests were conducted on AISI 348, 406, 410, and AM-350 stainless steels and Zircaloy-2; the remainder were conducted on a variety of nickel-base and refractory alloys.

Approximately 300 Zircaloy-2 tensile specimens from three N-Reactor process tubes have been prepared and characterized for exposure in the ETR G-7 and ex-reactor hot water loops. The tubes, designated CT-7, HT-37, and AT-50, were supplied by Chase Brass and Copper Company, Harvey Aluminum Company, and Allegheny Ludlum Steel Corporation, respectively. These tubes differ in fabrication history and contain from 18 to 35% cold work. Subsequent to fabrication, the tubes were autoclaved at 425 C (796 F) for 72 hours at HAPO. Flat tensile specimens aligned with the tube axis were cut from the wall of the tubes. The wide dimension of the gage cross section was oriented either normal or tangential to the tube circumference. In order to impart a protective oxide coating on the specimens for loop exposure, the specimens were autoclaved at 300 C (572 F) and 1500 psi for 72 hours. The coat achieved was adherent, but less dense than the normal process treatment at 425 C (796 F). Of the 300 specimens prepared, 162 were assembled into quadrant containers and were shipped to the ETR for irradiation in the G-7 loop, 84 were prepared for similarly programmed exposures in the ex-reactor loop, and the remainder were set aside to determine mechanical properties in the as-fabricated and as-autoclaved condition. Goal neutron exposures for the nine quadrants to be irradiated in the G-7 loop range from 5.0 to 10^{19} to 1.0×10^{22} nvt (fast).

Approximately 172 flat tensile specimens have been fabricated from sheet stock of AISI type 406 stainless steel supplied by Carpenter Steel Company. The sheet was hot-rolled to a nominal 0.125-inch thickness and shipped to HAPO in the as-rolled condition. The sheet was subsequently cold-rolled to introduce approximately 15 and

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25% cold work. During the month the material in its various fabrication conditions was characterized by metallography, and specimens were assembled into quadrants and shipped to the ETR for irradiation in the ETR G-7 loop.

Round, buttonhead tensile specimens of TZM molybdenum alloy, Cb - 1 Zr, and Cb-752 (Cb - 2.5 Zr - 10 W) alloys have been fabricated, placed in capsules, and sent to the ETR for irradiation at ambient water temperature in the ETR, G-6 position for one and two cycle irradiations. This marks the first irradiation of refractory alloys as part of the HAPO program. Corrosion coupons are presently being exposed in hot water at 300 C (572 F) to determine the feasibility of irradiating columbium, molybdenum, tantalum, and tungsten alloys in the ETR G-7 hot water facility.

Tensile specimens of Cb - 1 Zr, TZM, Cb-752, Mo, Ta, Cb, W, and W - 25 Re are being fabricated to determine mechanical properties as a function of temperature and environment. Three high temperature tensile tests were conducted during the month: a Cb - 1 Zr specimen at 1000 C (1832 F) in helium, a Ta - 10 W specimen at 1520 C (2768 F) in a vacuum, and a TZM specimen at 1150 C (2102 F) in a vacuum. The first specimen was heated by means of radiant energy supplied by radiant quartz lamps surrounding the specimen, and the latter two were inductively heated by means of an induction coil.

Zircaloy-2 specimens, identical to those irradiated in the ETR G-7 test water loop, have been exposed in an ex-reactor loop to determine what changes in mechanical properties are due to the hot water environment alone. The temperature record of the ex-reactor loop was programmed to duplicate the in-reactor history. Prior to loop exposure the Zircaloy-2 specimens were given a dual autoclave treatment; 48 hours at 300 C (572 F) in water and 48 hours at 400 C (752 F) in steam. Property changes in the as-prepared specimens due to this autoclave treatment were small in annealed material but were appreciable in cold worked specimens due to cold work recovery. Longitudinal specimens undergo greater recovery than transverse specimens. As a result, longitudinal specimens having 20% cold work exhibited a higher yield strength (by about 4000 psi) than transverse specimens before an autoclave treatment but had a lower yield strength (by about 4000 psi) after an autoclave treatment at 400 C (752 F). It was expected that as a result of prior thermal treatment at 400 C (752 F) no additional change in properties would occur due to loop operation at 280 C (540 F). The effective operating times at 280 C (540 F) evaluated to date range from 8.5 to 3460 hours. Within normal experimental scatter it can be said

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that the yield and tensile strengths of both 20 and 40% cold worked Zircaloy-2 given a prior autoclave treatment at 400 C (752 F) do not change during subsequent loop operation at 280 C (540 F). The same can be said for transverse annealed specimens of Zircaloy-2. However, the mechanical behavior of longitudinal annealed specimens is erratic after 1000 hours of loop operation. Some specimens exhibit an increase in yield strength (measured at room temperature) which is substantially beyond normal scatter, while other specimens show little change from the as-autoclaved condition. High values of yield strength after 1850 and 3460 hours of loop exposure are 63,400 and 68,700 psi, respectively, compared to a mean value of 49,000 psi in the as-autoclaved condition. The ultimate strengths of these same specimens do not differ from the as-autoclaved value. These observations must be considered tentative pending further examination.

The effects of autoclaving on tensile properties at 300 C (572 F) were also explored. Tests were conducted on specimens both before and after an autoclave treatment of 72 hours at 425 C (796 F). Annealed longitudinal specimens exhibited yield and ultimate strengths of about 19,000 and 30,000 psi, respectively, both before and after autoclaving. Annealed, transverse specimens exhibited an increase in yield strength from 18,000 to 22,000 psi but no significant change in ultimate strength. Transverse specimens having 20% cold work exhibited a decrease from 46,000 to 39,000 psi in yield strength and from 48,800 to 41,000 psi in ultimate strength due to the autoclave treatment. Corresponding decreases due to autoclaving in longitudinal specimens having 20% cold work were from 48,800 to 36,200 psi in yield strength and from 49,000 to 40,200 psi in ultimate strength. These decreases in strength are attributed to cold work recovery at 425 C (796 F), the autoclave temperature. As in the room temperature tests, it can be noted that longitudinal cold worked specimens have a higher yield strength at 300 C (572 F) than transverse specimens before and a lower yield strength after an autoclave treatment at 425 C (796 F).

Investigations of the effect of loading rate on the crack toughness properties of 23% cold worked Zircaloy-2 have given some insight into the fracturing mechanisms of this material. Charpy impact tests performed this month on 23% cold worked Zircaloy-2 specimens show a transition in impact energy in the temperature range 300 C to 350 C (572 to 662 F). This confirms work done by other investigators using different testing procedures.

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Similar Charpy specimens tested in three-point slow bending at a cross-head speed of 0.05 inch/minute gave a transition at approximately -175 C, thus indicating a marked strain rate effect on the transition temperature. These data when compared to the notch beam data show that there is a marked variation in the energy requirements for crack initiation. In the case of the Charpy specimens which contain a 0.010-inch root radius sufficient energy is stored in the system prior to crack initiation and propagation to cause gross plastic flow prior to fracture. Only at lower temperatures (-175 C (-282 F) and below) does the yield strength reach a level which prevents the occurrence of gross deformation prior to fracture.

Notch beams were tested at a cross-head speed of 2 inches/minute. Plastic bend angle measurements indicate a transition at approximately -50 C (-58 F); a transition 30 C higher than found with slower tests. These tests indicate that the higher the testing rate, the higher are the nominal notch bending stresses at fracture below the transition temperature. Like the low rate tests, the nominal notch bending stress decreased with decreasing temperature.

While tests on several steels by other investigators demonstrate a decrease in notched fracture strength with decreasing temperature below the ductile to brittle transition temperature, there is also a decrease in the notched fracture strength with increasing strain rate. An empirical relationship has been developed which shows that notched fracture strength is inversely proportional to the yield strength of the material. These results are partially substantiated by a purely theoretical classical mechanics approach. In Zircaloy-2, however, tests presently in progress indicate that a certain amount of deformation must take place before crack initiations can occur with subsequent catastrophic failure. The brittle behavior of the Zircaloy-2 beams below the transition temperature may, therefore, be attributed to a deformation mode or a combination of interacting modes which become operative in the high stress field in the immediate region of the fatigue crack. The fact that Zircaloy-2 is relatively rate insensitive in a tensile test at these temperatures indicates that if this mechanism does occur it occurs within a very short distance of the fatigue crack. It is only in this region that the strain rates would be high enough to significantly affect the ease with which the deformation can occur. Once, however, crack propagation does occur the size of this region of very high strain rate increases, thereby making the mechanism operative over a greater volume of material.

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Damage Mechanisms. The objective of this program is to establish the nature of the interactions between defects present prior to irradiation and those produced during irradiation, with emphasis on the role played by interstitial impurities. The investigation is presently concerned with high purity iron and its low carbon and nitrogen alloys.

Tensile tests of the zone refined iron obtained from Battelle Memorial Institute were performed during this period. A drop in load yield point of about 8000 psi indicated the material was not as pure as the zone refined iron previously tested. The introduction of impurities, however, may have taken place during reduction of the $1\frac{1}{4}$" diameter bars to the 1/8" diameter rod required for tensile specimens. The lower yield point of 16,800 psi was slightly less than that of the previous zone refined iron tested. The ductility was also greater than the previously tested zone refined iron. Grain size determinations are presently in progress.

Oxidation of Dispersion Hardened TD Nickel. Jost* has suggested that oxidation of metals may not be controlled entirely by diffusion through the oxide film when such films are relatively thin. He suggests that a phase boundary reaction may be significant in early stages of the reaction. These considerations yield a kinetic equation

$$m/k_i + m^2/k_p = t,$$

which is a more general form of the parabolic equation, $m^2 = k_p t$. Here m is weight gain per unit area, k_i and k_p rate constants for phase boundary and parabolic reactions, respectively. Wagner and Bauer, et al, have shown that this equation applies for oxidation of copper for weight gains up to 10 mg/cm^2 (13.3 μ film thickness).

The equation has been shown to apply to the oxidation of TD Nickel in the range 600-1000 C (1112-1832 F). A plot of t/m vs m yields a straight line in nearly all cases, demonstrating the applicability of the equation.

Tests have shown that both Inco 270 (99.97 Ni) and Johnson, Mathey Nickel (99.997 Ni) oxidize at a more rapid rate than TD Nickel.

*Jost, W., Diffusion in Solids, Liquids, Gases, Academic Press, 1952, p. 353.

If the thoria dispersion enhances diffusion in the oxide film, the result would be a higher rate of oxidation for TD Nickel than for pure nickel, which is not the case. One must conclude then that the rate of the phase boundary reaction is slowed to a value at least approaching that of the diffusion reaction.

The reaction at the oxide-metal interface may be affected, since thoria particles probably accumulate there. However, the pressure sensitivity of oxidation suggests that a reaction at the oxygen-oxide interface is affected. Either or both of these processes may be important. The relative significance of the two is as yet unresolved.

Gas Loop Development. A computer program was prepared for calculating interface temperatures and heat losses for the doubly contained pressure piping design using insulation between pipes. The program can be used, however, to calculate interface temperatures and heat losses through as many as eight layers of material plus the inside and outside film drops. Although the present program was prepared for the materials and helium coolant used in the prototype gas loop (Haynes-25, type 316 and 347 stainless steels, and Fiberfrax), equations for other engineering materials and liquid and gas coolants will be placed in the program to allow its widespread usage for this type of calculation.

Heat losses were calculated for the high temperature runs on the prototype gas loop. To provide a 2000 F (1098 C) test section temperature, the heater will operate at close to 2100 F (1149 C).

Preliminary design of the test section of the model high temperature gas loop was completed and final design is under way.

Mica as a Neutron Monitor. The passage of fission fragments through mica results in disrupted regions which after etching in HF are visible when viewed with an optical microscope. The purpose of the present study is to determine whether the phenomenon can be used to monitor neutron flux in graphite damage studies.

Impurity uranium is present in mica to the extent of approximately 10^{-11} atomic percent. For monitoring a high neutron flux this concentration yields considerable track densities for irradiation times on the order of a few hours to several weeks. Mica samples, both bare and cadmium-covered, are being irradiated in a Hanford reactor test facility. Fe, Ni, and Co flux monitors are included with each mica sample. These samples will be used to study the following questions:

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1. Are the track density counts reproducible for different mica samples which experience the same irradiation history?

2. Is there a correlation between track density counts and flux levels as given by the Fe, Ni, and Co monitors?

3. Is the relationship between track density and integrated flux linear as predicted?

The same studies are being made for low fluxes on the order of 10^6 nv using the PCTR facility. Since the low impurity content of uranium will not be sufficient for these low neutron flux levels, thin sheets of natural uranium will be placed next to the mica samples. Thus the tracks in the mica will result from fission fragments originating in the sheet of natural uranium.

The mica samples are prepared for microscope viewing or photographing as follows: the irradiated sheets are cleaved, etched in 50% HF solution at 25 C for 1 hr, mounted on a microscope slide and Al coated. Micrographs will be used for track density determination.

6. Gas-Cooled Reactor Studies

EGCR Graphite Irradiation. The sixth capsule, H-3-6, in the series of irradiations of EGCR graphite has successfully completed two cycles of irradiation. Number 5 thermocouple continues to operate erratically. The other eight thermocouples continue to function properly. The mean temperatures of the six samples from top to bottom of the capsule were 475 C, 625 C, 725 C, 800 C, 450 C, and 350 C, respectively, for the first cycle of operation. These mean temperatures are expected to vary less than 25 C over the scheduled four cycles of irradiation.

Thermal Oxidation of TSX Graphite by Small Partial Pressures of Water Vapor. The relationship between graphite sample size and rate of oxidation in helium containing small partial pressures of water vapor is now under study. Experiments are performed in a quartz reaction chamber with an internal diameter of about 4 inches which allows the exposure to a controlled atmosphere of cylindrical graphite samples 12 inches in length and up to 3.5 inches in diameter. Initial measurements are on a series of TSX graphite samples ranging from 0.5 to 3.5 inches in diameter.

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The following procedure has been employed for the initial rate determinations. The graphite sample is placed in the reaction chamber and the system is evacuated at room temperature to a pressure of about 0.5 μ. The sample is then outgassed overnight at the reaction temperature. Following outgassing, helium, purified from its trace oxygen impurity by copper at 350 C, is flowed through the reaction chamber; the volume flow rate is adjusted arbitrarily to a linear flow rate of 20 cm/min past the sample. The run is started by routing the helium through a trap containing liquid water at about 0°C to give a resulting water concentration of about 7000 ppm. Following a suitable period of oxidation, the trap containing water is by-passed and the graphite sample is cooled to room temperature in dry helium. The rate of oxidation is then obtained from the measured weight loss of the sample and the time of reaction. To date, two runs have been made on a sample whose diameter is 1.5 inches. Preliminary results at 710 and 836 C indicate reaction rates one-quarter to one-third of those calculated on the basis of rate constants derived from small samples, thus implying retardation due to a diffusion barrier.

7. Graphite Radiation Damage Studies

Irradiation of Pyrolytic Graphite. A maximum exposure of 4873 MWD/AT_K at 600 C has been accumulated after a second irradiation on samples of production-grade pyrolytic graphite specimens. Samples were rectangular rods 1/3 inch x 1/2 inch in cross section and 2 inches to 4 inches long. Total length changes from 15 measurements on four samples averaged -0.20% ± 0.03% in a direction. The average dimensional change rate between 2680 MWD/AT_K and 4800 MWD/AT_K was -0.1% per 10^3 MWD/AT in the a direction. The scatter of expansion in the c direction observed after 4800 MWD/AT_K was quite pronounced ranging from +0.67% to 1.0. The average rate of dimensional change in the c direction for the four samples was nearly constant ranging from 0.25 to 0.3% per 10^3 MWD/AT_K. Another sample of smaller dimensions, 1/2 inch x 1/2 inch x 1/3 inch, displayed an expansion of +3.8% at the same exposure. It is suspected that the extreme difference may be the result of delamination in the smaller sample.

These results confirm the trend of dimensional changes noted at shorter exposures. There can now be little doubt that pyrolytic graphite prepared at 2200 C contracts in the a direction and expands in the c direction upon high temperature reactor irradiation.

These results give strong support to the existence of a vestige of low temperature damage, that is, expansion in the c direction and

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contraction in the a direction, in graphite crystallites as hypothesized in the current theory of high temperature radiation-induced contraction of graphite.

Effect of Impregnation on High Temperature Contraction. The third irradiation has been completed on a series of samples which are intended to determine the effect of impregnation with furfuryl alcohol on high temperature radiation-induced contraction. Two types of graphite, HLM-85 used in HTGR fuel elements and TSX, were included. Total impregnant carbon added was 4% for HLM-85 and 8% for TSX. In general, contraction was greater in the impregnated samples than in the unimpregnated control samples. In all instances, however, the impregnated samples baked to 900 C were dimensionally more stable than the impregnated samples which were graphitized at 2650 C and 2900 C.

The total length changes ranged from -0.5% to -1.2% and the difference between the unimpregnated and graphitized impregnated samples was a minimum of 0.1%. Exposures are estimated in the range 1.9 to 3.2 x 10^{21} nvt, E > 0.18 Mev and irradiation temperatures are near 1000 C.

8. Boronated Graphite Studies

In the past several months an effort has been made to correlate boron loss and lithium buildup with irradiation history of boronated graphite samples; however, because of the necessity of performing other tests, only a few samples could be spared for chemical analysis. Analysis of samples from one capsule irradiated at 540 C indicated that boron migration occurred within the capsule, perhaps due to the presence of water vapor known to have been introduced as a contaminant in one of the samples. In a capsule irradiated at about 315 C, no migration was noted. Lithium analyses though scattered were in reasonable accord with estimates of lithium content based on measured thermal flux. The expected loss in boron for this exposure (5.68 x 10^{18} nvt, E > 0.18 Ni) was less than could be determined analytically.

Four samples from each of four 2-inch boronated graphite cubes were analyzed for boron and lithium to check homogeneity of black and gray material at two boron concentration levels. The average deviations for each of the four sets of data were respectively 2.0, 1.3, 2.2, and 4.2%. The average deviation for all 16 points was 2.4%. Eliminating one point, however, gave an average deviation of 1.9. Thus the gross variation of boron concentration in these four different materials was only about 2%. (Multiple analyses of

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homogenized samples indicated a precision of better than 0.5% for the method used.)

Boronated graphite will be irradiated in capsules which will shield the samples from slow neutrons responsible for the B (n, α) Li reaction, and yet permit exposure to the unperturbed fast component (E > 0.18 Mev). This will permit evaluation of the relative effects of alpha particles and fast neutrons in causing damage.

Neutron transport theory calculations have been made on tentative capsule designs which show that a suitable cadmium shield will reduce the B (n,α) Li reaction by a factor of 4 without appreciably perturbing the fast flux. Consequently, heat transport calculations are now being made to determine heating rates to be used in calculating heat transfer in experimental capsules.

9. Aluminum Corrosion and Alloy Development

Oxidation Characteristics of Aluminum in a Non-Isothermal Loop. Effects of pH and loop ΔT on the corrosion rate of aluminum are presently being investigated in the non-isothermal loop at a test section temperature of 330 C (626 F) and temperature drops of 8 to 55 C. Increasing the loop ΔT from 8 C to 55 C increased the corrosion rate by a factor of 2. (1.05 to 2.05 mils/10 days.) However, a decrease in pH from 6.4 to 5.4 caused the rate to decrease at high ΔT (55 C) by nearly a factor of 2 (2.05 to 1.15 mils/10 days). Subsequent increases in pH: 5.7, 6.1 and 6.4 caused concomitant increases in rate (1.35, 1.45, 1.54 mils/10 days). However, preliminary data from a recent run indicate that current rates at high ΔT are below the rate observed at beginning of the series at about the same pH.

In-Reactor Corrosion of Aluminum. Corrosion rates of aluminum coupons measured in the second test in H-1 Loop were slightly lower in-flux than out-of-flux, and slightly lower for X-8003 alloys (1.5% Fe, 1.5% Ni, 0.002% Si) than for X-8001 (0.5% Fe, 1.0% Ni, 0.2% Si). The in-flux corrosion rates were 0.81 and 0.63 mil/mo for X-8001 and X-8003, respectively; the corresponding rates out-of-flux (downstream) were 0.94 and 0.73. The conditions of the test were 37 days of exposure at 288 C, 25 ft/sec, pH 4.9 with phosphoric acid.

By comparison, the rates in the first test (pH 7.9, 46 days, 288 C) were 0.99 mil/mo in-flux and 2.84 mils/mo out-of-flux for both X-8001 and A-288 alloys. The reduction of corrosion by addition of phosphoric acid in the second test was not as great as was expected, particularly in-flux. In the second test both the in-flux and out-of-flux coupons were covered with crud; this supports the hypothesis that the difference

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between in-flux and out-of-flux rates in the first test was due to preferential crud deposition on the in-flux coupons.

The above data for the second test are from coupons cleaned by thermal shock followed by chemical cleaning in a phosphoric-dichromate-acetic mixture. This procedure removed the high temperature oxide very well. Other coupons, subjected to dissolution in iodine-methanol, gave very erratic results.

10. USAEC-AECL Cooperative Program on Development of Heavy Water Moderated Power Reactors

Thermal Hydraulic Studies

Hydraulic & Heat Transfer Characteristics of 19-Rod Bundles. Analysis was continued of experimental heat transfer and pressure drop data obtained with an electrically heated 19-rod test section, 6.3 feet long with 0.050-inch spacing between rods. The analysis includes determination of the two phase pressure drop, the heat transfer coefficients, and the degree of radial mixing in the bundle.

The analysis has not been completed, but several observations can be made at this time and are reported as follows:

1. The liquid phase friction factor appears to have a -0.1 power dependence on the Reynolds number and is about what would be calculated using an equivalent diameter calculated in the conventional manner.

2. During heat generation the test section pressure drop at outlet water temperatures close to, but less than saturation are 20 to 30% higher than the pressure drop with no heat generation. This is undoubtedly due to local boiling.

3. The conditions at the start of local boiling could be determined by noting where a change of slope occurred on plots of heat flux versus the surface temperature minus saturation temperature. It was found that the surface temperatures during local boiling were somewhat higher than predicted by the Jens and Lottes correlation

$$t_{surface} - t_{sat} = \frac{1.9(Q/A)^{\frac{1}{4}}}{P/900}$$

where: Q/A is the heat flux, B/hr-sq ft
P is pressure, psia.

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4. Average heat transfer coefficients, which ranged from about 1,500 to 5,000 Btu/hr-sq ft at flow rates of 500,000 to 5,000,000 lb/hr-sq ft, showed a dependence of the heat transfer on the 0.5 power of the flow rate rather than the 0.8 power commonly accepted for duct flow. There was no immediate explanation for this discrepancy.

5. The heat transfer coefficients improved markedly upon the start of local boiling. The improvement increased with increasing boiling and reached values of 10,000 to 15,000 Btu/hr-sq ft when bulk boiling was well established.

19-Rod Fog Cooling Studies. The 19-rod electrically heated test section for fog cooling studies which was damaged during testing has been repaired. It is being installed without the flow diverter used in the previous tests to determine the effect the diverter had on boiling burnout. The flow diverter was a ring of Al_2O_3 segments around the bundle about 14.5 inches upstream of the active section which tended to divert the flow into the bundle at that point.

Dome Seal Type Nozzle Closures

The dome seal with a modified hold-down mechanism using Belleville Spring-washers has been tested for a total of 15 cycles. There has been no permanent deflection of the dome as measured under 10X magnification since the start of this series. As previously reported, the cause of dome deflection was apparently related to stresses resulting from temperature gradients as the test section was valved into the hot (570 F) loop.

Upon five more cycles of "assembly-cycle-disassembly", the original test proposal will have been successfully completed. These tests are presently in progress. Consideration is being given to running thermal shock tests to evaluate the dome seal resistance to temperature change with the modified hold-down mechanism. The following conclusions are apparent from tests to date: (1) the dome seal is very leak tight - there has been no trace of leakage (discounting a few drops of condensate when the dome deformed 0.135 inch); (2) the major cause of dome deformation was found to be very rapid temperature change, which was eliminated by changing the test procedure; and (3) a minor cause of dome deformation was found to be the rigid hold-down mechanism, which was eliminated by modification of the retaining mechanism. The dome seal concept shows promise of being an effective closure device.

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11. Advanced Reactor Concept Studies

Fast Supercritical Pressure Power Reactor. Fuel cycle cost calculations for the most recent reference core design were completed during the month. For this core, fuel cycle costs were excessive (3.15 mills/kwhr) and were considerably in excess of the corresponding costs for the thermal SPPR (1.7 mills/kwhr). This is primarily attributable to (1) higher fuel fabrication costs assumed for the FSPPR ($300/kg fuel vs. $150/kg fuel), (2) a relatively low specific power in this reference core, and (3) a large breeding blanket. In order to identify the major contributing factors to the high cost, approximate fuel cycle costs were computed for a number of possible changes in the reference core design and in cost assumptions. These are summarized as follows:

Design Change from Reference Core	Approx. Fuel Cycle Cost Mills/kwhr
1. Reduce radial blanket from 30 cm to 15 cm thick.	2.68
2. Eliminate outer moderator and flux trap and make a 22 cm fast radial blanket.	2.63
3. Cut the core length to 5 feet - leave the radial dimensions the same.	2.37
4. Cut the radial dimensions of the 5-foot core, reducing volume by 19%, and increase burnup from 70,000 MWD/t to 100,000 MWD/t.	1.74
5. As above but reduce fuel element fabrication charges by one-half for both the core and blanket material.	1.19

Based on these estimates, it was apparent that the design would have to be reduced to a 5-foot core with reduced radial dimensions and a much smaller blanket region. Rather than spend the time developing a detailed fuel element design for the 5-foot core, it was decided to utilize the information developed for the 6-foot core. To do this, the number and diameter of tubes was determined by holding the Pratt and Whitney heat transfer parameter, $\frac{(q/A)\,D^{0.2}}{G^{0.8}}$, constant and the pressure drop constant.

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The following relationships were established:

$$N_5 = 1.419\ R\emptyset^{\ 1.925}\ N_6$$

$$D_5 = \frac{0.870\ D6}{0.770\ R\emptyset}$$

where RØ is the ratio of the peak to average flux in the 5-foot core to the peak to average flux in the 6-foot core. Besides the above relationships, the fuel to coolant ratio in each core zone was given some minimum value. These were as follows:

(Vf/Vc) 3rd pass = 1.5 (min)
(Vf/Vc) 2nd pass = 1.5 (min)
(Vf/Vc) 1st pass = 3.0 (min)

The void and cladding volume fractions for the 5-foot core were assumed the same as for the 6-foot core. These are primarily a function of the fuel element surface to volume ratio. Since the fuel element shape does not change, the only change in these volume fractions will come from slightly lower fuel to coolant ratios in the 5-foot core.

Region	Radius	
Core 1	29.6 cm	3rd coolant pass
Core 2	42.5 cm	2nd coolant pass
Flux trap	49.5 cm	
Moderator	52.5 cm	
Flux trap	59.5 cm	
Core 3	76.7 cm	1st coolant pass
Blanket	96.7 cm	
(Core Height = 5 ft)		

The specific power is 0.70 MWt/kg fissile with an initial critical mass of 966 kg fissile plutonium and a breeding ratio of about 1.2. The reduction in size now yields a slightly negative coolant void coefficient with only one moderating region. Some additional adjustment in critical mass may be made upon completion of burnup calculations.

A reevaluation of fuel fabrication costs is also being made, based on a more detailed fuel design.

Calculations were also initiated for a 1000 MWe core design to better evaluate the economic incentives in the larger fast reactor size range. The design effort here is just enough to obtain a reasonable fuel cycle cost estimate that can be compared with the 300 MWe fuel

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cycle cost. Again the number of tubes and their diameter was determined using the 6-foot core as a base and keeping the heat transfer parameter and pressure drop constant.

$$N_7 = 2.372\ R\phi^{1.925}\ N_6$$

$$D_7 = \frac{1.145\ D_6}{0.770\ R\phi}$$

The total coolant cross sectional area in each coolant pass was established from the above relationships. These were then modified to fit into what appeared to be an economic core diameter. The modifications necessary are based on obtaining a reasonable maximum heat flux with pressure drop comparative to the SPPR. The only pressure drop parameter considered here is the mass flow rate. The range of mass flow rates allowed is:

$$2.14 \times 10^6 < G < 3.81 \times 10^6\ (\text{lbs/hr-ft}^2)$$

(1st pass) (3rd Pass)

Preliminary drafts of several FSPPR report sections concerned with reactor description were completed.

Vendor information on the present outlook for commercial production of Rene' 41 tubing is not optimistic. Specifically, fabrication of small diameter, thin wall tubes has yielded unsatisfactory quality and excessive losses due to splitting and fire cracking during annealing. While additional investigations on future outlook will continue, alternate tubing materials are being considered for the FSPPR.

Plutonium Fueled Rocket Reactor. Preliminary correlations have been made relating the required core size and weight to coolant volume fraction and heat transfer rates. For a 1000 Mw(t) power level, a core 12 to 13 inches in diameter and approximately 18 inches long appears feasible. This core would weigh approximately 750 lbs; with a reflector and a minimal shadow shield, weight would be about 2500 lbs. Sizing of the core is based on a "honeycomb" cermet fuel with a 0.020-inch thick fuel web and square coolant channels 0.040-inch on a side (or hexagonal channels 0.020-inch on a side). The fuel would be formed into thin plates the full diameter of the core; these plates would be individually suspended within the reactor. Fuels Development has produced tungsten - UO_2 cermet honeycomb samples having a 0.020-inch fuel web with 0.125-inch square openings.

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The assumed average heat transfer rate for the core is about 5×10^6 Btu/hr-ft^2. At this rate the temperature difference between the fuel surface and the hydrogen coolant would be on the order of 800 F. It would appear desirable to skew the reactor power distribution strongly toward the inlet end, to boost fuel temperatures in that region (entering hydrogen temperature may be 200 to 400 R) and to ease the problems of fuel overheating at the exit end of the core.

This core arrangement poses potentially formidable problems in support of the thrust load from coolant flow through the fuel disks, accommodation of thermal expansion of the fuel disks, allowance for flow channels mismatch, and provision for avoiding vibration. A preliminary assessment of these problems is planned as the next step in core analysis.

Plutonium Fueled Spacecraft Reactor. The effect of vertical leakage on the control span of a spectral shift control region in the PFSR was studied this month. The control span appears to be 20% to 30% Δ k, which is somewhat lower than reported last month. However, the vertical leakage description used to date is too crude to be entirely satisfactory. More accurate definition of the vertical leakage will require the use of a two dimensional computer code.

D. DIVISION OF RESEARCH - 05 PROGRAM

1. Radiation Effects on Metals

This program is aimed at establishing the combined effect of impurities and neutron irradiation on the properties and structure of specific metals and deducing from thermally activated recovery processes how the damage state can be altered.

Single Crystal Molybdenum. Results of tensile testing of irradiated and unirradiated molybdenum single crystals are underoing further interpretation. Because of a certain degree of question as to the crystallographic nature of slip in unalloyed body-centered cubic metals, it has been deemed advisable to consider the possibility of slip on crystallographic planes other than the familiar {101}, {112}, and {123} families. A new 7090 computer program has been written which facilitites the computation of maximum resolved shear stress and shear strain on eight possible families of slip planes. The planes considered are {101}, {112}, {123}, {235}, {134}, {145}, {156}, and {437}. Since the slip direction has been definitely confirmed as < 111 > in the case of unirradiated molybdenum crystals, higher-index planes have not been considered.

This method of interpretation has clearly demonstrated the orientation dependence of deformation in both irradiated and unirradiated molybdenum. In the case of the unirradiated crystals, which apparently deform by slip on several systems, it is only possible to state that most of the deformation occurs on the plane of maximum resolved shear stress. In irradiated crystals, slip in the early stages of deformation appears to be entirely confined to the plane of maximum resolved shear stress.

Time-lapse photographic recording of tensile deformation of irradiated (10^{19} nvt, E > 1 Mev) molybdenum crystals exhibiting pronounced yield points has revealed that an offset occurs in the crystal after yielding, indicating gross localized slip. As plastic flow proceeds, the offset is gradually "healed", but rupture occurs at the point of the initial offset. This effect is ascribed to rapid dislocation multiplication on one slip system during the yielding process and formation of extensive dislocation pileups which form a region of high stress concentration.

Precision lattice parameter measurements on molybdenum single crystals have been discontinued. Excessive substructure in both unirradiated and irradiated samples, as well as a point-to-point variation in measured values of lattice parameters, indicated that the measurements would be of marginal value. Both these characteristics of the crystals can be traced to their method of preparation. The crystals were grown by an electron beam zone-melting technique, which generally results in a fairly high density of grown-in dislocations. The slow cooling rate associated with this technique permits considerable thermally-activated dislocation motion and subgrain formation, as well as extensive precipitation of carbides. Both the above objectionable properties can be greatly diminished by a high temperature anneal of about one-half hour at 2000 C (3632 F).

A second group of crystals is being prepared for irradiation in the annealed condition rather than in the as-grown state. The present samples will be studied further to determine the effect of irradiation on the substructure.

Polycrystalline Molybdenum. Transmission electron microscope examination of molybdenum foils containing three levels of carbon as an impurity has been completed. The foils were irradiated to 10^{19} nvt (E > 1 Mev) at 40 C (104 F), and then annealed for 2 hours at 900 C (1652 F). Defect structures introduced by irradiation were completely eliminated in the case of the high purity molybdenum (< 10 ppm carbon). Small clearly resolvable loops persisted in the

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molybdenum containing 150 and 450 ppm carbon, and in these materials the spot defects present after a 750 C (1382 F) anneal were completely eliminated by annealing at 900 C (1652 F). The absence of loops in the high purity molybdenum after irradiation and annealing is strong evidence that the loops are associated with point defects stabilized by impurity atoms. In the foils containing 150 and 450 ppm carbon, it is believed that the small loops present after irradiation are due to the clustering of point defects at trapping sites such as interstitial carbon atoms, followed by collapse to form a dislocation loop. The persistence of the loops suggests that the responsible defects are vacancies since the binding energy of a vacancy with an interstitial solute atom is greater than that of an interstitial solvent atom with an interstitial solute atom. The growth of the loops upon annealing at 750 C (1382 F) may be due to absorption of vacancies which are released from tightly bound clusters. The corresponding decrease in density of the spot defects suggests that the spot defects are the source of the vacancies. Shrinkage of the loops after the 900 C (1652 F) anneal is probably due to emission of vacancies and nonconservative dislocation motion.

A capsule containing eight high purity molybdenum electrical resistivity specimens has been discharged and opened after an exposure of 10^{18} nvt (E > 1 Mev). The specimens are too radioactive for safe handling after a decay period of five days and will be allowed to decay for a period of two more weeks before investigation begins.

Nickel. Nickel foils of 99.4, 99.6, and 99.97% purity have been encapsulated and submitted for reactor irradiation to 2×10^{18} nvt (E > 1 Mev). Two metallurgical conditions are represented: (1) foils annealed at 700 C (1292 F) for one hour, and (2) foils containing approximately 30% cold work. The foils will be studied by x-ray and transmission electron microscope techniques following irradiation.

Various techniques for electrolytic thinning of nickel foils are being investigated. After thinning in an electrolyte of 23% perchloric acid - 77% glacial acetic acid, the high-purity cold-worked material shows elongated grains with distinct grain boundaries in the optical microscope. It is not known if this is the result of a preferential etch at grain boundaries or an outline of a second phase present in the material. Transmission electron microscopy revealed subgrain boundaries consisting of a circular array of dislocations. Other electrolytes and polishing conditions are under investigation.

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A paper entitled, "Yielding Behavior of Neutron-Irradiated Nickel," has been prepared for submission to Acta Metallurgica.

A total of 120 inches of high-purity (99.997%) nickel single crystals has been ordered for deformation studies. Specific orientations will include [001], [111], [011], [112], [012], and [123]. Also on order is a total of 250 feet of ultra high-purity 0.020-inch diameter nickel wire.

Rhenium. Metallographic examination of 0.5 mm diameter rhenium wire supplied by the Rembar Company has shown the wire to be unsatisfactory for use in electrical resistivity measurements. The wire contains numerous surface cracks up to 0.15 mm deep, long longitudinal cracks in the center of the wire, and numerous regions of high porosity near the surface. Rhenium rods 0.1 inch in diameter supplied by the same vendor appear to be microstructurally sound and will be reduced to 0.020-inch diameter wire on-site.

Experimental Techniques and Apparatus. A high-temperature x-ray sample holder is being utilized for annealing studies on cold-worked and irradiated foils. The first samples to be examined are molybdenum foils, but nickel, iron, and rhenium samples will be examined as they become available. Parameters to be studied are lattice parameters, line breadths, and possibly the Debye-Waller temperature factor of the irradiated samples. The x-ray technique promises to be especially valuable in the study of annealing kinetics, as the annealing process can be followed continuously for any desired period.

An apparatus for quenching foil specimens for subsequent examination by transmission electron microscopy has been assembled and tested. Specimens of 0.003-inch thick nickel foil in widths of 1/8- and 3/32-inch have been successfully quenched from 1400 C (2552 F) at rates of approximately 5×10^3 degrees per second.

2. Plutonium Physical Metallurgy

The objective of this program is to determine some of the basic physical metallurgical properties of high-purity plutonium and to establish the effect of certain specific alloying additions on these properties. Two areas are under study: mechanisms of phase transformations and mechanisms of deformation and recovery.

Phase Transformation Studies. Time-Temperature-Transformation (T-T-T) curves of the $\gamma \rightleftarrows \beta \rightleftarrows \alpha$ transformations of high quality plutonium, less than 300 ppm total impurities, were obtained. The primary

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difference between these T-T-T curves and the curves published earlier for the corresponding transformations of lower quality metal is that they are shifted to the left due to the higher purity. The temperatures of the maximum reaction rate for the $\gamma \rightarrow \beta$ and the $\beta \rightarrow \alpha$ transformations were 100 C (212 F) and -30 C (-22 F), respectively. These temperatures do not appear to depend upon the quality of the metal. On the other hand, the noses of the $\gamma \rightarrow \beta$ and the $\beta \rightarrow \alpha$ T-T-T curves become increasingly sharp with increasing amounts of impurities. The degree of sharpness depends upon the type of impurity.

Specimens, one centimeter in diameter and two centimeters in length were thermally cycled eight times between 350 C (662 F) and 190 C (374 F) ($\delta \rightleftarrows \gamma$ thermal cycling), between 350 C and 110 C (230 F) ($\delta \rightleftarrows \beta$ thermal cycling), and between 260 C (500 F) and 110 C (230 F) ($\gamma \rightleftarrows \beta$ thermal cycling). The physical damage observed in these specimens was very small as indicated by a density decrease in each of less than 0.01 g/cc. This was much less than the physical damage associated with $\beta \rightleftarrows \alpha$ thermal cycling. The density decrease occurring during $\beta \rightleftarrows \alpha$ cycling is 0.03-0.6 g/cc depending upon the transformation temperature.

The study of the mechanisms of the $\beta \rightarrow \alpha$ transformation was continued on plutonium which had been hydrostatically pressed in the beta phase at 90,000 psi and 180 C (356 F) and then transformed under pressure. This procedure produced metal which had a density of 19.75 g/cc and in which microcracking was essentially eliminated. Wafers of this metal, $\frac{1}{2}$-inch in diameter and 0.075-inch in thickness, were beta heat treated 20 hours at 190 C (374 F), transformed from beta to alpha to yield 5, 10, 15, 25, 50 and 99% of alpha phase at 78.0 C (172.4 F), quenched to -75 C (-103 F) to complete the transformation, and examined metallographically. The incubation time for transformation to begin under those conditions was 4000-5000 seconds. This procedure produces a microstructure in which the alpha formed at 78.0 C (172.4 F) can be distinguished from the untransformed beta phase present at 78.0 C, but which then transforms during the quench to -75 C. These specimens and others are being examined metallographically to gain some knowledge of the mechanism of the beta to alpha transformation.

The electrolyte commonly used for electropolishing and electroetching alpha plutonium has been 2 parts tetraphosphoric acid, 3 parts water, and 5 parts 2-ethoxy-ethanol at an operating voltage of 20-24 volts for one to two minutes. This procedure has produced good polarized light photomicrography of the alpha phase. However, this etchant frequently causes excessive pitting in as-cast high purity

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plutonium which has been transformed at 60 C (140 F) and higher. Pitting has been nearly eliminated by beta pressing and decreasing the ratio of water to tetraphosphoric acid from 3:2 to 2:30; however, the electropolishing time must be increased to five minutes. In addition to decreasing the pitting, the electro-etching causes the alpha grains to become nearly as distinct under bright field illumination as under polarized light illumination.

The deformation during the alpha to beta transformation of plutonium initially containing (1) a fine-grained and (2) a coarse-grained alpha microstructure was determined under applied compressive pressures of 1000 and 2000 psi. The creep rates at 85 C (185 F) were found to be smaller for the coarse-grained specimens than they were for the fine-grained specimens. The creep rates during transformation of both types of specimens were greater by an order of magnitude than the rates of either single-phase alpha or beta. The metal containing coarse grains of alpha was prepared by heat-treating at 450 C (842 F) for one week and slow cooling. The fine grains were prepared by quenching the specimens from 180 C (356 F) to -75 C (-154 F). The average grain sizes were approximately 0.1 mm and 0.001 mm, respectively.

Grain Growth, Deformation, and Fracture Studies. It has been definitely established that plutonium castings with thicknesses up to about 0.125-inch can be reduced, by rolling, at least 90% at temperatures of 70 C (158 F). Reductions of up to 50% per pass have been successfully carried out. It appears that after an initial reduction of 10% to 20% at this temperature subsequent reductions are relatively independent of temperatures down to the lowest which has been attempted (25 C).

An attempt has been made to roll heavier plate castings with little success. Since it is desirable to have specimens of the highly worked material which are thicker than the 0.010-0.015-inch thick strip resulting from the 90% reduction of the 0.125-inch castings, further efforts to employ heavier cast sections have been undertaken. Round bars with a nominal diameter of 0.50-inch were cast in the normal manner and attempts were made to roll these into square bars prior to reduction to strip. An initial 10% reduction resulted in severe cracking perpendicular to the rolling direction. Attempts at reduction of 0.005-inch per pass permitted two passes between which the bar was rotated 90 degrees. On the third pass, however, a clean longitudinal fracture occurred which appeared to be related to the parting lines of the mold. Metallographic examination of these castings revealed severe microcracking and this condition undoubtedly has a bearing on the working characteristics.

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Future efforts will be directed toward the production of castings in which internal flaws are minimized.

A graphite mold has become available which will permit the casting of strips 0.125-inch x 1 inch x 7 inches. These are to be cut into two-inch lengths, fitted into a suitable tantalum mold which will also serve as a crucible. After milling and solidification the interior assembly will be quenched to produce a fine-grained material with a minimum of microcracking. A similar set of castings will be subjected to isothermal transformation in each phase as it cools from the melt.

Metallographic examination of the alpha-rolled plutonium which had been annealed at 180 C (356 F) for seven hours under a hydrostatic pressure of 180,000 psi revealed an equiaxed grain structure with grains approximately 0.03 mm in diameter. The grain growth resulting from the anneal appears to be insignificant. It is not certain that transformation had not taken place at this relatively high temperature although the surface veining which usually results from such a crystallographic transition was not apparent. This investigation is to be continued.

Fractography, the study of fracture interfaces by metallographic examination, has been initiated on plutonium. It is expected that this specialized technique will yield information unattainable by conventional metallographic procedures. Variables to be investigated will include temperature, crystal structure, and microstructure. Two distinct advantages of fractography are (1) the elimination of artifacts introduced by specimen surface preparation, and (2) an insight into the internal microstructure of a material, such as plutonium, which is difficult to obtain by normal techniques and procedures. Initial experimental work has consisted of impact fracturing two as-cast, alpha plutonium notched rods 1/4-inch in diameter at 20 C (68 F) and -80 C (-112 F), respectively. Macrographs (20X) and micrographs (50X) of the fractures were taken and electron photomicrographs were obtained from replicas of the fracture surfaces. Interpretation and evaluation of the microfractographs will be attempted after a sufficient number of tests have been performed.

Tensile testing of 0.54 w/o Al delta stabilized plutonium is continuing. Thus far, specimens tested at 20 C, 350 C, 400 C, 450 C, and 500 C (68 F, 662 F, 752 F, 842 F, and 932 F) show no evidence of the Portevin-LeChatelier effect.

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E. CUSTOMER WORK

1. Radiometallurgy Laboratory

Examinations and Measurements. Two N-Reactor inner and outer fuel elements were longitudinally sectioned and examined for weld, braze, or bonding defects.

In cooperation with Ceramics Research and Development personnel, fuel loading and welding equipment was installed in a hot cell. An irradiated fuel rod was opened, new fuel added, closed, inspected and shipped to NRTS for irradiation.

A Zircaloy-2 PRTR process tube was metallographically examined for hydride content.

Two irradiated enriched UO_2 fuel capsules were examined for fuel location and grain appearance.

Three failed PRTR Vipac UO_2-PuO_2 rods were examined and the mode of failure determined.

A Pu-Al fuel rod sample was examined metallographically and autoradiographically for plutonium distribution and cladding integrity.

A UO_2 electrical resistivity capsule was examined and the mode of failure determined.

Two Zircaloy-2 clad uranium fuel rods were mechanically declad and 36 samples sectioned for swelling studies.

Fission product gas was collected from seven capsules or elements, 40 samples were dissolved for burnup analysis, six samples were chemically declad and densities of 42 samples were measured. In addition, it was demonstrated that neither 13 M HNO_3 - 0.015 M $Hg(NO_3)_2$ nor 9.5 M HCl - 1.5 M HNO_3 attacked Zircaloy-2 cladding when used to dissolve out cores.

Density Cell. The procedure for obtaining and reporting densities has been modified. Henceforth, CCl_4 will be used exclusively for the liquid medium, and densities will be reported at the temperatures at which they were determined. The "basket buoyancy" factor will be eliminated. The balance will be zeroed without a basket, and tare weights in air and liquid will be established for each run.

High Gamma Radiation Alarms. Installation and calibration of the six high gamma, local area radiation alarms was completed and the alarms are now in operation.

Further details and conclusions from the above radiometallurgy examination work will be included in reports of the sponsoring research and development components.

2. Metallography Laboratories

Extensive metallographic assistance is being rendered to N-Reactor Department, in behalf of the heat exchanger tube investigation.

Uranium containing 600 ppm Al and 400 ppm iron was examined by electron microscopy to determine second phase grain size and distribution as a function of heat treatment. The best procedure for etching this material is first to polish for 10 seconds at 18 volts using a standard glycerol-phosphoric acid medium, followed by etching at 5 volts for 50 seconds.

Other work during the month will be reported as part of the respective research and development programs.

3. N-Reactor Design Testing

N-Reactor Charging Machine. The charging machine was used for the entire month in the conduct of Design Test 22-B. As reported last month, ten charges were made successfully into a process tube with foot deformation not exceeding 0.005 inch. In half of these tests, column loading was provided by a column of fuel; in the other half no column load was used. It was determined that the column load imposed by a column of fuel is about 700 pounds. When a column load of 700 pounds was imposed by a back-loading device (a piston in the process tube), no significant change in type or severity of damage was encountered.

Subsequent tests at higher column loads, using a piston to provide the column load, indicated that 700 pounds was about the "threshold" load at which damage occurs. This conclusion appeared independent of nozzle roll joint configuration.

To evaluate the effect of the diameter transition between the magazine and process tube, several tests were run using a process tube as a magazine. This arrangement provided a nearly constant bore for the entire charging path except for the roll joint area. Self-support flattening was significantly reduced at 1500 pounds column load. This

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series of tests indicated that the magazine taper was a major contributor to self-support flattening.

Additional tests are being run to determine (1) the effect of roll joints on self-support surface damage and (2) the magazine configurations on self-support deformation.

4. Special Plutonium Fabrications

UO_2-PuO_2 Fuel for the PCTR. Approximately 4000 UO_2-PuO_2 pellets were sintered. Polyvinyl alcohol was substituted for the paraffin base binder previously used, thereby eliminating laminations which occurred in pressing the pellets. Sintering in a nonexplosive atmosphere of argon - 8% hydrogen was initiated.

5. EBWR Plutonium Fuel Elements

Vibrational compaction techniques utilizing a long horizontal beam for transmitting energy to multiple rods have been developed for loading arc fused material to required densities of 86-89%. Investigation of the effects of multiple rod loading is under way.

Arc fused, depleted UO_2 for EBWR fuel rods was received, and analysis of the material is in progress. Preliminary analyses indicate the UO_2 meets specifications.

Delivery of Zircaloy tubing was delayed. Much of the tubing was one to three mils oversize and will require another reduction pass. Eddy current tests indicate subsurface cracks or inclusions which may cause rejection of much of the tubing. This phenomenon has been reported previously for tube reduced cladding. Selective cutting of the tubing may reduce the rejection rate. Eddy current and ultrasonic test results appear to conflict. High background "noise" is found in eddy current tests of the tubing after annealing but not before annealing. The reverse is true in ultrasonic tests. The background prevented the eddy current tests from picking up surface defects less than two mils deep. A one mil defect (the reject level) is easily picked up by ultrasonics. However, it does not appear that ultrasonics will pick up the subsurface defects.

FW Woodfield
KB

For Manager
Reactor and Fuels Laboratory

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PHYSICS AND INSTRUMENTS LABORATORY

MONTHLY REPORT

JUNE 1963

FISSIONABLE MATERIALS - 02 PROGRAM

REACTOR

N-Reactor Exponential Experiments

A re-measurement is under way of the control strength of samarium balls in the wet mockup exponential pile. These data should be more useful than those taken in the past because the arrangement is a closer mockup of the actual ball channel in N Reactor. The balls completely fill the channel in this experiment. Previously the channels were only partially filled by using ball confining tubes inserted into the channels.

Optimization of Re-tubed Lattices

Two horizontal traverses were performed in the "C" exponential pile containing dry CVIN (overbore) fuel. This completes all presently scheduled experiments. A final analysis on all data is now being completed.

K-Lattice PCTR Experiments

Measurements are nearly completed in the PCTR to obtain absolute k_∞ values for KVNS fuel pieces in zirconium process tubing in the K-lattices. The experimental work has now been completed for the dry unpoisoned case using a three by three cell array. The dry poisoned case is now in the PCTR and the correct mass of copper has been determined to poison the central cell to a k_∞ of unity.

The foil data for the wet cases have been reduced to gold and copper traverse data.

All measurements, including reactivity measurements on all spline samples and flux traverses, have been completed for the determination of spline worth in the K lattice.

The data from the reactivity measurements have been analyzed and a consistent set of data has been determined. A rough draft of an internal report on the spline experiment has been written.

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Computational Programming Services

LEAP and ADDELT, the thermal neutron scattering codes from Harwell, England, have been placed in the FORTRAN Library. Instructions for the use of both codes have been published.

ICEDT, the exponential data processing code, underwent a number of final revisions, principally concerned with good housekeeping.

A number of cases were prepared and run on SUMMIT to obtain thermal neutron scattering kernels for graphite at several temperatures.

Scattering Law for Graphite

The modifications to SPECTRE that produce punched card input for program S have been completed except for final testing. In addition to producing transfer cross sections, the resulting code will also generate first moment scattering cross sections. Analysis of PCTR experiments studying graphite will now be possible on a mechanized basis.

Instrumentation

Final testing of one production unit gamma energy spectrometer was witnessed at GE-APED. Twenty-four of these units are being fabricated at APED for use in the N Reactor Fuel Rupture Monitoring System. The tests included evaluation of pulse height discriminators, and high and low voltage power supplies. In addition to this work, a cooperative effort with Research and Engineering, NRD, was made to install one prototype gamma spectrometer in the KE test facility.

Considerable progress is being made on instrumentation for the PRTR experimental N Fuel Testing Loop. The flow controlling equipment has been ordered. A special design change, which affected the functions of the flow control system, was reviewed and accepted. Specifications were prepared for two scintillation monitoring systems, line regulation equipment, a pulse generator, and for other test equipment. Bids were reviewed for the six major data recorders and orders were placed for the relay rack cabinets and accessories. Plans were started regarding direct utilization of the loop test facility including tests on three specific fuel elements with known defects. Construction work was started in the sample cell room.

Review of N Reactor startup instrumentation is continuing with NRD and IPD personnel. Specifications were started for portions of the required equipment.

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System Studies

The multidecade N Reactor kinetics startup model was checked out and used to study various aspects of the startup process. The following transient situations were studied: (a) Critical period as a function of reactivity ramp rate with initial subcritical reactivity and effective neutron flight time as parameters; (b) Maximum power and period vs. reactivity ramp rate with power setback rate, neutron flight time, and temperature coefficients as parameters; and (c) Maximum uncontrolled power level (temperature turn-around) vs. reactivity ramp rate, neutron flight time, and temperature coefficients.

The N Reactor pressurizer model was debugged and made ready for use. Preparation of a test run is about 80% complete.

Tentative arrangements were made to measure the "zero power" transfer function of the PCTR loaded with a 3 x 3 N Reactor lattice using reactor noise techniques. This test may yield data which will be useful in connection with similar tests planned for the N Reactor during startup.

The concept of measurement of the equivalent structure of a large reactor was tested with an analog simulation of the D Reactor. The simulation utilizes calculated coupling coefficients for the interaction between modes. Measurements were made at simulation locations equivalent to those which would be accessible on a reactor to determine if the interrelation coefficients can be measured indirectly. However, perturbation tests run on the simulation provided data which required a matrix conversion. Consequently, an IBM 7090 matrix inversion program was initiated to determine the interrelation coefficients. As results compared favorably with the actual values used in the simulation, it is concluded that the concept is correct and the digital computer program is working properly. This test provides a background for the analysis of the data taken at the D Reactor production test last month.

SEPARATIONS

Experiments with Plutonium Oxide - Plastic Mixtures

Subcritical neutron multiplication experiments were continued with the Remote Split-Table Machine using PuO_2-polystyrene compacts as the fuel (H/Pu atomic ratio of 15; Pu concentration 1.14 g Pu/cc). The PuO_2-plastic fuels are being used to mock up the range of densities of plutonium precipitates and polymers which can form in separations plants.

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These preliminary experiments are yielding useful information for planning purposes in connection with the proposed critical experiments, which will begin as soon as approval of the Hazards Summary Report for the RSTM is received.

The initial neutron multiplication measurements were made with a non-reflected assembly consisting of a square base of six 2-inch blocks on a side; a six by four array on the stationary table and a six by two array on the movable half of the table. The height of the assembly was increased to within about 84% of the predicted critical height of 6.26 layers (12.5 inches). From the subcritical neutron multiplication measurements the critical mass is estimated to be 33.7 kg Pu.

The worths of the various control and safety rods, both poison insertion and fuel removal, were evaluated. A poison safety element, consisting of a hollow stainless steel blade 3/8-in. thick and 1-3/4-in. in width filled with gadolinium oxide, was found to be worth only 85 cents in reactivity. The reactivity appeared to increase on insertion of a 3/16-in. thick by 1-3/4-in. wide stainless steel blade in the control rod channel; presumably as the result of decreased neutron leakage from the otherwise open channel. A 60 mil thick cadmium blade with the preceding width was worth only about 40 cents in reactivity. However, a single column of fuel containing six 2-in. cubes located in the central region of the assembly was worth about $30.00 in reactivity. Therefore, it is planned to use fuel bearing safety rods (anti-control rods) in the initial critical experiments.

The change in reactivity with table separation was found to be nearly linear over the first 2-in. of table separation, with the change in reactivity being about $10.00 per cm of separation; during the last 2-in. of closure the table half moves at its slowest speed, 1/4 inch per minute.

The experimental assembly rests on a 1/16-inch thick aluminum plate positioned on a 12-inch thick low density aluminum sandwich of honeycomb construction. The combined worth of the plate and sandwich was determined by placing duplicate material on the assembly's top surface. The combination was found to be worth only about 0.07 inches in terms of the critical height, indicating that this is a satisfactory method of fuel loading for attaining an essentially unreflected assembly.

Data are now being obtained to estimate the effect of nearby hydrogenous reflectors. The latter information will be of use in evaluating nuclear safety during the loading of the RSTM in critical experiments.

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In view of the small worth of the gadolinium and cadmium safety blades a Monte Carlo calculation was made to determine the neutron spectrum (for an infinite system). The calculations indicated the characteristic neutron spectrum in the assembly to be strongly epithermal.

There have been some cases in which smearable contamination was found on the PuO_2-plastic cubes during handling, but this contamination has remained localized to their surfaces and has not presented a serious problem. Contaminated cubes are returned to Metallurgy Development for resealing the surface with aluminum paint and a layer of rubber coating.

Expansion of Plutonium Critical Mass Laboratory

Further work was done on the proposed expansion for the Plutonium Critical Mass Laboratory. The expansion does not include a second shielded cell, but rather proposes additions which are needed for efficient operation and effective utilization of manpower in the current facility. The expansion will provide needed facilities for decontamination of equipment, storage space for fissile materials, additional laboratory space for mockup of critical assemblies and other related purposes, together with several offices. Design criteria for the subject addition, prepared by Facilities Engineering, were reviewed by Critical Mass Physics.

Buckling of Partially Filled Spheres

It was found that an erroneous assumption had been made in the case of a bare hemisphere. Correction of this error in the necessary flux approximation enabled calculation of the buckling to one part in 10^4. The one-dimensional full sphere case was also calculated. Results follow:

Case	Analytic B^2 (Unit Radius)	Double Quadratic Flux Approximation B^2
Hemisphere	20.19073	20.18827
Sphere	9.86960	9.86947

Using an assumed convergence rate* of $e^{-\alpha N}$, where N is the number of lattice points, an extrapolation to an infinite number of points can be made using three runs with different meshes. This extrapolation

* First used in extrapolating successive eigenvalues by B. H. Duane in program S.

showed only second order effects in the approximate B^2, hence, a single run with the maximum number of points will be used.

The subroutines making corrections for the boundary conditions at the top surface of a general truncated sphere will be somewhat reworked to ease debugging. When these routines, representing $\int \nabla^2 \phi \, dV$ and $\int B^2 \phi \, dV$ are completed, the program package will produce the eigenvalue buckling for any truncated sphere, presumably with the same accuracy as above.

Subcritical Interactions

The reflected cubic arrays of cylinders measured critical at Oak Ridge were analyzed. In addition to the methods reported last month, the term by term solution of a determinant has been added, to obtain the reflector contributions to the system in terms of the fissile system itself.

A simple planar array was used as base point for finding the reflector coefficient for paraffin six inches thick. This coefficient was then used for three-dimensional arrays with the same reflector. Results of these hand calculations are as follows:

System	Separation	Equivalent Height	Radial Albedo	Calculated k
2 x 2	3.94		(refl. coeff. found = .447)	
2 x 2 x 2	8.99	21.72	.3981	.9983
3 x 3 x 3	16.53	19.92	.3922	.9820

An informal document describing these calculations has been issued.

It is obvious that accuracy rather than conservatism has become the goal in present interaction work. These reflector calculations, involving considerable matrix algebra, are now written and awaiting debug. The major source of discontent with the theory and approximations is the treatment of neutron shadowing between interacting components, although a fairly reasonable first approximation is now being written into the code.

Consulting Services on Nuclear Safety - Criticality Hazards

1. Nuclear Safety in HL

A nuclear safety review was made of the Horizontal Dynapak Hood in the 308 Building. This hood will be used to compress PuO_2 powder into a high density compound. There are hydraulic fluid lines to the hood,

but no water lines. If an oil leak were to occur, no more than a few grams of plutonium could become moderated. Consequently, the standard limit of 3.5 kg of plutonium was recommended. A specification similar to J-5 will be issued.

Comments were submitted to the PRTR Technical Planning Operation concerning the nuclear safety of the PRCF experimental tank. Technical Planning has been concerned about the possibility of an experimental assembly accidentally falling to the floor of the experimental tank. Consideration had been given to installing poison rods on the floor of the tank. The intent was to have the poison rods pierce the assembly as it fell to the floor. It was pointed out, however, that since some of the experimental assemblies will be undermoderated, the "poison trap" approach could not be relied upon to give 100% assurance against an excursion. The most reasonable approach, and the one that will be followed, is to strengthen the support structure of the experimental assembly so that a failure will not occur.

Comments were submitted to Fuels Testing and Analysis, 308 Building, concerning the nuclear safety of depleted and natural uranium. As long as there are no significant amounts of D_2O, carbon, or beryllium in the area, depleted and natural uranium are exempt from nuclear safety specifications. Where there is concern over the reflection of a plutonium system by uranium, a spacing requirement between the two materials will be given in the specification for the plutonium.

PRTR nuclear safety specification No. K-1 was revised to include a) the handling of stagnant water test elements, and b) the storage of fuel elements in "ruptured fuel element cans".

2. Nuclear Safety in NRD

Revised Specification NS 6.02, HW-47013, was reviewed for NRD Engineering and approved for criticality. This specification applies to the handling of 0.95% U^{235} enriched NPR fuel elements in the Chemical Processing Bay, 333 Building. The allowable number of fuel tubes processed in the solution tanks was increased to permit more operating flexibility; however, the limits are still within the safe limits recommended in HW-70500, "Nuclear Safety Specification Basis for NPR Fuel Elements".

3. Nuclear Safety of Off-site Shipments

The addition of 3.2 kg of plutonium, in the form of 250 g/ℓ $Pu(NO_3)_4$ solution, to a loaded Redwood car for delivery to the Dow Chemical

Company, Rocky Flats, Colorado, was reviewed and approved. The solution was contained in two steel jacketed polyethylene bottles, 5.5-in. O.D. by 5.0-in. I.D. x 48.5-in. long. Each bottle was shipped in a 24-in. by 24-in. by 57-1/2-in. long wooden birdcage. Precautions were taken to assure that the birdcage array would be maintained and that plutonium solution leaks would not occur in shipment.

Instrumentation and Systems Studies

A random pulse dividing circuit and an audio amplifier were developed for use in the Critical Mass Laboratory number two startup channel. The output applied to two conveniently located loud speakers audibly notifies laboratory personnel of flux level and flux level changes.

Two thermocouples were installed in the split table hood in order to detect polystyrene compact temperature. The temperatures of interest are at the center of the pile and the outer edge. The temperatures are temporarily read on a control room indicator pending installation of a recorder.

The electronic sentry unit has been separated from the control room telephone line and now has its own dial line.

NEUTRON CROSS SECTION PROGRAM

Scattering Law Measurements for Light Water at Elevated Temperatures

Measurements of the doubly-differential scattering of monoenergetic neutrons from H_2O at 95°C were resumed during the month following an extended reactor outage. Further measurements were made for large values of neutron-energy change to improve the statistical accuracy of the results. Other data were obtained to provide direct comparisons between the scattering observed from H_2O at 95°C and at 22°C and to compare with measurements previously made under different experimental conditions. During the reactor outage a new mechanical linkage was installed on the triple-axis spectrometer which now allows the measurement of neutron scattering to larger scattering angles. Analysis of the data obtained on H_2O at 95°C has continued.

Time-of-Flight Spectroscopy for Slow Neutrons

Design was completed on a neutron-beam shutter for the 4-B hole at 105-KE for a neutron source for slow-neutron inelastic scattering measurements by time-of-flight.

Work has been started on a computer program to reduce the data output from the 6144-channel, 12-detector time-of-flight analyzer for the slow-neutron inelastic measurements.

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Measurements have now been completed on the time jitter for fast neutrons for all available slow-neutron detectors of interest to the time-of-flight measurements. Measurements have also been made of the time jitter for slow neutrons for the BF_3 detectors using a time-delayed-coincidence measurement between the slow-neutron event and the resultant Li^7 de-excitation gamma ray.

Construction of the 6144-channel time-of-flight analyzer was completed, and most of the system's checkouts were completed. A test mode was added to allow the analyzer to automatically execute accumulative storage in each channel of a particular subgroup. The instrument performed satisfactorily during an overnight evaluation test.

Fast-Neutron Cross Sections

Data were obtained on the total cross section for neutrons of 3 to 15 MeV energy for 22 elements during a two-week run on the Van de Graaff. Little or no significant measurements previously existed for three of these samples: Ce, Yb, and Pb^{206}. The sample of Pb^{206} (> 89%) is a sample of radiogenic lead obtained on loan from LASL during the month. For six of the elements, Be, Si, Ge, Sb, Hg, and Tl there are some data in the literature, but these were the first Hanford measurements for these elements. The data on Si indicate that there are about 12 pronounced resonances in the energy region from 2.5 to 8 MeV whereas previous measurements have shown only about six resonances in this region. Measurements were made for the second time in the Hanford program on the elements Li, Na, K, Cu, In, La, Pr, Nd, Sm, Gd, Dy, Ta, and Au. At least some of the data obtained during these measurements are likely to be unacceptable in quality due to failure of the air-conditioning equipment in the 3745-B Building. The measurements were terminated earlier than scheduled because of failure of the ion source of the Van de Graaff. Reduction of the data obtained in these measurements is in progress.

REACTOR DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

High Exposure Pu-Al Lattice Studies

The plutonium and U-235 foil data from the measurements in the PCTR, using 19-rod clusters of 20.6% Pu-240 material in aluminum on 6-1/2, 8-3/8 and 10-1/2 inch pitch have been processed using computer program APDAC.

From the detailed copper foil traverses of the copper poison, the average activity in the poison has been calculated for the 8-3/8 and 6-1/2 inch lattices.

Low Exposure PuO_2UO_2 Fuel Elements

Work on the fabrication of these fuel elements was begun by the Plutonium Fuels Operation in mid-April 1963. Thus far, about one-half of the pellets have been sintered. The projected date for completion of pelletizing and sintering is August 15, 1963.

Plutonium Recycle Critical Facility

The startup measurements continued this month. A detailed control rod calibration was completed. Each control rod was calibrated in one-inch increments and control rod #2 was calibrated every one-half inch. The rods exhibited the characteristic "s-shaped" worth curve found for PCTR-type, shutter control rods. The total worths were 2.08, 1.86, and 1.86 mk for control rods 1, 2, and 3, respectively.

The kinetics experiment to measure the ratio of the prompt neutron lifetime to the delayed neutron fraction (ℓ/β) by the rapid insertion of cadmium has been completed. Four experiments were performed. The data from the first experiment have been partially analyzed. From this preliminary analysis, a value of ℓ/β of 0.0631 was obtained.

A motor of low inertia has been ordered to oscillate a small section of fuel rod from the center of the PRCF to a position outside of the reactive part of the core. A special cluster is being fabricated to make reactivity measurements (static and dynamic) of small fuel samples in the PRCF inside the cluster. The special cluster is designed so that Pu-Al, UO_2, or PuO_2-UO_2 fuel rods can be used for the cluster.

Three design drawings for the modification of the PRCF for H_2O moderator have been reviewed and approved. These are drawings of the Reactor Vessel Modifications, the Neutron Source Positioner and the Instrumentation Flux Monitor Chambers.

Theoretical Scattering Laws for Water

Coding of the Egelstaff analysis for the exact treatment of at least two Gaussian levels is nearly complete. In addition, the treatment of the effect of water molecule diffusion on neutron scattering has been included.

Phoenix Studies

Investigations of control rod effectiveness in a Pu-reactor environment reported during the last report period have been extended to include Hf rods of various thickness. As before, the so-called Mark I geometry

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($Zr-2/H_2O$ ratio = 1, 70 kg Pu loading in 500 liter core) was used. Pu compositions were again varied from 5 a/o Pu-240 up to ~30 a/o Pu-240.

The results of the calculations indicate similar trends for the Hf rods as for the previously investigated 1/v absorbers.

The evaluation of temperature coefficients for a typical Phoenix-fueled core is continuing. For the 70 kg, Mark-I core, temperature coefficients have now been calculated over the range of 68 F to 600 F. The temperature coefficients become strongly negative as the temperature increases. An important contributor to this trend is the neutron leakage effect which increases with increasing temperature.

Proposed Fast Spectrum H_x Pu Experiments

A feasibility study of carrying out reactivity coefficient measurement of H_x Pu samples in a suitable fast spectrum critical facility has been completed.

It is proposed to can PuO_2 samples in Al cylinders and to insert these samples into various locations of the fast critical facility. U-235 samples and empty Al cylinders would also be measured for reference purposes. Al cylinders of 6" length and O.D. of .150 would be used. Such cylinders will contain about 9-10 gms of Pu. It has been estimated that about 100 gms Pu per test sample would be necessary for a measurement. Consequently, for five test samples, 50-55 test capsules will be needed for the experiment.

In order to obtain a rough idea of the expected worth, S-XI calculations for the fast spectrum critical test facility were carried out. The core averaged danger coefficients of U-235 and the Pu isotopes were found to be:

	$(\Delta K_f/K_f)/gm$
Pu-239	1.54×10^{-5}
Pu-240	9×10^{-7}
Pu-241	2.12×10^{-5}
Pu-242	1.09×10^{-6}
U-235	1.03×10^{-5}

These calculated reactivity differences are judged to be adequate for the performance of a meaningful experiment.

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Fuel Re-Use

In preparation for a possible in-reactor experiment, the work reported in HW-74549, "Progress Report on Fuel Re-Use," is being extended. A more detailed examination of the fast reactor blanket burnup is under way. The single-region cylindrical blanket has been replaced, for purposes of calculation, by a four-region combination which has radii of 44.81, 49.89, 57.51, 70.21, and 95.61 cm. The radial blanket regions are exposed to different flux levels and, therefore, isotopic transmutation takes place at different rates. In order to optimize the fuel shuffling both within the fast blanket and between the fast and thermal reactor, this spatial variation of the isotopic concentrations must be known.

An additional problem with the fuel re-use concept is the axial power peaking in the thermal reactor due to the non-uniform plutonium enrichment from the fast blanket. Preliminary calculations show that a Fermi blanket element placed in the PRTR would have a peak-to-average power ratio of 2.31, while a uniformly enriched rod would have a ratio of about 1.55. If the blanket element is cut in the center and both halves flipped, the peak-to-average power ratio returns to about 1.61. Gross discontinuities in the axial power distributions were observed when the half rods were treated using five regions. More refined calculations are under way.

Code Development

CALX

The KONTROL code which provides over-all control for the CALX system appears to be working. A rough draft write-up of comments on the CALX system has been written. A series of cases which tests the various available options is being run for reference and debug purposes. The auxiliary routines COMPTAPE and LILLY2 which prepare and position the composite library tape are being rewritten to reduce significant tape manipulation in the standard operating sequence, and thereby to effect a significant saving in machine time.

HRG

The calculation of base cross sections in the resonance region for those isotopes with resonance parameter tables in the RBU Basic Library has been successfully incorporated in BARNS-H. The error in the resonance calculation in BARNS-H was also found. The code now apparently calculates satisfactorily the 68-group cross sections for isotopes.

As usual, one more last major change was required before practical use of BARNS-H was possible. This change was needed to permit the results of

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isotope calculations to be combined into cross sections for an element, prior to preparing a new HRG data tape. Several additional desirable changes have been included. The BARNS-H code to prepare an HRG data tape now consists of two chain links. The first, a specialized version of BARNS, provides resonance region and group-averaged cross section data for isotopes from the RBU Basic Library. The second, NUTAPE, provides an updated HRG data tape by adding to or changing nuclide data on the previous tape, using data either from BARNS or read in directly. NUTAPE also prepares the nuclide data for an element by combining the proper isotopic data from BARNS. Both links of the BARNS-H chain are being debugged.

GROUSS

Correlation of calculations done by the THERMOS code with calculations of programs I_2 (P_3), S-4, and S-X (S_4) has been done for the case of a Pu-Al rod, zirconium-clad, in a water moderated cell. The purpose of the correlation study was to determine the validity of monoenergetic calculations of epithermal resonance flux depression factors using various recipes of Σ_a, Σ_s, and the source terms as compared to the multi-energy group calculations of THERMOS. The monoenergetic calculations using a given recipe could then be used in GROUSS to predict flux depression factors, particularly for the Pu-240 resonance. The study showed that the use of code S-4 with the recipe of $\Sigma_a = \Sigma_a$, $\Sigma_s = \Sigma_s$, and $s = \xi\, \Sigma_s$ (infinite mass approximation) in the fuel and cladding, and $\Sigma_a = \Sigma_t$, $\Sigma_s = 0$, and $s = \Sigma_s$ (i.e., scattering treated as removal) in the moderator, gave good agreement, to within one percent, with THERMOS for the case considered.

RBU

Plans to distribute off-site, a customer-oriented package consisting of the RBU Basic Cross Section Library, and supporting library processor programs and documentation, have been formulated. At present, the package lacks a satisfactory processor to produce usable data from the library and plans for its construction are under way; the remaining portion of the package is virtually completed.

Increased effort is also being applied to complete the final system documentation for distribution late this year.

The limit of $\bar{\mu}_0(E_0)$, the average cosine of the scattering angle for neutrons of initial energy E_0, as $E_0 \longrightarrow 0$ has been taken and the results appear much as expected. Use will be made of the expansion in deriving values for the two-mass approximation to the scattering law for bound scatterers, during thermalization.

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ALTHAEA, A One-Dimensional Two-Group Survey Burnup Code

An informal report, HW-77023 RD, by E. T. Merrill and R. L. Watts, is well under way. This report will describe the physics model and the computational methods as well as the operation of the code. In the process of checking out the code, a burnup analysis has been made on the NRX fuel element using the data from (CRC-1095) with excellent results. The Cross-Section Library used is based on the cross sections recommended by B. R. Leonard, Jr. (HW-69342), and R. C. Liikala (HW-77389). The thermal flux depression factors were computed by the P-3 method using the IDIOT code. The resonance shielding index was calculated by the Bell formula with the other resonance shielding and shadowing parameters computed by GAM-1 and SPECTRE codes. Although the input parameters do contain some uncertainties, their effect on the results appear to be small.

EBWR Program - Experiment Theory Correlation

A calculation of the critical loadings to be expected in the PRCF experiments using the EBWR fuel has been made together with some perturbation effects. The success of the calculation is yet to be determined, but confidence in the results is very much enhanced by the simultaneous calculation (using the same cross sections and methods) of two series of critical experiments with very good results. All calculations were concerned with light water moderator and involved, in one case, 2.75% enriched uranium oxide, in stainless steel clad (Yankee power reactor critical experiments) and, in the second case, 1.82% plutonium-aluminum alloy rods in Zircaloy-2 clad. In all cases the calculated eigenvalues were the multiplication constants, and all were within 1.5% of the correct value of k = 1.0. The methods used involved the use of the GAM-1, THERMOS, and TEMPEST codes for preparing input for the HFN multi-group diffusion code from which the eigenvalues were obtained. Corrections to the projected critical loadings of the PRCF were inferred from the critical experiment calculations. Work on the proof of the method and the exploration of various perturbations and possible errors continue.

Mass Spectrometry

Isotopic analyses in support of Plutonium Recycle Program studies were continued. All of the analyses were from macrodrill samples of Al-Ni-Pu PRTR fuel elements; 4 samples from element No. 5051, 23 samples from element No. 5095, and 24 samples from element No. 5092. These analyses complete the scheduled isotopic analyses for these three fuel elements.

In a meeting with PRTR personnel in preparation of the automatic controller activation tests it was recommended that a simulation study be made incorpor-

ating the controller and moderator level systems prior to closing the reactor automatic control loop. This will provide training for operations personnel and will allow direct measurement of the dynamic characteristics of the complete system except the reactor kinetics which are believed to be straightforward.

An analog simulation program was prepared for a one mode simulation of the Plutonium Recycle Critical Facility using plutonium and/or uranium fuel and with six delayed neutron groups. The simulation includes provisions for scram tests and temperature feedback.

Purchase orders were placed for the scintillation detectors and isolation transformers for the PRTR Underwater Gamma Scanner for fuel rod and activated wire measurements. The required line filters were received.

The modified prototype and three final model gamma monitor instruments were completed for the PRTR Liquid Effluent Monitoring System. The instruments have been calibrated and installed at PRTR. The modified prototype will be used as a spare. Work was started to update the blueprints and to prepare the required operation manual.

HIGH TEMPERATURE REACTOR LATTICE PHYSICS PROGRAM

The design criteria document for the HTLTR (HW-76928) has been approved by the Richland Operations Office and design work by the Architect Engineer has been started.

A formal report (HW-77732) describing the HTLTR has been written. It is based on scope design information and will be used by the AEC to acquaint potential users of the reactor with its capabilities.

Hastelloy-X is at present being considered both as a cladding for the HTLTR driver fuel, and as piping material for part of the reactor gas flow system. Information from recent studies indicates that some components of Hastelloy-X may, to a greater extent than expected, form nitrides when in a pure nitrogen atmosphere at 1000°C. Further quantitative information on the rate of this reaction may soon be available from the Reactor and Fuels Laboratory where weight increases of samples of refractory materials are currently being measured as a function of time in various atmospheres at temperatures up to 1100°C. Additional high temperature tests in nitrogen will be required in order to measure the corrosion of Hastelloy-X, and alternative cladding materials, while in contact with graphite. Should it be indicated that Hastelloy-X or some other metal is not suitable, alternative methods suggested are to use a graphite cladding for the UO_2 fuel, or an unclad graphite matrix fuel.

In order to obtain some quantitative information on the nuclear properties of the HTLTR fuel elements some measurements with a few of the fuel elements inserted in the PCTR are being planned. The fuel temperature coefficient of reactivity will be measured, and possibly also the extent to which the moderator temperature coefficient can be influenced by gadolinium mixed in with the fuel.

NEUTRON FLUX MONITORS

Following evaluation of the neutron parameters r, T, and ø, an analysis was started to derive the relationship between r and the relative activity of bare and cadmium-covered cobalt samples to insure validity of the Westcott equation for the present experimental test irradiation conditions.

Regenerating (Phoenix) detectors were fabricated containing 28.4% Pu-239 and 71.6% Pu-240. This composition was within about one percent of the optimal composition determined from computer calculations. The samples were charged into the reactor test facility and are now being irradiated. Another computer calculation will be made to determine the anticipated behavior of the samples. Arrangements were made for discharging samples after incremental exposures and performing mass spectrographic analysis of the fission products.

Three Boron-11 beta current neutron flux detectors, fabricated offsite to HAPO specifications, were received. Preliminary checks indicate that fabrication was satisfactory and a request was prepared for establishment of a special water-cooled test facility in a HAPO production reactor. Design was started on the necessary shield plug and a production test for irradiation of the units was prepared. Notification of patent application was received for the Boron-11 beta current method of in-core neutron flux measurement.

Testing configuration studies were continued for the microwave neutron flux monitor. Equipment has been obtained which permits a full-scale laboratory mockup of one sample system. Reactor facilities were reviewed and the necessary instrumentation requirements were established. In essence, plans were established to insert three waveguide loops into the reactor test facility. One loop will contain a section filled with test gas, and a second will contain no gas. The third loop will be used as a spare. A number of parts for the loops were ordered. Calculations indicate that the test specimen portion should be about one meter long in order to provide 0.5 db attenuation.

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NONDESTRUCTIVE TESTING RESEARCH

Electromagnetic Testing

Evaluation of the multiparameter eddy current tester is proceeding. Additional tests were performed with a single frequency. The results of these tests indicate it may be possible to separate three parameters when two of these parameters are changing simultaneously. However, this apparent separation is not consistent with the theory in its present stage of development. Additional evaluation is being performed.

A study has been undertaken to determine ways of obtaining amplification of sonic signals. A library search revealed a traveling wave type of amplifier has been suggested. In this method, a semiconductor is used and amplification results if the electron speed of diffusion is slightly greater than the speed of sound through the substance. Also the parametric amplification of sonic waves is being investigated to determine its feasibility.

The mechanical framework parts of the polar type eddy current null plotter are being fabricated. Some difficulty has been encountered in obtaining an economical potentiometer for the phase shift circuit. Study is being given a method of mechanically producing the required phase shift function from a system of linear potentiometers and a cam action.

Heat Transfer Testing

Signals from the heat transfer test have been sent through telephone lines between 314 Building and the 3707-C Building analog computer facility. An improved radiometer calibrator was placed in operation on the equipment. Contact with the plasma arc jet manufacturer reveals that its heat output should be constant when the gas flow, supply voltage, etc., are held constant.

The average level of the 2 kc heat transfer test signal transmitted over the telephone line to the analog computer laboratory is about 0.1 VRMS, and the average amplitude of the returning signal is restricted to about .014 VRMS at present to avoid overloading the amplifiers. Less than .0003 VRMS noise is contributed by the telephone lines.

An improved radiometer calibrator consisting of a heated copper cylinder has been placed in operation. This allows calibration of the radiometers at any time without removing the test sample from the lathe.

Small variations in heat input to test pieces from the plasma arc jet become

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important when attempting to detect small over-all differences in surface to interior heat conductance. Variations in gas flow and electrical power input to the plasma head were not detected during initial measurements. Correspondence with the manufacturer indicated the need for more refined measurement of the operating parameters. Equipment for high accuracy measurement of gas pressure has been obtained.

Zircaloy-2 Hydride Detection

Laboratory check-out of the eddy current hydride detector has revealed the need for improved sensitivity. Fabrication of an experimental temperature compensated probe is nearly complete. A metal-working lathe is being modified for use as a scanning device for the testing of sections of Zircaloy process tubes. Although highly regulated power supplies and a crystal controlled oscillator were incorporated in the initial instruments, drift due to changes in circuit components has been troublesome. One instrument used complex plane signal presentation, and the other used a center of curvature reference voltage method to obtain probe motion compensation. The most troublesome components in the center of curvature method have been the bridge voltage detector and the high frequency bridge supply voltage. Attempts are being made to achieve improved instrument stability by employing signal comparison techniques. One technique under evaluation uses special circuitry to reduce the effects of changing vacuum tube characteristics; another method employs a chopper to switch the signal in such a way that the output signal may be compared with a reference voltage generated by the bridge input circuitry.

Fundamental Ultrasonic Studies

Boundary waves generated at kerosene-glycerine interfaces were experimentally examined in detail. Periodic increases and decreases in the boundary wave signal were observed as the receiverprobe was traversed in the direction of wave propagation. The distance between subsequent maximum signal points was approximately ten wavelengths. This distance was difficult to accurately ascertain because the received signals became progressively more distorted as the probe was moved along the boundary. The cause of this distortion is not known, but it may be partially due to the presence of the strong attenuation in the glycerine. Another contributing factor may be the result of incident waves having curved wave fronts. Also, extreme wave front curvature in the boundary wave was observed as the receiver probe was moved perpendicular to the interface. The theory predicts that the boundary waves should have plane wave fronts providing the incident waves are plane and constant amplitude. Efforts to obtain more uniform incident waves have, therefore, been renewed.

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The production of uniform plane waves by filtering ultrasonic waves with thin plates has been investigated. Waves transmitted by thin glass plates were observed to be very plane but had undesirably large exponential amplitude losses along the fronts. This exponential behavior is to be expected since there is a uniform loss of energy as the waves travel within the plate. However, it was hoped that over a limited wavefront portion, the wave amplitude would be essentially constant since glass has very low ultrasonic attenuation.

Another method for obtaining plane waves of constant amplitude was considered. The waves in the Fraunhofer region of an ideal flat piston driver have spherical fronts. By suitable collimation with an acoustic lens, it should be possible to obtain plane waves of fairly constant amplitude from flat circular transducers which are good approximations to piston drivers. Since the Fraunhofer zone is dependent upon transducer diameter, it was necessary to use very small transducers. The use of spherically focused transducers to further compress the zone was attempted but uniform amplitude spherical waves in the Fraunhofer zone were not experimentally observed. The spherical waves from a 3/22" diameter, flat transducer appeared, from initial observations, to be well formed and the extent to which they can be made plane will depend on the collimating lens. Additional measurements of wave curvature uniformity are being undertaken and a liquid lens having variable focal lengths is being fabricated.

As mentioned last month, the numerical solution of the frequency equation for Lamb waves in a hollow cylinder will require that an additional term in the approximation be found. For this additional term in the Bessel function expansion will be needed. A new procedure for determining this has been evolved, which will be much easier to apply than that used before. The new terms have not yet been calculated.

USAEC-AECL COOPERATIVE PROGRAM

Nondestructive Testing of Sheath Tubing

Evaluation of 3/16 inch diameter spherically focused crystals for inspection of 17 mil wall tubing is complete. Based upon their superior performance, these tranducers have been chosen for use in the tubing inspection station now under development. A further transducer refinement is being developed, however, which generates dual ultrasonic beams--one of which is used for defect detection purposes, and the other to provide an accurate time reference signal for operation of an electronic gate. Upon completion of this work the transducer design will be made firm.

Extensive studies have been made to evaluate the effect of wall thickness

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variations upon test performance. In summary, the data indicate that defects are detected without appreciable changes in defect signal amplitude for wall thickness variations as much as 25 percent of the nominal 0.017 inches. These experiments provided other useful information in that they further confirmed the correctness of the conventional zig-zag mode of wave propagation for these experimental conditions.

Attempts are being made to provide a method of fabricating calibration notches that are cheaper than the electro-machining process. Drilled holes have been found unsatisfactory because their echo signals are much larger in amplitude than signals obtained from standard one mill electro-machined notches. It is possible that a simple slit cut into the tube in a direction parallel to the tube longitudinal axis may provide a good working calibration standard. In this case, however, the tube is positioned to allow six internal echo reflections in order to allow the signal to attenuate to the point where its amplitude is approximately equal to that obtained from a one mill standard notch.

Continuing attempts are being made to devise a reproducible method of measuring and evaluating transducer operating characteristics prior to their use in ultrasonic inspection equipment. Routine procedures have been developed for measurement of ultrasonic radiated field strength, frequency, bandwidth and damping factor. These techniques have been of value to IPD and NRD fuel inspection efforts, as well as our own tubing inspection program.

Electronic portions of the prototype tubing inspection station is approximately ninety percent complete. Emphasis is now being given the design of the mechanical system.

BIOLOGY AND MEDICINE - 06 PROGRAM

Atmospheric Physics

Data from 363 diffusion experiments from major experimental programs were compared during the month. These data were collected at O'Neill, Nebraska (70 tests, sulfur dioxide tracer); Arco, Idaho (3 tests, iodine); Dugway, Utah (9 tests, iodine); Cape Canaveral, Florida (76 tests, fluorescent pigment); Vandenberg Air Force Base, California (109 tests, fluorescent pigment); and Hanford (66 tests, fluorescent pigment). General agreement between the testing sites with their respective tracers was found by considering diffusion to be time-dependent, rather than distance-dependent. The variability in the dosage measurements was reduced significantly by accounting for the meteorological variability of the atmospheric stability (temperature profile) and turbulent wind properties. The primary significance of this delineation is that many of the major differences which hither-

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to have been unresolved do achieve some degree of order when the above meteorological parameters are considered. Work is continuing to obtain further specific meteorological support data obtained during the experimental programs in order to pursue the development of an empirical prediction scheme similar to that which was recently completed for the Hanford data.

Three field tests were conducted during the month. One test was conducted during unstable daytime temperature gradients with the source height at 61 meters to simulate a stack discharge. Air samples were collected on concentric arcs about the meteorology tower to a distance of 1600 meters. Two tests were conducted during early morning stable conditions using a source height of 6.7 meters with air samples collected on both the horizontal and vertical sampling grids to a distance of 3200 meters. All equipment continued to work satisfactorily.

Preliminary analysis of earlier data from elevated source experiments has shown a systematic lack of agreement with existing diffusion models. As found in the ground source data, the results are best organized as functions of time rather than distance making the plume width vividly dependent on the intensity of the cross-wind turbulence. The maximum exposure normalized to unit source strength and wind speed and the cross-wind integrated exposure show a systematic decrease as the Richardson Number becomes more negative and as the travel time to maximum ground level exposure increases. These results are contrary to theory and reflect a lack of understanding of some very fundamental aspects of turbulent diffusion.

The Hanford Atmospheric Physics program was reviewed with representatives of the Division of Biology and Medicine on June 19 and 20, 1963. Current work was summarized and future plans explored in detail.

Iodine Release Experiment

Final details of plans for an iodine release experiment are being completed. It is expected that the experiment will take place during the latter part of July. This experiment is a cooperative effort involving participation by personnel from Atmospheric Physics, Chemical Effluents Technology, Radiological Chemistry, Biology and the Radiation Protection Operation. The iodine (about 0.1 curies)will be released on the experimental atmospheric grid during moderately stable atmospheric conditions. In addition to the samplers necessary for measurement of air concentrations and effluent characteristics the plans include special vegetation plots to investigate in detail the factors controlling deposition and subsequent retention by vegetation of various types.

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Preparations for the field release of radioiodine progressed with the comletion of the micro-plots at 200 meters distance from the source. At month end the rye grain was approximately three inches in height and the pasture grass was showing. Design of the portioned air samplers was completed and procurement initiated.

Analysis of the air and grass samples obtained by Hanford personnel during the radioiodine release experiment at the National Reactor Testing Station provided valuable design information for the Hanford release experiments. Both the air concentrations and deposition values found were consistent with predictions made from Hanford diffusion data. In the grass samples, approximately fifty percent of the total iodine deposition was found in the upper third of the grass plant.

Dosimetry

Preparations were completed and the field party left for this summer's whole body counting study in Alaska.

The survey-by-urinalysis program conducted this past winter and spring was completed. The final results were essentially the same as those reported last month.

In cooperation with Swedish Hospital some new Cs-137 calibration studies were made of the shadow shield whole body counter. We now have data for people with weight-height ratios in the range 0.9 to 2.9 lb/in.

The first of four units of a plutonium X-ray counter was put together. Anticipated electronic problems did not materialize. Completion of the counter will be delayed until fall because of postponed deliveries of material.

A new ion source and a new accelerator tube were put into the positive ion Van de Graaff. Otherwise, the accelerator operated satisfactorily during the month. While the accelerator was shut down, plans were made for fitting the helium ion source into it.

A study was begun of a spherical moderator-lithium iodide scintillation counter system that has been used at other laboratories to measure low-energy fast neutron dose rates. The system was used to make some measurements at PRTR. So far we have not been able to confirm the calibration of the system.

New methods of temperature measurement are being investigated for application in increasing the sensitivity of radiation calorimetry. The methods

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are based on pyroelectric, capacitance change, and volume change phenomena.

Instrumentation

A satisfactory method of molding Teflon conducting center rods for use in the recharging personnel dose meter has been developed. Specific constructional details for the complete dose meter are being prepared to permit offsite fabrication of a number of the units. Problems remaining include revision of the center rod charging device and establishment of a more satisfactory capacitor charging mechanism. Attempts are being made to make the instrument less sensitive to mechanical shock.

A number of discussions were held with Biology Laboratory personnel regarding specific problem areas. The reviewed problems included measurement of radionuclide deposition in animal lungs, a method for measuring internal air pressures in the thorax, an improved extra-corporeal blood pressure transducer which will respond to diastolic pressure, and a system for monitoring and regulating air flows in certain test chambers. The initial design and circuit breadboarding were completed for an experimental thoracic air pressure variation measuring instrument. A solid state circuit for monitoring the air flow and balance in animal test chambers was experimentally fabricated and is being tested. The circuit will energize an alarm if the air flow and balance conditions do not stay within required limits. Commercial automatic pressure regulator information is being reviewed to determine if adequate units are available.

Discussions were also held with Occupational Health personnel to determine the possible interest in a specialized heart sound detection and recording system.

Following receipt of the one millicurie Po-210 alpha source configuration from the vendor, a suitable source holder was designed and is being fabricated for use in the air filter trapped beryllium monitor. A suitable glove box and/or test hood for the detector assembly still needs to be established.

Anti-coincidence techniques are being investigated for possible incorporation in an air monitor for mixed fission products wherein the detector head must operate in modest gamma background fields. Fabrication of one experimental unit is nearly complete.

Circuit design was completed for a special solid state integrator, incorporating an electromechanical register, to be used with the HAPO portable solid state BF_3 neutron dose rate instruments. The dose rate integrator will operate plugged into the regular instrument phone jack. As designed, one digit on the three-decade register will equate to 0.1 mrem. This addi-

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tion should prove to be a valuable tool for neutron dose measurements under field conditions.

Development effort continued on a small-package dose telemetry method utilizing a recharging-type ionization chamber as a sensor and solid state circuitry. One experimental breadboard unit was test operated; however, considerable development work remains to be done.

Direct design and fabrication effort continued on the HAPO Radiotelemetry System. Radio frequency shielding and filtering was added to the modified data station to minimize interference and considerable testing was carried out on the Vibrasponders and amplifiers. At present, the one test data station in the 329 Building is being routinely "called" by the Central Station located at Atmospheric Physics. Functional operation of the data station is being recorded.

The test chassis was completed for the experimental scintillation logarithmic response building radiation monitor which employs a vibrating capacitor input and a solid state circuit. Circuit performance proved satisfactory; however, mechanical binding and stoppage of the vibrating capacitor was noted at elevated temperatures. Further work will be necessary.

WASHINGTON DESIGNATED PROGRAM

Isotopic Analysis Program

Isotopic analyses of program samples were provided at a reduced but acceptable rate during half of the month because of the heavy load of samples required for Plutonium Recycle Program studies.

Fabrication of the scintillation-type ion detector for mass spectrometer development studies was completed by Technical Shops. Most of the month was spent in locating and eliminating vacuum leaks in the detector. This work is still in progress.

Design drawings were completed for the alumina parts of a vacuum-lock sample changer for the mass spectrometer for this program.

TEST REACTOR OPERATIONS

Operation of the PCTR continued routinely except for a scheduled three-day maintenance outage. There were no unscheduled shutdowns. The K lattice experiments - k_∞ KVNS fuel dry were nearly completed during the month. Preliminary tests were made to determine the feasibility of irradiating rats in a predominantly fast neutron flux. The reactor room was pressure tested

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during the month. The gas door seal was satisfactory, but the electrical conduits through the shield were leaking badly. A three-day outage was necessary for testing and for correcting the leaks.

The TTR was not operated during the month.

The critical approach experiment for Pu-Al rods 20% Pu 16% 240 in light water with 0.66 inch lattice pitch was nearly completed during the month.

CUSTOMER WORK

Weather Forecasting and Meteorological Services

Consultation continued on the meteorological and climatological aspects of oxides of nitrogen release in the 300 Area. Consultation on local atmospheric dust loadings, particle size distributions, wind direction distributions, and dust storm frequency were provided the Commission for use in design of ventilation systems for electrical equipment associated with 100-N operations.

Meteorological services, viz., weather forecasts, observations and climatological services were provided to plant operations and management personnel on a routine basis.

Weather Summary

Type of Forecast	Number Made	% Reliability
8-Hour Production	90	86.9
24-Hour General	60	83.7
Special	156	86.5

Temperatures during June averaged slightly above normal. There was a 10-day heat wave centered near midmonth. However, the final 11 days were unseasonably cool.

Although precipitation occurred on 14 days, the monthly total was less than 40 percent of normal. The month was also considerably windier than usual. There were many cases of moderate to fresh speed, but no really high winds.

Instrumentation and Systems Studies

Specific circuit and detector development was started on a specialized face mask monitor for detection of low energy beta emitters for Protective Equipment Decontamination, CE&UO.

Circuit design work continued on the special soil moisture content measuring probe for Advanced Technical Planning, CPD, and Chemical Effluents Technology, HL. The general probe shell design for six-inch diameter well casing was established.

The probes and waste can holders were fabricated for the plutonium waste container measurement system being designed for Plutonium Process Engineering, CPD. The necessary NaI detectors were also received and assembly is ready to start.

A brief investigation was made regarding slight response nonlinearity in the Biology Laboratory portable field monitor and energy analyzer. It appears that mincr redesign of the solid state amplifier will be required.

Assembly was nearly completed on a scintillation coincidence counter for air filter samples for use in the 325 Building by Radiation Protection Operation, HL. Most parts required were received for a scintillation coincidence counter for air filter samples for use at the Fuels Recycle Pilot Plant.

General design was started on a special instrumentation system to measure U-235 enrichment in fuel for Metal Fabrication Development, HL.

Consultations were held with Reactor Metals Research Operation on methods of measuring displacements at high temperature. High temperature metals research involved a study of stress vs. strain of various metals at elevated temperatures; hence, the need for a displacement measuring system operable and accurate at high temperatures (to 3000°K). Several methods of high temperature displacement were discussed and it was determined that the following methods be explored: LVDT's, microwave resonant cavities, optics, and strain gages. It was requested that an accurate and flexible LVDT readout system be designed.

Construction of the creep capsule data logger is continuing and the completion target date of mid-August is expected to be met.

Simulation of a chemical separations C-column was started to produce a model more refined than the model simulated about a year ago. The initial simulation was utilized to explore the effects of parameter variations on the performance of the model. The new model will be used for the same purpose. The performance of the model is measured by the closeness of fit of computed curves as compared to measured curves of the aqueous and organic concentrations of material as a function of column location.

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Fabrication of the Eddy Current Motion Analyzer (ECMA-I) has progressed to the final phases of instrumentation assembly. This instrument is being developed for use in studying the fuel assembly vibrations which have been encountered in the PRTR.

Fabrication of the six channels of excitation and detection electronics has been completed as has the transfer panel. The various chassis have been installed in the cabinet and most of the interconnecting cables have been completed. Final checkout of the electronics is being accomplished and the instrument is expected to be operational by the end of the month.

A work order was received from CPD for the development and fabrication of a punch programmer for the Redox counting room. The system is required to generate a punched paper tape containing about 200 characters of information needed to instruct the IBM 7090 in the analysis of pulse height analyzer data.

Optics

The electrical readout traverse mechanism was used to traverse a process tube at 189-D Building. Sixteen runs were made. Four of these used the electromicrometer as a readout device. A d-c translator and electromicrometer were used for the other twelve runs. The calculated displacements obtained from the electromicrometer readings were accurate to 1/8 inch. The process tube was tested at two different bendings. Both horizontal and vertical distortions were changed although only the horizontal bending was measured. The traverse mechanism gave horizontal displacements accurate to 1/8 inch for bends in either horizontal direction and thus demonstrated the desirable insensitivity to vertical bends when horizontal bends are being measured.

Data obtained on the twelve runs using the millivoltmeter readout are being analyzed.

The use of photocells to measure the rail heights on fuel elements permits readings of ± 0.0002 inch on a 20 power projection comparator. Arranging for a method of rapid readout has proven to be difficult. Cadmium sulphide cells have too long a time constant, but it was found that cadmium selenium cells with 4 millisecond time constants would provide the desired accuracy. One photocell has been used with a servo amplifier and motor drive to position the fuel element edge to a reference line and a second photocell detects the height of the rail above the reference line. Although the accuracy of these measurements is adequate, the rate of scanning the eight rails is still too slow and our work is directed toward finding a suitable scanning arrangement.

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While equipment was being assembled for pulsing lasers in the Optical Shop, tests were made on the Nd^{3+} and U^{3+} doped rods using the thermal diffusivity measurement laser head. At an estimated temperature of -40°C, lasing threshold occurred with a 24.5 joule flash for Nd^{3+} and a 400 joule flash for U^{3+}. These figures point up the low threshold energies of these materials when it is noted that the corresponding threshold for ruby is greater than 800 joules and that the ruby rod is normally operated at 1200 joules.

When tests are begun in the Optical Shop, the rods will be cooled to approximately -196°C with liquid nitrogen. The lower threshold energies will facilitate the threshold measurement.

Capability for grinding and polishing laser rods optically flat is being established in the shop. The need for this capability was pointed out when the Nd^{3+} rod was chipped on mechanical assembly of the head. This will also give the shop more flexibility in enabling it to work with unfinished laser materials.

During the four-week period (May 19 - June 17) covered by this report, a total of 384 manhours shop work was done. The work included:

1. Repair of three borescopes for Irradiation Testing, IPD.
2. Resilvering one ruby laser rod for Ceramic Research, HL.
3. Fabrication of ten glass bearings for CPD.
4. Fabrication of one borescope camera adapter.
5. Repair of three crane periscope heads for CPD.
6. Fabrication of an eyepiece extension for a microscope for HL.
7. Fabrication of coil forms and accessories for eddy current testing.

Physical Testing

Technical assistance was rendered the Harvey Aluminum Company in the ultrasonic testing of Zircaloy-2 sheath tubes for Hanford. The tubes 0.442 inches in diameter with a 20 mil wall were tested for a 5% defect level or a 0.001 inch defect. The sensitivities and calibration of the testers had previously been determined at HAPO to test the small diameter thin-walled Zircaloy tubing. The testing equipment at Harvey Aluminum was modified, calibrated and certified to be within the requirements of the specifications for the test. During the time the equipment was being calibrated and the conditions for the test being set up, a number of off-site General Electric inspectors were trained at Harvey. These inspectors will now be able to follow the application of the tests on ultrasonic testing tubing to HAPO's requirements. Tentative test results indicate: (a) the ultrasonic test exhibits somewhat higher sensitivity than the

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pulsed eddy-current test, and (b) annealing the tubing reduces background noise of the ultrasonic test and increases the background noise of the eddy-current test.

Circular, in-motion radiography is being used to evaluate the repair of N fuel element reject welds. Radiography is also providing the means of viewing a number of BF_3 proportional counters for proper arrangement of their internal components prior to acceptance from the vendor. A 0.001 inch tungsten wire was resolved within the capsule chamber.

Over five thousand tubes have now been received and inspected for retubing the K Area reactors. Included in this number are the twelve hundred tubes that have been delivered to the reactor and successfully installed. Vanstone flanges were made on the tubes as they were installed in the reactors and inspected by fluorescent penetrant. Of the twelve hundred tubes installed, less than one percent failed on the in-pile Vanstoning operation. This failure rate is actually less than the failure rate of the aluminum tubes previously used in the reactor. The dry honing process developed by Physical Testing is continued to be utilized by IPD to virtually eliminate the Vanstone cracking problem.

Field tests were conducted on 32 different jobs during the month, customers for these jobs were every department and subcontractor at Hanford. A magnetic particle inspection was conducted on a DeLaval pump shaft from the 190-B high lift process pumps. Six crack-like indications were detected at the center bearing surface; the shaft is being sent back to DeLaval at New Jersey for repair. Extensive radiograph testing has been applied to such items as inspection of welds on the N Reactor hydraulic system, the 324 Building calcinator project, and air receivers throughout the 100 Areas. In most cases large amounts of weld areas are being found defective. These weld defect areas are carefully marked and removed by grinding.

Maximum effort is being made to provide the N Reactor program with field inspection services as required to maintain construction and startup schedules. Particularly heavy eddy-current and penetrant testing support have been provided this past month on an emergency top priority basis.

ANALOG COMPUTER FACILITY OPERATION

Analog computer problems considered during the month were:

1. PRCF Hazards.
2. NPR Pressurizer.
3. C-Column.
4. D Reactor Control Problem.

Computer utilization was as follows:

GEDA	EASE	
305	307	Hours Up
21	21	Hours Scheduled Downtime
10	8	Hours Unscheduled Downtime
0	0	Hours Idle
336	336	Hours Total

The purchase order for the new computer has been placed. As suggested by the AEC, negotiation meetings were held with the major contenders for the contract. Each bidder was informed as to which of the exceptions taken were acceptable and which were not acceptable. As a result, both bidders entered revised proposals. Their proposals were evaluated and the lowest bid was found acceptable.

The feasibility of utilizing telephone lines in connection with the analog computing equipment was tested with good results on the magnetic tape delay unit in connection with a heat transfer test being made by Physical Measurements Operation. The telephone line is between the 314 Building and the 3707-C Building. A 2,000 cycle per second signal from a radiometer is transmitted to the analog facility, to the tape delay unit, and back to the 314 Building. There is no apparent distortion or noise introduced by the use of the telephone line. It is anticipated that telephone lines can be used to test equipment at the PRTR, NPR, and other operating facilities. Plans were started to operate the PRTR moderator system and controller with the reactor critically safe, but simulated on an analog computer. There is a good possibility that later tests can be done through phone lines.

INSTRUMENT EVALUATION

Calibration testing and minor modification work was completed on the experimental scintillation solid state beta-gamma hand and shoe counter which uses gamma background compensation circuitry. EMI-9536-B multiplier phototubes were installed in place of the original RCA-6655-A tubes with a marked improvement in performance. Slight high voltage supply changes were necessary to use the new tubes. Fully successful operation with standard HAPO test sources can be achieved for the hand channels in about 1 mr/hr gamma background fields; whereas, a standard HAPO "Five-Fold" beta-gamma hand and shoe counter becomes a marginal performer in fields of about 0.05 mr/hr. Thus, an improvement performance factor of about 20 has been achieved. The experimental counter will now be moved to the 100 Areas for field tests.

The seven combination alpha-beta-gamma scintillation solid state hand and shoe counters being fabricated by Instrument Laboratory, Inc. of Seattle are nearly completed and will be tested during June. In addition, a contract was let to Tracerlab, Inc., to fabricate three more.

Twelve of 30 scintillation solid state portable alpha "poppies", fabricated by K-F Products, Denver, have been tested, accepted, and placed in service.

RS Paul

Manager
PHYSICS AND INSTRUMENTS LABORATORY

RS Paul:mcs

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CHEMICAL LABORATORY

RESEARCH AND ENGINEERING

FISSIONABLE MATERIALS - 02 PROGRAM

IRRADIATION PROCESSES

Release Studies

An unirradiated aluminum-clad bismuth element was heated at 500 C to explore the retentive capabilities of the can. After 52 minutes at temperature the can wall was breached at three points. Flow of liquid bismuth was from only one of the holes, but post-heating examination showed that the can wall was near destruction at many points. This indicated that storage or transportation temperatures of irradiated bismuth should be below the melting point of bismuth (271 C) to prevent escape from the aluminum can.

Characteristics of 100-Area Soils

Mechanical analyses were completed on soil samples from wells near the 100 Areas. The samples analyzed were from points every five feet from the tops of the wells to slightly below ground water. The following general conclusions were drawn from the results.

In general, soils are finer textured at greater distances from the river. More desirable locations of future cribs are inland rather than near the river bank. Inland locations would take advantage of greater flow path lengths and the greater decontamination ability of the finer textured soils.

The top 5 to 15 feet of soil is usually finer textured than the soil below.

A typical glaciofluviatile subsoil in the vicinity of the reactor areas would contain a great deal of gravel (25 percent) and sand (60 percent), but also would contain enough silt (8 percent) and clay (4 percent) to have considerable decontamination ability.

Film Adsorption Studies

Additional data have been obtained on the adsorption of radionuclides on aluminum coupons coated with various agents. These coupons were exposed for 30 days in reactor tubes downstream from

the flux zone. Of the 15 agents used, each of which had shown promise in laboratory tests, four were considerably superior. The average results from duplicate tests with these coatings are tabulated below:

Radionuclide Adsorption on Treated Coupons

Coating	Radioactivity Relative to Non-Treated Coupon			
	As-76	P-32	Np-239	Cu-64
Black Flo-Master Ink	0.38	0.24	0.57	0.91
Black Marks-a-Lot Ink	0.48	0.39	0.59	0.87
Silicone Resin 82	0.39	0.36	0.32	0.77
Silicone Resin 112	0.69	0.41	0.30	0.67

The black Flo-Master ink and the Silicone Resin 82 were the most effective in reducing the adsorption with the ink most effective for P-32 and the resin somewhat better for the Np-239 and Cu-64. Analyses for some additional radionuclides, including Sc-46, Cr-51 and Zn-65, are in progress. These coatings will next be tested in the flux zone of a reactor.

Deionized Water Studies

Installation of a raw water feed pump was completed, and maintenance and overhaul of the deionized water facility was accomplished during the reactor outage which occurred during the report period. Since many sample lines were removed during the outage and have not yet been replaced the deionizer is not yet back in operation.

The water treatment plant is operating well with aluminum nitrate nonahydrate. Using conditions of about 25 ppm of the flocculent, zero zeta potential, and a pH of 7, water with a turbidity of 0.003 is produced and filter runs of 8 hours are obtained. This compares favorably with the 0.015 turbidity water and 5-hour filter runs in this unit when operated on the regular reactor water treatment process.

In the half-reactor test at F-reactor to compare high and low alum conditions some measurements of Na-24, Ni-65 and Ga-72 were made as indices of relative corrosion rates. No significant differences were observed.

In the D-reactor half-reactor test comparing the two pH conditions of 6.6 and 7.0, measurements of Na-24, Ni-65 and Ga-72 did show significant differences, indicating that a reduction of corrosion is obtained at a pH of 6.6. Preliminary values obtained from Na-24

indicate a reduction of 20 percent, Ni-65 indicates a reduction of 50 percent, and Ga-72 a reduction of 15 percent. The wide deviation of the Ni-65 value may be real or may be due to the sensitivity to sampling line temperature conditions observed with this radionuclide.

SEPARATIONS PROCESSES

Disposal to Ground

The concentration of gross beta emitters in the ground water beneath the Purex 216-A-10 and Redox 216-S-7 process condensate cribs remained essentially unchanged during the past month. The maximum concentration in the ground water beneath these disposal sites ranged from $2 - 3 \times 10^{-3}$ μc β/cc during the current month.

Soil Permeability at Purex 241-A Tank Farm

The permeability of soil similar to that below the 241-A Purex Tank Farm was determined. The soil sample consisted of a composite of soil from the 55, 60, 65 and 75 foot depths from eight wells in the 241-A tank farm; only that part of the soil which would pass through a 2 mm screen was used. The permeabilities were determined for filtered and unfiltered synthetic Purex stored waste.

Measurements made at room temperature and atmospheric pressure with a falling head permeameter showed that the soil had a permeability of 6.2×10^{-6} cc/cm^2/sec with the unfiltered waste at unit gradient. A permeability of 1.2×10^{-4} cc/cm^2/sec was measured with the filtrate. Other permeability determinations were made at higher temperatures and higher pressures but cannot be interpreted until viscosity and density measurements are completed.

Ruthenium Removal Studies

Studies of ion exchange and sorption methods for removing ruthenium from Purex process acid recovery condensate were continued. Column experiments using activated charcoal, alumina, Dowex-1, Dowex-1 in series with Dowex-50, and a mixed bed of the latter led to some interesting observations.

At a low flow rate (0.04 col.vol./min) ruthenium broke through to 100 percent at 90 column volumes with Dowex-1 or Dowex-1 in series with Dowex-50. The ruthenium breakthrough curve in this case paralleled the hydrogen and nitrate ion breakthrough curves. After 100 percent breakthrough was reached, the double bed system gradually began removing ruthenium again and leveled off at about 33 percent

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breakthrough. This effect is believed to be related to the hydrogen breakthrough after which the cation resin becomes active with respect to certain of the ruthenium species present. It is unknown as yet whether the anion resin serves any purpose after breakthrough. A mixed bed of Dowex-1 and Dowex-50 showed promising results for ruthenium removal. A column containing 3 grams of Dowex-1 plus 2 grams of Dowex-50 removed about 90 percent of the ruthenium from 600 column volumes of condensate. The column volume number used is based on the Dowex-1 resin only. The flow rate on this same basis was 0.7 col.vol./min.

Results with a 30 to 50 mesh charcoal bed showed 13 percent ruthenium breakthrough at 500 column volumes of condensate at a flow rate of 0.04 col.vol./min. With a bed of 80 to 100 mesh alumina ruthenium exceeded 90 percent breakthrough after 350 column volumes. Either the alumina itself or impurities were observed dissolving in the dilute acid (pH 2).

Electrodeposition of Nickel or Uranium

The laboratory study of the effect of uranium surface condition upon nickel platability has continued with an investigation of the properties of nickel coatings produced in a variety of baths following different surface treatments. In this study, the uranium pieces were coated with a 19-21 micron thick layer of nickel, examined for hydrogen pitting, heated in air at 550 C for 30 minutes, cooled in air to 25 C, and examined for plate adherence and porosity. The 30-minute heat treatment in air is a harsh one, and may well require refinement for use with thinner plates. It has, however, yielded a striking demonstration of differences between surface preparation and plating techniques. The results of the study may be summarized as follows:

		Nickel Plate Properties					
		Anodic Etch in $HCl-H_3PO_4$ (1)			Anodic Etch in HNO_3 (2)		
Plating Bath	Additive	Pitting	Adherence	Porosity	Pitting	Adherence	Porosity
Watts	--	None	Good	High	Few	Poor	Medium
	H_2O_2	None	Good	High	Few	Poor	Medium
	XXX-D	None	Good	High	None	Fair	Medium
Thompson	--	Few	Good	Medium	Many	Poor	Medium
	H_2O_2	Few	Good	High	Few	Poor	Medium
	XXX-D	None	Good	High	Few	Poor	Medium
Watts (Br Substitution)	--	None	Good	High	Few	Poor	Medium
	H_2O_2	None	Good	High	Few	Poor	Medium
	XXX-D	None	Good	High	None	Poor	Low
Citrate	XXX-D	None	Poor	High	None	Poor	High
	Lissapol	None	Poor	High	None	Poor	High

[redacted]ized at 59 ma/cm^2 for 6 min. followed by pickling in 8 N HNO_3 at 40 C for 5 minutes.

(2) Anodized in 2 N HNO_3 at 75 ma/cm^2 at 25 C for 20 minutes.

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In addition to these results an anodic etch in trichloroacetic acid followed by the forementioned HNO_3 pickle, and a chemical etch in molten $FeCl_3 \cdot 6H_2O$ at 50 C were tested as possible surface pre-treatments by plating uranium from the Watts bath with the XXX-D addition. The first pretreatment gave a satisfactory plate while the second was satisfactory with regard to pitting and porosity but the plate was relatively non-adherent. These results lead to the following qualitative conclusions:

1. The best plating bath studied so far is the Watts bath with bromide substituted for chloride (substitution of bromide for chloride yields considerably less chemical corrosion).

2. The anodic etch in the H_3PO_4-HCl mixture gives more satisfactory results than in HNO_3 except as regards the porosity of the plate.

3. The anodic etch in trichloroacetic acid shows promise and will receive further attention.

The porosity of the nickel plate varies markedly with thickness. For example, the described tests showed the plate from the Watts bath with XXX-D addition to be essentially non-porous for thicknesses greater than 27 microns, and from the Watts bath with no addition plates thicker than 31 microns were relatively non-porous. However, since the test is very severe, it may be that a considerably thinner plate would be satisfactory.

The effect of pH was studied using the Watts plating bath with the XXX-D addition after the anodic etch in HCl-H_3PO_4 and HNO_3 pickle. The following observations were made: (a) current efficiency decreased very little from pH 5.0 through 2.0, but decreased more than 10 percent at pH 1.5; (b) hydrogen pitting increased from pH 5.0 to 3.0, but at pH 2.5 through 1.5 there was no pitting observed; (c) the porosity increased from pH 5.0 to 3.0 but from pH 2.5 through 1.5 the porosity was low; (d) the adherence was good for all cases.

Solid State Electrolysis

A 162-hour run at 900 C, produced by 125 amperes at 1.68 volts, has been completed on a uranium specimen. Spectrographic analyses and chemical analyses for carbon have been completed. Samples are yet to be analyzed for O, N, and H.

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Analytical data show that iron and carbon migrate to the anode end of the specimen. Curiously, tin is present at the cathode end of the specimen, a result which confirms a similar finding in a previous 50-hour run. The data also show a slight tendency for nickel to concentrate at the anode.

A 242-hour electrolysis of cerium metal has been completed in an effort to establish the behavior of carbon. The specimen was electrolyzed at 610 C, at 285 amperes/cm^2, and 1.16 volts. Radiochemical analyses for Zr-95, Sb-125, and Co-60, all of which are present, show that only Co-60 has migrated.

The data obtained from chemical analyses for carbon in this run together with similar data from two earlier runs show in general a higher concentration of carbon at the ends of the specimen than is present at the center. Moreover, the total level of carbon in the specimen diminishes with time at temperature. No selective migration toward either the cathode or anode is apparent.

T.A. Henrie has shown that C-14 tracer migrates to the surface, when electrolyzed, but does not migrate longitudinally. No effect is observed on simply heating the specimen to promote diffusion, i.e., the electric current is required to produce the effect.

The foregoing results confirm Henrie's finding that carbon does not migrate longitudinally. Moreover, if carbon migrates to the surface, it may react with oxygen present there and escape the specimen. This would explain the observed decrease in total carbon content with time at temperature. Likewise the specimens achieve a slightly higher temperature in the center than at the ends, a factor which would accentuate loss of carbon in the center by this mechanism.

The electrolysis portion of the first plutonium electromigration run has been successfully concluded. The specimen was maintained under satisfactory control at 500 ± 10 C for 170 hours using an average current of 37 ± 3 amperes at 1.45 ± 0.10 volt.

It proved difficult to remove the oxide coating on the surface of the specimen using nitric acid, so the decision was made to leave it on. This coating developed numerous cracks in a direction perpendicular to the longitudinal axis during the course of the run. On cooling the specimen, however, these appear to have closed up appreciably. The sample has now been removed and sectioned for analysis.

Extraction of Neptunium and Plutonium from Purex 1WW

When neptunium and plutonium are extracted from Purex plant 1WW solution with 0.3 M trilauryl amine (TLA)-Soltrol, some fission product ruthenium also extracts. Most of this ruthenium remains in the organic phase when neptunium and plutonium are stripped with 0.1 M oxalic. Removal of the residual ruthenium can be accomplished by washing the solvent with an alkaline permanganate solution.

A two-step washing procedure was most effective in laboratory tests. The TLA-Soltrol solution was first contacted with a 0.015 M $KMnO_4$ solution for one to two minutes at 25 C. Sufficient 50 percent NaOH was added to make the aqueous phase approximately 0.5 M NaOH and the mixing continued. Ruthenium DF's of 75 and 350 were obtained after 10 and 60 minute contact times, respectively, using 0.3 M TLA-Soltrol containing tracer Ru-106. The ruthenium decontamination factor obtained was relatively insensitive to temperature (25 versus 60 C) and NaOH concentration (0.5 to 5.0 M). The washed organic phase behaved normally in subsequent extraction of Np(IV) and Pu(IV) from synthetic 1WW solution.

Use of Uranium(IV) in the Purex Partition Column

Experimental results were reported previously which indicated that severe plutonium reflux could occur when U(IV) is used as the reductant in the Purex 1B column. The reflux would result from the oxidation of Pu(III) to Pu(IV) in the 1BS column, which, in the proposed flowsheet, would operate with only a holding reductant (hydrazine) present. It now appears that the plutonium reflux will be less than thought earlier. The earlier experiments were made at 0.01 full-level plutonium concentration. In recent experiments at higher concentrations, a lower percentage of the plutonium was oxidized. Indications are that the oxidation rate of Pu(III) in the two-phase, HNO_3-hydrazine plus TBP-Soltrol system, exhibits a dependency upon Pu(III) concentration which is much less than first order. Somewhat analogous behavior has been reported for the oxidation of U(IV) to U(VI) where, in HNO_3-N_2H_4, the oxidation rate is zero order with respect to U(IV) concentration (DPST-62-1-7).

WASTE MANAGEMENT AND FISSION PRODUCT RECOVERY

D2EHPA Processing Engineering Studies

The pilot plant pulse columns were used this month to test the performance of the D2EHPA process with tartrate-complexed feed which is currently favored because of the improved cerium extraction

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kinetics. The solvent contained 0.3 M D2EHPA, 0.15 M TBP.

In addition, the 1A column was modified in several of the runs to simulate the RA and RC columns from the old Metal Recovery (TBP) Process. These columns are available for installation in B-Plant. The RA simulation was a dual-diameter column containing a 12-foot-tall, 23 percent free area nozzle plate cartridge in the lower, 3-inch-diameter section and a 6-foot-tall, 10 percent free area nozzle plate cartridge in the upper, 4-inch-diameter section. The RC modification contained only a 12-foot-tall, 23 percent free area nozzle plate cartridge.

The scrub section in these RA-RC simulation studies was divorced from the 1A column and placed as a separate "1S" column with the spent scrub solution pumped to the top of the 1A column to blend with the 1AF. The 1S cartridge contained 10 feet of 2-inch-spaced, 10 percent free area nozzle plates. The performance of the separate scrub section was highly satisfactory.

In-Tank Solidification Studies

Boil-down tests using cold coating waste solution were completed satisfactorily using direct immersion electrical heaters inserted into the circulator. No scaling of either heater or circulator tube occurred. At a concentration of 4.25 to 1 the concentrated waste solidified completely on cooling over night. This method is being explored as a simpler and more economical alternate to that of heating air to effect the concentration.

Storage of Cesium and Strontium on Zeolites

Observation of the B-Cell zeolite cartridge, which is loaded with about 50 watts of strontium, continued during the month. Since no significant stable pressure (ignoring occasional transients) was observed at 460 C, the temperature has been raised to about 500 C and held at this temperature, except for several brief periods of heating or cooling - aimed at testing for possible leaks and at determining degree of reversibility of gas absorption or recombination. Phenomena observed, which include transient pressure excursions to ca. 30 psig, have defied any simple explanation or correlation in terms of desorption of water from the zeolite, radiolysis of water, gas recombination, or leaks. Recommendations are being formulated for a more comprehensive study aimed at elucidating the mechanisms involved.

Recovery of Rare Earths from Purex Tank Farm Sludges

An oxalate precipitation - caustic metathesis process was reported last month for the recovery of rare earths from the sludge in the Purex 106A waste tank. Analysis has since shown that the sludge contains an appreciable amount of lead (from the Purex Head-End strontium recovery operation) and that much of this lead will dissolve along with the rare earths in dilute acid, so that the lead content of the feed to the rare earth recovery step may exceed the rare earth content by as much as a factor of ten. The effect of lead was evaluated in a series of laboratory experiments and necessary flowsheet changes made. The presence of lead did not affect the oxalate precipitation step (provided a quantity of oxalate equivalent to the lead, rare earths, and iron was used) but did interfere with metathesis - apparently because of the presence of a large amount of oxalate in the precipitate and the relatively low solubility of sodium oxalate. This difficulty was eliminated in either of two ways: (1) by holding the NaOH concentration at 1 M and increasing the volume, or (2) by substituting KOH for the NaOH. Over 95 percent rare earth recovery was obtained by metathesizing the precipitate from one liter of feed (containing 0.1 mole of lead) with 500 ml of 1 M NaOH or with 100 ml of 5 M KOH, followed by dissolution in 100 ml of 2.5 M HNO_3.

Cesium Removal from Wastes

Studies were continued on the use of Duolite C-3 phenolic resin for removal of cesium from Redox alkaline supernatant wastes. At elevated temperatures (40 and 60 C) cesium breakthrough occurred earlier than at 25 C with little improvement in column kinetics. Thus, low temperatures are preferable.

Eighteen flowsheet cycles with one column of Duolite C-3 were completed using synthetic Redox "SX" tank farm waste. The flowsheet was changed several times during these runs, but the last and most satisfactory one included: (1) load, (2) wash with three column volumes of 0.01 M NaOH, (3) scrub with six column volumes of 0.2 M $(NH_4)_2CO_3$ - NH_4OH solution, (4) elute with six column volumes of 2 M $(NH_4)_2CO_3$ - NH_4OH solution, (5) backwash with two column volumes of 2 M NaOH, and (6) reload. The cesium breakthrough curve for the eighteenth cycle was essentially the same as that for the first cycle. The resin was then removed from the column, dried and weighed. Comparison with the original resin weight indicated a loss of less than 5 percent of the resin.

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Two additional inorganic exchange materials reported in the literature for selective cesium removal were synthesized and tested with synthetic Purex 1965 denitrated 1WW. The exchangers are zirconium phosphate and potassium molybdenum ferrocyanide. Cesium K_d values were 45 for zirconium phosphate and 300 for potassium molybdenum ferrocyanide as compared with 120 for clinoptilolite and Zeolon. Two column runs were made with the ferrocyanide exchanger. The 50 percent cesium breakthrough volume was 240 column volumes as compared with 120 column volumes for clinoptilolite and Zeolon. However, the ferrocyanide exchanger displayed less suitable physical properties as a sizable weight loss occurred during column runs and one column plugged near the end of a run.

Fission Product Packaging

Column experiments with a simulated CSREX 1BP solution and Linde 4A zeolite show a total cesium and strontium loading of 2.2 milliequivalents/gram of zeolite. The solution composition was 0.2 M $NaNO_3$, 0.027 M $CA(NO_3)_2$, 0.027 M $Sr(NO_3)_2$, 0.040 M $CsNO_3$ and a small amount of rare earth complexed with citrate ion. The 4A zeolite adsorbed 0.9 and 1.3 milliequivalents of cesium and strontium, respectively, which is near the equivalent ratio of the two elements in solution. The latter is significant in that little, if any, cesium selective zeolite will have to be mixed with the 4A for the combined packaging of cesium and strontium from CSREX 1BP solutions.

The total cesium and strontium loading predicted from binary exchange data is near that obtained by the column experiments. However, the amount of each cation is different. The predicted cesium and strontium loading was 0.47 and 1.76 milliequivalents per gram, respectively. The reason for the difference between predicted and experimental loading is unknown at the present time. The data indicate that a Na^+ to Cs^+ solution ratio of about 5:1 or less must be maintained for satisfactory cesium loadings on 4A zeolite.

Initial results with solutions containing high concentrations of sodium carbonate relative to cesium carbonate indicated that activity corrections would be necessary to obtain good cesium loading estimates for zeolites from binary exchange data. However, recent work with solutions in the expected concentration range for fission product packaging show that activity corrections do not significantly improve the accuracy of the loading estimates.

EQUIPMENT AND MATERIALS

Stress Corrosion Cracking of Mild Steel

The spheroidized structure formed in the heat sensitized area between base and weld metal, plastically deformed during welding, has been postulated to be mainly responsible for crack initiation in mild steel weldments. A specimen of mild steel, heat treated to form the spheroidized structure, was coupled to an untreated specimen through a zero resistance ammeter and exposed to 50 w/o $NaNO_3$ at 80 C. Current flow was essentially nil. No difference in polarization characteristics was noted when anodic and cathodic polarization of both specimens were determined in 50 w/o $NaNO_3$.

Two weldments each of ASTM A-283 Grade C and ASTM A-201 Grade B, exposed to synthetic Purex waste for 250 and 75 days, respectively, were inspected and found to be free of cracks. The two weldments of ASTM A-283 Grade C were removed from the waste solution and are now being exposed to 40 w/o $NaNO_3$ - 10 w/o $NaNO_2$ at 80 C. A cathodic current (ca. 100 μ amp/sq.cm) is being applied to one of these weldments.

Cathodic Protection of 304-L in Purex 1WW

Results of cathodic protection experiments with 304-L stainless steel exposed to boiling synthetic Purex 1WW indicated a ten-fold reduction in corrosion can be achieved at a current density of about 100 μ amp/sq.cm. In experiments to measure the distance over which protection was effective, pairs of 304-L speciments, electrically connected, were placed at varying distances from the anode. With one of the pair one inch, and the other six inches, from the anode, both specimens were protected. When the distance to the outside specimen was increased to 24 inches no protection of this specimen was obtained, even when the current density was increased four-fold.

PROCESS CONTROL DEVELOPMENT

Scintillating Glass

A sample of Nash and Thompson type GS1 scintillating glass was tested by total immersion in a solution of 20 percent TBP, 80 percent CCl_4 which had been equilibrated with 2 percent H_2SO_4 and 30 percent HNO_3. After 572 hours at 50 C and 368 hours at room temperature there was no detectable change in dimension or physical appearance.

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In-Line Plutonium Detectors

The Plutonium Detection Test System was completed and put in operation. Located in a 222-S Building hood, the system is designed to flow plutonium solutions of controlled concentrations through various in-line detection devices. Two detectors have been tested to date: A 17 kev X-ray scintillator, and a LiI crystal neutron detector. With the X-ray detector, 400 counts per minute were obtained at a plutonium concentration of 10^{-4} grams per liter. A linear relationship between count rate and concentration held up to the maximum concentration used, 1 gram per liter. Application to a plant plutonium waste stream is now under study.

The lithium iodide crystal neutron detector produced count rates of 7,000 to 60,000 per minute with plutonium concentrations of 0.1 to 1 gram per liter. This device is now being evaluated as an alternate to the BF_3 tubes for measuring plutonium concentration gradient in the new Plutonium Reclamation Facility columns.

Measurement of Column Density

Instrumentation and techniques for measuring pulse column density are under study, with particular emphasis on control requirements for the new Plutonium Reclamation Facility. The filtered static head measurement is equivalent to the time average static plus dynamic head. Analysis shows that this value may contain contributions derived from asymmetry of the pulse pressure wave, amplitude, frequency, and net flow through the column. An instrumentation system was installed on an experimental, air-pulsed column to determine whether the contribution from the dynamic head could be effectively rejected to give a more accurate measurement of static head, and the dispersed phase hold-up. The system uses a strain gage pressure transducer placed so as to measure the full dynamic and static head. The strain gage output is fed to a differential DC amplifier with circuitry arranged so as to amplify essentially only the DC component of the signal. With suitably chosen amplification and attenuation, this signal is suitable for recording and control. Although additional testing is planned, the system appears to be successful.

Advanced Process Control Development

A modified mathematical model of the C-Column has been developed which takes into account the fact that mass transfer takes place in the region above and below the cartridge section. Calculations have been carried out using the model to predict effluent concentrations. Four cases were compared: (1) no organic below feedplate and no aqueous

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above extractant plate; (2) organic extant below feedplate down to 10 percent of cartridge length and no aqueous above cartridge; (3) no organic below feedplate, and aqueous extant up to 10 percent cartridge length above extractant plate; and (4) organic below and aqueous above cartridge. Values of the mass transfer coefficient and equilibrium line slope typical of C-Column operation were selected for study. Several different values of diffusion coefficients for both phases were also used. In all cases it was demonstrated that the effect on waste effluent concentration was very nearly the same whether the aqueous was allowed above the cartridge or the organic allowed below, and that when both the conditions were obtained the effect was very nearly the sum of the individual effects (i.e., no interaction effect). Hence the conclusion is that the effective lengthening of the extraction zone is what is important and this can be accomplished either by increasing pulsing frequency or by raising the top interface. For the range of diffusion coefficients believed to be typical of C-Column operation, the improvement in extraction efficiency, before a flood occurs, due to this effective lengthening, is about 35 - 40 percent.

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REACTOR DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Salt Cycle Process

Crushing and Sizing of Electrolytic UO_2 - The -200 mesh size fraction for use in vibratory compaction of UO_2 fuel has been produced from -10 +25 mesh feed in two pieces of apparatus. A 60 rpm ball mill produced 99 percent -200 mesh particles in 13 hours of operation. The previously reported (HW-77709 C) paint shaker produced 94 percent -200 mesh particles in 30 minutes of operation at 1100 shakes per minute. The great improvement in its operation is directly due to increasing the number of pulverizing balls from 6 to 28, thus filling the container half full of balls. Fine UO_2 fraction preparation for the C-Cell program will be by ball mill.

Induction Heater Work Station Controller - Two work station controllers have been designed and are being fabricated for control of induction heated salt pots. The controllers are for use in Salt Cycle process studies in C-Cell in 325-A and in the Pyrochemical Test Facility. Approximately 500 hours of operation have been accumulated on a prototype controller, with no failures of the silicon controlled rectifiers or other solid state components.

Flowsheet Studies - Laboratory studies of the electrolytic deposition of UO_2 and UO_2-PuO_2 mixtures from molten chloride salt solutions have been extended to the CsCl-LiCl eutectic (58 mole percent LiCl). The results thus far show that, compared with the equimolal KCl-LiCl system, use of a CsCl-LiCl melt gives somewhat improved promethium decontamination and an increase in the extent to which PuO_2 co-deposits with the UO_2. The latter effect is strong enough that it is very doubtful that Pu-U partition can be achieved by electro-deposition of UO_2 from a CsCl-LiCl melt.

Plutonium Chemistry in Chloride Melts - Spectrophotometric studies of reactions involving plutonyl species in chloride melts have continued. The ratio of plutonyl(VI) to plutonyl(V) in O_2-Cl_2 sparged melts was found to decrease with temperature and, at a constant temperature, to be proportional to the square root of the concentration of the chlorine in the sparge gas, as expected for the equilibrium reaction:

$$PuO_2Cl_2 \rightleftharpoons PuO_2Cl + 1/2Cl_2$$

At certain temperatures and chlorine concentrations, a precipitate is formed, presumably via the reaction:

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$$PuO_2Cl \rightleftharpoons PuO_2 + 1/2Cl_2$$

The chlorine concentration in the sparge gas required to prevent precipitation of PuO_2 increases with temperature.

The plutonyl(VI):plutonyl(V) and plutonium(IV):plutonium(III) ratios in Cl_2-saturated melts were both found to be greater by a factor of about 3.5 in 1.4 LiCl-CsCl than in LiCl-KCl, at 550 C. Since both of these equilibria involve chlorine, the solubilities of chlorine in the melts must be known before a comparison of the equilibrium constants can be made. Preparations have now been completed for a study of chlorine solubility in various melts of interest.

RADIOACTIVE RESIDUE PROCESSING

Eighteen-Inch Radiant-Heat Spray Calciner

The Cold Semiworks reactor has been completely revised to provide a very flexible unit for optimization studies of draft tube and reactor geometries. The new unit is fabricated of Hastelloy X and is fitted with both a moveable telescoping draft tube and moveable conical bottom section. This arrangement allows the draft tube length to be easily changed and also allows the effective length of the reactor tube to be altered by positioning the moveable cone and sealing the lower part of the calciner shell by an extension tube from the cone to the reactor outlet. Tests are in progress to determine operating capacity and characteristics.

The venturis on the blow-back filter assembly have also been changed to a 3/4-inch throat and 14° divergent section. A detailed study of the blowback system has been initiated to provide quantitative definition of the effects of major design and operating variables.

During removal of the original Inconel X calciner reactor it was noted that many of the welds made in fabricating the cylindrical shell had developed cracks. It has been concluded that these weld failures are not the result of corrosive conditions inherent in the process. Rather, they were caused by mechanical stresses during operation and lack of solution heat-treating of welds during construction. Hastelloy X, used in the new reactor, should be a markedly superior material for the proposed operating conditions.

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Calcined Waste Melt Pot Materials

Samples of 310 and 446 stainless steel, Inconel, Hastelloy X, Duranickel, HAPO 20, INOR-8 (Hastelloy N), Alchrome D, Kanthal A, and 90 Ta-10W, were exposed at 950 C to calcium-stabilized spray calciner product, with phosphate added. Alchrome D, Duranickel, INOR-8, and 90 Ta-10W alloy all exhibited excessive corrosion rates. Kanthal A exhibited a rate of about 9 mil/mo and the remaining alloys exhibited rates of about 2 mil/mo. Longer exposures of the more promising alloys are in progress.

Full Level Calcination Studies

A series of runs with ammonia-neutralized synthetic feed were performed during the month in the "cold" 8-inch spray calciner and were followed with a full-level run (#17) in the hot-cell pilot plant. Additional analytical data were also obtained on the high-sodium-nitrate pot calcination runs reported last month and the first indication of pressure build-up was noted on the pots containing the latter calcines.

The dramatic reduction in ruthenium volatilization (run #12) caused by caustic neutralization of spray calciner feed was reported recently. A major drawback to use of caustic neutralization is addition of excess sodium ion, a drawback which might be overcome by use of ammonia (which would be driven off during calcination) rather than NaOH for pH adjustment, provided favorable ruthenium behavior is retained. Four runs were made in the 8-inch spray calciner with synthetic 1WW, to define conditions for the hot-cell test. Best results in terms of guaranteeing a meltable calcine (with the particular composition of 1WW on hand for in-cell runs) were achieved with NH_4OH equivalent to 0.6 moles per liter, no sugar, and sodium bisulfate ($NaHSO_4$) equivalent to 0.72 moles per liter of 1WW. The resulting melt was fluid at < 900 C. The subsequent in-cell run was uneventful, except for a slight loss of activity to the cell filters caused by loss of vacuum during start-up. Although the precipitate formed on ammonia neutralization was "stickier" than that with caustic, the slurry was pumped and atomized without difficulty. No analytical results are yet available; however, very preliminary indication is that ruthenium evolution was much less than in acid-side operation but not so low as with caustic neutralization. Additional hot-cell runs may be required to determine whether this difference is indeed due to substitution of ammonia for caustic or due to the deletion of sugar.

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Complete analyses on the pot calciner runs with high concentrations of sodium nitrate fail to resolve unequivocally whether the cesium evolution observed was due to true volatilization or to some other mechanism, such as preferential concentration in the liquid phase remaining at the end of the evaporation cycle, with carryover of some of this liquid by entrainment or "bumping". In any event, it appears that it is not desirable to calcine a nitrate waste with sodium much in excess of that needed to combine in the calcine with sulfate, carbonate, or perhaps phosphate, etc. The two pots containing the sodium nitrate calcines are also exhibiting the first pressure build-up observed with any of the calcines produced to date. Pressures were 1 to 2 psig at month's end, with observation continuing.

Glass Making Studies

A two-stage (Pyrex) evaporator for concentrating phosphoric-acid-containing solutions prior to feeding to a glass furnace has been designed and is being fabricated. A 15 kw 450 kc induction heating unit has also been received and is being installed for "cold" piloting of glass making. Provision is being made to operate both units either with a Brookhaven-type pot or with an inclined tube furnace. The latter would employ a ceramic tube in an Inconel susceptor and, if successful, would eliminate use of platinum.

Scouting experiments are also being performed with phosphate glass formulations, aimed particularly at reducing melting point, retaining sulfate in the glass, and finding a composition and melting point compatible with common materials of construction. Substitution of meta-phosphate for ortho-phosphate has resulted in lower melt temperatures and shorter dehydration periods. A phosphorous to metal ion ratio in excess of unit was required to produce true glasses, with devitrified "ceramics", actually of superior mechanical strength, produced at lower rates. A mixture having the mole ratios $P:Na:Ca:SO_4 = 2:2:1:1$ (presumably $P_2O_5 + Na_2O + CaSO_4$) produced a homogeneous solid with a density of 2.61 after less than one hour at 900 C. Remelting at 1000 C improved fracture resistance but raised the density only to 2.63. Melting and remelting were carried out in 304-L stainless steel, which suffered only nominal attack, implying that one-shot "fill-and-store" stainless steel crucibles may be feasible.

Exchanger Properties

The kinetics of a reaction of the type $CaSO_4 \cdot 2H_2O(s) + BaCl_2 \rightarrow BaSO_4(s) + CaCl_2 + 2H_2O$ were examined. This type of reaction can be used to remove specific cations from radioactive wastes.

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The $CaSO_4 \cdot 2H_2O$, or gypsum, spheres were immersed in a constant-composition bath of $BaCl_2$ solution containing Ba-133. The gypsum spheres were progressively altered to $BaSO_4$, and the Ba-133 was continuously monitored and recorded. The resulting curve of the replacement of gypsum by $BaSO_4$ represents a complete record of the replacement kinetics, and also gives the time necessary for the reaction to go to completion. Further analysis of the experimental data showed the replacement reaction to be diffusion controlled.

Condensate Treatment

A simple vertical-leaf filter was fabricated with the leaf enclosed in a section of 4-inch glass pipe so that the application of a thin zeolite bed could be demonstrated and visually observed. The bed support was made from 24 x 110 mesh plain dutch weave screen having a total surface area of 0.2 ft^2. Using 100 to 250 mesh clinoptilolite, a 0.25-inch thick bed was easily formed on the vertical leaf. Pressure drop across the bed was not measured, but a flow of 15 to 20 gpm/ft^2 was attained with a supply pressure of about 20 psig. A momentary flow interruption caused the bed partially to drop because of gravitational forces. This resulted in a bed thinner at the top after the flow was started again and demonstrated the importance of maintaining positive flow through a vertical-leaf type filter. Improved precoat filters will be used for further zeolite sorption-filtration testing of the condensate decontamination process.

Electrostatic Bubble Scrubber

The average charge per particle used in scrubber efficiency measurements was determined by measuring total charge transferred to a grounded filter and support from a known number of charged particles collected. From 20 to 120 electrons per particle would account for the charge transferred over the range of charging current used. The electrons per particle were found to be approximately linear with the square root of the charging current. Although the charge acquired is of the expected magnitude, the change in charge with charging current is not that expected for the 0.23 μ particles used. Field charging of the larger particles could be accounting for the discrepancy noted.

The deposition of charged particles on the wall of a spherical cavity due to space charge was calculated from theory and compared to the efficiency measurements of the 1/6-square-foot electrostatic bubble scrubber. A significantly lower efficiency than the 30 percent to 50 percent efficiency measured was predicted. Relatively small errors in charge per particle would materially change the calculated

efficiency and are presumed to be the primary source of disagreement, although bubble size and time of travel through the scrubber also influence the deposition. Measured deposition in a grounded cylinder was in much better agreement with theory than for deposition in a small sphere (bubble). It should be emphasized that these measurements were for space charge migration, and deposition of particles, and should not be compared with deposition of charged particles in a high voltage gradient.

The parametric study of the electrostatic bubble scrubber was concluded with these measurements. Some experiments will be performed to determine the deposition pattern of an electrostatic bubble scrubber of geometry similar to that used in the high level waste calcining research.

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BIOLOGY AND MEDICINE - 06 PROGRAM

TERRESTRIAL ECOLOGY - EARTH SCIENCES

Hydrology and Geology

"REPERM", a computer program for determining the necessary resistance values in the ground water analog from permeability data, is essentially completed. The program, which represents the end product of much effort in formulation and programming, carries out four essential operations:

1. The three-dimensional region for which resistances must be specified is isolated through using the several input functions describing the irregular boundaries of the project; i.e., basalt configuration, Columbia River coordinates, and water table configuration.

2. The region defined in Step 1 is further subdivided into grid points to be interconnected by resistors.

3. The value for each resistor is computed from input permeability and the geometrical shape of the soil elements simulated by each resistor.

4. The results are summarized, and a list of resistor values, a wiring plan sheet, and a resistance decoding list are printed out.

The program was written in generalized form to permit application to almost any flow system. The first application will be in establishing the "test" analog.

A series of three-dimensional cases was solved with the "Steady-State Flow" Program to evaluate the possible piezometric head measurement errors resulting from using only sand between piezometers installed in cased wells rather than a cemented sealed-off zone. The evaluations for both homogeneous and heterogeneous soils and various head differences showed the sand pack could be used effectively in obtaining accurate head measurements with depth.

A field test of the sand-pack installation was carried out in well 699-10-E12 by filling in around four plastic piezometer tubes, set to different depths with sand. The complete installation was carried out by two men in an 8-hour shift. The water level measurements taken following completion of the work showed the head in the

lowermost tube to be 27 feet greater than the head at the water table. This head difference is one foot higher than that observed in well 699-20-E12, located two miles to the north, and two feet higher than that observed in well 699-S11-E12, located four miles to the south. This method of installation will speed up considerably and will also lessen the cost of obtaining head measurements with depth.

Work has progressed in developing methods for describing unsaturated flow parameter curves with a single equation rather than several equations and/or tabulated data which are presently used as input to several computer programs. This will result in a simplified input and afford increased computer storage. Fitting methods were developed for the degree of saturation-capillary pressure curves, and the same general equation can be applied to fit relative permeability-capillary pressure data.

Field work by Geophysical Service, Inc., on contract SA-269 was completed on schedule. Two lines were surveyed by refraction and reflection seismic methods, one southeast from the Wye barricade and the other south from well 699-S6-E14. Both lines were deliberately selected to provide the least favorable geologic conditions at Hanford for successful seismic work.

Preliminary interpretation of results indicates a marked degree of success, appreciably exceeding expectations. Complete results will, however, not be available until data are programmed and evaluated by computers in GSI's home office in Dallas, Texas.

Data to date in general correlate well with earlier geological interpretations. Additional results were provided that locally will significantly modify the geological picture.

Rotary drills, used by GSI for shot-holes and for drilling of wells for logging purposes, proved completely feasible and practicable at Hanford even in the glaciofluviatile gravels along the two lines. Drilling rates ranged up to nearly seven feet per minute and averaged about 32 feet per hour. Costs appear to be less than $2.00 per foot for the mud-drilled, uncased holes. Caving of the gravels was no problem for a day or more following completion of drilling; hence, time could be available for logging of the well and installation of light-weight metal casing, plastic casing, or piezometer tubes. Electrical resistivity logs of the wells show considerable variation in the geologic units that suggests that such logs will more than offset the loss of quality of sediment samples taken during drilling.

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RADIOLOGICAL AND HEALTH CHEMISTRY

Radioiodine Release Test at Idaho Falls

During a controlled radioiodine release experiment conducted at Idaho Falls some sampling was accomplished using Hanford equipment to provide data basis to planning future Hanford radioiodine release studies. In this test 970 mc of I-131 was released over a 45-minute period from five generators spaced about 100 feet apart in a line at a right angle to the wind direction. Four samplers were placed near the center line 164 feet from the sources, four samplers at 328 feet, and one each at 656 and 949 feet. These samplers collected air at rates of one to four cubic feet per minute. They consisted of a membrane filter for removing particulate iodine, a silver mesh to remove reactive gaseous iodine species such as HI and I_2, and activated charcoal to remove any remaining iodine. Vegetation (crested wheat) was also collected from a measured ground area just in front of each sampler. Some of the data obtained are given in the table.

Distance from Source Line (ft.)	I-131 in Air (Avg.) (mc/ft^3)	I-131 on Vegetation After 45 Minute Exposure (mc/ft^2)
164	3.3 x 10^{-6}	8 x 10^{-4}
328	1.3 x 10^{-6}	4 x 10^{-4}
656	0.58 x 10^{-6}	2.0 x 10^{-4}
949	0.47 x 10^{-6}	2.2 x 10^{-4}

About 20 - 30 percent of the iodine was associated with particles and was removed by the filters; 50 - 60 percent was removed by the silver mesh, and the remainder by the charcoal. About one-half of the iodine deposited on the vegetation was found on the top one-half.

Radiation Chemistry

The variation of protection index with temperature was studied with sodium nitrite, benzene and sodium lauryl sulfate in order to obtain clues as to the nature of the radical-capturing processes in irradiated aqueous solution. The protection indices of both sodium nitrite and sodium lauryl sulfate increased as the temperature of the solution was decreased. This has been the general pattern found for amino acids, peptides and alcohols examined to date, and it is interesting to observe that compounds with such widely different chemical structures all show this effect. Benzene on the other hand appears to have a protection index which is independent of temperature

although the data are less convincing due to the loss of benzene vapor from solutions during irradiation at high temperatures.

One hypothesis to explain the loss in protective ability of compounds as the temperature increases supposes that erioglaucine has a large sheath of water coordinated about itself at even high temperatures while other compounds acquire this sheath only at low temperatures. One of the characteristics of a good protective agent might be to organize water about itself much like erioglaucine. Benzene may have this sheath at all temperatures or not at any temperature since the temperature effect is zero or at least small. If it does have an extensive sheath in which electrons can move from benzene to a hydroxyl radical at the surface of the sheath, the availability of these electrons must be poor as benzene is not an outstanding radical scavenger. Sodium lauryl sulfate was chosen because as a detergent it might be expected to have an unusual organization of water about itself. No unusual feature was found, however, as reported above, and it is probable that sodium lauryl sulfate is more active in organizing other sodium lauryl sulfate about itself as in micelle formation than in organizing water.

ATMOSPHERIC RADIOACTIVITY AND FALLOUT

Aerosol Sampling Study

Errors in sampling particles in five mile per hour air streams were experimentally determined for 25 micron (and somewhat larger) ZnS particles as a function of face velocity through the sampler filter. At a sampling rate 1/20 that for isokinetic flow, the number of particles collected was over twice that which would have been collected assuming that particle inertial effects were negligible. Even greater errors would be made at somewhat higher ratios of sampling rate to isokinetic rate, a result which requires further verification. Measurements of reproducibility and statistical significance show that entirely satisfactory precision was attained for these results.

ISOTOPES DEVELOPMENT - 08 PROGRAM

Radiochemistry of Promethium

A capsule has been designed for brief (ca. 3 hour) irradiation of 0.1 gram of U-235 in a production reactor to determine the independent fission yields of Pm-146 and the two Pm-148 isomers. Fabrication of the capsule will be initiated as soon as IPD approval is obtained. Incidental to this work, a gamma counting technique for determining U-235 was developed.

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In other promethium studies, a 0.121 mev gamma from promethium, which has been reported by several workers, has been verified. Ratio of this gamma to promethium brensstrahlung was identical for 8-year-old Brookhaven promethium and 2-year-old Hanford promethium, strongly implying that this radiation is associated with Pm-147 and not with Pm-146 or Pm-148. It is hoped to resolve this point by gamma-beta and gamma-gamma coincidence counting. (Existence of a gamma of this energy and low abundance does not affect the shielding requirements of promethium sources; however, its identification would aid our understanding of the decay schemes and energy levels involved in promethium decay.)

Pyrochemical Cerium-Trivalent Rare Earth Separation

Laboratory results of the initial studies on the thermal decomposition of cerium(III) nitrate using $Mg(NO_3)_2 \cdot 6H_2O$ as a fluxing agent indicate 97 percent cerium recovery. This material had a purity of 85 percent as CeO_2 (69 percent Ce).

W. H. Reas

Manager
Chemical Laboratory

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BIOLOGY LABORATORY

A. ORGANIZATION AND PERSONNEL

Seven summer hires reported to various operations in Biology during June.

Dr. W. J. Billings, Duke University, was assigned on the Summer Professorship Program to Radioecology.

Dr. F. P. Conte, Oregon State University, was assigned on the Summer Professorship Program to Aquatic Biology.

GENERAL

The Symposium on the Biology of Radioiodine was held on June 17, 18, and 19. It was the second in the series, the first one being held in May 1962. One hundred and forty scientists from off-site registered along with 75 on-site registrants. From all reports, the meeting was highly successful.

B. TECHNICAL ACTIVITIES

FISSIONABLE MATERIALS - 02 PROGRAM

Effect of Reactor Effluent on Aquatic Organisms

The experiment to determine the effect of two levels of effluent concentrations, 3 and 6%, and two types of corrosion inhibitors, sodium dichromate and quachrome glucosate, on the swimming performance of young chinook salmon has been terminated. A total of 273 swim tests on 91 groups with 11 or 25 fish each was completed. Each group was tested for duration of performance at three different water velocities. Statistical analysis of the data is not complete, but gross comparisons of the treatment means do not indicate any significant effect of either effluent concentration or type of corrosion inhibitor. The overall mean performance for all treatment groups, within the size range of 56 to 60 mm standard length, at 1.8, 1.6, and 1.4 fps water velocities were 152, 459, and 789 seconds, respectively.

Vertan 690

A total of 1400 young trout and 280 chinook salmon were tested for acute toxicity of Vertan 690 to help evaluate the biological significance of the proposed river disposal of 170,000 pounds of this chelating material at N reactor. Estimates of the 72-hour 10% tolerance limit (LD_{10}) were 1500 ppm and 2000 ppm Vertan 690 for trout and chinooks, respectively. These estimates serve as rough guides, and liberal safety factors must be applied to fix an upper limit which will not cause acute fish kill.

Considerable variation in the lethal response was observed, and the tests appeared to lack reproducibility. However, when the results of the tests were stratified into early and later tests, they suggested that Vertan 690 has some labile constituent or constituents which attenuates or loses toxicity with time. The color change in the stock Vertan 690 solution also indicated that chemical changes occur with time.

Algae grown on glass plates were immersed in solutions containing concentrations of 3, 70, 300, and 10,000 ppm of Vertan 690 for 5½ hours. No gross effects were noticed on the plates exposed to 3, 70 and 300 ppm, but the algae were reduced and bleached on the plates exposed to 10,000 ppm.

Concentrations (volume/volume) of Vertan in normal growth medium resulted in the following effects to the bacterium, E. coli:

10,000 ppm	Complete lysis of cells
1,000 ppm	Strong growth suppression
100 ppm	No observable effect on growth
10 ppm	Mild stimulation of growth
1 ppm	Mild stimulation of growth

Columnaris

Sampling of fish from the Columbia River during the month of June showed no positive samples for columnaris in the first sampling early in the month and less than 10% of the fish were contaminated in later samplings. From nearly 150 fish only one appeared to be actually suffering from a lesion caused by this organism.

In contrast, fish taken from the Yakima River at the fish trap near Prosser showed nearly 100% positive samplings for the presence of columnaris, and many of the fish showed heavy infection of lesions. The above data were for scrap fish. Positive samples were also obtained from downstream migrant chinook salmon but none of the salmon appeared to have lesions suggestive of columnaris infection. Water taken from the vicinity of the fish trap showed a count of 5 to 50 columnaris organisms per milliliter of water. The extremely high concentration of organisms in the water at this early time of the year is suggestive that the Yakima is, in this year at least, a primary source of this organism.

Weekly sampling of rainbow trout from the Aquatic Biology troughs has consistently shown no evidence of columnaris to date. Chinook salmon reared in 3 and 6% pile effluent were tested for their susceptibility to this organism. The higher percentage of effluent did not increase the susceptibility of the fish to the columnaris.

BIOLOGY AND MEDICINE - 06 PROGRAM

METABOLISM, TOXICITY, AND TRANSFER OF RADIOACTIVE MATERIALS

Copper

An experiment was initiated to determine the $LD_{50/30}$ for cupric acetate in rats. Animals receiving 40 or 50 mg Cu^{++}/kg, intramuscularly, died within four days. Animals receiving more than 10 mg/kg intramuscularly, or more than 20 mg/kg subcutaneously, showed extreme hemoglobinuria during the first four days. Extensive internal hemorrhaging was the most prominent post-mortem observation.

Iodine

Increasing the stable iodine intake of the dairy cow to 2 g/day (low normal intake is 3-5 mg/day) resulted in milk concentrations of iodine just under 10 mg/liter. Nine days following the cessation of high stable iodine feeding, the thyroid I^{131} burden of the experimental cows had increased 6 to 8 times while that of the control cow remained constant. Milk concentrations of I^{131} for the experimental cows increased 50 to 75 per cent in 7 days following cessation of high stable iodine feeding.

Histopathological studies were made on tissue specimens obtained from sheep, nine weeks after a single dose of I^{131}, or exposure to X-irradiation of the thyroid region. Radiation doses from X-irradiation ranged from 750 to 4500 r and for I^{131}, from 24,000 to 90,000 rads. The tissue changes resulting from the two types of radiation were not identical. Both showed varying degrees of vascular damage and fibrosis. In addition, the I^{131} exposed animals showed considerable follicle necrosis and inflammatory cell infiltration while minimal changes of this type were observed in the X-irradiated animals. Quantitatively, 2250 r X-irradiation was approximately equivalent to 45,000 rads from the I^{131}. This 20-fold difference is probably related to differences in volume of tissue irradiated (including peripheral vasculature), the radiation dose distribution, and radiation dose rate.

Plutonium

The ethyl ester of DTPA was compared with DTPA for its effectiveness in plutonium removal in rats. An intraperitoneal injection of 0.5 mM/kg was employed. This is one-third the level considered optimal for DTPA. Higher doses of the DTPA ester were acutely toxic. Results showed the DTPA ester to be generally inferior to DTPA. However, combined administration of 0.25 mM/kg of DTPA and the DTPA ester was somewhat superior to either agent alone, particularly as regards excretion via the feces.

Two white miniature swine were injected subcutaneously on each foreleg with 5 μc of Pu^{239}(IV) nitrate followed by a subcutaneous injection of 5,000 units of chymotrypsin. The animals were held for 16 days and then sacrificed. The proteolytic enzyme did not cause any localized tissue reaction during the 16-day holding period nor did it appear to increase translocation of Pu^{239} from the injection site to the liver, regional lymph nodes, or urine.

In a second experiment, the effect of cold packs or tourniquets applied immediately following the subcutaneous injection of 5 μc of Pu^{239}(IV) nitrate was investigated. The liver concentration while quite variable showed no significant effect of the treatment. With the application of a tourniquet, there is an apparent reduction in the plutonium content of the regional lymph nodes but since it cannot be correlated with the liver data, it is of questionable significance. The use of a cold pack may increase the plutonium content of the regional lymph nodes, but again there is no corresponding effect on the liver. It seems then, that the use of either a cold pack or a tourniquet is of questionable value.

Inhalation Studies

One of four dogs exposed to Ce^{144}-Pr^{144} aerosols nine months ago, died after showing two months of severe respiratory difficulty. Pathological lesions were found in the lungs and heart. At death the animal retained about one-third of the 2 μc initially deposited. The remaining three dogs show only decreased white cell counts at this time.

Two dogs were exposed to about 500 mc of Pm^{147} perchlorate, of which about 8 to 9 mc was deposited, as estimated from whole-body Bremsstrahlung counting. Two additional dogs received 9 mc of the isotope by intravenous injection. The isotope appears to be rapidly (hours) mobilized to blood and urine. One "inhalation" dog, sacrificed at four weeks post-exposure, shows possible lymph node pathology and high radioactivity in the lungs and liver.

Additional uranium ore exposures were made, using rats injected with atropine to reduce bronchial constriction. Amounts deposited were higher than in previous experiments. These animals are being used to study early clearance mechanisms.

A dog which had an initial deposit of 6.29 μc of Pu^{239} in its lungs, died at 1,204 days post-exposure. At death the body burden was 2.13 μc, distributed as follows: lung, 49%; bone, 18%; liver, 5%; muscle, 3%; pancreas, 0.8%; heart, 0.4%; spleen, 0.3%; and other, 0.5%. The total calculated lung dose was 14,500 r. Bronchial lymph nodes had the highest plutonium concentration, 2.4 μc/g; lungs contained 5×10^{-3} μc/g, and bone, 5×10^{-4} μc/g.

Milk Studies

As part of the study on transfer of Rb^{86} and Cs^{137} from plasma to milk, concentration of these radionuclides in blood cells were determined, for comparison with plasma values. In two of the animals, the ratio $\frac{\text{blood cell concentration}}{\text{plasma concentration}}$ at equilibrium, for both Rb^{86} and Cs^{137}, was approximately three; while in a third animal, the ratio was over 40 for Rb^{86} and over 10 for Cs^{137}. This difference, if confirmed, is noteworthy for two reasons: (1) the marked difference in the concentrating ability

of the animal for the two elements (Rb and Cs) within the same group. Further studies utilizing these animals might be fruitful in eliciting basic mechanisms of cell permeability and membrane transport.

Gastrointestinal Radiation Injury

Studies were initiated to determine the usefulness of the PCTR (Physical Constants Test Reactor) for biological neutron irradiation studies in rats, in collaboration with the Nuclear Physics group and Radiological Instruments and Calibrations group. Results to date are limited to calibration measurements which were somewhat disappointing as regards neutron/gamma ratios. We hope to study the effect of nuclear radiation on the GI tract, using leakage of I^{131}-labelled polyvinylpyrrolidone as a measure of damage.

Cell Proliferation in Fish

The study of cell proliferation in fish, utilizing labelled compounds (H^3-thymidine, H^3-uracil, 2-C^{14} thymidine, and 2-C^{14} uracil) was initiated. The first phase of this study will include an experiment on 40 silver salmon yearlings in fresh water acclimated to 10 C. An intraperitoneal injection of labelled thymidine will be given and the fish will be serially killed to determine the origin and migration of certain cells in the following tissues: gill and pseudobranch, kidney, blood, thymus, mid-gut, skin, and spleen.

This experiment will serve as a control for later studies in which the fish will be subjected to environmental stresses of hypertonic solution (salt water) and X-irradiation. This study should provide not only basic histological information on the tissues often associated with radiation damage, but also should help to explain the physiology of osmoregulation in anadromous fish.

Plant Nutrition

The removal of Pu^{239} from acid and alkaline soil was studied, using solutions of ammonium acetate, nitric acid, and DTPA. In all cases much more plutonium was removed by the treatment than was removed by plants growing in the soil. Both 0.1 N HNO_3 and 0.2 mM DTPA were quite effective, with nitric acid being most effective in acid soil, and DTPA least effective in acid soil. This may be a function of soil calcium content.

Potassium added with Cs^{137} to field plots in 1962 appeared to reduce the uptake of Cs^{137} into barley when the Cs^{137} and potassium were added to the surface, but there was no effect when the Cs^{137} and potassium were mixed into the soil. This result is not consistent with that obtained last year when no effect of potassium was noted under any conditions. The potassium was added at the rate of 500 pounds per acre.

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Plant Ecology

Above ground parts of cheatgrass harvested in May 1963 averaged 320 g/m^2 of dry matter (60-65 C). This is about three times as much grass as the same plots produced in 1962. The increased yield is attributed to the more abundant fall-winter precipitation of the 1962-63 cheatgrass growing season. Cheatgrass grown under field conditions in a greasewood community showed mature influorescences containing up to eight times more Se^{75} than leaves and culms on a weight basis.

Fallout

Fifty-one thyroids from deer and elk collected in California, Maryland, Montana, and New York were analyzed for I^{131} during the month; all were below the detectable limit (0.01 nc I^{131}/g wet wt). One deer thyroid from the Hanford Reservation contained 0.22 nc I^{131}/g wet wt.

Preliminary data from one inland village in Alaska indicates an average increase, over last year, of 25% in the Cs^{137} body burden. The maximum value obtained in 1962 was 790 nc, and in 1963, 1230 nc. The Eskimos of this village utilize large amounts of caribou for food and had higher body burdens in 1962 than did members of other villages. Data from other villages and foods will indicate whether this is a general increase or specific for this village.

Population Dynamics - Waterfowl

The annual survey of nesting Canada geese within the Hanford portion of the Columbia River was completed. Gosling production this year was about 820, or 17% greater than last year and 4% below the ten-year average. There were 26% more nests (233 total) than last year but 7% less than the ten-year average. Fertility of adults was 98.4%, as estimated from complete nest histories and examination of eggs. This is comparable to previous observations and indicates no detrimental effects upon the birds by their residence within Hanford environs.

A total of 154 adult and young geese and five deer fawns were banded and tagged in cooperation with state and federal agencies.

Sampling and Analysis of Natural Populations

Study of vegetational sampling methods was continued, with a small-scale investigation of methods for determining productivity of desert shrubs at Rattlesnake Springs. An attempt was made to estimate the weight of foliage on sagebrush and hopsage, using sub-sampling methods in a probability sampling scheme, to avoid the time consuming process of stripping leaves from entire shrubs. Results were generally satisfactory,

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and suggest that considerable gains in efficiency may be obtained by the sub-sampling process.

Statistical analyses were conducted of radionuclide data from Alaskan plants and animals, with principal emphasis on designing a sampling program for work planned in Alaska this summer.

Acting Manager
BIOLOGY LABORATORY

RC Thompson:es

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TECHNICAL INTERCHANGE DATA
BIOLOGY LABORATORY

I. Speeches Presented

a. Papers Presented at Society Meetings and Symposiums

McClanahan, B.J., D. H. Wood, and L. K. Bustad. Treatment of plutonium-contaminated wounds in swine. Eighth Annual Meeting of the Health Physics Society, New York City, N. Y. June 10-14, 1963. (Presented by R. C. Thompson.)

Cushing, C. E. Filter-feeding insect distribution and planktonic food in the Montreal River, Saskatchewan. Western Division of A.A.A.S. Meetings, Stanford Univ., Palo Alto, California. June 19, 1963.

Rickard, W. H. Mineral cycling by shrubs in southeastern Washington desert communities. Western Division of A.A.A.S. Meetings, Stanford Univ., Palo Alto, California. June 19, 1963.

Uhler, R. L. Chloramphenicol imbibition of salt absorption by intact plants. Western Division of A.A.A.S. Meetings, American Society of Plant Physiologists, Stanford Univ., Palo Alto, California. June 19, 1963.

Symposium on the Biology of Radioiodine, Richland, Washington, June 17-19:

Hungate, F. P., J. F. Cline, and R. L. Uhler. Root and foliar sorption of I^{131} by plants. (Read by Title)

Wood, D. H., E. E. Elefson, and L. K. Bustad. Effect of route of administration on I^{131} uptake. (Read by Title)

Casey, H. W., A. C. Case, R. O. McClellan and L. K. Bustad. Uptake of Te^{132}-I^{132} in sheep thyroids and milk. (Read by Title)

Bustad, L. K., D. H. Wood, E. E. Elefson, H. A. Ragan, and R. O. McClellan. I^{131} in milk and thyroid of dairy cattle following a single contamination event and prolonged daily administration. (Read by Title)

Hanson, W. C., A. H. Dahl, F. W. Whicker, W. M. Longhurst, V. Flyger, S. A. Davey and K. R. Greer. Thyroidal radioiodine concentrations in North American deer following 1961 - 1963 nuclear weapons tests.

Ragan, H. A., W. J. Clarke, R. O. McClellan, and L. K. Bustad. Effect of I^{131} on reproductive performance in ewes.

McClellan, R. O., W. J. Clarke, H. A. Ragan, D. H. Wood, and L. K. Bustad. Comparative effects of I^{131} and X-irradiation on sheep thyroid.

Watson, E. C., I. C. Nelson, D. H. Wood, R. O. McClellan, and L. K. Bustad. Effect of varying stable iodine in diets of cows fed I^{131} on uptake of I^{131} in man drinking the milk.

b. Seminars (Off-Site and Local)

Mahlum, D. D. Effects of radiation on cells. University of Washington Summer Institute for Radiation Biology, Seattle, Washington. June 25.

Mahlum, D. D. Biochemical effects of radiation. University of Washington Summer Institute for Radiation Biology, Seattle, Washington. June 26.

c. Seminars (Biology)

None

d. Miscellaneous

None

II. Articles Published

a. HW Documents

None

b. Open Literature

Bair, W. J., and G. D. Smith. 1963. Absorption of $Sr^{90}SO_4$ from the lung. Society for Experimental Biology and Medicine Proceedings 113: 16-17.

III. Visits and Visitors

a. Visits to Hanford

6/4/63 - R. Daubenmire, Washington State University, Pullman, Washington. To check field plots with W. Rickard.
6/5/63 - John B. Glude, US Fish and Wildlife Service, Portland. Discuss research with R. E. Nakatani.
6/8/63 - Dr. Harold B. Finger, NASA, Washington, D.C. Tour and discuss research with Dr. H. A. Kornberg.
6/10/63 - Dr. Dale Habeck, University of Hawaii. Discuss research with H. E. Erdman.
6/11/63 - Approximately 20 faculty representatives of northwest universities. Tour and discuss graduate programs with H. A. Kornberg and staff.
6/13/63 - C. Osterberg, Oregon State University and Dr. Folsom, Scripps Institute, La Jolla, California. Discuss research with F. P. Hungate.
6/14/63 - NASA visitors from Washington, D.C. Toured facilities and discussed research with H. A. Kornberg.
6/14/63 - Mr. Kahl, Scientific Inst. Company, Los Angeles, California. Discussed plankton sampling equipment with C. E. Cushing.
6/19/63 - Radioiodine Symposium Attendees (82) from various installations and countries toured the Biology Laboratory.

a. Visits to Hanford (continued)

6/25/63 - Portland Chamber of Commerce members toured Biology.

6/25/63 - Dr. Morton I. Goldman, Nuclear Utility Services, Wash. D.C. Discuss research with Biology staff.

6/26/63 - John Austin, University of California, Berkeley. Discuss research with R. E. Nakatani.

6/26/63 - Dr. Ben Ewing, University of Illinois. Discuss research with R. E. Nakatani.

6/26/63 - Dr. R. Daubenmire and W. Starr, Washington State University, Pullman. Check plots with W. Rickard.

6/26/63 - 3 Kiwanians and 5 Pakistanians accompanied by Mr. Cameron toured Biology with W. J. Clarke. All were from Pullman, Wash.

6/28/63 - Dr. Hooper (escorted by Dr. Conant), Veterans Administration, Washington, D. C. toured Biology with L. A. Temple.

b. Visits Off-Site

6/3-6/8/63 - F. P. Hungate attended conferences regarding radioecology research in Washington, D.C. Contacted CM Barnes, USAF, and VanDyken, Schultz and Wolfe in the AEC.

6/5/63 - R. E. Nakatani sampled fish for columnaris at Prosser Dam.

6/6-6/13 - R. C. Thompson attended the Health Physics Society Meeting and presented a paper, and attended NCRP Committee Meeting in New York.

6/12/63 - L. L. Eberhardt, C. Cushing, and W. Rickard collected game specimens at the Wooten Game Range, Dayton, Wash.

6/15-20 - R. L. Uhler presented a paper at the AAAS Meetings at Stanford University, Palo Alto, Calif.

6/16-20 - C. E. Cushing presented a paper at the AAAS Meetings at Stanford University, Palo Alto, California.

6/16-20 - W. H. Rickard presented a paper at the AAAS Meetings at Stanford University, Palo Alto, California.

6/20-21 - L. K. Bustad worked on the ionizing radiation study with Prof. Ruch at the University of Washington, Seattle.

6/13 - R. E. Nakatani sampled water along the Yakima River at Prosser.

6/20-9/1 - W. C. Hanson will be conducting research in Alaska.

6/22 - L. L. Eberhardt discussed research at the University of Washington Department of Math and Laboratory of Marine Mammals and the Fish and Wildlife Service.

6/24-25 - F. P. Hungate attended the meeting on Columbia River Studies in Portland, Oregon.

6/25-26 - D. D. Mahlum gave two lectures at the Summer Institute in Radiation Biology at the University of Washington in Seattle.

6/27-28 - L. K. Bustad lectured at the Summer Institute in Radiation Biology at the University of Washington in Seattle.

6/27 - P. A. Olson and M. P. Fujihara sampled water along the Yakima River near Prosser.

IV. Achievements

No degrees were earned, nor did any professional licensing or certification occur.

V. Honors and Recognitions

None

VI. Professional Group or Organization Assignments

None

APPLIED MATHEMATICS OPERATION

MONTHLY REPORT - JUNE, 1963

ORGANIZATION AND PERSONNEL

R. L. Buschbom returned to work on June 3, 1963, after completing the requirements for an M.A. in Biostatistics at the University of California. L. D. Coffin transferred into the operation on June 1 from Electronic Data Processing Operation, C&AO. Jon C. Stouffer, a technical graduate, joined the operation on assignment and Michael B. Woodroofe, a student at the University of Oregon, joined the group for the summer.

OPERATIONS RESEARCH ACTIVITIES

Work on the IPD Data System was continued. The program to evaluate outage activities was somewhat modified and is in its final testing and debugging state. Data inconsistencies continue to cause difficulties.

Work on the Tri-City Area Economic Model continues. Emphasis has been on data analysis and revision (in that order). Employment data furnished by the State of Washington was found to contain inconsistencies. Some time and effort were required, working with state agencies, to straighten out that problem.

STATISTICAL AND MATHEMATICAL ACTIVITIES FOR OTHER HAPO COMPONENTS

N-Reactor Department

Statistical analysis of data on longitudinal weld cracks in NPR primary piping has been completed. The results were forwarded for inclusion in a document which covers all relevant aspects of the problem.

A systematic sequential sampling plan was derived for determining whether the proportion of defective parts in certain N-reactor equipment was within acceptable limits. The sequential nature of the plan reduces the amount of sampling greatly when the proportion is excessively high or substantially lower than required.

A test was designed to determine whether there are significant differences between lots, between strips within lots, and between times of manufacture with regard to dimensional characteristics of support parts for N reactor fuel elements.

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An analysis was made of employee attitudes results obtained by a special department survey.

Irradiation Processing Department

Analysis of considerable amounts of diffusion data from the hot-die-sizing end-bonding test showed that the depth of the Al-Ni diffusion layer and the type of bond depend quite strongly on time and temperature. The data gave consistent results throughout the extensive range of measurement which included most of the fuel element bonding layers. The reported results included prediction formulae from which the experimentor can determine the canning conditions which lead to the desired bonding characteristics.

A study is being made to determine whether the transformations now in use on measurements made for the quarterly audit of non destructive bonding integrity measurements using the MERCY program are adequate for stabilizing the variance.

Results from the analysis of a sector probolog test indicate that several factors such as the speed, pressure, and flow affect the value of the probolog reading.

Assistance was given in the interpretation of MERCY results on a C-basin instrument which measures fuel element internal diameters.

Assistance was given in the interpretation of the operating characteristics of the present acceptance specifications for the percentage of U-235 in natural and enriched uranium. It was determined that while the procedure gives very little chance of rejecting a good ingot, it also has very little power to detect out-of-specification ingots under many conditions.

A discussion was held regarding the proper analysis of data which will be forthcoming from a test to compare the failure rates of cold versus idling turbines exposed to immediate and heavy demand situations.

The designs of several forthcoming production tests which will compare oil versus water-quenched, vacuum outgassed versus normal, and induction versus salt heat treated fuel elements were discussed with interested personnel.

Work is continuing on the problem of determining the distribution of minimum annuli when there is ellipticity in the fuel elements.

Mathematical assistance on the development of the process tube traversing mechanism was concluded this month.

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Chemical Processing Department

The use of cumulative sum control charts was adopted for both detection of any shift in the average Pu-240 content of weapon components using neutron counting measurements and of any difference between neutron counting and mass spectrograph measurements.

Current status of minor constituent (70-58) content control indicates not only will 100% inspection be required but also replicate measurements with test limits inside specification limits.

For delta components a current problem is the apparent lack of dimensional stability under thermocycling. A preliminary examination of process parameters with measured dimensional change failed to clearly demonstrate the controlling parameters.

The use of thermoinic emission mass spectrographic measurements for the estimation of U-235 content of depleted UO3 shipment will be discontinued. Measurement on a single depleted and all enriched shipments will be made to provide some degree of independent confirmation. The U-235 content of shipments are to be determined by the receiver.

The possibility of establishing the calibration of the slag and crucible neutron counter by dissolution of a limited number of slag and crucibles having widely varing plutonium content was suggested to operations.

STATISTICAL AND MATHEMATICAL ACTIVITIES WITHIN HANFORD LABORATORIES

2000 Program

Further analysis was done on the organic volume fraction profile data from a block of 48 experimental runs on the pulse column. A gamma type mathematical function expressing organic volume fraction as a function of linear position in the column has been fitted to each of these runs. Current efforts are directed at correlating the three parameters of this function with the six independent variables, extractant stream temperature, extractant stream acid concentration, feed stream concentration, feed stream and extractant stream flow rates and pulsing frequency, which determine the operating conditions of the column. A variable, thought to be of importance in controlling the operation of an extraction column, is the column pressure drop which is routinely measured for production columns. A regression analysis is in progress using the above mentioned 48 experimental runs to correlate the column pressure drop with the independent driving variables to see exactly which of these variables can be predicted from pressure drop data.

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A new boundary value approach is being taken toward the solution of the non-linear system of second order differential equations which express the mass transfer of uranium from organic to aqueous streams in the column. Conceptually the column is broken up into a large number of small compartments in which the system of differential equations is assumed to be linear. A smooth transition is made across compartment coundaries by forcing concentrations and concentration derivatives with respect to column position to be equal on the boundary. Sufficient data is available at the top and the bottom of the column and at the extractant and feed stream ports to render a unique solution to the system. An algebraic manipulation is in progress to reduce the resulting system of 4K equations where K is the number of compartments to a set of 4 simultaneous linear equations, which can be solved on the 7090.

A design was constructed for an experimental program to investigate the chemistry of hydrozine reduction of $[N_p^{+5}]$. The suggested design consists of a one-half replicate of a $3^1 2^5$ fractional factorial experiment. The factors to be investigated are [H+] at three levels, $[NO_3-]$ at two levels, [Fe+++] at two levels, hydrozine concentration at two levels, temperature at two levels, and $[SO_4--]$ at two levels. The experiment is complete with respect to a sixth factor, time, as $[N_p^{+5}]$ measurement will be taken ten minutes after the initiation of the experiment and a second equilibrium concentration will be taken about six hours later. The experiment is of a screening nature to determine whether or not the variables have a pronounced influence on the reduction process. More detailed experiments will follow where the investigation is limited to those variables known to be of importance.

Consultations were held concerning the physical implications of certain assumptions that might be made on mathematical models of the stress-strain relationship for metals.

Functional relationships between isotopic activity and downstream tube location were determined for seven isotopes based on a harmonic-type regression model. The results characterized the activity-location relation as being peaked above that of a cosine model but with no indication of skewness. The total activity estimate obtained by integration was found to agree well with those obtained by other and more direct methods.

3000 Program

An improved inside contour instruction tape has been developed for the numerically controlled Gorton lathe prototype. The tape has not yet been thoroughly tested on the lathe itself.

Work continued on the development of an EDPM program to produce magnetic tapes for the numerical control conversion of the Sheffield rotary contour gauge.

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4000 Program

A number of sets of Ziess particle size data, pore size distributions from photographs of cross section irradiated uranium, were analyzed with the Fortran language program SWELL to determine the three dimensional pore size distributional properties and estimate fission gas void fraction, fission gas density and total number of atoms.

A computer program for numerically inverting a Laplace transform was written. The method upon which this program is based consists of fitting a Lagrange polynomial in 1/P to the transform of the function. This method was tried on three transforms with known inverses. For simple inverses and moderate ranges of the independent variable the results were good but for rather complex inverses or a large range of the independent variable the accuracy was unsatisfactory. Work has begun on computer programs based on two other methods. The immediate application of the numerical inversion of Laplace transforms will be to the spray calciner.

The particle size and relative amounts of each size of particle were evaluated for five different tubular fuel elements. The computations were based on a single model of packed spheres having a density ratio of sphere volume to tube volume of 90% for the three-size model and 95% for the four-size model. A previous experiment has yielded a density ratio of 93.3% for the three-size model.

In the course of providing assistance to Chemical Research and Development the velocity potential in a ground water diffusion problem was evaluated symbollically.

A series of discussions were held on the construction of mathematical models of and numerical methods for solving several problems on ground water flow.

A regression analysis is being done of plutonium homogeneous spherical critical mass experimental data to determine the relative merits of several reactor physics code systems which theoretically calculate k_{oo} and critical mass. It is hoped that this study will show which of the systems does the best job of simulation for the plutonium homogeneous spherical system and that it will point up any inconsistencies in the physics and chemistry input data.

5000 Program

Effort is being directed toward improving the method for estimating individual radionuclides in the IRA system. A Monte Carlo program is being used to note the effect of changes in channel grouping of the energy spectra, of variation in the length of counting periods, and, of inclusion in the model of extraneous nuclides.

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Improvements were made in the program GEM and a new deck placed in the SPL library for convenient use.

A program was written to test a truncated range outlier test using Monte Carlo techniques. Debugging has just started on this program.

The final rough draft of the formal report HW-76279, "Fixed Time Estimation of Counting Rates With Background Corrections" is now being typed.

Work on the program to index hexagonal and tetragonal crystals using powder patterns was documented in June as HW-77714. Work is continuing on the problem of speeding up the program to index orthorhombic crystals.

Assistance was provided in compiling and using a program to analyze crystal structure.

6000 Program

Work was started on a problem of deposition of material from the atmosphere. It is assumed that this deposition results from random one-dimensional motion of particles which have been released from a source at or above the ground. A computer program for such a process has been written and is nearly operational.

Work was begun on a theoretical development of some aspects of distance sampling

A statistical analysis of data from experimental studies being conducted by Biology on Tribolium was initiated. The effects of x-irradiation, temperature, time, species (Tribolium confusum and Tribolium castaneum) and group-of species (separate or mixed) on the number of adult progeny by mating pairs of Tribolium are being investigated.

Other

A sampling plan was outlined to calculate the precision with which the location and elevation of project wells can be determined. This information is needed to assess statistically the several sources of variation that may enter the in-place measurement of the permeability distribution for the project.

Carl C. Bennett

Manager
Applied Mathematics

CA Bennett:bsh

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REACTOR DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Curium-244 Production

The computations for the study of Cm-244 production in central station power reactors are being completed. All codes and data tapes were brought to final form. The balance of the effort has been in the direction of writing a code to organize, summarize, and plot the results. After examining the results of extensive efforts to establish equitable dollar values for Pu-239, Pu-240, Pu-241, Pu-242, and Am-243, a more limited definitive study was designed to complete this part of the program.

Fuel Conservation Calculations

The conservation of fissile material in a variety of reactor types for both batch and graded irradiation was studied. The batch and the graded irradiation methods are idealized extremes that will bracket most practical methods. In batch irradiation, all of the fuel is placed in and discharged from the reactor as a unit although it may be shuffled during the irradiation. In graded irradiation fuel is charged and discharged continually. The batch cycle presumes that the excess neutrons are absorbed in the control system while in the graded cycle no neutrons are lost to the control system.

The reactor simulations considered so far are as follows:

102 - D_2O moderated, zirconium clad

104 - H_2O moderated, zirconium clad

105 - H_2O moderated, high fast effect

108 - H_2O moderated, stainless steel clad.

Note that in the MELEAGER burnup code used in this study, the fast fission factor ϵ is an arbitrary input number. Therefore, reactor number 105 was obtained from number 104 by chainging ϵ , the fast fission factor, from 1.03 to 1.10. (The Westcott reaction rate formula used in MELEAGER gives essentially the product ηfp. Thus, to obtain the formula $k_{\infty} = \eta \epsilon fp$, a value for the fast fission factor must be supplied.)

Four different fuel conservation indices are computed in this analysis. They are similar in that each is the ratio of the heat produced during the irradiation in megawatt days (Mwd) to some amount of fissile material in grams.

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They differ by the manner in which this latter amount is determined. This kind of formulation is particularly convenient because neutron induced fissioning of one gram of U-235 and essentially all heavy isotopes will produce very nearly one megawatt day of heat.

The fuel conservation indices have been assigned the symbols ψ, ψ_{net}, Υ and Υ_{max} which are defined as follows:

(1) ψ = heat produced per gram of U-235 contained in the natural uranium as UF_6 required in the diffusion cascade to supply the enrichment for the reactor.

(2) ψ_{net} = heat produced per gram of U-235 in natural uranium minus the fissile grams of plutonium discharged from the reactor. (That is, the same as ψ except that a credit is taken for the fissile plutonium available to a fast breeder.)

(3) Υ = heat produced per net fissile gram lost where the U-235 in tails composition uranium as well as that which absorbed a neutron is considered lost.

(4) Υ_{max} = heat produced per fissile gram actually destroyed during the burnup.

Table I shows values for these indices for both batch and graded irradiation in reactor simulation number 104 for a range of initial enrichments. Note that, although five indices are presented the final figure, Mwd/t natural uranium, is merely a multiple of ψ.

The general behavior of the four conservation indices is illustrated by the data of Table I. With increasing initial enrichment, Υ_{max} decreases continually and ψ increases continually, while Υ and ψ_{net} increase to a maximum and then decrease with further increases in enrichment. Also shown in Table I is the fuel cost for each enrichment which, as is well known, decreases to a minimum and then increases with further increases in the enrichment.

The influence of reactor type is shown in Figure 1 wherein the conservation index Υ is shown for the four reactor types studied. Note that these data were obtained by considering a tails composition of 0.2531% which corresponds to the present AEC uranium price schedule. It can be seen from Figure 1 that the magnitude of Υ is quite strongly dependent on reactor type. It is apparent that the exposure for which Υ is a maximum is greater in the reactors with poorer neutron economy. This analysis technique is now being applied to plutonium recycle fueling systems which will include successive recycle.

TABLE I

FUEL COSTS AND FUEL CONSERVATION INDICES(1) FOR A WATER MODERATED REACTOR SIMULATION WITH VARIOUS FISSILE ENRICHMENTS

AEC Uranium Price Schedule Established July 1, 1962
14% Use Charge - $20 per pound FEFJ

Initial Enrichment Weight %	Exposure, Mwd/t	Total Fuel Cost, mills/kwh$_e$	Υ_{max} Mwd per Fissile Gram Destroyed	Υ Mwd per Net Fissile Gram Lost(2)	Ψ_{net} Mwd per Net Gram U-235 in Natural Uranium(3)	Ψ Mwd per Gram U-235 in Natural Uranium	Mwd/t Natural Uranium
				Batch Irradiation			
1.20	4,100	2.86	2.35	0.98	0.37	0.31	1,990
1.48	8,000	1.89	2.04	1.03	0.56	0.46	2,990
1.81	11,700	1.67	1.84	0.99	0.63	0.53	3,440
1.98	13,400	1.63	1.77	0.97	0.65	0.55	3,570
2.47	18,100	1.63	1.62	0.91	0.67	0.58	3,750
2.72	20,600	1.64	1.57	0.89	0.67	0.59	3,820
2.96	22,700	1.67	1.53	0.87	0.67	0.60	3,840
				Graded Irradiation			
1.20	5,600	2.29	2.38	1.16	0.52	0.42	2,700
1.48	13,800	1.29	2.28	1.39	1.01	0.80	5,140
1.81	20,900	1.12	2.18	1.39	1.17	0.95	6,150
1.98	24,100	1.11	2.14	1.37	1.20	0.99	6,410
2.47	32,900	1.14	2.03	1.32	1.22	1.05	6,800
2.72	36,800	1.17	1.99	1.29	1.21	1.06	6,840
2.96	40,400	1.21	1.95	1.26	1.20	1.06	6,860

(1) Conservation indices involving the grams of U-235 in natural uranium consider that the natural uranium is in the form of UF_6.

(2) A gram of U-235 is considered "lost" when it either absorbs a neutron during the irradiation or is discharged in the tailings of the diffusion cascade.

(3) Each gram of fissile plutonium discharged is considered to compensate for one gram of U-235.

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FUEL CONSERVATION INDEX FOR GRADED IRRADIATION
IN VARIOUS REACTOR SIMULATIONS AS A FUNCTION OF THE FUEL EXPOSURE

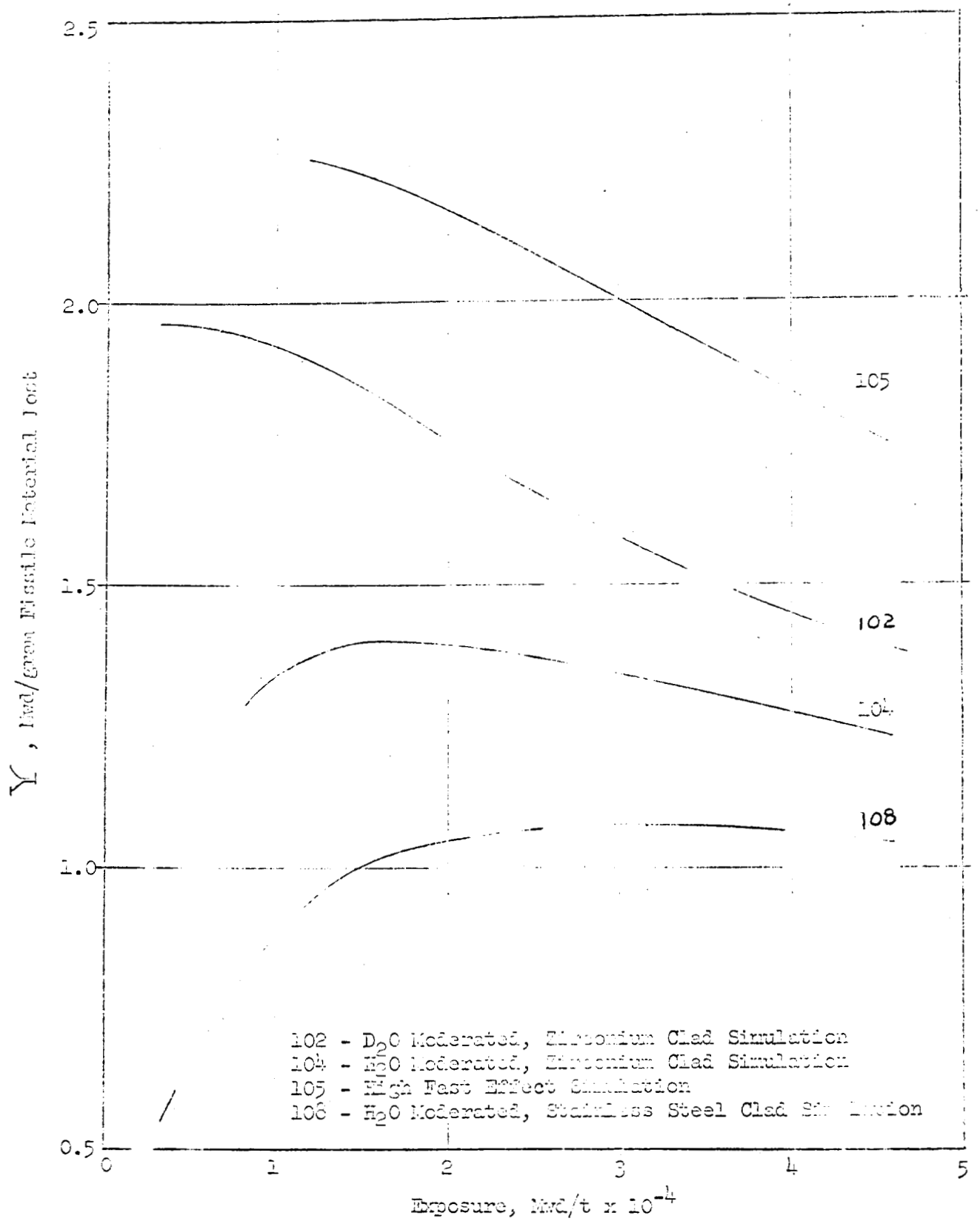

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FIGURE 1

Bred Fuel Value

It has been shown (in HW-72219) that the value of the plutonium bred in a thermal reactor is proportional to the price of fully-enriched uranium (per gram of U-235 contained) in the AEC price schedule. The effect on the fuel cost of ignoring this finding was investigated for graded irradiation in a water-moderated- and in a heavy-water-moderated-reactor simulation. The minimized fuel costs were calculated for various natural uranium costs and the results are shown in Table II.

Table II shows the initial enrichment, the exposure, and the fuel cost for minimum fuel cost operation considering both a fixed plutonium credit of $8 per gram and a credit equal to two-thirds of the price of 90% uranium. Evidently, neglecting to adjust the plutonium credit with an increase in the price of uranium can cause a significant difference in the fuel cost when the price of natural uranium is above $50 per kilogram. Note that this difference would be even greater if the comparison is made between cases having the same enrichment rather than the minimized cases.

Table III shows the unit plutonium credits that correspond to the feed costs shown in Table II.

TABLE III

UNIT PLUTONIUM CREDITS CORRESPONDING TO THE FEED COSTS

Cost of Natural Uranium as UF_6, $/kg of U	Unit Plutonium Credit Equal to Two-Thirds the Price of 90% Enriched Uranium,* $/gram of Plutonium
10.00	5.85
23.50	8.00
30.00	8.91
50.00	11.51
75.00	14.50
100.00	17.34
200.00	28.06
500.00	58.19
1,000.00	106.69

* Assuming $30 per kilogram of uranium separative duty cost.

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TABLE II

MINIMUM FUEL COST OPERATION OF A D_2O AND AN H_2O MODERATED ZIRCONIUM CLAD REACTOR SIMULATION

Graded Irradiation - 14% Use Charge - $40 FEFJ - 12.5% Economic Interest

Cost of Natural Uranium $/kg	D_2O Moderated Reactor						H_2O Moderated Reactor					
	$8 Plutonium Credit			Proportional Plutonium Credit			$8 Plutonium Credit			Proportional Plutonium Credit		
	Mills/kwh_e	Initial Enrichment	Mwd/t	Mills/kwh_e	Initial Enrichment	Mwd/t	Mills/kwh_e	Initial Enrichment	Mwd/t	Mills/kwh_e	Initial Enrichment	Mwd/t
10.00	0.86	2.06	31,400	0.92	2.12	32,500	0.99	2.55	33,900	1.04	2.63	35,300
23.50	1.15	1.90	28,500	1.15	1.90	28,500	1.34	2.33	30,200	1.34	2.33	30,200
30.00	1.28	1.85	27,700	1.26	1.81	26,900	1.49	2.30	29,700	1.48	2.27	29,200
50.00	1.63	1.78	26,400	1.57	1.73	25,300	1.93	2.22	28,400	1.87	2.14	27,000
75.00	2.06	1.75	25,800	1.94	1.65	23,900	2.43	2.15	27,200	2.31	2.04	25,200
100.00	2.48	1.72	25,200	2.28	1.59	22,700	2.91	2.12	26,700	2.72	1.98	24,100
200.00	4.03	1.65	23,900	3.57	1.47	20,200	4.73	2.06	25,500	4.30	1.88	22,200
500.00	8.44	1.60	22,800	7.18	1.39	18,500	9.90	2.00	24,500	8.69	1.77	20,200
1,000.00	15.60	1.57	22,300	12.97	1.33	17,000	18.22	1.97	24,000	15.81	1.73	19,300

Analytical Representation of the Westcott Non-1/v Factors

The study to determine the best way to analytically represent the Westcott non-1/v factors g and s was concluded. It was learned that a satisfactory method would be to institute a sixth order polynomial to represent the g factors and a fifth order to represent the s factors. The basis of this decision is shown in Tables IV and V wherein a figure of merit (applied after the best least squares selection has been made for each order) is shown for each order of fit for the parameters of seven different isotopes. The figure of merit F is defined as:

$$F = \frac{m \sum_{i=1}^{N} \left| \epsilon_i \right|}{N}$$

where

m = order of the polynomial

N = number of empirical data points

ϵ_i = difference between the polynomial representation of the ith data point and the empirical value.

That is, the figure of merit is the product of the average absolute error per point and the order of the polynomial so that the value of increasing the order by one can be estimated. Note that this formulation does not provide meaningful comparisons between the representations of different isotopes but only between different order representations of one isotope. Also, because s is, in a MELEAGER computation, multiplied by r -- a number of order 0.1 -- the accuracy of s need not be as good as for g.

Computer Code Development

A revised computation of r in MELEAGER and the removal cross section for neutrons from the epithermal to the thermal group in ALTHAEA has been coded and debugged, but not yet incorporated into the chain system. The value of r calculated in MELEAGER and in ALTHAEA can now be calculated with less external calibration.

PLOTTER has been revised to permit calculation of special properties tables for as many selected intermediate time periods as desired. Purity and heat production are now based on input data and are thereby generalized to permit calculations for fission products or other heavy elements as well as americium and curium.

TABLE IV

FIGURE OF MERIT(1) FOR POLYNOMIAL FITS OF ga FACTORS

Order	U-238 x 10^4	Np-237 x 10^4	Pu-240 x 10^4	Am-241 x 10^4	U-235 x 10^4	Pu-239 x 10^4	Pu-241 x 10^4
1	5.0*	236.0	2,400.0	1,060.0	74.0**	865.0	216.0
2	4.2	91.0**	2,070.0	1,430.0	90.0	1,580.0	380.0
3	2.4	15.0*	710.0	420.0**	39.0	690.0**	162.0**
4	1.4	3.2	103.0**	190.0	4.8*	120.0	17.0*
5	0.93	1.1	111.0	180.0	3.1	155.0	19.0
6	0.95	1.3	13.0*	66.0*	2.7	71.0*	9.2
7	1.1	1.6	15.0	11.0	2.9	13.0	2.5
8	1.3	1.8	1.8	12.0	3.2	6.6	2.1
9	1.4	1.7	2.1	8.5	3.6	5.2	2.4
10	1.5	1.8	1.1	8.3	3.9	4.6	2.6

(1) Figure of Merit = average absolute error per point times order of the fit.

* Order for which $\bar{\epsilon} = \frac{\sum |\epsilon_i|}{\sum |y_i|} < 0.1\%$

** Order for which $\bar{\epsilon} = \frac{\sum |\epsilon_i|}{\sum |y_i|} < 1\%$

TABLE V

FIGURE OF MERIT(1) FOR POLYNOMIAL FITS OF sa FACTORS

Order	U-238 x 10^2	Np-237 x 10^3	Pu-240 x 10^3	Am-241 x 10^0	U-235 x 10^4	Pu-239 x 10^2	Pu-241 x 10^2
1	39.4	193.0	1,420.0	0.79	233.0	55	13.0
2	16.7*	15.0*	270.0*	1.08	352.0	102	24.0
3	6.5	9.9**	270.0	0.78	106.0	44	8.4
4	2.4**	12.8	76.0**	0.90	144.0	59	10.4
5	9.0	6.8	14.0	0.77	61.0*	33	5.5
6	3.8	1.1	10.0	0.76	74.0	39	4.8
7	1.5	1.1	5.6	0.71	43.0	22	3.5*
8	1.0	1.3	3.8	0.67	49.0	24	2.3
9	0.99	1.5	3.9	0.64	34.0	14	1.9
10	1.11	1.5	4.2	0.55*	35.0	15	1.1

(1) Figure of Merit = average absolute error per point times order of the fit.

* $\bar{\epsilon} < 1.0\%$

** $\bar{\epsilon} < 0.1\%$

$\bar{\epsilon}$ = average absolute error divided by the average value of the absolute ordinate

$$= \sum_{i=1}^{N} |\epsilon_i| \Big/ \sum_{i=1}^{N} |y_i|$$

A revised version of the service routine RDYTP is now in use. The routine permits a calling routine to determine if a tape is ready before it is selected for reading or writing. A second entry, UNLDTP, has been added which permits a calling routine to unload any tape. Proper use of this subroutine will minimize operator errors and program delays due to tapes not being ready.

OTHER ACTIVITIES

High Temperature Lattice Test Reactor

The design criteria, HW-76928, for the heating and cooling of the HTLTR were reviewed. A number of changes in the proposed equipment were recommended, including reduction of the core heating input, elimination of the saturable reactor for heating control, enlargement of the cooling system, and provision of a coolant backup for the gas system. These changes were, in general, favorably received in a June 27 discussion with members of HL and CE&UO.

Synchronous Motors (Four, 3500 h.p. Units) for River Pumps, N-Reactor

Performance shortcomings of the original motors have been analyzed and reported during the past year. One motor has been rebuilt and returned to Hanford by the manufacturer (Fairbanks-Morse). Factory and field test data on the rebuilt motor have showed the performance substantially improved.

All aspects of performance which were formerly unsatisfactory were discussed at a meeting with representatives of AEC-RLOC, GE, Kaiser, and Burns and Roe, and acceptance of the rebuilt motor recommended. Since there was no disagreement, it is expected the motor will be accepted as recommended.

HAPO I - Fission Product Cask - Proposed Buffer Redesign

The proposed redesign of the impact-absorbing buffer has been reviewed, and a number of changes recommended. Also the supports used under this and the HAPO II cask during shipment have been cracking. Calculations have shown this to be the result of resonant vibration and a different type support to eliminate the cause of cracking has been recommended.

Milton Lewis

Acting Manager,
Programming

M. Lewis:jm

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RADIATION PROTECTION OPERATION REPORT FOR THE MONTH OF JUNE 1963

A. ORGANIZATION AND PERSONNEL

G. E. King transferred from Radiological Development and Calibration to Composite Dose Studies and Records. T. L. Ryan accepted an assignment with RD&CO until mid September when he returns to school to begin studies under an AEC Health Physics Fellowship. Dr. Ben B. Ewing, Professor of Sanitary Engineering at the University of Illinois, and Harold N. Hauser, instructor at Columbia Basin College, joined Environmental Studies and Evaluation for the summer. S. A. Hodgin joined the External Dosimetry Operation as a secretary. D. E. Newman rotated into EDO as a Technical Graduate. W. P. Howell joined Radiation Monitoring as an Engineer. W. M. O'Bryan, RMO, terminated. L. A. Braby rotated into Radiation Monitoring as a Technical Graduate. Blaine A. Barron, David L. Heffner, Kenneth B. Free, and Richard J. Bresina joined Composite Dose Studies and Records for the summer.

B. ACTIVITIES

Occupational Exposure Experience

The total number of individuals who have received internal plutonium deposition at Hanford is 318. With the resignation of one employee, the number of these deposition cases currently employed remains at 229.

During the month there was one HL incident involving 13 employees and one CPD incident involving a single employee all requiring special bioassay sampling for plutonium analysis. The following is a brief description of these incidents.

Twelve HL employees and one CPD employee were exposed to air-borne plutonium contamination from 3×10^{-12} μc Pu/cc to 4×10^{-9} μc Pu/cc for one to eight hours at the 231 Building on June 10. The air contamination was detected through the regular processing of routine room air samples about 24 hours after collection of the filter samples. The contamination apparently resulted from work with UO_2PuO_2 pellets in the arc melt furnace hood. A contamination survey at that time had revealed contamination to 30,000 d/m on one of the hood gloves and on an employee's surgeons glove.

A CPD employee received facial contamination of 40,000 d/m during the disposal of plutonium analytical samples at the 234-5 Building on June 28. Removal of a cork stopper from one of the sample bottles resulted in a splattering of plutonium nitrate solution, contaminating his protective clothing and face. Extensive decontamination efforts failed to reduce the contamination to less than 10,000 d/m. After application of a liquid bandage at the 200-West Area First Aid facility, he was released by the industrial physician.

Also during the month six employees were involved in minor incidents requiring evaluations by Internal Dosimetry personnel for traces of internally deposited nuclides. All results were negative. Three of the six employees were examined in the whole body counter for an indication of the deposition of activation products, two employees submitted urine samples for uranium analysis, and one employee was examined with the wound counter for evidence of fission products in a minor injury.

Several other incidents of significance which occurred during the month are summarized below.

A small particle of fission product contamination was detected on the skin of a CPD employee following decontamination work on a Purex canyon crane on June 11. Based on radiation monitoring dose rate measurements and the maximum estimated time of exposure of one hour, dosimetry calculations indicated that the beta dose to a small area of skin (< 1 cm^2) on the shoulder of the employee may have been as high as 450 rems.

Regular processing and evaluation of the film badge dosimeter worn by a HL maintenance employee at the RMO facility for the four week badge period ending June 14 showed a gamma dose of 1.2 rems. The dose exceeded the four week operational control that limits the whole body dose to one rem (RPS No. 3.1). Preliminary investigation of the employee's work activities, which consist of maintenance planning and scheduling, failed to provide an explanation for the exposure. The accumulated whole body dose for the calendar year to date, including this exposure, was 1.8 rems.

A survey of the ground in the vicinity of the waste tanks at 100-K on June 7, 1963, showed beta-gamma contamination up to 100,000 c/m on a road around the tanks and under the heat exchanger. A more extensive particle survey in this area on June 10, 1963, revealed particulate contamination in concentrations up to 25 particles per 100^2 ft. and dose rates up to 3 mrads/hr (uncorrected) in an area between the 107 basin and the east perimeter road. The highest concentration was found near an overflow riser where an overflow was reported to have occurred on May 15, 1963. A survey outside of the exclusion fence by Environmental Monitoring on June 7, 1963, showed contamination along the east fence ranging from one particle per 100 square feet to a maximum of eight particles per 100 square feet. At locations approximately 500 feet from the east fence, the concentration had decreased to five to six particles per 100 square feet and at the railroad, approximately 1000 feet from the fence the maximum concentration was three particles per 100 square feet. A survey of the road that runs between the central fire station and B Area showed two locations within the first mile from the station where the particle concentration was two particles/100 square feet. No contamination was found along the road from the central fire station to the 200 Areas, at the turnoff to 100-N, or at the 100-N Area.

A critical radiation alarm signal was received at 300 Area Patrol Headquarters from the 326 Building on June 22, 1963. Investigation showed that

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personnel had not evacuated since the building alarm had not sounded. A survey of the building by radiation monitoring personnel failed to disclose any abnormal situation. The alarm signaled again at 10:22 and two more times between 10:30 and 11:00 in Patrol Headquarters. Approximately one-half minute after the 326 alarm signaled, a signal would also be received from the 333 Building. The electricians who were dispatched to check out the system found that the problem existed in the transmission line. The troubles were corrected on the same day and the system returned to proper operation.

A hood exhaust sampling system was recently installed for the hood in Room 2, 308 Building. Installation of this sampling system was prompted because plutonium contamination was detected coming from a similar system in Room 131. A two week sample was contaminated to 400,000 d/m which corresponds to an average of 2.1×10^{-10} μc Pu/cc. Investigation was initiated as to the source of the plutonium contamination.

Two iron workers from the 1100 Area made an uncontrolled entry into the A Cell of the PRTR during reactor operation at a power level of 70 megawatts. The door was found "unlocked" and the men made a hurried entry as they were aware of the relatively high dose rate in A Cell. The entry was later discovered by the maintenance foreman. Inspection of the electric door verified that the door did not always latch when closed. The maximum exposure received was 100 mrem including 50 mr.

An authorized entry was made into A Cell at a reactor power level of 67 megawatts for inspection of primary piping. The maximum dose rate was 7.8 rem/hour including 4.8 r/hour adjacent to primary pump No. 2. The maximum dose received by the personnel was 100 mrem.

Environmental Experience

Concentrations of particulate fallout in the atmosphere ranged from 1.7 to 13 pc β/m^3 at various locations in the Pacific Northwest. The average for the month was 7 pc β/m^3 - about half that measured during the last week of May.

Five aerial surveys were made. Two of the flights were made to measure the activity of the Columbia River, two were made to observe the water level and channeling in several slough areas of the local river, and one was of standard patterns about the project to determine background radiation levels.

The City of Richland began feeding filtered Columbia River water into the municipal water system. Columbia River water has been used since early May to recharge the North Richland well field. Upon completion of the laboratory facilities in the water plant, routine radiological surveillance will begin. Meanwhile, weekly grab samples are being taken at the water plant.

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The following 290 biological, produce, and food samples were obtained for radiochemical analysis:

Milk	72 samples	193 gallons
Pasture grass	60 samples	120 pounds
Beef thyroids	20 sets	
Oysters	2 samples	4 pounds
Ground round	3 samples	6 pounds
Fresh fruit and vegetables	27 samples	54 pounds
Fish	106 samples	

Studies and Improvements

Columbia River water samples collected on three traverses at the 300 Area and Pasco were analyzed for radionuclides. The objective of this study is a determination of how representative the routine sampling sites are of the river cross section, and simplification of analytical and evaluation methods. Results of these initial samples are being analyzed to identify the need for possible modifications in river sampling and analysis.

Collection of river temperature data continued during the high water period. Traverses were made at Pasco, Richland, 300 Area, Ringold, and Hanford. Above the plant, river temperatures were only 0.5 to 1.0° C lower than that in 1958, the highest river temperature year of record. A rapid response temperature monitor for use from a boat was received and has performed very satisfactorily in early tests.

The prototype instrument for measuring directly the GI tract dose resulting from drinking Columbia River water was designed and procurement of the component parts begun.

Work was begun on the programming of mathematical models which described the retention and distribution of parent-daughter isotopes in mammals. An analog computer for this purpose has been obtained from Instrument Research and Development.

An investigation of the capabilities of the Shadow Shield assembly in the Mobile Whole Body Counter to measure I-131 in the thyroid revealed that a 15 minute count directly beneath the crystal would disclose about 0.5% of the maximum permissible organ burden. The capability of the thyroid counter in the iron room is about 0.05% of the MPOB on the same basis.

Interlaboratory calibration of I-131 in thyroid measurements were made at New York University Medical Center and Brookhaven National Laboratory. Measurements agreed to within three percent.

Gamma darkening in the open window area of NTA film frequently makes track detection in this section of the film difficult or impossible. This darkening was reduced by placing a 1/16" thick lead shield in the open window

area of several dosimeters. These shields did not interfere with fast neutron penetration. Following this work, lead shields were installed in 10 hood badges routinely used in the 234-5 Building, to determine the effects under field conditions. These badges frequently receive sufficient gamma darkening in the open window to make neutron track counting difficult. Again the lead shields eliminated the gamma fogging without interfering with the fast neutron penetration. Lead shield pieces have been procured for installation in all personnel badges as time permits, starting with 234-5 Building badges.

A study on the applicability of using single collision or multiple collision neutron dose calibrations was made. The calibration practice at Hanford has been based on single collision neutron dose. Because the fast neutron spectrum from PuF_4 which is one of the principal sources of neutron exposure at Hanford, has an effective energy of 1.4 Mev, the scattered radiation has a good possibility of having an effective energy which is below the response level of the NTA film ($\sim$ 0.7 Mev). For this experiment, several Hanford neutron film badge dosimeters were exposed to identical neutron fluxes; one group in air and a second group with a badge backed with a double moderator neutron dosimeter. Two fast neutron sources were used, viz., the PuBe source with an effective energy of 4.5 Mev and a PuF_4 source with an effective energy of 1.4 Mev. With the PuBe source there was a 15% increase in the number of recoil tracks in the films that were backed with the moderator. With the PuF_4 source, however, no difference was observed; presumably due to the fact that the effective energy of the scattered neutron was below the threshold of the NTA film. It is planned to change the basis for the neutron calibration procedure from a single collision RBE dose to a multiple collision RBE dose. The effect will be an apparent increase in the neutron dose received by some employees in the 234-5 Building and in reactor areas. Improved control over the storage location of these dosimeters when not in use in the production plants will reduce the background on these dosimeters and will have a compensating effect to the change in calibration procedures. The net effect on exposure control should be minor.

Special neutron dose and neutron spectrum measurements were made at the PCTR facility for the Biology Laboratory. The measurements were directed to determining the neutron dose and the gamma dose within a small section of the reactor which is used for the irradiation of animals. Studies involve the use of the Hanford personnel film badge dosimeter, the lithium neutron spectrometer, and the silicon diode dosimeters. Although some difficulties in analysis of the foil spectra results were encountered due to the large number of thermal neutrons present, the combination of these three measurement techniques appeared to provide a measurement of the neutron dose to within $\pm$ 20%.

The neutron spectrometer system first successfully operated in the coincidence mode. Neutron spectrum measurements were taken of PuF_4,

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PuBe, and PCTR neutron energy distributions. The PCTR data were analyzed as an aid in determination of the neutron dose in the test core. The PuF_4 spectrum measured has a peak just below 1.0 Mev and compares favorably with the spectrum calculated by an empirical formula. The theoretical spectrum has a rather broad peak at about 1.2 Mev. In an actual physical case, the spectrum is usually somewhat degraded. A PuBe spectrum was accumulated and the raw data appears reasonable.

Seven air sample filters from 234-5 Building were exposed to nuclear track film plates for 12, 120, 1200 and 1.4×10^4 minutes. These exposure times permit estimation of plutonium particle diameters by track counting over the range of 0.1 to about 20 microns. The tracks per particle and number of particles were determined over an area of 180 square millimeters on each nuclear track film plate. Preliminary analysis of results from three of the filters indicated that 20 to 50 percent of the particles were 0.1 micron or smaller based upon a plot of accumulated percent of particles versus particle diameter on log normal probability paper. The largest particle found was about 3 microns in diameter and contained about 25 d/m of plutonium.

Standard r-meter checks were made on all calibration film jig exposure positions. The dose rates at each exposure position were correct to within $\pm$ 3%.

A total of 11 Emergency Monitoring Kits were serviced during the month. A total of 112 instruments received an audit calibration as part of the Calibrations quality control program.

The updated 300 Area Emergency Plan was issued to 300 Area personnel. Additions to the plan include 1) training material for use by 300 Area supervision and management for personnel safety in the event of a criticality accident, 2) supporting plans for emergency action in the event of criticality by Security Patrol, Fire Protection, Radiation Monitoring, and the Emergency Director which were included in copies issued to the 300 Area Emergency Director and alternates and certain other persons having key responsibilities, and 3) a tab was provided in the manual for insertion of local building emergency procedures.

Wallet sized cards were issued to 300 Area supervision to assist them in the event of a criticality incident in the 300 Area. Visitor information regarding emergency signals and appropriate action to take in an emergency was prepared on wallet sized cards and arrangements completed for their issuance to visitors along with the Hanford film badge dosimeters.

C. RELATIONS

Three suggestions were submitted by personnel of the Radiation Protection Operation during the month. Six suggestions were rejected. One suggestion is pending evaluation.

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Safety meetings were held throughout the Section during the month. A bulletin on "Safety in the Home" was prepared by D. McConnon and distributed to all Radiation Monitoring personnel.

Mouth-to-mouth artificial respiration instruction cards have been issued to all Radiation Monitors.

Several Radiation Monitoring personnel attended a demonstration on the use of various types of fire fighting equipment.

The movie "Radiation in Perspective" was shown.

Two talks on maximum permissible exposures and radiation units were presented to Metallurgy Development personnel at the 231 Building. Orientation talks were presented to two Metallurgy Development employees at the 231 Building and one Chemical Effluents Technology employee at the 222-U Building.

A two hour general discussion on radiation problems was held with firemen of A and B shifts at the Central Fire Station. The current emergency radiation procedure for fire personnel was also reviewed.

Five Biology employees, including three summer employees, were given a radiation orientation talk.

D. McConnon and G. A. Little completed the CPD Nuclear Safety Training Course. K. R. Heid completed a 30-hour course on Nuclear Safety presented by Critical Mass Physics, HL.

Three 4-hour sessions on Disaster Monitoring were presented in the 202-A Conference Room. These sessions were attended by 33 persons from Radiation Monitoring and first-line supervision from CPD, IPD and HL.

In the 300 Area five radiation orientation lectures were given with emphasis on the evaluation of internal emitters and self-monitoring.

D. SIGNIFICANT REPORTS

HW-76525 5 - "Radiological Status of the Hanford Environs for May, 1963" by R. F. Foster.

HW-76526 - - "Evaluation of Radiological Conditions in the Vicinity of Hanford for 1962", edited by R. H. Wilson. (A special summary of this report was also issued separately).

HW-77126 - - "Radioiodine Sampling with Activated Charcoal Cartridges" by D. McConnon.

HW-78057 - - "Monthly Report for June 1963 - Radiation Monitoring Operation" by A. J. Stevens.

PERSONNEL DOSIMETRY AND RADIOLOGICAL RECORDS

External Exposure Above Permissible Limits	June	1963
Whole Body Penetrating	0	1
Whole Body Skin	0	0
Extremity	0	0
Hanford Pocket Dosimeters		
Dosimeters Processed	6,465	39,077
Hanford Beta-Gamma Film Badge Dosimeters		
Film Processed	9,485	56,718
Results - 100-300 mrads - β	175	1,019
- 300-500 mrads - β	10	101
- Over 500 mrads -β	6	23
Lost Results	25	138
Average Dose per Film Packet - mrad (ow)	8.0	6.9
- mr (s)	35.9	31.8
Hanford Neutron Film Badge Dosimeter		
Slow Neutron		
Film Processed	1,601	10,148
Results - 50-100 mrem	3	10
- 100-300 mrem	0	2
- Over 300 mrem	0	0
Lost Results	10	76
Fast Neutron		
Film Read	463	2,622
Results - 50-100 mrem	10	209
- 100-300 mrem	11	388
- Over 300 mrem	0	4
Lost Results	10	55
Hand Checks		
Checks Taken - Alpha	35,326	219,837
- Beta-gamma	52,069	354,303
Skin Contamination		
Plutonium	18	143
Fission Products	36	239
Uranium	3	4
Tritium	0	0

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Whole Body Counter

Subject	Number of Examinations			
	747-A WBC	1963	Mobile WBC	1963
GE Employees				
Regular	53	385	30	30
Incident Cases	4	97		
Terminations	26	55		
New Hires	176	264		
Special Studies	69	308		
Non-Employees				
Children	0	5		
Visitors	10	21		
Environmental Studies	0	9	—	—
	338	1,144	30	30

Bioassay

Analysis	Current Reporting Limit	Results Above Reporting Limit		Samples Assayed	
		June	1963	June	1963
Plutonium	2.2×10^{-8} µc/sample	95	567	527	3,949
Fission Products	3.1×10^{-5} µc/sample	24	62	505	3,723
Strontium	3.1×10^{-5} µc/sample	45	45	45	45
Tritium	5.0 µc/l	85	867	183	1,488
Uranium	0.14 µgm/l	0	0	238	969
Special Studies		0	0	44	299

Calibrations

	Number of Units Calibrated	
	June	1963
Portable Instruments		
CP Meter	1,024	6,354
Juno	242	1,602
GM	528	3,379
Other	191	1,150
Audits	112	636
	2,097	13,121
Personnel Meters		
Badge Film	972	4,760
Pencils	60	720
Other	372	1,826
	1,404	7,306

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	Number of Units Calibrated	
	June	1963
Miscellaneous Special Services	1,935	11,197
Total Number of Calibrations	5,436	31,624

Manager
RADIATION PROTECTION

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TECHNICAL INTERCHANGE DATA
RADIATION PROTECTION OPERATION

I. Speeches Given

"Advances in Personnel Dosimetry at HAPO" by L. F. Kocher to the annual Health Physics Society Meeting in New York City on June 13, 1963.

"Accumulation of Zn-65 From Prolonged Consumption of Columbia River Fish" by R. F. Foster to the annual Health Physics Society Meeting in New York City on June 11, 1963.

"Determination of River Dispersion Factors" by G. E. Backman to the annual Health Physics Society Meeting in New York City on June 12, 1963.

"The Relationship Between I-131 Concentrations in Various Environmental Samples" by J. K. Soldat to the annual Health Physics Society Meeting in New York City on June 13, 1963.

"Effect of Varying Stable Iodine in Diets of Cows Fed I-131 on Uptake of I-131 in Man Drinking the Milk - Interim Report" by E. C. Watson to the Symposium on the Biology of Radioiodine, in Richland, Washington, June 19, 1963.

II. Articles Published

None

III. Visits and Visitors

See attached Visits and Visitors form.

IV. Achievements

None

V. Honors and Recognitions

B. V. Andersen was notified of his certification as a Health Physicist by the American Board of Health Physics on June 21, 1963.

VI. Professional Group or Organization Assignments

None

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FINANCE AND ADMINISTRATION

ACCOUNTING

Cost Accounting

The Hanford Laboratories' Control Budget for FY 1963 was adjusted during the month, including fund transfers between the HAPO components, to gain optimum utilization of program funds. A summary of these adjustments, by research and development program, follows:

(Dollars in thousands)	Previous Control	Adjustment Increase (Decrease)	New Control
02 Program			
HL Reactor Technology Development	$ 89	$(20)	$ 69
HL Separations Development	350	(8)	342
HL Columbia River Studies	50	(6)	44
HL Plutonium Nuclear Safety	375	(41)	334
IPD Sponsored Reactor Program	755	12	767
CPD Sponsored Waste Management	522	(30)	492
08 Program			
HL Fission Products Production Study Sponsored with CPD	45	(10)	35
Project Whitney			
Fabrication Program	200	25	225
Scrap Recovery Program - Fabrication	72	(25)	47

Activities for which special accounting codes were established are described below:

.3M Preparation of Book on Decontamination - AEC has authorized $49,700.

.8A Consultation with State of Montana, Department of Fish and Game - L. L. Eberhardt will lecture on the population dynamics of the white-tail deer. Authorization is for travel and subsistence.

.8B Consultation with APED - Review of critical mass safety program by C. L. Brown.

.1V Borated Graphite Irradiations Program - Perform research and development for the Power Reactor Development Company at the request of AEC. A new program authorization of $100,000 received in June, 1963 is additive to the previous authorization of $12,000.

1233398

The following organizational code changes became effective July 1, 1963:

Codes Established

7124 - Technical Information - General
7125* - Technical Publication
737B* - Laboratory Maintenance - General
737C* - 321 and General Area Maintenance
737D* - Maintenance Landlord
737E* - Mechanical Maintenance
737F* - Electrical Maintenance
737G* - General Area Instrument Maintenance
737H* - Laboratory Area Instrument Maintenance
737J* - Instrument Shops - Portables
737K* - Instrument Shops - Other
737L* - Instrument Shops - Tubes
737M* - PFPP Maintenance
7463* - Reactor Studies

Codes Cancelled

7124 - Visual Displays
7125 - Technical Information - General
7370 - Laboratory Maintenance
7371 - Instrument Shops

*Cost purposes only

Considerable effort during the month was applied to the preparation of data for "AEC Ten Year Cost Study Estimates."

General Accounting

Following is the status of letters seeking AEC concurrence in proposed actions:

AT-293	Payment of Page Costs for Papers Published in Scientific and Technical Journals	Approved by AEC
AT-295	Professional Research and Teaching Leave - K. R. Merckx	AEC still considering
AT-298	Participation in Standardizing Activities - R. H. Scott	In hands of AEC
AT-300	Participation in Standardizing Activities - ASTM Committee B-3 - Corrosion of Non-Ferrous Metals	In hands of AEC

The following revised OPG's were issued during June:

OPG No.	Title
3.1.6	General Electric Product Purchase Plan
3.4.10	Regular Part-Time Employees and Temporary Employees
2.3.1	IPD General Manager Position Guide
1.1	Organization and Policy Guide System
2.3.5	Hanford Utilities and Purchasing Operation - Manager Position Guide
22.3.1 (pp. 3, 4, 9 & 10)	Approval Authorizations
2.3.8	HAPO Counsel Position Guide
1.7	Production Forecasts and Schedules

During the month, $454,600 were transferred to Plant and Equipment accounts from Work In Progress accounts.

Hanford Laboratories' materials investment at June 1, 1963, totaled $26.1 million as detailed below:

	(In thousands)
SS Material	$24 796
Reactor and Other Special Materials	969
Spare Parts	332-1)
	$26 097

(1- Includes a reserve of $78,064.

The value of nuclear material consumed in research by Hanford Laboratories this fiscal year to June 1, 1963 is $3.6 million comprised as follows:

02 Program	$ 1 007
03 Program	1 029
04 Program	1 535
	$ 3 571

Classification activity for the month included the review of 862 purchase requisitions, 834 work orders and 12 appropriation requests for capital or expense determination, compounding, work review and for reimbursability. The following statistics reflect the trend of Hanford Laboratories' classification activities:

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Documents Processed	FY 59	FY 60	FY 61	FY 62	FY 63
Work Orders (average per mo.)	591	717	717	614	742
Requisitions (average per mo.)	523	691	687	748	970
	1 114	1 408	1 404	1 362	1 712

Equipment procured by HAPO to support University of California Lawrence Radiation Laboratory research and development programs during FY 1962 was transferred to Hanford Laboratories during the month. This equipment valued at $24,502 with a reserve of $1,921 was added to record by use of the Non-Fund Adjustment Account.

Certification inventory reports for the physical inventory of Other Special Materials for period ending June 30, 1963 were prepared and submitted to Laboratories' material holders for completion and certification. Upon receipt of the requested information and reconciliation with Hanford Laboratories' Financial records, a report of results will be issued.

Mechanization of Hanford Laboratories' Storage Pool transactions began this month. All loaned equipment was programmed into a new system and plans are to program expense and uncatalogued type items on the new system by the end of August, 1963. Hanford Laboratories Property Accounting will maintain manual records parallel with the new system for a period of three months or until the system is proven workable.

Mechanized Pool records will facilitate (1) updating and maintenance of history and utilization data for items retained in the Storage Pool and (2) preparation of routine reports and those heretofore not readily produced.

New metal racks installed in the 3718-A Building during the month provide an additional 800 square feet of storage space, more accurate equipment control and aid housekeeping efforts.

Laboratory Storage Pool activity is summarized below:

	Current Month		FY to Date	
	Quantity	Value	Quantity	Value
Beginning Balance	1 364	$741 557	1 081	$ 562 200
Items Received	216	105 978	1 713	841 855
Items Reclaimed by Custodians	(82)	(33 114)	(254)	(250 326)
Equipment Transfers	(18)	(2 901)	(238)	(87 032)
Items Disposed of by PDR			(181)	(20 380)
Items Excessed			(641)	(193 532)
Adjustment				(41 265)
	1 480	$811 520	1 480	$ 811 520-1)

(1- Includes 134 items valued at $113,843 on loan at June 30.

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During the month, 32 items valued at $16,414 were loaned and/or transferred in lieu of purchases. A total of 375 items valued at $200,726 has been redirected to useful purposes this fiscal year. Operating cost for the same period was $15,428 indicating a net saving of $185,298 for this fiscal year.

Equipment redirected to useful purposes by the Laboratory Storage Pool since the Laboratory Pool was activated (December, 1959) is valued at $398,307 while operating costs for the same period totaled $44,175. Total investment in three buildings (3718, 3718-A and 3718-B) is $120,436. Assuming that equipment redirected to useful purposes was placed in lieu of requisitions, the result was a total net saving of $233,696 through June 30, 1963. Total disposal by Excess or PDR during the fiscal year was 822 items valued at $213,562.

The PRTR heavy water inventory at the end of June, 1963 showed a loss of 555 pounds amounting to $7,700, while the PRCF had a gain amounting to 2 pounds valued at $29. Heavy water scrap generated during the month amounted to 1,902 pounds resulting in a $1,818 charge to operating cost. Heavy water accumulated at June 30 for return to SROO amounted to 9,669 pounds valued at $121,629.

Contracts processed during the month were:

DDR-168 Oregon Metallurgical Corporation
DDR-173 Field Emission Corporation

Effective July 1, 1963, the accumulation and distribution to projects of General Indirect Construction Expense will be discontinued. Future project estimates will include 1 1/2% of contractor labor for Workmen's Compensation and 1% of value of equipment and materials procured by General Electric Company for Purchasing, Expediting and Receiving. Welder Testing, Radiation Badges and Pencils, and Washington B&O Taxes will be charged directly to applicable projects. The remainder of the items which comprised the General Indirect Construction Expense will be absorbed in HAPO components' overhead and billed to contractors.

Initial planning was completed and instructions were issued for the first step necessary to mechanize EWIP accounting and reporting. Effective with FY 1964 business, all authorizations for procurement and installation of equipment will be processed through the EDP Work Order System. The machine tabulations will serve as cost ledgers; however, commitment accounting and reporting will continue to be performed manually until the new Purchasing and Accounts Payable machine accounting systems are placed in effect. Latest estimate for this accomplishment is December 1, 1963.

Personnel Accounting

G. E. Benedict and J. L. Swanson received Patent Award No. HWIR 1503 for Separation of Plutonium from Uranium and Trivalent Rare Earths in Molten Chloride Salt Solution by Precipitation of Plutonium Oxide.

As a result of the recently announced Savings & Security Program options to change compensation arrangements, twelve employees elected to receive the non-participating rate effective July 1, 1963, and three effective October 1, 1963. Three employees who had originally refused the plan elected to receive the participant rate and participate in the plan.

Personnel statistics follow:

Number of Hanford Laboratories Employees Changes During Month	Total	Exempt	Nonexempt
Employees on payroll at beginning of month	1 662	698	964
Additions and transfers in	113	73	40
Removals and transfers out	19	7	12
Employees on payroll at end of month	1 756	764	992

Overtime Payments During Month	June	May
Exempt	$ 6 193	$ 7 161
Nonexempt	67 139	27 009
Total	$ 73 332	$ 34 170

Gross Payroll Paid During Month		
Exempt	$ 697 172	$ 684 802
Nonexempt	729 740	548 497
Total	$1 426 912	$1 233 299

Participation in Employee Benefit Plans at Month End	June		May	
	Number	Percent	Number	Percent
Pension	1 520	99.3	1 484	99.4
Insurance Plan - Personal	420		399	
- Dependent	1 277	99.8	1 256	99.9
U. S. Savings Bonds				
Stock Bonus Plan	158	41.5	156	42.3
Savings Plan	66	3.7	65	3.9
Savings and Security Plan	1 165	84.7	1 144	88.2
Good Neighbor Fund	1 249	71.1	1 194	71.6

Insurance Claims	June		May	
Employee Benefits	Number	Amount	Number	Amount
Life Insurance	1	$15 370	0	$ 0
Weekly Sickness and Accident	8	631	11	713
Comprehensive Medical	41	2 876	69	3 872
Dependent Benefits				
Comprehensive Medical	90	7 539	118	9 611
Total	140	$26 416	198	$14 196

TECHNICAL ADMINISTRATION

Employee Relations

Thirty-four nonexempt employment requisitions were filled; thirty-four remain to be filled.

Suggestion plan activity included 51 submissions, 20 adoptions and 41 rejections. For the third consecutive month, the number of suggestions (125) in process at month end was less than the preceding month.

Information and Presentations

Plant tour activity:

	Number	Total People
General public relations tours	4	143
Special tours	6	171

Visitors' Center activity:

June attendance	3 718*
Average attendance per day open	124
Cumulative attendance since 6-13-62	47 780
Conducted groups	11 (totaling 780 people)

*Includes 353 persons who attended the First Anniversary Open House on June 15.

Document information flow during the month was comprised of 1,757 titles (12,825 copies) received at Hanford and 54 titles (5,941 copies) sent off-site.

Professional Placement

Advanced Degree - Thirteen Ph.D. applicants visited HAPO for employment interviews. Twelve offers were extended; eight acceptances and five rejections were received. Eleven offers are currently open.

BS/MS (Direct Placement) - Twelve offers were extended. Eleven acceptances and seven rejections were received. Three offers are currently open.

BS/MS (Program) - Two offers were extended. Five acceptances and twenty-seven rejections were received. Current open offers total four.

Technical Graduate Program - Six Technical Graduates were placed on permanent assignment. Thirty-four new members were added to the roll and two members terminated. Current Program members total sixty.

FACILITIES ENGINEERING

Projects

At month's end Facilities Engineering Operation was responsible for ten active projects, having total authorized funds in the amount of $6,435,000. The total estimated cost of these projects is $10,680,000. Expenditures through May 31, 1963 were $698,000.

The following summarizes project activity in June:

Number of authorized projects at month end	10
Number of new projects authorized	0
Number of projects completed	0
New projects submitted to the AEC CAH-106 - PRTR Storage Basin and Experimental Facilities Modifications	1
Projects awaiting AEC approval CAH-106 - PRTR Storage Basin and Experimental Facilities Modifications	1
Project proposals complete or nearing completion PRTR Decontamination and D_2O Cleanup Heat Transfer Apparatus for Model Studies	2

The current status of projects authorized or awaiting approval is:

CAH-916 - Fuels Recycle Pilot Plant - A construction schedule has not been established. Construction is two percent complete. The contractor is excavating for the building foundations and utilities. J. A. Jones Construction Company made two tie-ins to the 8" sanitary water line. A 300 KVA transformer was loaned to the contractor for temporary power. Several shop drawings have been received for review. Temporary construction buildings have been erected.

CAH-922 - Burst Test Facility for Irradiated Zirconium Tubes - Construction is 28 percent complete and on schedule. The building foundation walls and wet basin were poured. The cofferdam has been installed, and installation of the transfer tube and accessories between the existing storage basin and the new wet basin is under way. Invitations to bid have been issued for providing the instrument panel. All other Company procured equipment has either been received or is on order.

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CAH-958 - Plutonium Fuels Testing and Evaluation Laboratories - 308 Building - Construction is 25 percent complete and on schedule. Installation of the ceiling support steel is being performed by the plastering contractor and is being integrated with the electrical work and duct modifications being performed by the CPFF Construction Service Contractor. Fabrication of the metallograph hood is 25 percent complete. An order has been placed for the metallograph.

CAH-962 - Low Level Radiochemistry Laboratory - Detailed design by the Architect-Engineer is 35 percent complete and on schedule.

CAH-977 - Facilities for Radioactive Inhalation Studies - A meeting of Company and Commission representatives was held on June 5, 1963, to discuss the design and cost of the project. Upon completion of Title I design, the Architect-Engineer's construction estimate exceeded the amount requested in the original project proposal. The increase resulted from an enlargement of the structure when designed by the Architect-Engineer and from escalation during the twelve months since the proposal was submitted to the Commission for authorization. The Architect-Engineer was instructed to proceed with detailed design.

CAH-982 - Addition to Radionuclide Facilities - 141-C Building - A comment meeting was held with the Commission on June 10, 1963, to discuss the design criteria document. Minor changes were agreed to and incorporated into the document. The criteria document was returned to the Commission on June 18, 1963, for approval and negotiation of a design contract.

CAH-985 - Addition to the 222-U Building - Following a decision to drop this project, the project proposal has been recovered from RLOO-AEC.

CAH-986 - 300 Area Retention Waste System Expansion - The Commission returned the project proposal unapproved.

CGH-992 - Additional Fuel Loading Equipment - 308 Building - Construction is 80 percent complete and on schedule. The loading pit surfaces have been sacked and painted. Structural steel is being placed and ventilation equipment is being installed.

CAH-995 - 309 Building Air Conditioning Modifications - Construction is 35 percent complete compared to a scheduled 41 percent. Total construction funds were authorized the CPFF Construction Service Contractor on June 19, 1963, and construction has been resumed. The air conditioning unit was received on June 18, 1963, and Trane Company reports maximum effort to deliver the 60-ton chiller by the July 15, 1963, promised delivery date.

CGH-999 - Plutonium Recycle Critical Facility Conversion to Light Water - Directive Number HW-550, dated May 29, 1963, directs the Company to manage the project and authorizes expenditure of $145,000 total project funds. Detailed design is about 65 percent complete.

1233406

CAH-100 - High Temperature Lattice Test Reactor - The design criteria was approved and distributed on June 10, 1963. Copies were given to Vitro Corporation. A meeting of Vitro Corporation and Company representatives was held to discuss design of this project.

CAH-106 - PRTR Storage Basin and Experimental Facilities Modifications - The preliminary project proposal was transmitted to the Commission on June 20, 1963. The proposal requests authorization of total design funds in the amount of $47,000.

Engineering Services

Consulting engineering services provided to research and development personnel included study of 1260 Building mechanical and electrical service and equipment for laboratory use, engineering for 308 Building vibratory compaction equipment installation, study of 300 Area requirements and potential equipment needs for paper incineration, investigation of air filtration requirements and solutions where particulate limitations are less than present filters, review with field personnel of conduit runs and wiring for installation of 105-C irradiation studies loop, and the engineering on instrumentation for 314 Building test loop.

Pressure Systems

Engineering review and surveillance of pressure systems continued during the month. Major items receiving attention included (1) C-1 loop installation, (2) 314 Building high temperature gas loop, (3) 300 Area propane gas system, (4) 325 Building hydrogen gas system, and (5) safety and relief valve inspection and test program. The third party inspector was consulted concerning the strainer and orifice of the rupture disc line on the C-1 loop.

Plant Engineering

Consulting services were provided to operating and maintenance forces. Active jobs during the month included (1) modification of retention waste sampling system, (2) study of noise and ventilation problems - 747 Building, (3) 306 process sewer study, (4) engineering for ventilation of 326 electrical shop area, (5) study for obtaining freer security access to laboratories, (6) engineering for installation of diesel generator for 325 power supply back-up, (7) engineering of electrical modifications - 325 and 326 Buildings, (8) electrical design for Project CAH-999, (9) testing and modification of 309 Building emergency warning signals system, (10) waste line radiation monitoring instrumentation, (11) design criteria for 3705 Building lighting improvement, (12) preliminary studies of 300 Area facilities to replace the 189-D Thermal Hydraulics facility and to relocate 231-Z unclassified plutonium research, and (13) hypothetical studies of operating and capital costs associated with operation of 189-D and 108-F (Biology) facilities without support from the operating reactors.

Items requiring trouble-shooting during the month included return of 3745-B refrigeration unit compressor to the vendor for repair and temporary ductwork to provide ventilation to the 325 Building mezzanine laboratories.

Facilities Operation

Landlord costs for the month of May were $191,028, which is 120 percent of the forecast for the month. Total costs to date for the eleven-month period are $1,891,762, which is 101 percent of predicted. During this month, improvement maintenance cost was $29,815 as compared to the forecast of $15,000. Expenditures for FY 1963 are expected to stay within the landlord budget.

The Interim Procedure for the Criticality Alarm System was revised and issued. Audible alarm checks will become a monthly routine.

The following tabulation summarizes waste disposal operations:

	April	May
Concrete waste barrels disposed to 300-N burial ground	4	20
Loadluggers of dry waste disposed to 300-N burial ground from the 325 Building	4	4
Loadluggers of dry waste disposed of to 300-N burial ground from 300-A sites other than the 325 Building	25	25
Crib Waste (gallons)	235 000	300 000

Three of the 307 retention basins exceeded activity levels of 5.0×10^{-6} μc-β/ml. The highest was 7.8×10^{-6}.

Drafting

The equivalent of 135 drawings were completed during the month for an average of 20 man hours per drawing.

Major jobs in progress are: (1) PRTR shim rod control, (2) PRTR cladding cutter assembly, (3) as-built drawings - inhalation studies hood, (4) salt cycle equipment for C-cell-325 Building, (5) scope design - fast supercritical power reactor concept, (6) scope design - PRTR D_2O system decontamination process, (7) 314 Building high temperature gas loop, and (8) HTLTR mock-up core.

Work performed by CE&UO included the DCMA-1 panel layout and diagrams. Work performed by Bovay Engineers included PRTR as-builts and revised steel framing drawings for 324 Building. Work performed by Vitro Corporation included PRTR gas loop as-builts, PRTR cask, fuel fabrication "gun chamber" and PRTR as-builts.

1233408

Work assigned to Vitro Corporation during the month amounted to an estimated 344 man hours. No work was assigned to Bovay Engineers or CE&UO.

Work performed by CE&UO was 83 man hours, by Bovay Engineers 160 man hours and by Vitro Corporation 222 man hours.

Construction Supervision

Activity during the month on construction work (J. A. Jones Company) being performed for Hanford Laboratories' components is given below:

	Unexpended Balance	Waste Calcination
Orders outstanding beginning of month	$312 075	$165 211
Issued during the month (Incl. sup. and adj.)	82 535	15 450
J. A. Jones expenditures during month (Incl. C.O. cost)	266 224	157 017
Balance at month end	128 386	23 644
Orders closed during month	124 572	

In addition, work on one maintenance work order having a total face value of $920, issued to plant forces, was supervised.

Major active nonproject jobs in progress are: (1) 108-F modification of rooms 402 and 403 and installation of furniture and hoods in room 405; (2) install X-ray machine - 141-C; (3) building modifications - 146-F; (4) build sheep pasture - 100-F; (5) fabricate and install glove box - 231-Z; (6) repair dams at Rattlesnake Springs; (7) construct material storage yard - 300 Area; (8) modify lighting - 306 Building; (9) purchase and install water filter - 306 Building; (10) replace and repair roofs - 306, 3705 and 3746; (11) replace steam lines - 308 Building; (12) 309 Building - install gas loop heater, install shielding, install pump low speed controllers, fabricate and install reactor inlet and outlet mock-up, construct rupture loop annex, modify rupture loop pressure control system, fabricate and install filters in fan pit and make electrical and mechanical modifications to gas loop; (13) make repairs to 314 Building and construct gas bottle facility; (14) install PRTR tube removal prototype equipment - 314 Building; (15) construct computer room - 321 Building; (16) 325 Building - replace ductwork and filter boxes, install additional electrical service, remove and modify cell shielding door and install basement ventilation system; (17) replace 326 air conditioning unit; (18) install demineralizer - 327 Building; (19) construct offices - 328 Building; and (20) modify load-out system - 340 Building.

1233409

Fabrication work released to the Construction Services contractor on the waste calcination demonstration prototype equipment is 80 percent complete.

Eleven requisitions were processed during the month with an estimated value of $2,560. Total value of equipment being purchased is $112,000. M & E lists were issued for Projects CGH-999, CAH-958 and CAH-922.

W Sale
Manager
Finance and Administration

W Sale:lpg

1233410

04 PROGRAM - REACTOR DEVELOPMENT

PLUTONIUM RECYCLE PROGRAM

Plutonium Recycle Test Reactor

Operation

Reactor output for June was 1289 MWD (a new monthly record) for an experimental time efficiency of 76.1% and a plant efficiency of 61.4%. There were nine operating periods during the month, of which seven were terminated manually and two were terminated by scrams. A summary of the fuel irradiation program as of June 30, 1963, follows:

	Al-Pu		UO_2		PuO_2-UO_2		Other		Program Totals	
	No.	MWD	No.	MWD	No.	MWD	No.	MWD	No.	MWD
In-Core	15	1017.5	12	1652.4	58	3027.7			85	5697.5
Maximum		105.7		183.8		95.2				
Average		67.8		138.2		53.2				
In-Basin	28	1850.7	54	3724.7	12	464.2	1	7.3	95	6046.9
Chem. Process.	32	2309.3	1	78.0	—	—	—	—	33	2387.3
Program Totals	75	5177.5	67	5455.1	70	3491.9	1	7.3	213	14131.7

Note: (MWD/Element) 20 MWD/TU for UO_2 and PuO_2-UO_2

The status of the various test elements on June 30, 1963, is shown below. Those test elements which had reached their assigned goal exposure or had been permanently discharged for other reasons prior to June 1, 1963, have been deleted from this table.

Test No.	Channel Location	F.E. Number	Description	Date Initial Charge	Date Discharged	Approximate Accumulated MWD
14	1956	5097	Moxtyl-Swaged	4/2/62	--	53.0 repad
14	1356	5098	Moxtyl-Vipac	5/8/62	--	92.5 repad
14	1758	5099	Moxtyl-Vipac	5/8/62	--	76.2 repad
37	Basin	1096	UO_2 Physics	5/8/62	--	82.3
37	1649	1097	UO_2 Physics	5/12/62	6/13/63	90.1
37	1552	1098	UO_2 Physics	5/12/62	--	87.1
37	1548	1099	UO_2 Physics	5/12/62	--	89.3
37	1651	1100	UO_2 Physics	5/12/62	--	78.2
48	Basin	5150	Moxtyl ($\frac{1}{2}$"x$\frac{1}{2}$" pads)	8/1/62	6/29/63	61.9
54	1948	5116	Moxtyl (clip-on pads)	5/8/62	--	75.9 (60.4 w/clip)
54	1855	5118	Moxtyl (clip-on pads)	5/8/62	--	85.5 (70.5 w/clip)
61	1150	5179	Moxtyl-Physics	5/28/63	--	19.3
61	1443	5185	Moxtyl-Physics	5/28/63	--	16.8
61	1756	5186	Moxtyl-Physics	5/28/63	--	17.0
61	1847	5187	Moxtyl-Physics	5/28/63	--	19.8

The second of the six instrumented UO_2 elements for PRTR Test 37 was discharged at goal exposure during the month.

D_2O and indicated helium losses for June were 554 pounds and 95,119 scf, respectively.

Equipment Experience

A total of 81 reactor outage hours were charged to repair work. Of this amount, 28 hours were for primary pump repairs, 16 hours were used to install new effluent activity monitors, and 24 hours were for helium compressor and helium valve repairs.

Primary seals were replaced on primary pump No. 1 after about 2500 hours of running time.

Preventive maintenance required 413.5 hours or 8% of the total maintenance effort.

Improvement Work Status (Significant Items)

Work Completed

Primary Loop Drain and Flush Valve Modifications
Replacement of Effluent Monitors
Shim Rod Load Milliameters

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Work Partially Completed

Inline Gas Sampling
Process Tubes Level Indicator
Independent Criticality Alarm System of the PRTR Control Room
Recorder Ammeter Installation for Primary Pumps
Deionized Water System
Inlet Gas Seal Replacement
Backup Emergency Pump Low Speed Controllers
E-7 Replacement and Air Supply Adjustment
Helium Compressor Unloading Orifice Modification
125 Volt Battery Disconnect Contactor
Control Wiring for 13.8 KV Motor Operated Switches
Refrigerative Cooling of Stack Pit
Water Softener Controls
Filtered Water Pump No. 3
Shim Rod Shroud to Top Cap Modification
Improved RTD Connector Sealant and Bracing

Design Work Completed

Provide Separate Emergency Backup Water for FEEF
Flow Monitor Tubing Snubber Installation
Autoclave Installation for Zr-2 Fretting Corrosion Studies
Revision of PRTR Exhaust Fan to Emergency Power
No. 2 Exide 125 V Battery Charger
Explosion Proof Receptacle Outlet
Helium Compressor Piping Modification for Snubber Installation
Compressed Air Supply Revision
Pressurizer to Stack Valve Relocation
Actuator with Hydraulic Snubber for Bottom Blowdown Line
Flash Tank Modification
Gamma Scanner Installation

Design Work Partially Completed

Additional Fuel Storage and Examination
Vibration Snubbers for Earthquake Protection
Control Room and Instrument Calibration Shop Air Conditioning
Decontamination Building and D_2O Cleanup
Instrument Power Transfer System
DT-1 Storage Tank Sight Gauge
Stiffener on Air Baffle
Flux Wire Scanning System
Supplemental Emergency Water Addition

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Process Engineering and Reactor Physics

Daily primary coolant samples during reactor operation were taken for radioiodine analysis. These samples continued to show uniform iodine concentrations in the primary system during the month indicating that the core is free from leaky fuel.

PRTR Test No. 66, Calibration of Effluent Activity Monitors, was completed. Sufficient radioactive material was not available in either the main storage tank or the waste storage tanks to give the desired radioactivity concentration at the effluent monitoring units. Other methods of calibration are being considered.

Procedures

Revised Operating Procedures issued	4
Revised Operating Standards issued	6
Temporary Deviations to Operating Standards issued	11
Revised Process Specifications Accepted for Use	5
Maintenance Manuals issued	3

Drawing As-Built Status:	June	Total
Approved for As-Built	23	984
In Drafting		89
In Approval	11	11
Deleted or Voided	2	81
		1 165
Scheduled for Review		350
		1 515

Personnel Training:	Manhours
Qualification subjects	192
Specifications, Standards, Procedures	72
Emergency Procedures	45
Maintenance Procedures	85
	394

Status of Qualified Personnel at Month-end:

Qualified Reactor Engineers	9
Qualified Lead Technicians	6
Qualified Technicians	17
Provisionally Qualified Technicians	2

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Plutonium Recycle Critical Facility

Operation

The cadmium bullet experiment was accomplished without incident.

Preparations for irradiated fuel experiments included (1) a continuation of last month's critical experiments (with cold fuel) to develop reactivity measuring techniques for use in a climate of massive photoneutron flux, (2) modifications and refinements to equipment and (3) operational testing of the thimble coolant system.

Improvement Work Status

Work Completed

Installation of Moderator Heater
Scaler Modifications

Design Work Partially Completed

PRCF Light Water Conversion

Process Engineering

An evaluation of the proposed control system to be used with light water was reported in document HW-78043, PRCF Control System Evaluation for Light Water Conversion.

Procedures

One Process Specification and three PRCF Special Conditions were accepted during the month.

Forty hours of personnel training was accomplished. One PRTR technician became qualified for PRCF operation.

Fuel Element Rupture Test Facility

Work Status

Work Completed

Rupture Loop Sampling System
pH Sample Return
B Cell Leakage Collection System and Sump Alarms
Installation of Test Section in B Cell

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Work Partially Completed

Revised Cleanup System Pressure Relief

Procedures

Fifty-six hours were devoted to training.

GAS COOLED POWER REACTOR PROGRAM

Pressurized Gas-Cooled Loop Facility (Project CAH-822)

Project Status

Blower procurement has been completed and the three blowers are installed in the loop. The project is 98.6% complete; the remaining work, test section installation, will not be done at this time.

TECHNICAL SHOPS OPERATION

Total productive time for the period was 27,840 hours. This includes 15,976 hours performed in Technical Shops, 6822 hours assigned to J. A. Jones Company, 4778 hours assigned to off-site vendors, and 264 hours to other project shops. Total shop backlog is 25,530 hours, of which 90 percent is required in the current month with the remainder distributed over a three-month period. Overtime worked during the month totaled 1519 hours.

Distribution of time was as follows:	Man Hours	% of Total
N Reactor Department	2,748	9.87
Irradiation Processing Department	5,482	19.69
Chemical Processing Department	311	1.11
Hanford Laboratories	19,289	69.29
Construction Engineering and Utilities	10	0.04
	27,840	100.00

LABORATORY MAINTENANCE OPERATION

Total productive time was 17,100 hours of 19,400 hours potentially available. Of the total productive time, 88.5 was expended in support of Hanford Laboratories components with the remaining 11.5% used in providing service for other HAPO organizations.

Manpower utilization for June was as follows:

A. Shop Work		2400 hours
B. Maintenance		6500 hours
1. Preventive Maintenance	1500 hours	
2. Emergency or Unscheduled Main.	1800 hours	
3. Normal Scheduled Maintenance	3200 hours	
4. Overtime (included in above)	2300 hours	
C. R&D Assistance		8200 hours
		17100 hours

Three new items of standards equipment were received and placed in service during June: (1) electronic standard clock to replace the pendulum clock; (2) certified class "S" weights to extend our capability to 5 kg; (3) a 30 KV voltmeter.

DR Koberg

for the Manager
Test Reactor and Auxiliaries

DR Koberg:dde

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INVENTIONS OR DISCOVERIES

All persons engaged in work that might reasonably be expected to result in inventions or discoveries advise that, to the best of their knowledge and belief, no inventions or discoveries were made in the course of their work during the period covered by this report except as listed below. Such persons further advise that, for the period therein covered by this report, notebook records, if any, kept in the course of their work have been examined for possible inventions or discoveries.

INVENTOR	TITLE OF INVENTION OR DISCOVERY
J. T. Russell	The Measurement of the Acceleration of Gravity
V. E. Sipes	Title: "Curve Following Head"
H. J. Anderson, Co-author - F. A. Scott	"Method of Preparing UOS and Other Uranium Sulfides," March 14, 1963 (HW-76963)

Manager, Hanford Laboratories

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