HANFORD LABORATORIES
MONTHLY ACTIVITIES REPORT
SEPTEMBER 1964

OCTOBER 15, 1964

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON
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MONTHLY ACTIVITIES REPORT
SEPTEMBER 1964

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HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

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Table I - Hanford Laboratories Force Report

Date: September 30, 1964

	At Beginning of Month		At Close of Month		
	Exempt	Salaried	Exempt	Salaried	Total
Chemical Laboratory	157	130	153	130	283
Reactor & Fuels Laboratory	213	204	212	196	408
Physics & Instruments Laboratory	138	81	128	81	209
Biology Laboratory	43	65	43	63	106
Applied Mathematics Operation	17	6	16	7	23
Radiation Protection Operation	42	84	49	85	134
Finance & Administration Operation	126	150	122	153	275
Programming Operation	13	4	5	2	7
Test Reactor & Auxiliaries Operation	59	301	60	299	359
General	2	6	2	5	7
TOTAL	810	1031	790	1021	1811

[redacted]

BUDGET AND COST SUMMARY

September operating costs totaled $2,758,000, an increase of $162,000 from the previous month. Fiscal year-to-date costs aggregate $7,995,000 or 22% of the current control budget for FY 1965.

Hanford Laboratories' research and development costs for September compared with the previous month and the current control budget are shown below:

(Dollars in thousands)	COST Current Month	Previous Month	To Date	Budget	% Spent
HL Programs					
02	$ 67	$ 56	$ 175	$ 542	32
04	1 252	1 073	3 417	16 076	21
05	115	100	333	1 694	20
06	295	284	887	3 570	25
07	2	4	7	--	--
08	37	43	119	500	23
	1 768	1 560	4 938	22 382	22
Sponsored by					
NRD	127	137	421	1 594	26
IPD	16	13	54	425	13
CPD	185	158	545	2 207	25
Total	$2 096	$1 868	$5 958	$26 608	22%

RESEARCH AND DEVELOPMENT

1. Reactor and Fuels

The swelling resistance of iron-aluminum stabilized uranium when irradiated to 1530 Mwd/ton was substantially better than normal uranium under identical conditions.

A coproduct driver element test irradiated to 1850 Mwd/ton increased 3.3% in volume, but no clad or closure instability was apparent upon radio-metallurgical examination.

[redacted]

A method to prevent bonding between lithium-aluminum core material and aluminum cladding at the high reductions encountered in production extrusion presses has been demonstrated. Nonbonding is desired as a diffusion barrier for tritium.

The fabrication of beryllium-zirconium brazing alloy wire by successive coextrusion was successfully accomplished.

Nickel-plated aluminum fuel elements are being irradiated in the C-1 Loop in 260 C (500 F) water.

Fretting corrosion of an N-Reactor process tube was observed in an out-of-reactor loop test as a result of the vibration of fuel elements and a spacer against the tube. This was the first observance of fretting in out-of-reactor loop tests where an external vibration was not applied to the process tube.

Analyses of laboratory experiments indicate that an N-Reactor front connector break would not result in large pressure surges but would give sufficient indication of the incident for detection.

A fuel element band broken from a long exposure PRTR fuel rod cluster showed evidence of corrosion up to 1 mil in depth at crevices. Hydrogen content near the fracture exceeded 200 ppm.

The technical design criteria for the PRTR High Power Density (HPD) Core were issued for comment. Transition plans from the present PRTR loading to HPD loadings are being prepared.

Fuel elements for the PRTR high-power-density core are being fabricated. Four standard PRTR fuel elements are ready for irradiation.

Initial fretting corrosion tests of the PRTR Mark I fuel element for the proposed high power density core indicated a relationship between the rotational position of the fuel and fretting.

[redacted]

Tube power calculations for the PRTR high power density core indicated permissible tube powers ranging upward from 2500 kw depending on inlet coolant conditions and flow rate.

Aluminum samples, some contaminated with boric acid, suspended in the gas space above the moderator of the PRTR, showed little weight change during a 1000-hr exposure to moist (D_2O) helium.

Ceramic fuel washout studies were performed in an out-of-reactor loop on a section of Zircaloy-2 clad UO_2-1/2 wt% PuO_2 fuel element, fabricated by the Vipac process, and irradiated to 5000 Mwd/ton in PRTR. After 14-day exposure to water at 300 C, 1650 psi, and 13 fps, the fuel washout through a slit 1-1/2 in. long by 1/16 in. wide has been negligible, as determined by activity readings throughout the loop.

Examination of three leaking and one nonleaking PRTR tube-nozzle gaskets revealed stress cracking in the spiral rings of the gaskets. The cause of the cracking has not been determined.

Maximum calculated exposures of the 12 in-reactor (MTR) and 20 discharged EBWR prototype fuel rods are 3.1×10^{20} fissions/cm^3 (11,300 Mwd/ton of fuel) and 2.7×10^{20} fissions/cm^3 (10,000 Mwd/ton of fuel), respectively.

Latest observations indicate the unprotected, zirconium oxide-free surfaces on the inner surface of a fuel rod (such as weld areas) are particularly susceptible to catastrophic gas-phase hydriding attack. If hydrogen-producing contaminates are present in the fuel material, a crevice is not essential for the reaction to occur.

Power generation corrections for the Mark IX-B UO_2 full length inverted cluster fuel element indicate that the maximum tube power was approximately 607 kw (115 kw/ft maximum) during its irradiation in the PRTR Rupture Loop facility.

[redacted]

A full length rod with a swaged UO_2 core contaminated with 165 mg of I_2 has now operated out-of-reactor for 4 weeks at 400 C without failure.

A four-rod cluster designed to demonstrate the feasibility of replacing individual rods in PRTR elements was fabricated for irradiation in the MTR.

Studies are continuing on characterizing potential fast reactor fuel material obtained by ball-milling and impacting UO_2-PuO_2 powders.

Metallographic examination of the BeO-PuO_2 composites indicated the BeO matrix was bonded regardless of whether or not MgO had been added as a sintering aid, and the fast neutron activity resulting from the alpha-neutron reaction was not intense enough to present a radiation hazard even though the nickel coating had not remained intact.

Before charging in the M-3 Loop of the ETR, a vibrationally compacted thin wall UO_2 tube-in-tube fuel element was autoclaved at pressures ranging from 1000 to 2000 psi at 400 C for a maximum of 64 hr.

Seven stainless clad, stainless-30 vol% UO_2 cermets (~ 0.640 OD x 3-1/2 in. long) with powder stainless end caps were fabricated by pneumatic impaction and will be further reduced by hot extrusion at an area reduction of approximately 10 times.

High purity uranium specimens of several geometries irradiated in the beta phase (about 700 C) to 0.05% burnup exhibited volume increases from 0.5 to 3%. The "R" values (ratio of percent swelling to percent burnup) varied from 10 to 60, which are smaller than those observed with high purity uranium irradiated at 625 C (1157 F).

The defect structure observed in uranium foils irradiated to 10^{17} nvt (thermal) is very similar to the defect structure observed in the non-irradiated, as-extruded foils.

The Materials Engineering high-temperature helium loop in the 314 Building was operated near the maximum design value of 2000 F in the test

[redacted]

section. Performance characteristics of metallic foil insulation in flowing helium—information urgently needed for the design of the Advanced Test Reactor Helium Loop—was obtained before it was necessary to shut down the loop because of a leak between the primary piping and the shroud piping. Operation of all components exceeded expectations.

Application of thermodynamics to the problem of brittle fracture has yielded certain relationships in close agreement with experimental data and provided insight into the fracture governing the ductile-to-brittle transition of metals and the embrittlement of metals through irradiation.

An electrolytic oxygen probe involving a solid electrolyte shows promise of oxygen chemical potential measurements in gases and liquid metals well below the 1 ppm range.

Weight losses after descaling of molybdenum and four TZM molybdenum alloy samples exposed to 1000 C (1832 F) air ranged from 1 to 5 mils/yr.

Satisfactory agreement between weight losses and concentration of reaction products has been obtained in studies of the reaction of graphite with large graphite bars.

The reaction of carbon dioxide and hydrogen is not catalyzed by purified nuclear graphite; however, a catalytic effect was observed with graphite containing impurities.

The coefficient of thermal expansion transverse to the extrusion direction of CSF graphite is increased 5 to 7% by irradiation to 6×10^{20} nvt ($E > 0.18$ Mev) at about 400 C. In the parallel direction no significant change was found.

An accelerated expansion (up to 3%) appears to occur in boronated graphite at a thermal neutron exposure of approximately 10^{21} nvt.

The third irradiation test (2C-3) on Fermi boronated graphites has been charged and is operating satisfactorily.

Weight loss data (before cleaning) for the aluminum-clad fuel elements recently tested in C-1 in-reactor loop at 260 C, pH 4.5 flowing water showed a maximum corrosion rate of 3.3 mils/month, as compared to 14 mils/month previously measured under similar conditions but at neutral pH.

Full size thorium-uranium fuel elements being irradiated in the ETR have now reached 9000 Mwd/ton exposure with only theoretical minimum volume increase.

An analysis of plastic flow in irradiated iron to determine the rate controlling process has shown that at temperatures of 200 K (-100 F) and below, the damage produced by neutron bombardment plays no role.

Sections from a bent, irradiated single crystal of molybdenum have been cut parallel to the (111) planes, thinned, and examined in the electron microscope. A one-to-one correspondence between slip lines observed on the surface and the dislocation channels seen by transmission electron microscopy has been established.

A detailed analysis of the X-ray line broadening resulting from irradiation of high purity molybdenum foils to 1 x 10^{20} nvt (fast) show a very high density of small defect clusters. The susceptibility of the foil to intergranular cracking during handling suggests that the normal deformation processes have been altered.

The activation energy for creep of beta-phase plutonium formed from gamma is 34-38 kcal/g-atom and is significantly higher than the 28 kcal/g-atom for beta phase plutonium formed from alpha. The strain associated with the beta-to-alpha transformation of plutonium subjected to compressive stresses has yielded indirect information on the mechanism of this transformation.

2. Physics and Instruments

Reactor physics analyses in support of the Phase III (power only) operation of the N-Reactor were completed. Minimum fuel costs were obtained as a function of fuel exposure for two proposed fuel types.

Foil irradiation data obtained during both cold and hot startup tests at N-Reactor have been documented. These data will be useful in prediction of temperature coefficients and product formation.

Critical mass measurements were made with plutonium nitrate solutions in a 15.2-in.-diam water-reflected sphere. For an acid molarity of 0.5, the critical plutonium concentration was 24.4 g Pu/ℓ (critical mass 0.74 kg).

A series of exponential and neutron multiplication measurements were begun with 1.25 wt% U^{235} enriched tubular fuel elements (2.4 in. OD, 1.8 in. ID) in light water. The results provide needed data for nuclear safety guidance in processing and storing enriched N-Reactor fuels. For a lattice spacing of 2.8 in. (H_2O/U volume ratio of 2.5) the material buckling was $4620 \times 10^{-6} cm^{-2}$. At this lattice spacing it would be possible to obtain criticality with as few as 88 fuel elements ($\sim$ 2870 lb uranium).

Monte Carlo calculations were used with apparent success in the analysis of a bare plutonium solution critical assembly (15.2 in. sphere).

Three Class I HL-designed shipping containers have been received for testing purposes. Class I shipping containers are unique: the material in their construction prevents neutron interaction with other units and "isolates" the fissile material within each container.

The modified subcritical monitor, including the prototype hybrid preamplifier used with the fission counter, performed successfully at N-Reactor during a number of startups.

All laboratory and calibration tests were completed on a Pu^{239} liquid sample counting system which measures the 17 kev X-rays from sample vials, and the instrument was delivered to the 234-5 Building for field tests and routine use.

Analog simulation studies of N-Reactor primary pump coastdown rates indicate that the primary control loop system gain changes as a function of primary system flow rate. Variations of the governor positioner are believed to be the cause.

Reliability calculations were made for the Ball 3X systems for the small reactors. The K-Reactor system was chosen as a standard against which to compare proposed new systems. A calculation made for one proposed system indicated no significant increase in reliability over the existing system.

Fluorescent penetrant inspection of over 13,000 end caps for N-Reactor Fuels detected three with cracks completely through the wall of the cap.

Eight hundred N-Reactor fuel end caps have been successfully tested ultrasonically. The inspection was done using developmental prototype equipment.

A prototype ultrasonic bond test for lithium-aluminum target elements has been incorporated into a N-Reactor fuel test station. Results of first tests are being compared with destructive test data.

A prototype X-ray fluorescence tester (NT-2) has been installed in the 333 Building and is being evaluated as an advanced inspection method for detecting uranium contamination in the end cap braze areas.

Modifications were made to the slow-neutron time-of-flight spectrometer as indicated by the initial test operation last month. A new copper crystal monochromator was aligned and mounted. This crystal shows promise of significant improvement in the time and energy resolution of the spectrometer.

[redacted]

A measurement series of 3- to 15-Mev total cross sections was completed. Measurements included samples of the separated isotopes Ca^{42}, Ca^{44}, Cr^{53}, W^{182}, and W^{186}, which have not been previously measured elsewhere.

A listing from the NBS of analyses performed on the NBS isotopic standard of plutonium showed that the Isotopic Analysis Program mass spectrometer gave results that were of higher precision than the results obtained by the other seven participating laboratories.

The new ceramic vacuum-lock sample changer for the Isotopic Program mass spectrometer was operated successfully on the test bench.

The critical experiments using EBWR fuel in a mockup of the EBWR lattice were completed. These experiments supplement the subcritical UO_2-PuO_2 experiments, and provide, for the first time, critical data on these fuels for comparison with computer calculations.

The first critical loading of plutonium-aluminum fuel in light water was achieved during the month in the PRCF. These critical experiments give more data for comparison with calculations than the subcritical measurements already completed.

Two very sophisticated neutron transport codes for the IBM 7090 were obtained from Los Alamos. Test cases have run satisfactorily. These codes allow one- and two-dimensional problems to be solved with the rigorous transport equation.

To illustrate the principle of the Phoenix fuel concept, reactor physics survey calculations were done in support of the proposal to fuel the MTR with an H_x plutonium fuel. Initial reactivities, power distribution, and fuel endurance were calculated for various plutonium isotopic concentrations.

Preliminary results from a study of the effect of plutonium concentration on its value indicate that the value will decline slightly ($0.20 to $0.40)

at concentrations above that which is naturally produced in a uranium fuel burnup.

Spectral shift control systems used in conjunction with the seed-blanket reactor concept have been shown to reduce fuel cost as much as 0.40 mills/kwh$_e$ when compared to the movable seed control. This cost reduction does not include the cost of D_2O degrading and inventory charges.

A new table of cost information that is especially useful for analyzing reactors that have existing fabrication and separation facilities, such as at Hanford, has been added to the QUICK economics code.

One U^{234} regenerating in-core neutron flux monitor was received following offsite fabrication. The other chamber is being rebuilt due to excessive flaking of the U^{234} coating. Testing was completed on one experimental B^{11} beta current neutron flux monitor chamber and cable system.

Hydride regions of 300 ppm in reactor process tube samples were detected with a 0.210-in.-diam scanning type test coil.

A method of displaying the cross section of a tube being nondestructively tested to show the location of detected defects was demonstrated.

A commercial vendor has successfully supplied a glass sample having a planer disk defect that will be suitable for ultrasonic wave diffraction studies.

Techniques for fatiguing aluminum, copper, and stainless steel specimens have been developed. Ultrasonic mechanical manipulators have been fabricated and are being assembled. Eddy current measurements were made on stainless steel, aluminum, and copper samples.

Theoretical work has been performed to better understand the physics of the demonstrated ultrasonic shadow-imaging technique. Thermoplastic film, thermosensitive phosphors, electroluminescent phosphors, and thermal sensitive liquid crystals are being investigated as other imaging techniques.

[redacted]

A number of II-VI group compounds appear applicable for development of junction devices for ultrasonic transducers. Special attention is being given barium titanate and lithium sulfide monohydrate.

A final prototype, pocket-size, signaling dosemeter was completed and is being field tested. The dosemeter includes a modified, automatic-recharging, ion chamber as a sensor plus solid state circuitry. The signal level is 50 mR.

Four of the five new remote data stations developed for use in the Atmospheric Physics radiotelemetering system have correctly operated in the field.

The analog computer facility is being used to convert wind component data previously recorded on magnetic tape in spherical coordinates to rectangular coordinates.

Sonic leak detection methods were used to successfully locate a hole of unknown origin in the supply line to the 100 Area Central Fire Station. Removal of the hole solved the problem and eliminated the need to remove and replace the pipes buried in the concrete floor.

Another whole body counting trip to Alaska was completed. The average Eskimo body burden of Cs^{137} was 1100 nCi compared to 1280 nCi measured in July.

A large plastic scintillator was successfully tested as an anticoincidence shield for whole body counting purposes. A new calibration technique for the shadow shield whole body counter was investigated also. The technique is good to ± 15 to 25% absolute accuracy.

The helium ion separator being developed to adapt the Van de Graaff to accelerate He++ ions has been tested with beams up to 4 Mev and 0.3 microamps. The linearity of the He^3 neutron spectrometer was found to be very good.

Two atmospheric dispersion field tests with elevated releases from 365 ft were conducted in September. This completes the year's tests planned to investigate the effect of source height in stable atmospheres. Comparison of the 185-ft source data to previous 23-ft data shows that, for travel times beyond 20 min, both exposure curves asymptotically approach the mean curve for ground-level sources. For short travel times, however, large differences in exposure are noted.

3. Chemistry

In development studies on nickel plating solutions, the presence of halide was found necessary for high anode current efficiencies.

U^{233} process studies disclosed (1) an adverse effect of aluminum on protactinium scavenging with manganese dioxide, (2) the desirability of eliminating sugar denitration, and (3) the desirability of backcycling MnO_2.

Laboratory studies are now underway to investigate proposed flowsheets for thoria processing in the Purex plant. One minimixer-settler run has been completed in which thorium recovery and decontamination were simulated; thorium losses were essentially as predicted by the flowsheet. Corrosion studies showed that combined use of AISI 304-L stainless steel and HAPO-20 alloy in thoria process solutions would not introduce significant galvanic corrosion problems.

Thorium oxide dissolution studies in a pilot scale annular dissolver confirmed laboratory studies predicting low dissolution rates. Purex plant dissolvers may be limited to less than 1 ton of thorium per dissolver day. The low rates are attributed to poor contact of the dissolvent (fluoride-catalyzed nitric acid) with the thoria cake that forms in the dissolver bottom. Studies are continuing to define operating conditions and possible dissolver design modifications to minimize the dissolution time cycle.

The distillation of Po^{210} from 0.25 molar nitric acid solutions containing organic complexants was demonstrated.

[redacted]

The use of a high purity hydrocarbon was recommended for the cerium rare earth separation process. HEDTA and citric acid were shown useful for preventing precipitation of rare earth sulfates.

Process assistance for the second technetium recovery run included demonstration of sugar denitration.

The Brookhaven continuous phosphate glass process was demonstrated in the first of several scheduled runs in the High Level Radiochemistry Cell.

Two methods are being evaluated for adding glass-forming chemicals to a coupled calciner-melter system for high level waste solidification. Additions to liquid feed to the calciner have been successfully demonstrated; work is now underway to investigate solids addition directly to the melter. Two runs were made in which glass frit was added to calcined simulated Purex waste in about a 2 to 1 ratio. Some foaming occurred in the melter, impairing discharge of the glass product.

Electrodialysis of Columbia River sediments revealed that Co^{60}, Zn^{65}, and Mn^{54} were removed as cationic species but Cr^{51} and Sc^{46} were not removed.

Multidimensional gamma-ray spectrometry has proved to have great sensitivity for Cu^{64}, Na^{24}, As^{76}, Sc^{46}, Zn^{65}, Co^{60}, Na^{22}, Co^{134}, and Cs^{137} in biological samples.

A program has been established to determine whether Cs^{137} body burdens can be correlated with Cs^{137} content of hair.

In the Radioanalytical Methods Evaluation program, an established radioanalytical procedure for Tc^{99} was found to be inapplicable to metabolized Tc^{97}.

Molybdenum, AISI 310 stainless steel, Hastalloy-C, -N, -X, and Haynes-25 were compatible with rare earth oxides (simulating Pm_2O_3) in a 1000 hr test at 1100 C. In the plasma jet rare earth metals (simulating promethium) melted readily. Stainless steel clad oxides, however, resisted melting.

A short range study was started to demonstrate the behavior of coproduct N-Reactor elements upon heating in a steam atmosphere to temperatures anticipated in reactor accidents.

The minimum travel time for water to move from 1301-N Crib to the Columbia River estimated before crib use was given additional credence by in-use measurements.

Ruthenium and cesium in Purex Tank Farm condensate were decontaminated by factors of 50 and 400, respectively, by a three-cell eletrodionization unit processing 2500 column volumes through the resin-filled dilution chambers.

Design and procurement activities for the Containment Systems Experiment continued. Fission product simulation research and development included an evaluation of the suitability of various high temperature resistant materials as a container for molten UO_2. All combustion boats tested to date were penetrated within 20 min.

4. Biology

It was shown that salmon migrating in the Columbia River occasionally develop an immune-response to columnaris infection. It appears that this response is a result of a challenge by the infecting organism, since all fish do not show the presence of antibodies.

Pathological lesions in lungs resulting from plutonium that had been inhaled by dogs continued to occur. Dogs are now dying up to four and one-half years after the initial exposures. The amount of plutonium found at death is several hundred times the maximum permissible body burden for the human. (The originally deposited amount is probably much higher.)

The pathway of tryptophan metabolism in Neurospora continues to be elucidated. Recent findings show that a hitherto unknown conversion can occur in mutants of this fungus. There is a spur in the tryptophan cycle of this organism that involves the converions of tryptophan and pyruvate to indolepyruvate and alanine in the presence of vitamin B_6.

The RBE for fast neutrons in producing dominant lethals in flour beetles was found to be one-third to one-half.

Measurements taken of Alaskans in Anaktuvuk Pass during September showed their body burdens of Cs^{137} decreasing as compared to last July.

A special technique developed here to enhance an autoradiographic image was found to be of great sensitivity and of possibly potential value in detecting and measuring very small quantities of alpha emitters.

TECHNICAL AND OTHER SERVICES

The Nuclear Health and Safety function, formerly in Programming, was transferred to the Radiation Protection Operation on September 1 under the continued direction of R. L. Junkins.

On June 12, 1964 the swamps that receive cooling water from the Purex plant became grossly contaminated as a result of a leak in the cooling coils of a process tank. Backfilling of the inlets to the swamps and some of the shore line, increased depth of water in the swamps, and time for fixation of the contamination in the bottom of the swamps have virtually corrected the the conditions. The status of "B" Swamp has been satisfactory since August. Efforts to eliminate the radiation problems still remaining at the Gable Mountain Swamp continued through September. The contamination in the water is on the order of 5×10^{-5} μc/cc and is no longer a problem. The mud in the bottom of the swamp is still highly contaminated and the major efforts have been directed at raising the level of the water so that the mud will be less accessible to ducks.

Closed form solutions were obtained to several mathematical models of chemical processes associated with waste recovery.

The power curve was developed for a two-stage acceptance sampling plan associated with the purchase of temperature detectors.

A diagnostic routine for the recently installed process control computer is being written. Debugging is still in progress on functional programs associated with the initial application to the C-column test facility.

A computer program has been completed that will aid in the investigation of the attenuation of ultrasound. A first draft of the mathematical model used as a basis for the program has been written.

Assistance was provided in determining precision lattice constants of hexagonal crystals subsequent to their indexing, and a computer program prepared.

The analysis was completed of data from a study to investigate the effects of physical and biological conditions on the deposition and retention of I^{131} on plants.

SUPPORTING FUNCTIONS

Plutonium Recycle Test Reactor output for September was 1, 587 Mwd for an experimental time efficiency of 83% and a plant efficiency of 76%. There were eleven operating periods during the month, eight of which were terminated manually, two were terminated by scrams and one operating period lasted through month-end. A summary of the fuel irradiation program as of September 30, 1964:

	Al-Pu		UO_2		PuO_2-UO_2		Other		Program Totals	
	No.	Mwd	No.	Mwd	No.	Mwd	No.	Mwd	No.	Mwd
In-Core	0		7	1842.1	77	13426.5			84	15268.6
Maximum				338.0		355.8				
Average				263.1		174.4				
In Basin	7	572.5	26	2687.1	46	5334.5			79	8594.1
Buried							1	7.3	1	7.3
Chemical Processing	68	5465.8	35	1965.8	—	—	—	—	103	7431.6
Program Totals	75	6038.3	68	6495.0	123	18761.0	1	7.3	267	31301.6

(Note: Mwd/Element x 20 ≃ Mwd/ton_U for UO_2 and PuO_2-UO_2)

Estimated heavy water loss and indicated helium loss for the month were 1300 lb and 154, 781 scf, respectively.

A total of 55 outage hours were charged to repair work. All outages were directed to emergency repairs with minimum reactor downtime. Valves constituted the main repair items.

Initial demonstration tests of the mocked up PRTR Pneumatic Irradiation Facility were made. A sample capsule was transmitted through the simulated out-of-reactor piping at the designed 50 ft per sec.

Irradiation of a longitudinal slit defected UO_2 (Test 7) in the Fuel Element Rupture Testing Facility continued through September 7. During this period in September, the fuel element was cycled through five critical periods including three in which the reactor power exceeded 60 Mw. The fuel element was subjected to one scram from 63 Mw. The test element was discharged from the loop on September 7 after a scram caused by the failure of the pressure control valve. Because of the increasing number of control valve and small line failures caused by vibration problems, the loop was taken out of service until the necessary changes could be made to decrease the frequency of these failures.

Total productive time in Technical Shops Operation for the period was 20, 782 hr. Distribution of time was:

	Manhours	% of Total
N-Reactor Department	3 084	14. 8
Irradiation Processing Department	3 805	18. 3
Chemical Processing Department	310	1. 5
Hanford Laboratories	13 583	65. 4

Total productive time in Laboratory Maintenance Operation was 17, 200 hr of 18, 800 potentially available. Of the total productive time, 95% was expended in support of Hanford Laboratories components, with the remaining 5% directed toward providing service for other HAPO organizations. Manpower utilization (in hours) for September was:

A. Shop Work		2 000
B. Maintenance		5 900
1. Preventive Maintenance	2 400	
2. Emergency or Unscheduled Maintenance	1 300	
3. Normal Scheduled Maintenance	2 200	
C. R&D Assistance		9 300

The heavy water inventory at the end of September, 1964 showed a loss of 1, 300 lb valued at $17, 979 for the PRTR. Heavy water scrap generated during the month amounted to 3, 500 lb, resulting in a $4, 375 charge to operating costs. Total scrap on hand at September 30, 1964 amounted to 14, 039 lb valued at $134, 760.

Cumulative data of Hanford visitations:

	Number of Visitors	
	In September	Since 6-13-62
Visitors Center	1 443	79 538
Plant Tours	138	---

HAPO professional recruiting activity for September:

	Plant Visits	Offers Extended	Offers Accepted	Offers Rejected	Offers Open
Ph. D.	2	2	2	5	4
BS/MS (Direct Placement)	0	0	1	0	1
BS/MS (Program)	0	0	0	0	1

Four Technical Graduates were placed on permanent assignment. Two new members were added to the roll and one terminated. The current program numbers 39.

Authorized funds for thirteen active projects total $10, 729, 000. Total estimated costs of these projects is $11, 880, 000. Expenditures through July 31, 1964 were $4, 640, 000.

R S Paul

Acting Manager, Hanford Laboratories

HM Parker:JEB:da

[redacted]

REACTOR AND FUELS LABORATORY MONTHLY REPORT

SEPTEMBER 1964

TECHNICAL ACTIVITIES

A. FISSIONABLE MATERIALS - 02 PROGRAM

1. Metallic Fuel Development

Comparative Swelling of Uranium Alloy Fuels. Two KSE-5 fuel elements irradiated in KER Loop 2, to about 1530 Mwd/ton, for the purpose of comparing swelling performance of two fuel compositions under identical irradiation conditions are being examined in the Radiometallurgy facility. One fuel element contains uranium with a nominal N-fuel composition of iron and silicon additions (~120-140 ppm each), and the other fuel element contains uranium with 400 ppm iron and 800 ppm aluminum.

Peak fuel swelling determined by pre- and post-bulk density measurements was 2.1 vol% for the iron-silicon bearing fuel compared to 1.2 vol% for the iron-aluminum bearing fuel. Density determinations on the fuel in Radiometallurgy agree well with these data. Metallographic study reveals grain boundary tearing voids in the cooler zones and clusters of spherical voids oriented to some degree with deformation bands or twins in the hot central zones of the iron-silicon bearing uranium. Examination of the uranium with iron-aluminum additions reveals it to be free of either of these two types of voids.

Alternate Uranium Compositions. Studies are in progress to evaluate uranium base alloys in terms of composition, fuel fabrication history, corrosion behavior, and irradiation performance. Seventeen alloys planned for irradiation in NaK capsules have been fabricated in Zr-2 clad rods which are now awaiting heat treatment.

The cladding-fuel interface of the coextruded rods from the five alloys that contained approximately 2 wt% of either Zr, Nb, or Mo is smooth and the cladding thickness is uniform. On the coextruded rods from the remainder of the alloys there is little variation in the cladding thickness, but the cladding-fuel interfaces are, in some rods, rough and irregular. This undoubtedly resulted from large grains in the fuel core coextrusion billets. The large grain size has been traced to the heating cycle used in the beta heat treatment of the as-cast billets

prior to the primary extrusion step. The coextruded rods, however, are usable, and irradiation samples will be machined from them following the heat treatment step.

Post-irradiation Evaluation of Co-Product Driver Elements. Radiometallurgical examination is being conducted on a 1.25% enriched co-product driver element irradiated in KER Loop 3 to about 1850 Mwd/ton. The element experienced a 3.3% increase in fuel volume as determined by comparison of pre- and post-bulk densities. Metallographic examination of the end closures, which are of the tapered or "chevron" design reveals no instability. A crack was observed in the fuel between the clad wall and tapered side of the cap, but there is no accompanying deformation in the clad. Possibly the crack is a result of post-irradiation handling of the 40-pound fuel element. Metallographic examination reveals a considerable amount of grain boundary tearing in the fuel adjacent to the clad. This region displays a "hashed" or swirled microstructure characteristic of uranium irradiated at about 400 C. More grain boundary tearing is observed on the OD side of the fuel than on the ID side. The hot central zone of the uranium displays a recovered or recrystallized structure that is heavily twinned. Considerable spherical porosity is resolvable at 1000X magnification, and it appears to be clustered and oriented to some degree with the twins.

Coextrusion of Aluminum Clad Target Material. A series of six coextrusion billets containing 1-1/2% Li-Al cores were extruded from the 4-inch container at a reduction of 34.3 to 1 in an effort to determine billet interface conditions which will prevent the aluminum cladding from bonding to the Li-Al core at higher reductions. The higher reductions will be encountered when extruding the target material on the product department extrusion press. The Li-Al cores were dry machined to final size and the aluminum billets cans were degreased and dried. The core OD's and can ID's were then prepared before final billet assembly as follows:

Billet No.	Core	Can
1	As machined	As degreased
2	As machined	Dry blasted and powdered graphite wiped on.
3	Dry blasted and powdered graphite wiped on.	Same as core

Billet No.	Core	Can
4	Dry blasted and -325 mesh ZrO_2 wiped on.	Same as core
5	Same as #3	Same as #3
6	Dry blasted and powdered lead wiped on.	Same as core.

Following preparation of the interfaces, the billets were sealed by vacuum beam welding. The billets were heated to 300 C and extruded with a ram speed of 15 in/min through tooling heated to 250 C.

The results of the clad-to-core bonds in the extrusions were as follows:

#1 - nearly complete bond
#2 - very light bond (less than 5% of possible)
#3 - no bond
#4 - light bond (less than 10% of possible)
#5 - no bond
#6 - very light brittle bond.

The above results show that by dry blasting the core and clad surfaces and rubbing powdered graphite onto the blasted surfaces, enough graphite can be held in the billet interfaces to prevent bonding. A flaked graphite was tried; however, it would not stay on the blasted surfaces. Apparently the flakes were too large to rub into the pits created by the dry blasting.

The powdered graphite technique is just as effective, if not more so, than a coating of Aquadag previously tried in preventing bonding. The Aquadag introduces a greater possibility of hydrogen contamination as it is initially a water solution until it dries, and it is doubtful that all the water is removed in drying. The powdered graphite can be vacuum dried to reduce the possibility of contamination from moisture which may be held in the powder. The graphite used in the above test was not dried.

Target Element Core Material. The development has been initiated on a ceramic or cermet core for target elements that will withstand sustained temperature excursions up to 1200 C. Two basic systems are under investigation, those with lithium aluminate and those with lithium meta silicate. The silicate system has received the most attention thus far because of the higher lithium density and the ability to form low melting glasses, thus facilitating tritium recovery. Of all the compositions investigated, the systems with 5% Li_2CO_3 + 95% Li_2SiO_3 and 5% Al + 95% Li_2SiO_3

appear the most promising. In both of these cases the additives tend to give the compact green strength and the compacts sinter into a very hard pellet. A means of quantitative evaluation for each pellet is being developed.

Target Element Development. As part of the continuing program for the evaluation of the irradiation performance of alternate target materials, samples of $LiAlO_2$ and Li_2SiO_3 were irradiated in KER Loop 2 as aluminum cermets, mixtures of the two powders, and as separate powder samples. The target materials were sealed in an inner can of aluminum and an outer can of Zr-2.

From mass spectrometer analysis of the free gas evacuated from inside the aluminum cans, it appears that tritium product release at the irradiation temperature was greater from $LiAlO_2$ than from Li_2SiO_3 + $LiAlO_2$ mixture. Tests to determine the amount and composition of gas released during post-irradiation heating of these cores are planned.

To obtain additional data on the gas composition and tritium release during irradiation, two target elements of $LiAlO_2$ and two of Li_2SiO_3 have been fabricated and charged in KER loops. During fabrication, careful control was exerted to assure that before charging the target cores were free of moisture and extraneous gases.

A final report on the corrosion testing of intentionally defected Li-Al alloy cores doubly canned in Zr-2 and aluminum has been written.

Target Elements. The high melting point (1145 C) Be/9 wt% Li alloy was further tested this month by induction heating samples in vacuo in a small iron capsule within a quartz tube to the maximum temperature obtainable with the equipment. Because of the smaller size of the iron susceptor, maximum temperature achieved was between 900 and 1000 C. This temperature was held approximately 20 minutes at $\sim 10^{-5}$ Torr. Although there was some sublimation of the bismuth, with recondensation on the wall of the quartz tube, there was no evidence of fusion or liquation of the specimen.

Reconsideration of the requirements has brought up the question of whether iron would be suitable as an inner jacket because of (a) its relatively high neutron cross-section, and (b) its high radioactivity after irradiation. It has been suggested that an aluminum inner jacket would be preferable. The fact that the

aluminum would melt at the transient temperature is not considered harmful, since it would be molten in contact with the Zircaloy jacket for an estimated maximum of two hours which would be too short a time for deep penetration to develop. The advantages of low neutron cross-section and short half-life daughter products make aluminum better suited to the recovery process which involves mechanical removal of the Zircaloy jacket, with transfer of the cartridge to the extraction cell, and probably heating to remove the H^3.

It is planned to make some prototype specimens of the kinds described to study: 1) Compatibility of components at ~1000 C, 2) Behavior of core material in high temperature steam, 3) Behavior during irradiation, and 4) Extractability of tritium.

N-Reactor Department requested a load of target elements for precise measurements in the PCTR. The specifications required that the lithium content be controlled to ± 2% for the elements on which the actual measurements were to be taken and to ± 3% for the rest of the load. Variation in lithium content over the length on an individual element had to be controlled to ± 4%. This degree of control could not be achieved in lithium-aluminum materials, nor could the materials even be analyzed with this accuracy. Lithium fluoride was suggested as a substitute and accepted. Materials were procured, fabrication methods were developed, and the elements were completed within a five-week period. The most critical elements showed a variation of ± 0.4% along the length and a maximum variation of ± 2.0% for the rest of the load. The total lithium content is known to within a few milligrams. Thus, the original specifications were not only met, but exceeded.

Welding of Lithium Fluoride Target Elements. A group of target elements were made from pellets of lithium fluoride canned in aluminum tubes and then in Zircaloy tubes.

The aluminum tubes were fabricated in three steps. An end cap was welded in one end of the empty tube using AC TIG with argon gas; after filling with pellets the second end cap with a 1/16-inch weep hole was welded into the second end. The tube was then evacuated while the circumference was welded using AC TIG and argon gas. A pin was then driven in the hole, and it was closed using DC TIG and helium gas. This operation was manual and required rapid welding to minimize heating of the tube and, consequently, weld porosity.

The Zircaloy tubes were welded in a helium filled glove box using DC TIG. Supports had previously been welded onto the tubes by resistance welding over an expanding copper mandrel.

Be-Zr Wire Fabrication. NRD requested that the fabrication of 0.025-inch Zr-5% Be wire be attempted by a process of successive coextrusion as proposed by MFDO. Two 3-inch diameter ingots of Zr-5% Be were extruded in mild steel cans to 1.03-inch diameter rods at 800 C. These were recanned in mild steel and swaged at 800 C to 0.25-inch diameter, cut to 6-inch lengths, and bundled into a mild steel can. The spaces between the 101 round rods in the can were vibrationally packed with iron powder to about 80% of theoretical density, and the can was vacuum sealed. The canned bundle was preheated to 800 C, extruded to 1.03-inch diameter, and swaged at 800 C to 0.75-inch diameter. At this point a break in the mild steel clad occurred which released molten material. The break was trimmed off, the rod recanned in stainless steel, and swaging resumed until another break occurred. The rod was again recanned in stainless steel and swaged at 725 C to final diameter. The resulting rod is currently in an acid bath to remove the iron and mild steel.

Apparently a major portion of the rod has been overheated sufficiently to cause formation of an Fe-Zr-Be eutectic which is difficult to remove by etching without adversely affecting the wire. Approximately two feet of the rod will provide usable wires after etching. Both extrusion and swaging data indicate that the basic process will be successful by using lower temperatures.

N-Fuel End Closure Development. Ellipticity of cladding after chemical milling, and particularly lack of concentricity of cladding are problems hindering development of the "TIG Braze" and the "Electron Beam Welded" closure for N-outer and N-driver fuel elements. Tooling has been designed, fabricated, and demonstrated for sizing and truing the free standing cladding (after chemical milling) in the end closure region. The outer cladding is sized by spinning, and the inside cladding is sized and trued (with respect to the outer cladding) by a device which approximates tube rolling. Initial experiments have produced excellent cap fit up resulting in welded closures that have consistent welding conditions.

N-Reactor Fuel Support Development. Mechanical properties data are being obtained as ground work for possible design changes in the N-inner fuel support. Load-deflection characteristics and

fatigue data are being obtained from test assemblies that duplicate support configuration of an assembled inner fuel element. To do this, three supports are attached to an inner fuel tube, and the assembly is processed through all the manufacturing steps, including sizing up within an outer fuel element. Load-deflection curves have been obtained for assemblies using 1/8, 3/16, and 1/4-inch wide supports from the standard 0.036-inch gage strip, and fatigue curves are partially complete. Work has been started to obtain similar assemblies having 1/8-inch wide supports from 0.040-inch and 0.050-inch gage strip.

Fuel Measurements. Ten columns of fuel element assemblies with 1.25% enriched spike outers have been weighed and measured for NRD. These 144 assemblies which will be charged into N-Reactor on October 1 will be remeasured after discharge to aid in evaluating in-reactor performance.

2. Corrosion and Water Quality Studies

Corrosion of Aluminum-Silicon Alloys. Aluminum alloys containing from seven to ten percent Si and 0 and one percent Ni are being evaluated for use in the present reactors. The first series of tests have been completed, and the results are being evaluated. In general, the results indicate little difference in the corrosion resistance of any of the alloys with the exception of one which contains no nickel. This alloy is less corrosion resistant than the others, especially at high temperatures. The second series of tests have begun. These tests will evaluate material which has been through the anticipated manufacturing process for the fuel elements. Longer term data in the nonisothermal loop are also being obtained.

Evaluation of Nickel-Plated Aluminum. An in-reactor test to evaluate nickel-plated aluminum for high flux applications is being conducted in the C-1 Loop. Three plutonium-aluminum fuel elements and five aluminum dummy elements were plated by a chemical nickel process. The elements were heat treated at 400 C (752 F) for 2.5, 10, and 40 hours to form relatively thick diffusion layers in an attempt to preclude in-reactor spalling of the plate, observed in previous in-reactor tests.

The C-1 Loop has been at temperature (260 C, or 500 F), neutral water, since September 6, 1964. A thermocouple inserted in one

of the PuAl elements is reading 282 C and has remained at this temperature since the beginning of the test.

Out-of-reactor tests at 330 C (626 F) in pH-7 water (low flow) and pH-10 water (25 ft/sec) are continuing.

Fretting Corrosion of N-Reactor Process Tube. To evaluate possible fretting corrosion problems in N-Reactor, two N-Reactor fuel elements and an N-Reactor tubular spacer were exposed in a horizontal 6-foot length of N-Reactor Zircaloy-2 process tube in TF-7 for 45 days to a water flow of 35 gpm at 277 C, pH-10 with NH_4OH. Boroscope examination showed eight fretting marks on the lower half of the process tube where it had been contacted by the suitcase-handle supports, and two other marks caused by the projections on the carbon steel spacer. No marks were found on the upper half of the tube. The depth of the marks has not been determined. There was no damage to the supports; the carbon steel shoes remained attached. Fretting corrosion of the process tube had been observed in previous tests with external vibration applied to the tube; this is the first fretting test in TF-7 without an external exciting force other than that induced by the flow and pump.

Corrosion Probes. Corrosion probes (which continuously monitor corrosion by measuring the change in electrical resistance of the sample) are being developed for use at the temperatures, pressures, and pH present in the N-Reactor primary and secondary cooling systems. One probe in a 320 F steam atmosphere and two in pH 9-10 boiling water have performed satisfactorily for 38 days. One steam probe failed due to swelling of the electrical insulator after 24 days.

Testing of NH_4OH in KER-1. Two instrumented crud detectors (thermocouple elements) were charged at the upstream and downstream ends of KER-1 to monitor the effect of temporary loss of coolant quality on crud formation, deposition, and transport. These detectors are an improvement over previous designs in that they have cermet rather than ceramic cores to minimize possible changes in temperature readings due to enrichment shift.

It had been intended to start the test with standard N-Reactor water quality to establish a reference point for later intentional variations. However, the water quality was very poor following startup. Fine black magnetic particles (magnetite) were found in nearly all coolant samples with solids concentrations up to 10,000 ppb, compared to a normal 20-30 ppb. The loop

strainer became badly plugged with fine brown-grey particles which were very radioactive. The filters in the cleanup system also became clogged. Specific resistance has been very low (18,000 ohm-cm), indicating much dissolved ionic material in addition to NH_4OH. Limited improvement in the water quality has been obtained since startup by ion-exchange and feed-and-bleed cleanup.

The identity and source of the foreign material is not known. The process tube was decontaminated during the outage prior to the start of the test. It is possible that some of the decontaminating solution was trapped in dead legs. If so, this could account for the conditions observed.

All eight thermocouples in the detectors are functioning. The cladding temperature has increased about 10 C in 10 days, presumably as a result of crud deposition but appears to have leveled out as the coolant quality improved.

Corrosion of Copper Alloys by Ammonia. Stressed corrosion samples of several copper alloys exposed in N-Reactor piping compartments to air in which ammonia vapor was present from leaking valves were examined for corrosion cracking. None was found, even on stressed samples of B-147 manganese bronze which had been found cracked in previous tests.

No ammonia stress corrosion cracking or pitting was found on two bronze valve-stem bushings exposed for 3-1/2 months in an ex-reactor test loop to vapors from high temperature ammoniated water leaking through the valve-stem packing.

Interference Effects in Chloride Analysis. The automated spectrophotometric procedure used for chloride analysis at N-Reactor is subject to interference by NH_4OH and N_2H_4. It was found that the NH_4OH interference could be eliminated by reversing the reagent addition sequence to acidify the sample stream prior to adding the mercuric thiocyanate reagent. The reagent addition technique does not appear to be effective for N_2H_4 interference.

100-K Heat Recovery System. Tests were conducted to determine the effect of commercial glycol-base anti-freeze mixtures on the corrosion of heat exchanger tubes in the 100-K heat recovery system. Several copper alloys were exposed in static tests for six months at 90 C. The corrosion in the commercial products was lower than in the present ethylene glycol by factors of 3 to 29.

3. Gas-Atmosphere Studies

Graphite-Zirconium Compatibility in N-Reactor. An interim report (HW-80527) has been completed that describes the mathematical model used to analyze the compatibility problem and presents data current to the time of calculation of the operating range for water-vapor partial pressure in the N-Reactor gas. The following additional results relevant to the compatibility range have been obtained recently.

Calculations indicate that the radiation-induced water-carbon monoxide reaction will go to completion in the dose field expected in N-Reactor (1-3 x 10^9 R/hr). Sufficient experimental data are not yet available, however, to determine the equilibrium value in the radiation field.

The prior calculations used rate constants for the water-graphite reaction determined at zero percent burnoff. However, it has been determined (see HW-SA-3439) that the reaction rate is also influenced by the extent of burnoff. The calculated effect of changing the rates to account for burnoff is to reduce the range of permissible water concentrations in the reactor. However, when the latest data on the rate of diffusion of water through hot graphite are used, the effect is to increase the range of permissible water concentration. Experiments in progress in the gas compatibility loop should serve as an experimental check on these computer calculations.

4. Thermal Hydraulic Studies

Transient Heat Transfer Experiments for N-Reactor. The analysis of results of a laboratory experiment investigating loss-of-coolant accidents for N-Reactor fuel tubes was completed, and a document (HW-84104) "Transient Thermal Hydraulic Experiments--N-Reactor Connector Break" was prepared. In these experiments the changes in flow, pressures, and temperatures following a simulated rupture of the inlet connector to a single tube were investigated. Tests were performed on an electrically heated, full-scale model of the downstream half of an N-Reactor fuel column with prototypic pressure tube and fittings. The simulation of the break was accomplished by means of quick-acting valves. Hot pressurized water was supplied to the test section from a 1000-gallon pressure vessel during the transient. The heat generated in the test section was reduced at a rate corresponding to a 1500-inhour scram; scram delays following the simulated break ranged from 1.5 to 27 seconds.

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On the basis of these experiments, the following conclusions regarding reactor operation under similar circumstances were made:

1. Pressure fluctuations during the flow reversal would damp out in one or two seconds without large pressure surges.

2. The inlet connector venturi pressure differential would experience some violent fluctuations following the break and should provide a good indication of a break, provided the safety circuit response to these fluctuations is adequate.

3. The flow reversal would establish in less than a second following the break.

4. Two criteria were found for a tolerable scram delay for a postulated "worst possible connector break." This break was assumed to occur upstream of the butterfly valve in the central zone; the butterfly valve closing to its stop during the reverse flow. The first criterion states that the scram should occur before the arrival of a two-phase coolant mixture at the closed butterfly valve after the flow reversal. If a two-phase coolant mixture in reverse flow passes the butterfly valve before its closure occurs, the second criterion states that the scram should occur before the butterfly valve closes.

5. With a 1.5-second scram delay, a 5000 kw tube should survive the above postulated accident. Should conditions be such that a boiling burnout occurs on the heat transfer surfaces following the accident, average fuel temperatures would not rise more than 375 F based on conservative estimates.

6. For breaks downstream of the butterfly valve, the flow rates would be much higher than for breaks upstream of the valve. Therefore, longer scram delay could be tolerated.

On the basis of laboratory experiments, a semi-analytical model was developed to describe the temperatures in an N-Reactor fuel column following a break of an inlet riser supply line. These experiments were performed on an electrically heated model of the downstream half of an N-Reactor fuel column with prototypic

connectors and fittings. The break was simulated by quick-acting valves, and the electrical heat generation was reduced in such a manner to simulate N-Reactor scram curves. During the experimentation the transient temperatures of the simulated fuel element were measured by thermocouples embedded at various locations along and around the element. Because of the small variations in the internal heat transfer characteristics between the simulated and the actual fuel, it was necessary to develop analytical models to relate the observed temperatures in the simulated fuel to predicted temperatures of the actual fuel. Such an analytical model was developed and tested by comparison to the experimental results. This comparison resulted in partial verification of the model for the early seconds of the transient when heat losses are small in comparison to the total heat generated. Further comparisons will yield information necessary for the quantitative establishment of losses. Once these losses are known empirically, appropriate corrections to the analytical model will be made.

Hydraulics Tests for the Present Production Reactors. Flow tests were performed on a 2-1/2-inch Fisher pressure regulating valve used to regulate horizontal control rod coolant at C-Reactor. Following an offsite modification to change the flow characteristics of this valve, it was noticed that it was unexpectedly operating in apparent cavitation. The purpose of the test was to investigate the reason for the apparent cavitation and to develop methods or procedures to correct it. Upon testing and examination of the valve, it was found that flow conditions in the valve were not favorable for cavitation, and the noise thought to be cavitation was actually mechanical vibration. This vibration was found to be the result of the use of an incorrect valve stem guide bushing which allowed excessive radial movements of the valve stem.

An investigation was performed to determine the effect of a 64-inch long tubular dummy in the upstream portion of a C-Reactor spline tube. The purpose of this dummy piece would be to facilitate rapid and efficient upstream charging. It was found that the use of the tubular dummy would be satisfactory from the hydraulic standpoint provided a 5-inch perforated piece is used to separate the tubular portion of the charge from the spline cap and from the fuel column. The pressure drop across this tubular piece was found to be within 2 psi of that of the normal upstream all-perforated dummy charge presently being used.

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5. Shielding Studies

N-Reactor Shield Evaluation. N-Reactor shield temperature data are now being collected from the permanent shield thermocouples. Experiment data have been fully processed. Additional calculations with MAC will be made when some revisions to the MAC decks have been debugged. Tables, charts, and illustrations are being prepared for the final report.

MAC Development. Two changes were made in MAC. One allows the fixed removal group structure to be correctly fitted to a variable neutron diffusion energy group structure. The other change allows the fission gamma ray production data to be read in, and properly used, independent of capture gamma ray production.

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 Fabrication and Development. Four regular PRTR fuel elements are assembled and ready for shipment to the reactor when needed.

Production of the new 2% PuO_2 mixed oxide, 5-foot fuel elements is now under way; however, contamination of the welding box (unrelated) has held up completion of the rods. Material for two Vipac clusters has been processed, and the elements will be completed soon after the welder is in operation.

Swaging studies on the new short cluster rods indicate a 43-inch stock tube, 0.750" OD x 0.030" wall, when swaged to PRTR rod diameter (0.570-0.575" OD), will consistently provide a fuel core of 90% theoretical density.

A short-core fuel element consisting of UO_2-filled rods assembled into a 19-rod cluster is being evaluated in the EDEL-1 loop. Short term, low temperature tests were performed by the Equipment Development Operation, using applied vibration to compare the fretting characteristics of this element with a normal 19-rod configuration. After testing at 7.5×10^5 cycles, minor fretting (0.3 mil) was observed on the process tube adjacent to a lower support pad. However, tests at 1.5×10^6 and 8.8×10^5 cycles produced no further attack. The fuel element is now being exposed to 282 C water without applied vibration to determine behavior under sustained loop operation.

UO_2-PuO_2 Fuel Preparation. Since the installation of the new outgassing facility in July 1964, nearly 900 Kg of UO_2-PuO_2 for EBWR and PRTR fuel fabrication have been successfully outgassed. The treatment was accomplished using a shortened time cycle, in which the material is heated in vacuum to 250 C in 3-4 hours, followed by a 1-2-hour hold at 250-350 C. As a result of improved process control, none of the outgassed UO_2-PuO_2 was rejected because of excessive oil, carbon, moisture, or other foreign contaminants.

Processing of UO_2-1.5 wt% PuO_2 for EBWR fabrication is near completion. Approximately 300 Kg of this material was prepared from UO_2 obtained via the least expensive route; i.e., converting depleted uranium to U_3O_8, followed by hydrogen reduction to UO_2. It was necessary to heat-treat the UO_2 in wet hydrogen (1000 ppm water vapor) for six hours at 1700 C to eliminate an impurity (as yet unidentified) which undergoes gaseous decomposition during heating at 1200 C in vacuum prior to pneumatic impaction. With few exceptions, the mixed oxide prepared from the high-fired UO_2 was impacted to bulk densities exceeding 98% TD.

Process changes introduced in the Nupac operation to improve the density characteristics of the mixed oxide have resulted in a 1% improvement. The average density is 10.80 g/cc as compared to 10.71 g/cc prior to controlling the O/U ratio to greater than 2.015 and the particle size to <65 mesh.

Much of the UO_2-2 wt% PuO_2 previously prepared for the fabrication of PRCF fuel rods was rejected because of inadequate Nupac densities (96-98% TD). The low densities were attributed to initially low O/U ratios of the normal UO_2 ($\leq$ 2.01). Therefore, the mixed oxide (215 Kg) was recycled by crushing to -20, -35, or -65 mesh, air roasting at 130 C for 16 hours and redensifying

by pneumatic impaction. Resultant densities averaged 98.5% TD, with oxide from all Nupac cans exceeding 98% TD. No major differences in density were noted for the different mesh size starting materials.

The installation of the new preheat furnace system for the Nupac operation has been started. The new system will have seven furnaces as compared to three in the present system.

PRTR Fuel Element Performance. Latest laboratory and post-irradiation observations indicate that unprotected, zirconium oxide-free surfaces, such as weld areas on the inner surface of a fuel rod, are particularly susceptible to catastrophic gas phase hydriding attack. If hydrogen-producing contaminates are present in the fuel material, a crevice is not essential for the reaction to occur.

Post-irradiation examination of two rods from a failed vibrationally-compacted UO_2-1 wt% PuO_2 PRTR fuel element (FE-5233) with an exposure of 1900 Mwd/ton is continuing. The examination revealed that the defective rod had actually failed in both the top and bottom end cap regions and that an incipient failure was progressing in the top end cap region of a suspect nonfailed rod. These two rods from this element contained fuel material suspected of organic contamination.

Inverted Cluster Fuel Element. Power generation corrections (necessitated by erroneous thermocouple readings) for the Mark IX-B UO_2 full length inverted cluster fuel element indicate that the maximum tube power was approximately 607 Kw (115 Kw/ft maximum) during its irradiation in the PRTR Rupture Loop facility. An average fuel exposure of 153 Mwd/ton was accumulated during 500 hours of operation. During this time the element was subjected to nine operating cycles including three reactor scrams, two of which were from full power.

Post-irradiation examination of the fuel cross-section in the highest power generation region of the element indicates that maximum fuel temperatures were approximately 1500-1600 C (marginal sintering), in agreement with the recalculated values.

A dummy inverted cluster fuel element with spike rods was designed, fabricated and assembled, and is now ready for flow testing.

Refurbishing. Three new bands were placed on fuel element #5118, and the element was returned to the reactor for further irradiation.

Cladding Evaluation. Tests to determine the effect of fission product iodine on Zircaloy cladding are continuing. A full length rod with a swaged UO_2 core contaminated with 165 mg of I_2 has now operated for four weeks at 400 C without failure.

Additional studies have been initiated. Capsules of Zr-2 with and without iodine are being exposed to 350 C, 150 psig steam. One set of capsules contains steel cores to induce stress conditions approaching yield, the remainder are pressurized with He to produce stress conditions 50% of yield.

Wire Enriched Fuel Elements. It has been proposed that fuel elements containing sintered UO_2 pellets enriched with 85% plutonium-zirconium alloy wire be investigated. One of the approaches being considered for the fabrication of the wire is extrusion. The dies and billet holders have been fabricated, and preparations for making the initial extrusion studies are in progress. In addition, preparations for making some UO_2 pellets on-site are under way pending the receipt of pellets ordered from off-site.

PRTR Fuel Element. A four-rod cluster designed to demonstrate the feasibility of replacing individual rods in PRTR elements was fabricated for irradiation in the MTR.

Hot Wall Heterogeneous Enrichment. Components were assembled for an irradiation test to evaluate the "hot wall" heterogeneous enrichment concept, which involves plutonium-enriched powder packed around a central column of pellets. This concept offers simplified procedures and lower costs of fabricating plutonium-enriched fuels.

Corrosion and Water Quality Studies

PRTR Corrosion Surveillance. A fuel element band which was broken from a 19-rod cluster, possibly during or after discharge, is being examined to determine the cause of failure. A few localized corrosion spots about one mil deep were found associated with crevices. The hydrogen content of the metal near the fracture was about 220 ppm. Tensile tests and metallography are still in progress.

A package of 10 Type 6063 aluminum coupons was suspended in the gas space above the moderator in PRTR for about 1000 hours of operating time. The gas consists of helium and D_2O vapor at atmospheric pressure with minor impurities of D_2, O_2, and N_2. The

coupons attained a temperature of 240-260 C during operation and are probably typical of shroud tubes in the gas space.

Prior to exposure, six of the coupons were autoclaved 37 hours in high purity D_2O at 120 C, and four of the coupons in D_2O containing 1000 ppm H_3BO_3. Of the six coupons autoclaved in high purity D_2O, two were spotted with the 1000 ppm solution of H_3BO_3 before exposure in-reactor. Although there were some differences in the weight changes during exposure, the weight change was less than 1.5 mg/dm^2 for all coupons.

An assembly of Zircaloy-2 and Zircaloy-4 coupons attached to a PRTR 19-rod fuel element has been charged. Initial operation appears satisfactory. These coupons will yield information on corrosion and hydriding in the PRTR core when discharged in about nine months.

High Corrosion Rate Duplication Experiments. Recent attempts have been made in out-of-reactor environments to duplicate the high corrosion rates experienced on Zircaloy-2 samples exposed in the ETR. Two different techniques have been employed.

In the first method, Zircaloy-2 samples were exposed in 280 C (536 F) 0.01 molar sodium dichromate solution adjusted to pH 3 with nitric acid. Following 30 days of exposure in the dichromate solution, freshly etched samples of Zircaloy-2 showed weight gains of approximately 90 mg/dm^2 compared to 12.7 mg/dm^2 for freshly etched samples exposed simultaneously to deionized water of the same temperature. Preautoclaved samples of Zircaloy-2 exposed in the same dichromate solution for the same length of time had weight gains of 9.1 mg/dm^2 compared to 2.0 mg/dm^2 for preautoclaved samples.

In the second test, the Zircaloy-2 samples were made anodic with voltages of 1.5, 3, and 6 volts. During exposures of four days at each of the voltages, corrosion rates were normal. The Zircaloy-2 samples which had been charged with +6 volts had an unidentified powdery-white coating on the surface opposite the stainless steel cathode. This white powder was easily removed from the normal Zircaloy-2 oxide surface.

Charging of Bulk Metal Comparisons. It has been found that slow thermal cycling of Zircaloy-2 specimens coated with a layer of hydride can cause charging of the bulk metal with hydrogen beyond the terminal solubility. An experiment was conducted to determine whether the rate of heating and cooling during each cycle is

important. A sample of Zircaloy-2 coated with hydride was placed in a molten lead bath at 410 C (770 F), held for five minutes, then quenched in boiling water. After 50 cycles, supercharging of the bulk metal had occurred, but it was less than that found after the same number of slow thermal cycles.

PRTR Pressure Tubes. PRTR tube 6084 was discharged from channel 1253 on August 25, 1964. It has an average exposure of 479.4 Mwd (1.4×10^{21} nvt E>1 Mev). A piece of this tube was burst tested at room temperature. The piece burst at a pressure of 12,240 psig, but the maximum pressure sustained was 12,490 psig. The maximum hoop stress at the maximum pressure was 142,600 psi. Before bursting the specimen displayed hoop elongation in the amount of 6%.

The resistance to crack propagation of annealed unirradiated PRTR Zircaloy-2 pressure tube material has been measured at room temperature for cracks of 0.38 inch long to 2.0 inches long. These data indicate that the nominal stress at propagation is inversely proportional to the 1.477 power of the crack length. Extrapolation indicates that a nine-inch long crack would propagate at PRTR operating pressure and room temperature.

Zirconium Investigation. Preliminary test results of the effects of a direct current on zirconium hydride in Zircaloy-2 indicate a migration of hydrogen from the anode to the cathode of the sample. Massive hydride was observed at the cathodic end of strip Zr-2 (initially 275 ppm average hydrogen) subjected to 55 amps DC at 1.4 volts for approximately four days. Further testing will determine if the observed migration of hydrogen is actually due to the direct current or whether it is a thermal phenomena.

Ceramic Fuel Washout. The first of a series of ceramic washout tests was started in the IRP Loop using a Zircaloy-2 clad UO_2-1/2 wt% PuO_2 fuel rod fabricated by the Vipac process. This fuel rod had been exposed for about 5000 Mwd/ton in the PRTR. Prior to IRP testing, the rod was cut to length, special holder-seals installed on each end, and a slit defect 1-1/2" long by 1/16" wide made on the rod. IRP filter activity increased about 100 mr/hr during several hours at the start of the test, and no further increase has occurred after 14 days of exposure at 300 C, 1650 psi and 13 fps. The initial activity increase was probably due to washout of loose material from the machining operation.

Corrosion of PRTR Gaskets. Three leaking PRTR tube-nozzle gaskets were removed after 18-20 months of service and examined. Stress cracking was observed on all three. The gaskets consisted of alternate wraps of stainless steel and asbestos. On two gaskets limited areas of cracking were found on the outer wrap; the inner wraps were not examined. On the third gasket extensive cracking was found over most of the surface of the outer ring. Both radial and lateral cracks were observed; some extended through the thickness of the wrap. The next three layers of stainless steel wrap were similarly, although less severely, attacked. A nonleaking gasket with 20 months of service also showed extensive cracking extending over the outer five wraps; some cracks completely penetrated the thickness of the metal. The gasket materials are being analyzed to determine the reason for the cracking phenomenon.

PRTR Radiation Levels. Systematic measurements have been made since 1962 of the radiation levels at several points on the PRTR primary system during shutdowns to obtain data on activity buildup trends. A least-square analysis of these data was completed which shows that the average activity has built up since the 1962 decontamination from comparatively low levels to levels (8 hours after reactor shutdown) ranging from 34 mr/hr on the bottom of the DT-2 tank to 129 mr/hr at the inlet to the lower ring header. Many of the apparently high levels are actually lower than those in 1961 and 1962 before the PuO_2-MgO fuel element rupture and decontamination, and on occasions following operation with fuel leakers in 1963. The data do show a general rise in radioactivity; considering the long, half-lived species involved, this can be expected to continue.

Plutonium Oxide Dissolution. Additional tests were conducted to determine the ability of various decontaminating solutions to dissolve PuO_2. Sulfuric acid solutions (0.068 and 0.105 N) at 80 and 100 C were found to dissolve only about 3×10^{-5} g/l of Pu from 200 mesh granular PuO_2 in one hour. The standard oxalic-peroxide-peracetic and oxalic-peroxide-gluconic decontaminating solutions at 40 C each dissolved 2.4×10^{-4} g/l of Pu from 200 mesh granular UO_2-1% PuO_2 in one hour. The latter concentration is higher by a factor of 10 than was obtained in previous tests with the same solutions using PuO_2 rather than mixed oxides. The reason for this difference is not known.

PRTR Chemical Shim. Evaluation of boric acid enriched to 92% B^{10} rather than antural B for addition to the PRTR moderator as shim control was continued. It was concluded that the enriched B can

be used without severe economic penalties if an effective method can be developed for recovering B^{10} from the exhausted ion-exchange units.

Reactor Engineering Studies

Second Generation Mechanical Shim Rod. The shim rod assembly is undergoing environmental testing to characterize water coolant flows and heat balancing of the driving head and heat sinks. Also, a new shim-to-calandria helium seal for the lower assembly has been developed; the seal will use a gasket that remains on the shim rod assembly during installation and removal.

Fretting Corrosion Investigations. A short Mark I fuel element of the tentative high power density (HPD) core configuration is undergoing fretting corrosion tests in EDEL-1. In initial tests involving external vibration of the process tube inlet jumper, the Mark I fuel and PRTR pressure tube combination was subjected to center tube motion of about 9 mils double amplitude at 38 cps and to loop flow conditions of 123 gpm at 150 F and 500 psig. Three test runs of 77,500; 1,500,000 and 882,000 vibration cycles were made with the fuel in different rotational positions. There was no fretting corrosion except for one mark encountered in the first run. The mark (less than 1/2-mil deep) was caused by contact with a lower fuel support pad. These preliminary results indicate a dependency on rotational orientation of the fuel element which is being investigated further.

In the EDEL-1 vibration analysis, the first three eigenvalues and eigenvectors have been calculated for the pressure tube assembly. The tube was assumed 13.08 feet long and clamped-clamped with two separate weight distributions; one with the tube empty and the second with the tube filled with water. The pressure-tube assembly was divided into three equal mass systems for analytical purposes. The resulting characteristic modes and mode shapes of the tube which agree favorably with vibration data taken from EDEL-1 are presented below:

Mode	Frequencies, cps		Mode Shape
	Empty Tube	Tube & Water	
1	26.40	16.55	1, 1.29, 1
2	82.4	51.6	1, 0.32, -1.4
3	190.8	119.5	1, -1.55, 1

Fretting tests with sharpened and unsharpened centering feet (1/16 inch wide) on UO_2 fuel elements have continued in the TF-7 loop. Earlier tests that resulted in fretting being associated with the unsharpened feet and not the sharpened feet, raised the question of whether there had been contact between the sharpened feet and the pressure-tube. The latest test appears to provide the answer. The fuel element was installed with the sharpened end bracket centering feet contacting the south side of the vertical test section, whereas the mechanical vibrator was located on the opposite or north side (coolant flow is north to south prior to entering the test section). After 27 days of exposure with loop coolant flow at 530 F and 123 gpm and a center of the test section vibration of 5 mils amplitude at 27 cps, the following observations were made.

Contact and Pad Location	Pad Type	Test Section Penetration (mil)
S - top	Sharpened	2
S - bottom	Sharpened	1-2
NW - top	Not sharpened	0
NW - bottom	Sharpened (a)	1-2
NE - top	Sharpened	0
NE - bottom	Not sharpened	<1

(a) This pad not sharpened to an edge but narrower than an unsharpened pad.

Because all the sharpened pads did not cause fretting, it is concluded that the contact conditions between the bracket feet and the test section can vary appreciably and thereby have a significant effect on the fretting corrosion that takes place.

In the next test the fuel element will be installed so that at least one of the unsharpened pads will be at the contact location designated south.

Gasket and Closure Test Station. In a development effort for gaskets to minimize D_2O loss at the PRTR pressure-tube and nozzle seals, various gaskets are being obtained and tested in the EDEL-1. Results of 20 simulated PRTR reactor cycles in 104 hours with one test station used for the present PRTR-type gaskets and two stations used for vendor-recommended gaskets include the following: for the outlet nozzle closure, spiral-wound SS-asbestos cap gaskets recommended by one manufacturer

leaked 2 ml/hr, whereas a similar type cap gasket presently in use at the PRTR leaked 1 ml/hr. For the inlet gasket both the test gaskets and the reactor gaskets (both spiral-wound type) had no leakage. For the nozzle-to-tube closure, again both the test gaskets and the reactor gasket (both spiral-wound type) had no leakage except for one test gasket which improved from a leakage of 9 ml/day to 2 drops/day.

PRTR - High Power Density Core. A rough draft, "Technical Design Criteria - PRTR High Power Density Core," HW-83932-RD, was issued for comments. These criteria set forth the general guidelines for design of the high power density core which strives to meet the Plutonium Recycle Program objectives for the next few years.

Transition from the present core loading to the high power density core is being investigated. Transition plans from the present core to both batch and graded fuel cycles are being considered in detail and will be presented in an informal document.

Adjoint and direct neutron flux calculations were completed for the 55-tube short core. The neutron lifetime and delayed fraction obtained were 1.44×10^{-4} seconds and 0.0028, respectively, for the hot, clean core. Both of these values are lower than previously experienced in PRTR and will result in faster response to reactivity changes.

Thermal Hydraulics Studies. Calculations were made using a recently proposed method to determine permissible tube powers for the PRTR reduced core. This method handles in an exact analytical manner those nonsteady process variables whose magnitude ranges within known limits. The method further accounts for those variables which cannot be identified quantitatively by requiring that the boiling burnout heat flux

Calculations were also made which show that the boiling burnout limits for the present core determined by the new method considering the worst applicable case of axial flux skewing found in the PRTR critical tests would be about the same as determined using the older method in conjunction with an unperturbed axial flux distribution.

An adaptation was made of a semi-analytical computational technique developed offsite to study the heat transfer in "water-tube" fuel elements such as have been proposed for the PRTR. A computer code based upon this method was prepared to calculate temperature distributions within the fuel and the quantity of heat rejected to the various coolant passages.

This code can be used to compute the temperature distribution and heat rejection ratios of a water-tube fuel element cooled on the outer surface and by either one or two rings of coolant passages and/or a central cooling passage. The heat generation rate can be assumed a function of radius, but, at present, only constant thermal conductivities can be considered.

At the present time no experimental verification of the general computation scheme has been performed, and appropriate care is required in the treatment of the results. Plans have been formulated to verify the method by the use of an electrochemical heat transfer analogy.

The above described computer code was used to analyze the heat conduction in a PRTR Mk-IX B fuel element. The fuel element was assumed to be operating at a peak level of 6 kw/cm with a 10% radial flux depression at the center. The following heat split information was calculated:

Heat flow to center hole = 11.707% of total
Heat flow to one hole of ring = 9.421% of total
Heat flow over outside surface = 31.765% of total.

For a fuel thermal conductivity of 0.03460 watts/cm/C and a coolant temperature of 265 C, a maximum fuel temperature of 1581 C was calculated to occur between the center hole and the ring of holes. The highest temperature observed between the ring of holes and the outside was 1494 C.

Further calculations were performed to find the radius on which the ring of six coolant holes should be placed so that each hole and the center hole assumes an equal percentage of the total heat

generated. This radius was found to be 2.38 cm in comparison to 2.55 cm radius used in the Mk IX B. Under these conditions, 35.3% of the heat generated is removed at the outer surface of the fuel element.

2. Plutonium Ceramics Fuel Research

UN-20 wt% PuN Irradiation. The second of a series of three capsules containing UN-20 wt% PuN solid solution pellets is undergoing post-irradiation examination. The fuel in this capsule has an average exposure of about 5×10^{20} fissions/cm^3 with a calculated surface heat flux of 615 watts/cm^2.

Both the fuel pellets and the MgO guard pellet in contact with the fuel exhibited extensive central void formation. There was evidence of a fuel-clad reaction zone about 0.02 cm thick in the 304 stainless steel cladding. The temperature of the clad at the interface was about 600 C.

Plutonium Ceramics Irradiations. Post-irradiation examinations of a PuN-W cermet (GEH-14-539) and a PuN-Pu cermet (GEH-14-550) are continuing.

Although little microstructural change took place in the tungsten matrix of the PuN-W cermet (burnup ~13 $\times 10^{20}$ fissions/cm^3), the PuN grains appeared to have become more porous due to irradiation.

The PuN-Pu cermet (burnup 22 $\times 10^{20}$ fissions/cm^3) did not retain any of its original dendritic microstructure. An unidentified metallic appearing phase is present in the specimen.

PuO_2-SS Cermets. The 20 vol% PuO_2-SS cermet pellets heat treated to 900 C in vacuum for up to 400 hours were mounted and are being polished for metallographic examination. Twenty vol% PuO_2-SS cermet pellets for irradiation testing were pneumatically impacted using compacts pre-pressed to about 78% TD.

UO_2-PuO_2 Fast Reactor Fuel. Studies are continuing on characterizing potential fast reactor fuel material obtained by ball-milling and impacting UO_2-PuO_2 powders. Specimens of coprecipitated and sintered $(U,Pu)O_2$, 4-hour and 64-hour ball-milled and impacted UO_2-PuO_2, impacted PuO_2, and impacted UO_2 were prepared in a single metallographic mount for electron microprobe analysis.

Mylar film normally used as a contamination preventive was found to have no effect on autoradiographic resolution of UO_2-PuO_2 samples but did not reduce the number of alpha particles reaching the emulsion by about 10 or 20%.

BeO-PuO_2 Studies. Metallographic examination of the pneumatically impacted BeO-PuO_2 composites indicated the BeO matrix was bonded. It was also evident that at least part of the nickel coating of the PuO_2 particles had liquified during the heating and was liquid during impaction. Phosphorous impurities in the nickel coating are a probable cause of the liquification. A nickel phosphide could have formed which would be molten and account for the "metallic-appearing" stringers in the samples.

The important results of the experiment are: (1) the BeO matrix was bonded regardless of whether or not MgO had been added as a sintering aid, and (2) the fast neutron activity resulting from the alpha-neutron reaction was not intense enough to present a radiation hazard even though the nickel coating had not remained intact.

In these experiments about 8 grams of PuO_2 were involved, and in only one of the impaction cans (about 4 g PuO_2) was the neutron activity intense enough to detect. This indicates that small quantities of PuO_2 particles can be handled safely in the presence of BeO.

Transuranic Oxide Vapor Pressure Studies. Equipment for measurement of the dissociation pressures of transuranic oxides has been installed. A cryostat and Cu_2O/CuO equilibration furnace allow continuously variable oxygen pressures to below 10^{-30} atm. Initial runs were made on cerium and praseodymium oxides and served to evaluate the system. Both AmO_2 and PuO_2 were heated to 1050 C in ultra dry hydrogen (obtained by passing H_2 over H_2O at -196 C), and both compounds reacted severely with the platinum sample container.

Another run at 1050 C was made with a few milligrams of AmO_2 and PuO_2 in contact with platinum and hydrogen gas that had been passed over H_2O held at the sublimation temperature of CO_2 ($P_{O_2} = 10^{-26}$ atm) and again a reaction occurred. This reaction is surprising since CeO_{2-x} was compatible with platinum under the same conditions. Current work is directed toward obtaining an inert sample holder.

Supporting Facilities for Plutonium Ceramics Electron Microscopy. The transfer and decontamination chambers required for direct electron microscopy of plutonium ceramics were completed and installed in a section of the existing uranium ceramics microscopy facility. The transfer chamber consists of a portable clear

plastic glovebox fitted with a shaped connector for attachment to the microscope specimen port and two large bag ports to facilitate disassembly and transfer of the column sections to the decontamination chamber. The latter is fitted with an exit to an open front hood, allowing more convenient final cleanup of nonsmearable contamination. These facilities will make possible the application to plutonium compounds of most of the dynamic electron microscopy techniques already being used for study of uranium compounds. Final outfitting and cold run testing are in progress.

3. Ceramic (Uranium) Fuel Research

Tube-in-Tube Fuel Development. Autoclave testing of a vibrationally compacted thin wall UO_2 tube-in-tube fuel element was performed at pressures ranging from 1000 to 2000 psi at 400 C temperature for a maximum of 64 hours. This element was charged into the M-3 loop of the ETR. It is clad in 0.063 cm (0.025") thick Zr-2 and is designed to produce 200 Kw/ft.

Thoria Irradiations. The series of thoria irradiations has been completed. This series consisted of ten elements which were irradiated in the GEH-4 loop of the MTR. Radiometallurgy examination has been completed on seven of these elements.

UO_2-Stainless Steel Cermets. Seven stainless clad, stainless-30 vol% UO_2 cermets with powder stainless end caps were fabricated by pneumatic impaction. These cermets (≈0.640 OD x 3-1/2" long) will be further reduced by hot extrusion at an area reduction of approximately ten times. This method of fabrication is to be evaluated as a means for fabricating quality fast reactor fuel pins in three-foot lengths with integral end caps.

Magnetic force welding development for joining Nupac-fabricated stainless steel cermet fuel pins was initiated during the month. The purpose of this work is to produce structurally sound joints between the core and cladding of fuel segments without exposure of UO_2 in the weld-flash. The fuel pins (0.200" OD x ≈4" long) are to be joined into 36-inch long fuel elements.

Work to date indicates the major process problems to be resolved in this area are those of joint design and weld current distribution.

4. Basic Swelling Studies

The first controlled pressure-temperature swelling capsule has continued to operate successfully at 450 C (842 F) and 1000 psi. A total of ten specimens of high purity uranium, U + Fe-Al and U + Fe-Si, representing several metallurgical states are included in this capsule. A similar capsule has been assembled and is being readied for bench testing prior to insertion into a reactor.

Post-irradiation Examination. A general swelling capsule controlled at 700 C (1292 F)(beta phase) was opened, and the high purity uranium specimens exposed to 0.05 at% B.U. were recovered. Solid cylinders, 1/8 inch, 1/4 inch, 3/8 inch, and 1/2 inch in diameter, and split tubes, 1/2 inch in diameter with 0.030 inch, 0.060 inch, and 0.120 inch thick walls, were included. All of the samples looked in excellent condition with little or no surface bumping or general warpage. Density measurements revealed volume increases of from 0.6 to 3.1%. The "R" values obtained by dividing the percent swelling by the percent burnup varied from 12 to 62 with most of the values being in the 20-40 range. These are somewhat less than the "R" values observed with high purity uranium specimens irradiated at high alpha temperatures--625-650 C (1157-1202 F). Metallographic examinations are in progress. There was no indication that the geometry of the specimen in any way influenced the irradiation behavior.

Supplemental Studies. Several thin foils of uranium of several compositions have been examined before and after irradiation to 10^{17} nvt (thermal). The defect structures in both irradiated and nonirradiated specimens look very similar. Additional specimens are being prepared for more extensive examination of defects in nonirradiated and irradiated uranium. Attention will be focused on high purity uranium.

5. Irradiation Damage to Reactor Metals

Several nickel base alloys are being studied to determine the effects of irradiation and environment upon their mechanical properties. These alloys are being irradiated at temperatures from 50 C to 740 C (122 F to 1364 F) and tested at both room temperature and 700 C (1292 F). Ninety specimens irradiated at 280 C (536 F) to exposures varying from 5.4×10^{19} nvt to 8×10^{20} nvt (E>1 Mev) were shipped to the Radiometallurgy Laboratory for testing during the past month. Tests during the next month will be made at room temperature. Tensile tests at 700 C (1292 F) will be made when high temperature test facilities are completed.

Refractory metal specimens of TZM, molybdenum, and tungsten-25 Re alloys were received by Radiometallurgy Laboratory. These specimens were irradiated at 50 C (122 F) to an exposure of 1×10^{20} nvt (E>1 Mev). Initial tests will be made at room temperature as part of a study to determine the effects of irradiation upon the tensile ductile-to-brittle transition temperature of refractory metal alloys.

Metallographic examination of an Inconel 600 nonirradiated control specimen was continued. Electron microscopy studies indicate that after thermal aging at the irradiation temperature few precipitates were formed in the single phase alloy. This was in contrast to the irradiated specimen which showed that large amounts of needle-like precipitates had formed at the grain boundaries and in the matrix of the material.

In-Reactor Measurements of Mechanical Properties

In-reactor creep tests on annealed 304 SS at temperatures of 500 C and 600 C (932 F and 1112 F) and 20,000 psi stress were terminated this month. The 500 C test exhibited a creep rate of 8.8×10^{-6}/hr at 800 hours and the 600 C test showed less than the minimum resolvable rate of 2.5×10^{-7}/hr after 2000 hours. No reactor outages of substantial length occurred during these tests; consequently, it was impossible to establish whether any definite change of creep rates occurred upon cessation of irradiation.

An ex-reactor creep test at 600 C - 20,000 psi yielded a creep rate of 2.1×10^{-5}/hr at 1000 hours. Creep rates of 9.3 and 7.6×10^{-7}/hr were observed after 1000 hours for two ex-reactor 550 C (1022 F), 20,000 psi creep tests. The in-reactor creep test at these conditions had a creep rate of 1.1×10^{-6}/hr as reported in the June 1964 monthly report.

Irradiation Effects in Structural Materials

Creep and stress rupture data will be obtained to evaluate effects of cold work and aging on the time at temperature properties of selected nickel alloys. A test apparatus has been constructed for control and hot cell work. The device consists of a dead weight loading frame in which eccentric loads are minimized. Specimens are heated by direct high frequency induction coupling. A proportionating temperature controller regulates the induction generator. Time monitoring and heat input are terminated by a microswitch at specimen fracture.

Work has progressed on the development of a thermally activated fracture theory. Basically, this theory relates crack velocity to the activation energy for the separation process. Approximate calculations of the activation energy have been made from empirical relationships between the total energy of the atoms and their distance of separation. An experiment has been devised in which the crack velocity can be accurately controlled and measured, and also the energy absorption rate can be accurately measured. The correlation between theory and experiment is excellent.

Closer examination of the theory has revealed certain insights into the fracture behavior of metals. By making a definite distinction between the fracture process and the deformation process in metals, it has been found that all of the physical embrittling effects in metals (studied to date) can be charged to the nature of the deformation process. Some progress has been made in the past month toward relating the various features of the deformation process to the thermally activated fracture theory. Qualitatively, the reason why some metals undergo a ductile-to-brittle transition and others do not is related to the metals rate sensitivity and its strain hardening characteristics. The magnitude of the shifts in the ductile-to-brittle transition temperature as a result of radiation damage is in agreement with the theory.

Damage Mechanisms

The objective of this program is to determine how interactions between irradiation-induced defects and dislocations modify plastic deformation mechanisms in a metal. The role of interstitial impurities in alpha-iron is currently being investigated.

The initial analysis of irradiated Ferrovac E and Battelle zone-refined iron by means of thermally activated flow methods has been completed. It was found that the damage introduced by neutron bombardment played no significant role in the deformation at low temperature other than the temperature independent increase in the long range back stresses reported in an earlier monthly report. The situation changed, however, at room temperature where it was quite apparent that the defects produced by irradiation were now responsible for the slowest process in the deformation and, hence, rate controlling.

The unirradiated materials appear to have the same rate controlling process at 200 K (-100 F) and lower, but different processes are controlling at room temperature. The low temperature barrier for both irons is believed to be the Peierls stress hill. This is also thought to be the barrier at room temperature in the purer

zone-refined iron, while an impurity mechanism is postulated for Ferrovac E at room temperature.

Small changes in the activation volume with strain are commonly observed and attributed to changes in the rate of dislocation multiplication or changes in substructure size. Very large changes in the activation volume as a function of strain are observed in the irradiated samples with the change toward the value for the unirradiated samples. These changes are believed to be evidence of the "channeling" previously observed in molybdenum where deformation occurs in localized regions which are subsequently swept free of the defects.

Further analysis of these results and subsidiary tests to confirm certain points are under way at the present time.

Environmental Effects

The first cycle (Cycle 65) of the special ETR G-7 loop test employing hydrogen overpressure for oxygen control was shut down in mid-August, and five quadrants of zirconium alloy corrosion test specimens were shipped to the Hanford Radiometallurgy facility. Normal G-7 loop operations were interrupted toward the end of the cycle by rupture of a fuel element in the parallel M-3 facility.

The G7-M3 system was chemically decontaminated and flushed prior to charging fuel elements and specimens for the startup of Cycle 66. However, a heavy deposit of crud formed on all loop components in the active zone shortly after reactor startup forced a shutdown and discharge of the samples. The crud is largely of organic origin and can be removed mechanically by swabbing or by use of polar organic liquids with ultrasonic agitation.

Continuation of specimen exposures in hydrogen-bearing water will very likely be delayed three to five months because of other test program commitments for the next several reactor cycles.

ATR Gas Loop Studies

Model Loop Operation. One operational goal of the model gas loop is to flow 2000 F (1093 C) helium through the test section. This goal was approached during a recent experiment when helium entered the test section at a temperature of approximately 1900 F (1038 C) after leaving the heater at 2050 F (1121 C).

Measurements were made of temperature changes across a layered metallic foil insulation liner installed in the test section. The loop ran successfully for about six hours. A number of conclusions important to the ATR Gas Loop can be made as a consequence of this run:

1) The heater exceeded the required heat transfer capacity. The present heater is designed for a maximum of 100 Kw power input, with a required capability to transfer 187,000 BTU/hr (55 Kw) to the flowing gas. During this run a maximum heat transfer of 200,000 BTU/hr (59 Kw) occurred through the heater with a power input of only 80 Kw.

   Preliminary examination of the test data indicated a more efficient regenerative heat exchanger than was expected. A more thorough analysis showed that the attemperation flow was so effective in reducing the gas temperature that the inlet temperature to the regenerative heat exchanger was 600 F (315 C) below the design condition. Even at this low temperature and the reduced flow conditions of the run, there was a drop of 900 F (482 C) in the gas temperature across the exchanger versus a design temperature drop of 1050 F (565 C). Future runs will include a variation in temperatures and flow rate to determine the effect on heat transfer in the heater and regenerative heat exchanger.

2) The gas chromatograph measured impurities in the fractional ppm range and gave early warning of buildup of undesirable impurities.

3) The type and design of bellows used during this run of the model loop is not recommended for use in the high temperature portions of the ATR Gas Loop. This does not preclude the use of special bellows or other design concepts to compensate for the differential expansion between the inner and outer pipes in a double contained system.

4) Preliminary calculations of thermal conductivity of foil insulation produce values obtained in circulating high temperature helium significantly higher than values published for static helium. The next run of the model loop will be instrumented to obtain accurate thermal conductivity values.

5) Even after outgassing to low pressures, subsequent warm operation caused condensation of water vapor out of the all-metal primary circuit onto the cooled housing of the circulator. This suggests that the ATR Gas Loop should have provisions for drainage.

6) Nonmetallic insulation can be outgassed and purified adequately on a laboratory scale, but if it is required for field installation, special precautions and careful handling will be necessary. These problems do not appear to be as difficult with metallic insulation and a single contained helium system. Present research and development efforts are continuing to investigate potential problems and their solutions that are associated with both single and double contained systems.

Helium Purification System. A temporary helium purification system was assembled to fulfill model loop and other requirements for high purity helium pending checkout of the commercial purifier by the vendor representative. The temporary system utilizes a long column of charcoal at liquid nitrogen temperature to remove all impurities but hydrogen. Significant savings in helium will be realized as soon as the 2500 cubic foot vapor balloon now on hand for receiving discharged helium can be installed in the top of the 314 Building and connected to the inlet of the helium purification system.

Chromatograph Development. The CMO chromatograph was dismantled and parts reassembled to build an essentially new instrument. All critical parts were placed in a helium-filled box to reduce air leakage. The reassembled instrument is now operational in the 314 Building. The changes reduced background noise a factor of two, which resulted in extra sensitivity. The chromatograph is now capable of detecting less than 1 ppm O_2, N_2, CH_4, CO, and CO_2. Some interference of H_2 and N_2 was observed below 5 ppm H_2, but it appears 1 ppm H_2 can still be detected. Quantitative calibrations at the 1 ppm level will be made when ultrapure helium from the 314 Building purifier is available.

Oxygen Probe Development. A ZrO_2-CuO oxygen probe was constructed, patterned after a GERL design. This device is an electrolytic cell with a reference oxygen concentration on the inside of a hollow ZrO_2 - 7-1/2% CaO tube which serves as a solid electrolyte for the transfer of oxygen ions at 700-1500 C (1292-2732 F). An electrical potential is measured which can be related to the unknown oxygen partial pressure outside the probe.

Initial tests in a vacuum system showed the device performed very well, following changes in oxygen almost instantly. The probe has extreme sensitivity and with further development has excellent potential to measure oxygen concentrations in gases and liquid metals well below the 1 ppm level.

Gas Heater Studies. Molybdenum and TZM oxidation has now been investigated at air pressures of 1×10^{-5}, 1×10^{-4}, 2×10^{-4}, and 1×10^{-3} mm Hg. Rates of attack, calculated from the weight of metal lost after descaling the oxidized samples, varied from 0.906 mil per year at 1×10^{-5} mm Hg to 34.9 mils per year at 2×10^{-4} mm Hg. At 1×10^{-3} mm Hg the previously reported rates of 349 and 351 mg/decimeter/day (49.5 mil per year) for molybdenum were calculated from the weight loss due to volatilization of MoO_3 and were therefore low.

Dynamic Materials Test Facility. The large temperature difference across the test section of the Dynamic Materials Test Facility was found to be due to improper seating of the ceramic test section in the platinum tube. The ceramic test section was hand lapped in place and then shrunk into the taper by differential thermal expansion after the test section was in the loop. Temperatures at the entrance and exit of the test section can now be brought together by adding heat from the "guard heater."

A test run of about 110 hours was made at 1830 C (3326 F) after changing the loop heater controller. A test scheduled to run 72 hours is now in progress. The temperature is 2050 F (1121 C), and the test sample is Haynes Alloy 25. Flow past the sample is about 550 fps. Initially, a rapid gettering of the oxygen in the grade "A" helium was observed and a slow buildup of hydrogen and carbon monoxide. The buildup is presumed to be from organic matter in the loop combining with moisture.

Studies of Hastelloy-X and Haynes 25. Oxidation, carburization, and metal evaporation studies of Hastelloy-X and Haynes Alloy 25 coupons at 1120 C (2048 F) are in progress. The carburization of these alloys in a static methane atmosphere at ~25 mm pressure takes place rapidly. The rate of carbon pickup by the alloy is such that 88% of the total weight gain attained by the sample in 4000 minutes is reached in about 750 minutes. The kinetics of carburizing seems to be dependent on the diffusion of CH_4 through the H_2 corrosion product for controlling the reaction. Oxidation of Hastelloy-X in a replenished 97 μ oxygen atmosphere proceeds at a rate influenced by the oxide layer formation. Two successive parabolic rates were observed.

6. Nuclear Graphite

Thermal Oxidation of Large Graphite Samples by Water Vapor. Measurements of the rate of oxidation of relatively large TSX graphite samples by helium-water vapor mixtures as determined by weight loss measurements have now been compared to the rate obtained by the chromatographic analysis of the reaction products in the effluent helium stream. The purpose is to check the reliability of the latter method for determining rates over short periods of time. This comparison revealed that agreement within 8% was obtained when water vapor was added by bubbling the helium through liquid water. The analysis of reaction products can be done continuously, if desired, and will make it possible to study the effects of graphite burnoff on the reaction.

Kinetics of the Reaction of Carbon Dioxide with Hydrogen. The effect of product concentration on the reaction rate of carbon dioxide with hydrogen ($CO_2 + H_2 \rightarrow CO + H_2O$) is being studied to determine to what extent water vapor will be formed in a reactor from this reaction. If thoroughly degassed water vapor is added to the inlet stream, the rate of the reaction is identical to the rate observed with no water added. We have investigated this effect with water vapor at pressures from 0 to 20 torr and at a temperature of 940 C. Failure to outgas water vapor thoroughly causes an increase in the rate of reaction. This effect is another indication of the large accelerating effect caused by small concentrations of oxygen.

The effect of an increase in carbon monoxide pressure from <0.5 to 120 torr at 940 C is to decrease the rate by 13%. The effect is nonlinear since most of the decrease is observed at a carbon monoxide pressure of less than 40 torr.

Another property of considerable importance is the catalytic effect of graphite on the rate of the carbon dioxide-hydrogen reaction. The reaction is known to be strongly catalyzed by certain solid surfaces, especially the metal oxides. Earlier tests had indicated an increase in the rate in the presence of graphite, but when the graphite was removed from the reaction vessel, it was highly pitted, indicating the presence of impurities. Therefore, it was questionable if the catalytic effect was due to the graphite or the impurities. The experiment was repeated with a rod made of TSX graphite with known history. In handling this rod special precautions were taken to avoid contamination. No increase in the rate of the reaction in the presence of graphite over that with no graphite was observed.

Change in Coefficient of Thermal Expansion from Irradiation of Graphite. The change in thermal expansion of graphite is being determined on irradiated graphite to aid in the interpretation of dimensional changes. Three capsules each containing two parallel and two transverse CSF quarter-round samples were first annealed at 1500 C for one hour, and then the thermal-expansion coefficients (CTE) from 25-700 C and lengths were measured prior to an exposure of 6×10^{20} nvt, E>0.18 Mev, in the ETR at about 400 C. The CTE's from 25-700 C and lengths were remeasured after irradiation. It was found that the CTE's transverse to the extrusion direction all increased 5 to 7%. Small negative or positive CTE changes were observed on parallel samples, with the over-all change tending toward zero. Some length annealing occurred during the thermal expansion remeasurements and will be reported later with other annealing data.

Changes in Graphite Porosity with Temperature. An indication of the changes in porosity in graphite has been obtained from the ratio of bulk-to-crystallite volume change for heating to a particular temperature. It is found that the porosity of the three grades tested, TSX, CSF, and CSGBF, decreases quite substantially between 100 and 700 C. The decrease is attributed to the expansion of crystallites into the pore structure and to the closure of microcracks between layer planes. An interesting observation is that the change in porosity of TSX is smallest of the three grades tested even though this graphite has the highest density. This behavior could result from a more loose matrix of crystallites or a greater concentration of microcracks between layer planes than in the other materials.

Irradiation Exposure Units. A source of difficulty in comparing U.K. and Hanford graphite irradiations has been the difference in exposure units. At Hanford the unit is n/cm^2 (E>0.18 Mev), which includes correction for spectral shape. In the U.K., no correction is made for spectral shape to obtain an equivalent nickel dose, but a "relative damage effectiveness" is determined experimentally to make this correction. The detailed spectral data for U.K. irradiation facilities have now been secured from Harwell and were analyzed by the Hanford procedure to convert U.K. exposures to Hanford units. From this analysis the conversion may be made on a completely consistent basis for the first time. For most of the U.K. irradiation facilities satisfactory agreement is obtained between the "relative damage effectiveness" obtained experimentally and that calculated using the Hanford analysis.

7. Boronated Graphite Studies

Nontemperature-Controlled Capsule. All eight of the initial B_4C graphite capsules irradiated in the ETR have been disassembled and the samples measured for dimensional changes. Twenty B_4C samples in all were irradiated, twelve being 7 wt% B "grey" material and eight 5 wt% B "black." Temperatures were measured in two samples, and others were estimated from heat-generation rates. They varied from about 300 to 550 C depending on capsule design. Neutron exposures varied from 0.86 to 11.7×10^{20} nvt, E>0.18 Mev.

The 7 wt% grey material initially contracted with exposure, then expanded to about 2% at an exposure of 10^{21} nvt without preference to orientation. The 5 wt% black material exhibited a continual contraction parallel to the axis of extrusion totaling about 1% at an exposure of 10^{21} nvt. The 5 wt% black transverse samples appear to contract and then expand with exposure. The expansion of the 7 wt% grey and the transverse 5 wt% black samples appear to be exhibiting a "breakaway" type expansion. However, this could be the result of lower temperatures caused by swelling of the samples, and further data at controlled-temperature conditions are required beyond 10^{21} nvt to explore this possibility. Chemical and microscopy analyses are planned on several samples to determine boron burnup and appearance of the graphite structure.

Temperature-Controlled, Shielded Capsule. The temperature-controlled capsule containing 26 B_4C-graphite samples was charged in the M-6 position of the ETR during late August. The capsule is surrounded by a boron-steel shield tube to obtain a fast-to-thermal flux ratio to about 15. The temperature is controlled by the proportions of helium and argon gas that pass over the test samples.

Following reactor startup, the sample temperature reached 250 C with 100% He and 175 Mw reactor power. By adjusting the gas composition to approximately 30% He, 70% Ar, the sample was brought to the goal temperature of 540 C. Initial operating characteristics indicate temperature control can be maintained within about 5 C at heating rates from 30% less and to approximately 300% more than at startup.

Replacement of the boron-steel shield tube with a fresh (non-irradiated) shield is planned at the end of the present cycle. Capsule removal is scheduled after two irradiation cycles.

2-C Irradiation Tests. The third term experiment, 2C-3, has been installed into the reactor and is functioning satisfactorily. Because the samples expanded during previous irradiations, it was necessary to redesign the 2C-3 sample holders to prevent possible binding. Also, varying amounts of B^{10} burnout, proportional to the exposure of the three sample sections, had affected the base heat generation of the capsule. The combination of the gap and anticipated heating-level changes required an over-all redesign. The presently observed temperatures are in good agreement with previous experience; however, the #1 section is somewhat lower than expected, probably due to underestimation of the B^{10} burnout.

8. Aluminum Corrosion and Alloy Development

Data on weight losses before cleaning have been obtained for aluminum-clad fuel elements recently exposed in the C-1 Loop at 260 C outlet temperature and pH 4.5 with phosphoric acid. The maximum corrosion rate (near the downstream end of the charge) was 3.3 mils/mo. This may be compared to a maximum rate of 14 mils/mo in a similar previous test at neutral pH and to a rate of only 0.06 mil/mo obtained in out-of reactor tests in TF-6 at the same surface temperature and pH 4.5. The corrosion of A-288 and KYZ alloys was about 30% lower than of X-8001; this is in agreement with results of the C-1 test at neutral pH and of out-of-reactor tests. Weight loss data after cleaning are being obtained.

9. Metallic Fuel Development

Irradiation of Thorium-Uranium Fuel Elements. Irradiation of three tubular Zircaloy-2 clad thorium-2.5 wt% uranium-1.0 wt% zirconium fuel elements continued successfully in the ETR-P7 loop. The integrated exposure is 3.1×10^{20} fissions/cm^3 (9000 Mwd/ton). Fuel swelling continues to be no more than that expected from the solid fission products.

Irradiation Testing of Metallic Uranium with Sub-micron Uranium Carbide Dispersions. The irradiation performance of fuel rods containing a sub-micron dispersion of uranium carbide in uranium is being evaluated in the ETR. Of the three irradiation test capsules, two contain fuel rods identical in uranium compositions, but with one having a uranium carbide size of 2-5 microns produced from arc-melted uranium and the other a uranium carbide particle size of less than 0.5 microns produced from the uranium shot. The third capsule contains two fuel rods with the fine carbide.

One capsule has achieved goal exposure of 0.3 at% burnup and has been shipped to Radiometallurgy for examination. The remaining two capsules operated at a maximum fuel temperature of 600 to 625 C during the first cycle of irradiation. A drop in power in that region of the reactor resulted in a decrease in fuel temperature to the 475 to 500 C range during the second cycle of irradiation. The exposure at the end of the second cycle in these two capsules was slightly greater than 0.1 at% of burnup.

Examination has been started on capsule GEH 14-609 which reached a fuel burnup of 0.3%. The average maximum uranium temperatures for the fine carbide uranium was approximately 500 C and for the coarse carbide uranium it was approximately 410 C. It was found on opening the capsule that the cladding on the fine carbide uranium sample had split longitudinally the full length of the 2.75-inch long rod. Further examination has shown that the split has the characteristics of a brittle failure. Brittle failure of Zr-2 cladding at very low strain has been experienced in other NaK capsule irradiations at mean cladding temperatures below 350 C and cladding thicknesses of 0.025-inch or greater. Loss of cladding restraint on this sample resulted in a 3.2% diameter increase and a density decrease of 6.3%.

The cladding on sample 1 with the coarse carbide in uranium was undamaged. There was no measured diameter increase on this sample, but the density of the uranium showed a decrease of 2.3%. A valid comparison of fuel performance cannot be made because of the obvious differences in restraint. Optical metallography and replication on the as-irradiated fuel from both 31 and 1 are under way. Metallography and replication will also be performed on specimens from each of the fuel rods that are now being post-irradiation annealed at 600 C.

D. DIVISION OF RESEARCH - 05 PROGRAM

1. Radiation Effects on Metals

This program is directed toward 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. Present studies involve single and polycrystalline specimens of molybdenum, nickel, and rhenium.

Sections parallel to a {111} plane have been cut from an irradiated molbydenum single crystal which was deformed in bending. These sections have been electrolytically thinned and observed by transmission in the electron microscope. A one-to-one correlation was established between the slip lines observed on the surface of the bend crystal and the channels seen by transmission electron microscopy. The channels seen in the {111} sections are irregular and branching, as are the slip lines on the {001} face of the bent crystal. This particular appearance results when the Burgers vector of the dislocations producing the channels (or slip lines) is perpendicular to the plane of observation. The commonly-encountered Burgers vector in the case of B.C.C. metals is 1/2 a <111>. Planes normal to this vector exhibit irregular slip lines since these slip lines reflect the offsets produced by screw dislocations, which cross-slip profusely. When the observation plane is parallel to the Burgers vector, the slip lines are straight, for in this case the offset is due to edge dislocations which cannot cross-slip.

Polycrystalline molybdenum tensile specimens with exposures of 1×10^{17}, 5×10^{17}, and 1×10^{18} nvt (E>1 Mev) have been received and are ready for testing. A total of 72 specimens are available for each exposure level. Post-irradiation annealing treatments are now in progress; annealing temperatures of 435, 525, and 875 K are being employed in order to produce different defect structures. The lowest temperature is that at which the maximum rate of recovery (from electrical resistivity measurements) occurs; a pronounced hardening reaction occurs at 525 K, and prismatic loops are first observed at 850-875 K. Strain-rate change and temperature change experiments will be used to evaluate the effects of these different structures on dislocation motion.

Preparation of single crystal specimens for deformation experiments is continuing. Techniques for electrolytic machining of these specimens have been developed to a point such that it is now possible to maintain the diameter of the reduced sections of a tensile specimen to a variation of no more than 0.0005 inch over a one-inch section. Tensile specimens have been machined from zone-refined nickel using an electrolyte consisting of a 5% solution of nitric acid in methanol. A capsule suitable for irradiation of these extremely soft crystals is under design. The use of compression specimens is being explored; such specimens are attractive for several reasons: (1) they provide greater sensitivity in the case of a specimen which has a low rate of strain-hardening, such as irradiated molybdenum; (2) they are easily prepared; (3) they have a low mass and resultant low level

of radioactivity after irradiation; and (4) a large number of specimens may be irradiated simultaneously in a standard-size capsule. A compression cage suitable for testing in the range 77-550 K is now under construction and will be evaluated in the near future.

Foils of high purity and carbon-doped molybdenum are being examined by transmission electron microscopy and x-ray diffraction after an exposure of 10^{20} nvt (E>1 Mev). Preliminary observations disclose an extremely high density of small defect clusters in all the foils. Some of the spots were noted to be associated with a complex interconnecting dislocation network which in some cases formed closed rings of an irregular shape. The high purity foil exhibited intergranular cracking as a result of normal handling. Deformation associated with handling generally manifests itself in the form of straight dislocations near the thin edges of the foil; no such dislocations were observed. Obviously, the energy for the formation and motion of a dislocation through the mass of irradiation-produced defects is extremely high, and grain boundary cracking occurs preferentially. This will be further investigated by deforming the foils in tension and observing the behavior at grain boundaries.

Examination of electron diffraction patterns from these foils reveals several anomalies which are presently being evaluated. Forbidden reflections are present, and streaking of spots parallel to <110> has been observed. Extremely pronounced x-ray line broadening was also observed in these foils. After this high exposure the width at half height of the (400) line at 156.4 degrees 2θ ($CuK\alpha_1$) is 1.1 degree 2θ, as compared to a value of 0.25 degree 2θ after 10^{19} nvt. This pronounced broadening appears to be independent of impurity content and pre-irradiation heat treatment.

X-ray line breadths for all available reflections were found to vary linearly with tan θ, indicating that lattice strains are responsible for the broadening. This was confirmed by Fourier analysis of accurately-measured line profiles for the (200) and (400) reflections of a high purity foil. Particle sizes determined by this technique were greater than 1000 A, or sufficiently large that broadening attributable to particle size effects was slight. Lattice strains with a root-mean-square value of 0.06% extending over 150 to 200 A were determined to be responsible for most of the observed broadening. At greater distances the strains approached 0.03%, corresponding to the

observed increase in lattice parameter. Other peaks of the high-purity foils and of foils with higher impurity content are being analyzed.

Electron Diffraction Contrast. The development of an appropriate theory for the diffraction of electrons through thin foils is required for interpreting the electron micrographs of various defect structures. Since the electrons have strong interactions with the potential field caused by the nuclei and electronic configurations of the film, the "dynamic theory" (theory accounting for the interactions of the transmitted and diffracted electron waves) must be used to obtain the expected intensity distributions which would exist after an electron beam passes through a thin metallic foil. A two-beam approximation consisting of a transmitted and one diffracted wave provides realistic estimates of either the bright or dark field beam intensity after diffraction through the foil. The two-beam dynamical theory for foils with defect structures has been developed and reported in the literature. A computer program of the resulting differential equations has been written so that the displacement functions of any defect structure can be analyzed. The displacement function for a straight dislocation with arbitrary orientation and Burger's vector has been programmed. Tabular and graphic records of the diffracted and transmitted intensities are the output of these programs. Such analyses can be used to prescribe observational conditions and analyze observed electron micrographs so that the Burger's vector, tilt, and depth of a dislocation can be determined.

2. Plutonium Physical Metallurgy

The objective of this program is the derivation of fundamental information relative to (1) the kinetics and mechanics of the phase transformations in plutonium, and (2) the mechanisms by which monoclinic plutonium deforms.

The creep resistance, yield strength, and ultimate strength of the beta phase formed from the gamma phase have been found to be much greater than the corresponding values for beta formed from the alpha phase. The compressive creep activation energy is 28 kcal/g-atom for beta formed from either alpha or gamma. This information has been utilized in preparing specimens used in experiments on the beta to alpha transformation.

Highly textured alpha plutonium has been produced by transforming beta to alpha under an applied compressive stress of 20,000 psi. At the temperature of transformation (115 C or less),

little or no beta deformation occurs at this applied stress.

The total strain ($\Delta L/L_o$) associated with the beta to alpha transformation in plutonium subjected to compressive stresses reaches a constant value at 8-10,000 psi. This strain, 0.09, is only three times the unit length change expected for transformation under no applied stress. If transformation proceeds by a diffusion process, the concentration of defects and their mobility should be high, and, as a consequence, considerable strain during transformation might be expected. The fact that transformation strain is not high may be used as an argument in support of the contention that the beta to alpha transformation is diffusionless.

Previous experiments showed that plastic deformation by compression of beta phase formed from alpha decreases the subsequent beta to alpha transformation rate. It might be expected that plastic deformation of beta formed from gamma should result in a greater decrease of the beta to alpha transformation rate because more energy is required for the plastic deformation. This has been confirmed experimentally. For example, plastic deformation by compression at 150 C decreased the maximum beta to alpha transformation rate at 90 C from 6% per minute to 0.100% per minute and increased the incubation time from 150 seconds to 8000 seconds. The proper interpretation of these observations must await a detailed explanation and understanding of the low temperature phase transformations of plutonium.

Analysis of pole figure data of textured, alpha plutonium had led to the conclusion that more precise positioning of specimens is required. The complexity of the monoclinic structure apparently makes positioning much more critical than in studies of the more simple crystallographic systems. Accordingly, a new sample holder was designed and fabricated. Its initial use has demonstrated the increased reliability of the data derived.

It has been firmly established that in the columnar grained alpha plutonium, resulting from the transformation of beta under a compressive load, the (020) plane is perpendicular to the direction of applied stress. The identification of the planes parallel to the stress direction, and the zone axis of these planes has not as yet been established. It is apparent, however, that there can be, and undoubtedly are, a large number of such planes due to the complexity of the structure. Pole figure data are also being obtained on the texturing in plutonium rolled in the alpha phase.

E. CUSTOMER WORK

1. Radiometallurgy Laboratory

Examinations

The results of routine examinations and measurements are, or will be, reported as part of the sponsoring research and development programs. Radiometallurgy examinations and operations for the month include:

Metallography samples processed	53
Photomosaics	4
Autoradiographs	26
Replicas	20
Burnup dissolutions	18
Fission-gas samples	7
Decladding dissolutions	7
Tensile tests (elevated temp.)	19
Tensile tests (room temp.)	24
Rockwell hardness tests	31
Densities	16

Equipment

High Temperature Tensile Testing. Tungsten-carbide specimen grip wedges and extensometer clamps were designed and ordered for elevated temperature tensile testing. It is expected that these tungsten carbide parts will provide a solution to the problem of gripping specimens at temperatures up to the 3000 F limit of the testing furnace.

"B" Cell Modification. All "B" north in-cell equipment was removed, and final decontamination is in progress preparatory to installation of improved viewing, manipulating, and process equipment.

"E" Cell Metallographic Equipment. Fabrication of the remote metallograph parts was completed, and assembly is in progress. Design of a metallographic specimen grinder, which uses an orbital grinding motion, was completed, and fabrication is in progress. The unit will be mounted on a 9-inch diameter cell plug to permit grinding of a larger number of specimens at the same time.

"I" Cell Microhardness Blister. Testing of the remote microhardness tester and controls continued, and a number of equipment

modifications were made to improve operation of the unit. Final testing with calibrated standards is in progress.

Strain Gage Spot Welder. Fabrication of the remote spot-welding head designed to spot weld strain gages on the surface of irradiated process tubing was completed. Functional testing is in progress.

Remote Belt Sander. The sample manipulating device was completed and successfully tested. Minor modifications are in progress, and the complete sander is being tested prior to final design of the hood and baffle required to contain the sample coolant.

Stereo Zoom Viewer. Fabrication of the sample positioner for use with the stereo zoom microscope continued in Tech Shops. The ball-bearing spline was received and installed. Preliminary tests indicate that improved rigidity of the screw jack will be required to eliminate a small amount of vibration during elevation of the slide.

2. Metallography Laboratories

Routine Metallography Laboratories activities will be reported as part of the sponsoring research and development component's work; however, items of unusual interest or representing departures from routine operations will be reported here. During the report month, 356 samples were processed, a total of 533 micrographs and macrographs taken, 2035 negatives printed, and 6294 prints processed.

Tests have been conducted in the N Fuels Engineering Operation to evaluate the metal integrity of certain Zircaloy cap material used for N-Reactor fuel closures. Two suspect fuel elements were placed under an extended autoclave test. One element failed completely and the other suffered complete penetration of the cap. The path of corrosion, as shown by metallographic sectioning, was through the base metal of the Zircaloy cap, not through the braze alloy. These caps are cut from extruded Zircaloy rod, and the direction of extrusion is coaxial with the fuel elements after assembly. Therefore, it follows that when an impurity, stringer, or inhomogeneity occurs in the Zircaloy extrusion, this will appear in the cap as a possible corrosion path. At the present time, several caps displaying such inhomogeneities are under study to determine the nature and cause of these defects.

A report was written and issued on "Failure Analysis of Valve Stem for a 24-inch Valve from N-Reactor," HW-83831.

3. High Temperature Lattice Test Reactor (HTLTR)

The four graphite heater rod elements have been installed in the large HTLTR mockup. Power circuitry continuity checks were completed, and no malfunctions were observed. Total resistances of individual rods were acceptably balanced. Numerous weighed graphite samples and metallic coupons have been installed for test and comparison. The doors have been installed, and checking of the seal integrity of the entire system is in progress.

The ability to enlarge a graphite channel hole and also to machine penetrations through the outer shell and brick was demonstrated; two graphite channel holes were enlarged from 2-3/4 inches to 3 inches in diameter. Also, a 1-1/4-inch diameter hole was drilled through a brick side wall and two graphite blocks to permit observation of a portion of a heater element.

Preparations were completed for obtaining mechanical test data at 1000 C on graphite-base materials to be used in fuel and control rods. Environmental tests of these materials are also being prepared to obtain detailed information on interactions between UO_2-graphite and TD nickel and between B_4C-graphite and TD nickel.

4. EBWR Fuel Elements

EBWR Plutonium Fuel Loading. All the UO_2-1.5 PuO_2 fuel rods required for criticality testing of the first EBWR plutonium core loading have been completed. Yet to be fabricated are 300 rods required for power operation and for spares and 25 special physics fuel rods containing plutonium with 8, 20, and 26% Pu-240.

The first batches of mixed oxide (1.5% PuO_2-UO_2) utilizing high fired UO_2 were processed where the O/U ratio was controlled by blending in U_3O_8. The advantages of blending U_3O_8 with UO_2 to achieve an initial O/U ratio >2.015 for Nupac densification control are: (1) blending the U_3O_8 with the UO_2 makes the control of the particle size (surface area) less critical in the subsequent Nupac operation, (2) the blending of a relatively small amount of U_3O_8 in a large amount of UO_2 makes final O/U ratios

insensitive to weighing errors, and (3) potential gas pickup in the UO_2 during roasting is eliminated.

EBWR Fuel Element Tubing. Replacements have been received for previously rejected (replacement) Zr-2 cladding tubes; preliminary information indicates that the tubing will be acceptable after ultrasonic inspection.

Irradiation Testing of EBWR Prototype Fuel Rods. Twelve capsules (one with prototypic fission gas plenum) are being irradiated in the MTR, and 20 (six with plenums) have been discharged. Maximum calculated exposures of the in-reactor and discharged specimens are 3.1×10^{20} fissions/cm^3 (11,300 Mwd/ton of fuel) and 2.7×10^{20} fissions/cm^3 (10,000 Mwd/ton of fuel), respectively. Two of the capsules with plenums and one without were examined and continue to indicate that the EBWR fuel rods will perform satisfactorily under proposed EBWR conditions.

Over 60 typical EBWR fuel rods have been selected for irradiation testing in Hanford reactors. Work is currently in process to evaluate fuel density variation along the length of the rods with the gamma absorptometer.

5. Other Customer Work

Phoenix Fuel. The fabrication of 20 wt% Pu-Al disks in support of the Phoenix Fuel program was completed. Aqproximately 8100 disks, 0.020 inch thick, were fabricated.

PRCF Fuel Fabrication. A hood facility has been prepared so that PRCF rods may be vibrationally compacted in a vertical position using a resonating plate. A 25-inch extension piece will clamp to the lower end of the fuel rod and couple it to the resonating plate.

This system should eliminate the long vibration periods that these short (36") rods required on a horizontal beam system. The combination of long vibration periods and clamping at the top of the rod resulted in the cracking of several rods on the horizontal system.

UO_2-Graphite Physics Fuel Elements. A 69 wt% UO_2-graphite sleeve approximating HTLTR control rod dimensions was formed using an organic binder, carefully controlled heating rates, and cold pressing techniques. Further work is in progress to improve mechanical properties preparatory to fabrication of pilot quantities for the HTLTR "hot mockup" tests.

Pu-Al Fuel Elements. Two "dummy" elements were fabricated using hydrostatic pressing to achieve a core-to-clad contact fit. This facilitates assembly, eliminates weld area contamination, and results in 100% core-to-clad contact area. The fabrication of twelve 20 wt% Pu-Al I&E fuel elements for IPD-HAPO irradiation is scheduled for completion by month-end.

Pu-240 Studies. Ten samples of Pu-Al varying from 1 to 50 wt% Pu and ~8 to 27% Pu-240 were provided to Radiation Monitoring for purposes of developing exposure data on high Pu-240, high wt% Pu, alloys.

Boiling Burnout for the Advanced Test Reactor (ATR). In preparation for the boiling burnout experimentation for the ATR, tests were performed to determine the degree of simulation of the reactor hydraulic characteristics obtainable with the low pressure heat transfer apparatus. It is desirable to simulate the hydraulic characteristics of the ATR during the boiling burnout experimentation because it is anticipated that hydraulic instability will be a very important factor which could limit the maximum attainable heat flux.

In the ATR there are about 800 coolant channels through the core connected by large plenums at each end. Therefore, the hydraulic supply curve to individual flow channels will be essentially "flat." The most practical manner to simulate this type of supply characteristic with the heat transfer apparatus involved bypassing large amounts of coolant around the test section. Alterations to the apparatus to accomplish this have been performed.

The hydraulic experiments performed on the resulting modified piping system of the heat transfer apparatus demonstrated that an adequate simulation was accomplished over much of the range of test section flow rates anticipated. However, at very low flow rates (simulated operation during a power outage), the accuracy of the simulation was reduced somewhat. This was due, in part, to the influence of the special flow and temperature measuring instrumentation in the coolant supply passages on the pressure drop. The accuracy of simulation at these low flow rates cannot be determined conclusively until the test section demand characteristics are determined with heat generation in the test section.

Pressure and flow oscillations were also investigated during these preliminary tests. Various pressures and flow rates in

the system, and particularly in the test section, were measured continuously by means of semi-high-speed instrumentation. Similar pressure fluctuations as observed in most high flow rate piping systems were measured at most points in the apparatus. Observations were made regarding the adequacy of the proposed instrumentation system to respond to either the pressure fluctuations or average pressure as required.

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PHYSICS AND INSTRUMENTS LABORATORY

MONTHLY REPORT

SEPTEMBER 1964

FISSIONABLE MATERIALS - 02 PROGRAM

REACTOR

N-Reactor Lattice Parameter and Spectral Measurements at Startup

Document HW-84083, "Lattice Parameter and Spectral Index Measurements on the N-Reactor Lattice at Two Temperatures, Part I: Data," has been reproduced for distribution.

Coproduct Experiments for NPR

Experiments are being planned for the PCTR and exponential piles to measure the infinite medium multiplication factor k_∞, the conversion ratios of both driver tube and target rod, and the material buckling B_m^2 of coproduct elements. Additional experiments are planned to measure control strength in the lattice. Initial plans have been formulated for positioning of foils in the 1.95 w/o outer fuel tube. Outer tubes to complete the PCTR load are scheduled to be ready early in October. All target rods are on hand.

NPR Utilization Studies

The NPR Phase III (power only) fuel cycle analyses requested by NRD have been completed. This work, carried out in conjunction with NRD, covered the nuclear characteristics of UO_2 and ThO_2 fuels in the present NPR geometry. Previous work (by others) had indicated that minimum fuel costs would lie between 10,000 and 20,000 Mwd/t for the enriched UO_2, and around 30,000 Mwd/t for the U-235 enriched ThO_2. The present results tend to support these estimates.

Utilization of Plutonium Fuel

Calculations in support of the planned PCTR experiment on void and Doppler coefficients for I&E Pu-Al production reactor elements are continuing. A 1.0 w/o case has been added for both the L_x and H_x compositions. Past and present calculations make use of the ZODIAC code with the built-in TEMPEST and GAM codes for microscopic cross section averaging. An effort is now under way to make use of THERMOS to obtain improved parameters.

Instrumentation

The N Reactor subcritical monitor and fission counter preamplifier performed successfully during several startup tests. Minor transient noise problems are being resolved as the causes are determined. Circuit modifications are being made to the positioner motor control chassis to isolate wires in the signal conduits. These changes should materially reduce the noise problem. In addition, fabrication was continued on two more preamplifiers for use with the subcritical monitor system, and it was determined that portions of the main chassis circuitry should be modified further.

The shielding properties of a commercially available cask were reviewed to determine acceptability for use in cross-country shipments of irradiated N Reactor fuel elements. A letter was prepared summarizing the conclusions.

Data analysis was conducted regarding the irradiated fuel age monitoring technique following acquisition of considerable experimental measurement data. The technique, as developed and demonstrated in a series of tests, appears to be adequate for measuring the cooling "age" of irradiated, discharged fuel elements.

System Studies

An analog model of the N Reactor pressurizer was coupled with the primary flow and volume contraction models to study the effects of variable primary pump coastdown rate on pressurizer level. A noisy differentiating circuit made it difficult to couple the volume contraction model to the primary flow model; however, most of the required runs were completed.

Primary pump data were recorded from the primary pump controller at the N Reactor. Plots of the data show a change in system gain for higher primary flow rates, probably due to the governor positioner. Recorders were located in the system in order to obtain data when a scram occurs; however, no data have as yet been available.

Reliability calculations of the IPD Ball 3X system for the small reactors continued during the month. Redesign of the electrical part of the Ball 3X system of some reactors is being considered. The existing systems are being used as a standard against which to compare proposed systems based on an analysis of reliability and ability to handle special circumstances. Reliability analyses for D and K Reactors were calculated and documented (HW-83889). Reliability calculations on the electrical portion of a proposed Ball 3X safety circuit under study were also completed.

SEPARATIONS

Critical Experiments with Plutonium Solutions

Criticality measurements were continued for obtaining basic data for nuclear safety guidance in handling Pu solutions. The measurements were made with a 15.2 in. diameter thin-walled stainless steel sphere of 30.2 liter volume. The vessel was fully reflected with water. Criticality was obtained with Pu nitrate solutions having Pu concentrations in the range of 24-29 g/ℓ. The effect on criticality of the stainless steel vessel wall was also investigated; the thickness of the vessel wall was increased by adding thin stainless steel nesting shells to the sphere. Measured critical concentrations (and masses) for the water-reflected sphere when exactly full (30.2ℓ) are presented below:

Critical Values for 15.2 in. Sphere Reflected with Water

Stainless Steel Vessel Wall Thickness	Acid Molarity	Total Nitrate	Critical Pu Conc.	H/Pu Atomic Ratio	Critical* Mass
47 mils	0.52	58.2 g/ℓ	24.4 g/ℓ	1062	0.74 kg Pu
127 mils	0.54	59.5 g/ℓ	25.2 g/ℓ	1028	0.76 kg Pu

* Includes 4.6 wt% Pu^{240}.

Gold foil irradiations were made for determining the extrapolation length (and buckling) of the water-reflected sphere. A series of irradiations with gold and copper foils, shielded with boron solutions of different concentrations, were completed for determining the neutron energy spectrum within the critical sphere. The latter information is needed to help facilitate the correlation of theoretical methods with experiment.

Subcritical Experiments with Enriched N-Fuels for Nuclear Safety Guidance

A series of exponential and neutron multiplication measurements were begun with 1.25 wt% U^{235} enriched tubular fuel elements (2.4 in. o.d., 1.8 in. i.d.) in light water. This work, which is being performed in the 326 Building, will provide needed data for nuclear safety guidance in processing and storing enriched N reactor fuels. In addition to the buckling values obtained from the exponential measurements, and the critical masses estimated from neutron multiplication curves, pulsed neutron source experiments are also being performed that provide data on the prompt critical number of fuel tubes in the lattices together with

information on the neutron lifetime and k_{eff}.

Each fuel column of the cylindrical array was 52 in. in length, being comprised of two zirconium clad fuel elements. A hexagonal loading pattern is being used for the lattices; the lattice cell is an equilateral triangle with equal distance between adjacent rods. The spacing for the first lattice was 2.8 in. (H_2O/U volume ratio of 2.5) which gives near optimum moderation for these fuel elements.

Preliminary results of the measurements on the 2.8 in. lattice are presented below.

Subcritical Experiments with 1.25 wt% Enriched Uranium Tubes
(2.4 in. o.d., 1.8 in. i.d.)

Lattice Spacing	H_2O/U Volume Ratio	Material Buckling	Measured Extrapolation Length	Computed Critical No. of 52 in. Tubes from Buckling	Estimated Critical No. of 52 in. Tubes from Neutron Multiplication
2.8 in.	2.53	4620×10^{-6} cm^{-2}	7.8 cm	62.6	63±2

Prompt Critical No. of 52 in. Tubes from Pulsed Neutron Source Experiment	Computed Critical No. of Tubes (Fuel Elements) for Cylinder Height of 26 in.
66.7±1	88 ($\sim$ 2870 lbs. U)

The critical number of tubes as computed from the measured buckling, and as estimated from the critical approach (the assembly contained $\sim$ 0.75 of critical number of tubes) are in good agreement with one another. The difference between delayed and prompt criticality is about four tubes. The measurements also predict that only 88 of the 26-in. fuel elements could be made critical at this spacing. From the viewpoint of nuclear safety and criticality in water, the 1.25 wt% enriched 26-in. fuel element is perhaps the worst length possible, for in this case, criticality is obtained in a cylindrical array with the height-to-diameter of the cylinder being near unity.

Further experiments will be performed at other lattice spacings with these tubes, and also with tube-in-tube assemblies.

Pulsed Neutron Source Experiments

Pulsed neutron source experiments were performed for determining the prompt neutron lifetime in the Pu solution of a critical 15.2-in. diameter water-reflected sphere. The measured lifetime in the 30.2 sphere was 39 μ sec for a Pu nitrate solution containing 24.4 g Pu/ℓ (H/Pu atomic ratio of 1062) and 58.2 g NO_3/ℓ.

Pulsed neutron source experiments were also made in conjunction with exponential and neutron multiplication measurements on a lattice of 1.25 wt% enriched uranium tubes (2.4 in. o.d., 1.8 in. i.d.) in light water. For a lattice spacing of 2.8 in. (H_2O/U volume ratio of 2.5) the neutron lifetime in the cylindrical assembly of 52-in. length was estimated to be ~37 μ sec at delayed criticality. The H/U^{235} atomic ratio of the lattice was 283.

GAMTEC Cross Section and Lattice Parameter Code

A number of changes have been made in the GAMTEC cross section and lattice parameter code since it was placed on the SPL library tape about a year ago. The input format has been changed to the so-called "Listin Method" and the cross sections have been put on one magnetic tape to minimize tape handling. The fast effect is now determined by n-flight collision probabilities instead of first flight. An error was also found in the old code and corrected. The new version of the code is now on the SPL library tape and may be used under the name "GAMTEC2."

SMC, A Monte Carlo Code for Spherical Geometry

One of the bare Pu solution critical assemblies (a 15.2 in. sphere of 30.2ℓ volume) is being analyzed by Monte Carlo techniques. The critical concentration of Pu in the 15.2 sphere under analysis was 39.0 g/ℓ, including the 4.6 wt% Pu^{240} present in the Pu. The H/Pu atomic ratio was 661.7. The stainless steel vessel was assumed to have an average wall thickness of .047 in. Four thousand neutron histories were traced in the Monte Carlo calculations; the results are presented below.

Monte Carlo Calculations for 15.2 in. Bare Pu Solution Sphere

Material	No. of Epithermal Absorptions (Above 0.68 eV)	No. of Epithermal Fissions (above 0.68 eV)	No. of Thermal Absorptions (below 0.68 eV)	No. of Thermal Fissions (below 0.68 eV)
Pu^{239}	96.18	57.16	1957.7	1337.1
Pu^{240}	54.00	0.19	21.9	
H	15.96		340.7	
O	15.29		0.02	
N	1.10		17.0	
Stainless Steel	0.59		5.3	
Total	183.12	57.35	2342.6	1337.1

Epithermal Neutron Lifetime (above 0.68 eV)	Epithermal Neutron Leakage (above 0.68 eV)	Thermal Neutron Lifetime (below 0.68 eV)	Thermal Neutron Leakage (below 0.68 eV)
0.826 μsec	1330.9	17.58 μsec	135.5

$$k_{eff} = 1.007 \pm .038$$

To be in agreement with experiment, the computed value of k_{eff} should be unity, and within the uncertainty of the Monte Carlo calculation this is so. It is apparent, however, that additional neutron histories must be traced in order to reduce the statistical errors involved.

Consulting Services on Nuclear Safety--Criticality Hazards

1. Nuclear Safety in HL

New nuclear safety specifications and changes in existing specifications were reviewed as follows:

a) Temporary Specification No. 5 for Technical Shops Operation, covering 1.95 wt% U^{235} enriched uranium N fuel, was revised.

b) Specification C-16 for Critical Mass Physics, covering subcritical exponential experiments with slightly enriched uranium metal in light water, was issued.

c) Specification C-17 for Critical Mass Physics, covering the handling of NRD fuel pieces in 326 Building, was issued.

d) Specification K-8 for PRTR, covering EBWR fuel elements, was revised.

e) Specification S-2 for Testing Methods Engineering, covering Pu-Al alloy fuel elements, was issued.

2. Nuclear Safety in Shipment of Fissionable Materials

A Class I shipment of 37 lbs. of 0.95 wt% U^{235} enriched uranium metal was reviewed and approved.

Three Class I HL-designed shipping containers have been received for testing purposes. Class I shipping containers are unique in that the material in their construction prevents neutron interaction with other units, and isolates the fissile material within each container. Thus, there is no limit on number of containers for criticality reasons. These special containers have received Bureau of Explosives approval for use in shipment of fissile material.

Critical Mass Laboratory Instrumentation

Improvements in nuclear safety have been obtained at the Critical Mass Laboratory through a simple procedure now being used to routinely measure the time response of the control and safety rods. The measurement gives added assurance of reliable operation of the safety and control rod system. (The scram time of the safety rod now being routinely measured during each pre-startup check is about 0.2 sec.)

The major components of the noise analysis system for the Pu Critical Mass Laboratory have been received. Forty channels of Twin-T filters and smoothing networks and associated amplifiers are being installed in the control room. The installation of the noise analysis system is 75% complete.

Separations Instrumentation and System Studies

A counting system which measures the Pu-239 concentration in liquid samples by monitoring emitted 17 KeV X-rays has been tested and calibrated in the laboratory, and delivered to 234-5 Building for routine, field use.

METALLURGY - Nondestructive Testing

N Fuels Testing

1. Fuel Element Testing - End Closure

A test to measure end cap thickness is required by N Fuels to monitor a potentially faulty manufacturing process. Following encouraging feasibility studies, a prototype ultrasonic test station was installed in the 333 Building for use by Quality Control Engineering. Details of the testing technique were reported last month. Basically the test utilizes existing production equipment in conjunction with an oscilloscope readout. Since initial installation, Quality Control Engineering has successfully inspected a group of more than 800 end caps, and found the entire group to be within specified manufacturing tolerances. A proposal to build a production unit with automatic readout is being drafted and will be submitted to N Fuels upon completion.

2. Clad Thinning Test

Development is continuing on an ultrasonic test to detect clad thinning over the brazed regions of N Reactor fuels. Two 1-megacycle transducers were fabricated to study the response of 1-megacycle boundary energy to clad thickness changes. Results are thus far encouraging, and a probe is being constructed to enable testing of the cap clad region on an inner tube fuel. The depth of penetration of 1-megacycle boundary energy in Zircaloy is estimated to be about 0.140 in., which is considered adequate to detect changes in nominal clad thickness.

3. Bond Test - Target Elements

A prototype ultrasonic test for detecting the bond quality of lithium-aluminum target elements has been incorporated into one of the N Fuels testing stations. A test group of target elements have been inspected, and the tester results are being compared with destructive test data. The test group consisted of samples having both bonded and unbonded regions and an encouraging correlation between the ultrasonic and destructive tests was noted. Evaluation of the effectiveness of this test is temporarily postponed pending a better definition of bond condition by N Fuels Engineering. Since bonding is the undesirable condition in this case, conventional circuitry has been conveniently employed to monitor the absence of a return echo at the unbonded region. Further correlation with destructive test data is planned to substantiate these preliminary results.

4. Braze Contamination Test

A prototype X-ray fluorescence tester (NT-2) has been installed in the 333 Building and is being evaluated as an advanced inspection method for detecting small amounts of uranium contamination at the end cap braze areas. This inspection is presently being accomplished by autoradiographic and alpha counting techniques, both of which leave much to be desired in terms of production rate and unit cost. The X-ray fluorescence unit shows good promise of improvement in both of these areas, and early indications are that increased sensitivity may also be realized.

Production usage of this unit was reduced this month as a result of a failure of some critical components for which replacement parts were not immediately available. Spares for these critical parts have been ordered. A maintenance manual for this system has been ordered, and additional standards are being developed in conjunction with N Fuels personnel.

5. Surface Contamination Test

An improved system to detect uranium contamination on finished fuel surfaces is presently being designed. Fabrication of this unit is expected to commence upon completion of the detailed design drawings of the mechanical portions. The electronic portions of this unit have been designed and fabricated and are presently undergoing lab checkout.

6. Enrichment Test

A Hanford-developed tester which monitors the percentage enrichment of as-received uranium billets has been in use for some time by N Fuels Quality Control. Now that this unit has been accepted as a production line quality control tool, data are being accumulated in preparation for writing a complete operating and maintenance manual.

7. Irradiated Fuel Test

Design of the mechanical portions of the remotely operated, irradiated fuel, testing station (UT-10B), for use in the 105-N fuels examination basin, has been completed. A new control panel for this unit has also been designed. Recent funding problems have necessitated curtailment of all fabrication and development work on this project.

Development efforts on this project during the past month have been primarily directed towards upgrading the electronic portions of the system for use in the 105-N storage basin. Items requiring attention included test frequency evaluations, establishment of appropriate amplifier band widths, loading problems resulting from longer cable lengths, and relocation of various adjustments to facilitate setup and maintenance procedures. As a result of this effort, complete interchangeability has been attained between the bond tester, the core tester, and an auxiliary chassis.

Upon receipt of recently revised requirements for a proposed cladding thickness tester from N Reactor personnel, a proposal letter describing an eddy current clad thickness tester has been submitted. As a result of changes in required tester capability and versatility, the current proposal represents a cost reduction of some $8,100 in development effort required to meet the revised test requirements.

N Reactor Testing - Dump Condenser

The final draft of a testing report describing an eddy current test which was employed to assess the integrity of tubing in the N Reactor dump condensers, has been prepared and documented (HW-83899).

AlSi Fuels Testing

At the request of IPD a prototype eddy current sector gage which measures the wall thickness of reactor process tubes was evaluated. Results were documented with recommendations for obtaining improved performance of the instrument.

NEUTRON CROSS SECTION PROGRAM

Triple-Axis Spectrometer

The operation of the spectrometer was very limited during the month due to reactor operations and the use of the spectrometer to align monochromating crystals for the time-of-flight spectrometer. A study is again under way to determine the efficiency of the analyzing spectrometer in order to obtain improved accuracy in absolute values of differential scattering cross sections.

Time-of-Flight Spectroscopy for Slow Neutrons

Analysis was continued on the operating characteristics of the TOF spectrometer from the test runs made in August. During September the spectrometer was not available due to reactor operations and a number of improvements

and modifications were made to the spectrometer during this period. These included cadmium lining the interior of the scattering chamber, installation of the two new transmission-type beam monitors which arrived during the month, and miscellaneous improvements to the spectrometer and scattering chamber shielding. A copper monochromator was aligned in a rotor and preliminary measurements indicate that this crystal will substantially improve the time and energy resolution figures obtained with the first aluminum crystal. A new slit system was designed for the mechanical chopper for use with the copper crystal and fabrication of the system is nearly complete.

Fast-Neutron Cross Sections

A series of 3- to 15-MeV total cross section measurements was completed during the month. Prior to the measurements the new transistorized side-channel instrumentation was put into service. Development done on the neutron detector time resolution resulted in the restoration of the best resolution previously achieved on this system. A drastically curtailed series of measurements was finally completed following several malfunctions of the neutron detector, a failure of the 400 channel analyzer and the separate replacements of a charging belt and ion source for the Van de Graaff. Most of the measurements made were unique in some respect. Two measurements were made on each of the separated isotopes Ca^{44}, W^{182}, and W^{186}. A first measurement was made on Ca^{42} and Cr^{53} was measured for a second determination at Hanford. None of these separated isotopes have been previously measured elsewhere. In addition, the total cross section of platinum was measured for the first time at Hanford. The PDP-5 computer of the mass spectrometer laboratory was used to correct some punched paper tape output for which one channel of the tape punch was not operating.

REACTOR DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

PuO_2-UO_2 Graphite Lattice Studies

Experiments have begun which will yield data on graphite-moderated, air-cooled lattices fueled with clusters of nineteen PuO_2-UO_2 fuel rods. The rods are 0.5" in diameter and clad in zirconium. The PCTR will be used to determine the mass of copper required to poison the unit cell such that its neutron multiplication factor is unity, and radioactivant foils with selected absorption characteristics will be activated in the lattice.

Critical Experiments with Pu-Al Fuel

The PRCF was loaded to critical with 1.8 w/o Pu-Al fuel and H_2O moderator. The fuel rods are 0.500" in diameter and 44" long and are clad in 0.030" thick Zircaloy-2. The rods were divided into three groups according to their Pu-240 content, the three groups containing 5.0, 5.5, and 6.0 a/o Pu-240. In order to minimize the number of fuel rods needed for a critical loading, a three-zone loading was used. The fuel rods with the lowest Pu-240 content were placed in regions of highest fuel element worth, and those with the highest Pu-240 content were placed in regions of lowest fuel element worth. With such a loading the reactor is critical with 486.3 fuel rods. This is 24 rods less than the number arrived at in an approach-to-critical experiment when the rods were loaded randomly (i.e., not in zones). After reaching criticality, a calibrated BF_3 chamber was placed in the center of the reactor and a power calibration was performed.

Hafnium Rods

Several rods, containing from 0 to 50 volume percent hafnium, are being fabricated. The first of these is now ready for inspection. These rods will be used to investigate the effectiveness of hafnium as a control rod material in various plutonium cores.

Kinetics of Plutonium-Fueled Cores

The analysis of the data from the poison injection experiments for the two-zone D_2O core and the EBWR H_2O core indicates that the ratio β/ℓ will agree with the same ratio obtained from the noise analysis by taking the average slope of the prompt neutron decay and that of the shortest lived delayed group weighted by their respective flux magnitudes at zero time. The product of this averaged slope and the magnitude of the remaining delayed groups at zero time is the ratio β/ℓ.

Thus, in the equation

$$\phi/\phi_o = \frac{\beta}{\beta-\rho} e^{\frac{\lambda\rho}{\beta-\rho} t} - \frac{\rho}{\beta-\rho} e^{-\frac{\beta-\rho}{\ell} t}$$

given in Glasstone and Edlund, "Elements of Nuclear Reactor Theory," $\frac{\beta-\rho}{\ell}$ is the weighted average slope of the prompt neutron decay and that of the shortest lived delay neutron group. $\frac{\beta}{\beta-\rho}$ is the intercept of the delayed neutron decay at zero time.

Therefore,

$$\frac{\beta}{\ell} = \frac{\beta-\rho}{\ell} \cdot \frac{\beta}{\beta-\rho} .$$

The relationship between the prompt neutrons and the shortest lived delayed neutrons is not constant between different core configurations.

Code Development

1. RBU

Volumes II and III of the scheduled three volume RBU publication are completed. A limited number of pre-publication proofs have been prepared (these do not contain the Monte Carlo flow diagrams which are yet to be photographed) to supply internal needs. A substantial portion of Volume I has been assembled. This portion represents an estimated 20% of the total effort needed for completion of that volume.

2. Program TEMPEST

An error was found in the coding of the BINRD subroutine in the section that writes error messages to tape. The error was introduced during conversion for use at this site. The corrected binary deck is available for use.

3. FTRANS

FTRANS is an IBM 7090 subroutine for calculating Fourier transforms by numerically integrating over half-cycles of the sine or cosine and using the Wijngaarden transformation to accelerate convergence. An informal document describing this program and its theoretical basis is being prepared.

4. The Scotsman

The Scotsman is an IBM 7090 program for optimizing a polynomial fit to a known function at a specified level of accuracy. The optimization is achieved by expanding the function in Tschebyscheff polynomials.

5. SINH

SINH, an IBM 7090 subroutine, for calculating the hyperbolic sine has been developed by this technique. An informal document describing the Scotsman and the use of Tschebyscheff polynomials is being prepared.

6. Two-Dimensional Multi-Energy Transport Codes

Two multi-group transport codes (DTK and DDK) have been obtained from LASL. DTK handles slab, cylindrical, or spherical geometries with one spatial dimension (z for slab; r for cylinder and sphere). DDK has the same geometric flexibility; however, it handles problems with two spatial dimensions (x,y for slab; r,z for cylinder, r,θ for sphere). Both are capable of dealing with non-isotropic scattering. One test case (supplied with the package) has been run successfully. Other tests are currently being run to determine the reliability of the program.

7. ZUT

The General Atomic code, ZUT, which calculates resonance integrals from parameters for resolved resonances, has been adapted to the HAPO 7090, and a test case has been successfully run. In addition to the customary infinite mass (IM) and narrow resonance (NR) approximations available in GAM and HRG, ZUT optionally finds resonance integrals from direct numerical integration of the collision density in the vicinity of the resonances. The companion code, TUZ, which calculates unresolved resonance contributions, has not yet been adapted.

Modified 710 Reactor Study

A reactor physics investigation of the feasibility of using either Pu-239 or U-233 fuel in a 710-type cermet reactor has been started. Pu or U-233 fuel may be advantageous for this reactor because it offers the possibility of smaller critical size for a given core life, or a longer core life for a given reactor size. Extensive reactor statics calculations are being prepared.

Isotopic Analyses of PRTR Samples

Isotopic analyses were performed on 34 samples of PRTR-irradiated fuel elements. Of these 6 were plutonium and 9 were uranium burnup samples from PuO_2-UO_2 fuel element number 5187, 10 were plutonium microdrill samples from Al-Ni-Pu element number 5103, and 9 samples were reruns from UO_2 elements numbers 1006, 1041, and 1101.

Instrumentation and System Studies

Laboratory experiments were conducted using a collimated, lead-shielded, solid state diode detector to delineate the migration of plutonium in sections of experimental fuel elements. The detector was counted on a

machine-type dividing head to permit controlled movement and accurate positioning. A 60-micron depletion depth detector was used and collimation was achieved using a square hole, 0.040 inches per side. One fuel element section was partially mapped using 0.1 inch intervals, and some 300 data points were obtained. Data reduction was initiated.

A number of instruments were received for incorporation in the PRTR experimental fuel element rupture loop system. One complete counting channel was obtained for use with the GM tube detectors, along with new flow control valves and other items. Delivery is expected soon on the remote recorder for use in the PRTR control room.

Preparations continued for the forthcoming test of the PRTR automatic controller in the startup and period modes of automatic control. It is planned to use telephone lines between the PRTR control room and the 3707-C Building in order to operate the controller and moderator system using an analog simulation of the reactor kinetics. The wide dynamic range required in reactor power for the tests require that one of the large general purpose analog computers be used rather than a portable computer as was used in a previous test in the power range. Sufficient fuel will be removed from the reactor to insure that criticality will not be reached when the moderator level is at maximum height. A logrithmic analog simulation was prepared and given preliminary tests with good results.

PHOENIX FUEL PROGRAM

MTR H_x-Pu Fueling Proposal

Work on the MTR H_x Pu-Fueling Proposal is continuing. The initial reactor physics survey calculations were started on Pu-Zr cores. Additional information on Pu-Al cores has been obtained since then. The purpose of the survey calculations is to obtain initial reactivities for a wide range of reactor compositions and sizes.

Core widths were varied from 9" to 15", core M/W's from .5 to 2.0, and fuel concentrations from .03 to .60 kg/ℓ of core. Four Pu composites were considered as follows:

Type	w/o Pu-239	w/o Pu-240	w/o Pu-241	w/o Pu-242
1	67.25	27.00	4.75	1.00
2	75.80	20.45	3.40	.35
3	85.15	13.10	1.65	.10
4	95.6	4.3	--	--

In the initial calculations, the cores were completely homogenized. This situation corresponds to "very thin" fuel plates.*

Initial reactivity values and initial power distribution data are now available from these calculations. The high power peaks at the core edge can probably be reduced by fuel zoning. Peak-to-average values along the reactor length are estimated at 1.19 (using a "chopped" cosine distribution). For the 23.5" MTR core height the axial $P/\overline{P}$ is estimated at 1.31 (also based on a chopped cosine distribution). This power factor is expected to rise, when realistic control rod positioning is taken into account.

For the initial burnup calculations, the 15", 0.20 kg/ℓ core with M/W of 1, 1.5, and 2.0 was chosen. These three reactors were selected because they have an initial k_{eff} near 1.1, which is representative of the early (1958) MTR Pu core. Results of the "thin plate" burnup calculations for these three cores are available. Endurances of the order of 3000 to 10,000 EFPH seem possible.

It is now planned to extend the burnup calculations to a wider range of core sizes, fuel loadings, and more realistic fuel element geometries. The possibility of including burnable poisons will also be considered.

MTR Plutonium Loading Analysis

Detailed analysis of MTR cycle 108 (L_x-Pu loading) has been carried further during this reporting period. Comparison of some computed results with those obtained experimentally have been augmented by the inclusion of time dependent xenon and samarium effects during burnup (including power changes). Serious difficulties remain in the estimation of worth of zenon to first saturation in the MTR. This is complicated by the large fraction of the core which is influenced by shim rod shadowing and shadowing changes shortly after startup to power.

Pu-Al Light Water Experiments in the PCTR

The first of a series of polyethylene-moderated experiments has been completed using U-235 in aluminum fuel. Data reduction and analysis is in progress. The objectives of this experiment are to check procedures and results using U-235 prior to beginning the plutonium-fueled experiments. The principal experimental determinations were: The spatial variation of

* This correspondence is only approximate due to the inexact Pu-240 treatment in the GAM calculation.

Cd ratios for Au, Mn, and BF_3; the critical boron concentration for H/U-235 $\cong$ 240 (atom/atom); and the variation of Cd ratios with boron concentration. When $k_\infty = 1$, it was found that: B/U-235 $\cong$ 0.55 (atom/atom); Cd ratio (Au) $\cong$ 1.6; Cd ratio (Mn) $\cong$ 5; and Cd ratio (BF_3) $\cong$ 9.

More accurate values await detailed analysis. The value of B/U-235 predicted by theory differs from the above value by less than 5%.

An order has been placed for 10,000 borated polyethylene disks. These disks, which contain 1.0 w/o boron, will be available for plastic-moderated U-Al and Pu-Al experiments after the middle of November, 1964.

Zirconium Hydride Studies

The zirconium hydride study has been completed and a terminal report has been prepared on the results. The original objective of the study was completed in that a successful computer scheme has been developed for the calculation of prompt temperature coefficients in a reactor core model containing zirconium hydride as a moderator. Since estimates of the TRIGA reactor temperature coefficient were available, this core was selected as a test case for verification of the technique. The agreement with the accepted value of the coefficient is excellent based on a limited number of calculated points.

Using the TRIGA core model, two sets of calculations were made. In one case, the hydrogen in the water and the zirconium hydride were treated with a water kernel. In the second case, they were treated using the newly developed zirconium hydride kernel. For the particular case studied, the selection of one kernel or the other for a given case appeared to make an insignificant change in the final temperature coefficient values. Further examination of the problem will be necessary to determine whether or not this is true for zirconium hydride cores containing no water moderator.

Reactivity Effects of Transplutonium Isotopes

Some difficulties in updating the TEMPEST library of the ZODIAC code have delayed the progress of this study. It is believed these difficulties will soon be resolved. The first case to evaluate the effects of Am-241, Am-242, and Am-243 has been submitted for one time step. If this is successful, the burnup calculations will be expanded to eight time steps.

EBWR PROGRAM

EBWR Calculations

The calculations of the temperature, void, and boron coefficients of re-

activity reported last month for the EBWR core have been repeated using HRG in place of GAM-I. The results show essentially the same coefficients (e.g., $\Delta k_{eff}/^{o}C$) with a renormalization in the absolute value of k_{eff} of approximately +1%.

Resonance Integral Calculations

Calculations of the effective resonance integrals for UO_2 rods have been performed using HRG with comparisons made to experiment. The evaluation covered a range of rod sizes and fuel temperatures. Agreement with experimental values (Hellstrand) is approximately 2% throughout the range of temperatures and S/M values. This uncertainty in the effective resonance integrals may lead to an uncertainty in calculated Doppler coefficients of roughly 20%. The results are tabulated below:

Resonance Integrals for UO_2 Rods

Rod Radius (cm)	Resonance Integrals (I_{eff}, barns) 300°K Calc.	300°K Exp.	600°K Calc.	600°K Exp.	900°K Calc.	900°K Exp.	1200°K Calc.	1200°K Exp.	1500°K Calc.	1500°K Exp.
0.250	27.41	27.95	29.24	29.71	30.67	31.47	31.84	32.96	32.91	34.27
0.500	20.62	21.10	21.80	22.13	22.71	23.29	23.44	24.27	24.12	25.12
1.0	15.39	16.23	16.14	16.28	16.70	16.97	17.14	17.55	17.55	18.06
2.0	12.06	12.79	12.60	12.65	12.99	13.11	13.29	13.50	13.56	13.84

HIGH TEMPERATURE REACTOR PHYSICS PROGRAM

The construction of the prototype testing mockup of the HTLTR has been completed. It is essentially a furnace with a central 2' x 2' x 10' core of graphite surrounded by about 2' of insulating brick. Both core and insulation are enclosed in a steel shell strong enough to be evacuated. The graphite is traversed longitudinally by many holes into which prototype components can be inserted. Heat is supplied electrically by four graphite heater rods which match those presently designed for the HTLTR. The general plan of the work to be done with the mockup has been outlined. It will take four to five months to perform. In an initial run the system will be cleaned of contaminant and corrosive gases and the heaters and thermocouples tested at high temperature. In a second run the control and safety rod prototypes will be inserted. In a third run the differential expansion of parts of the control rod and the frictional forces to be encountered by the oscillators when moving hot sections of graphite will be investigated. Preparations for the initial run have been completed. Ceramic and metal samples have been placed at several locations in the mockup and will be examined at the end of the run. A device is being built for inserting other

material samples during the course of the high temperature portion of the run.

The environmental testing of ceramic materials in small heated capsules is also proceeding and has been extended to include some measurements of their mechanical strengths. Equipment is available for strength measurements at temperatures up to 960°C.

A series of criticality calculations has been started for a few typical configurations of the HTLTR. Calculations done in the past will be extended to other core sizes and driver fuel geometries. The information will be used in the preparation of the final safeguards analysis, in driver fuel development, and in planning experiments.

Final results on the outgassing tests of Tipersul and Fibrefrax show that although the corrosive components are about the same, the amount of gas evolved by Fibrefrax is about one-tenth that of Tipersul. Fibrefrax has, therefore, been recommended as a replacement for diatomaceous earth in the HTLTR. The details of this work have been reported in HW-83837.

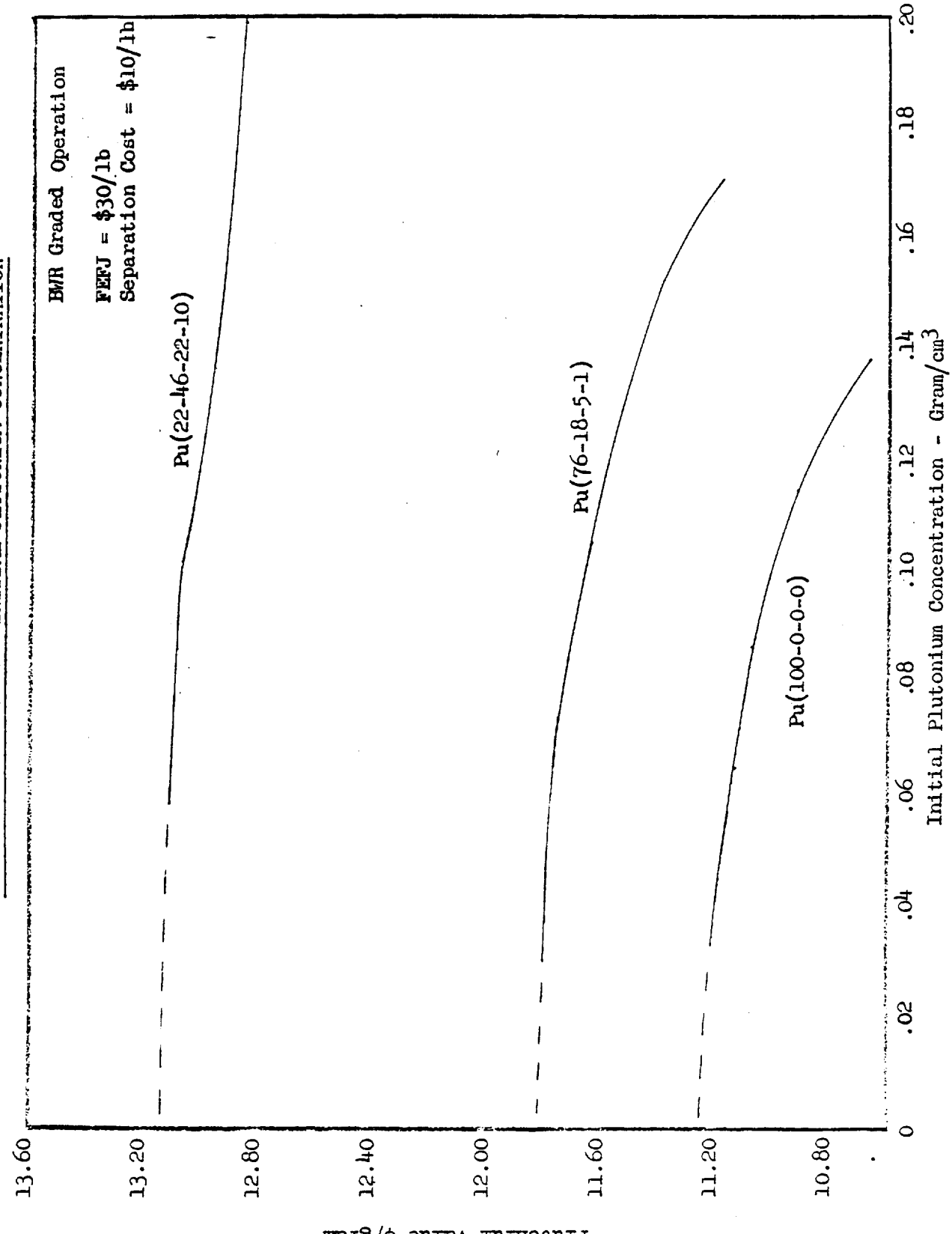
FUEL CYCLE ANALYSIS PROGRAM

Plutonium Values as a Function of Concentration

A study is being made to determine the value of plutonium at various concentrations. Three plutonium compositions have been examined: (1) A somewhat academic case where the plutonium is 100% Pu^{239}; Pu(100-0-0-0), (2) a case using an isotopic composition representing plutonium after 15,000 Mwd/ton; Pu(76-18-5-1), and (3) a case representing second or third recycle of plutonium; Pu(22-46-22-10). The reactor chosen for this study was a simulated boiling water (BWR) with graded fuel management.

Figure 1 shows partial results of this study. For each composition the value declines as the concentration increases. This is caused by two effects; (1) As more plutonium is incrementally added, it replaces uranium of lower enrichment, thus, lower priced, which by comparison yields a lower plutonium value, and (2) a higher plutonium concentration causes a shift in the neutron spectrum to higher energies which is no longer optimum, thus reducing the value. Figure 2 shows the minimum fuel cost for the same range of concentration. The curves in both figures are extrapolated at very low concentration because the effect of very small quantities of plutonium are difficult to determine. But, with some small adjustments to the computing system, the data will soon be available.

PLUTONIUM VALUE VERSUS INITIAL PLUTONIUM CONCENTRATION



FIGURE

1229659

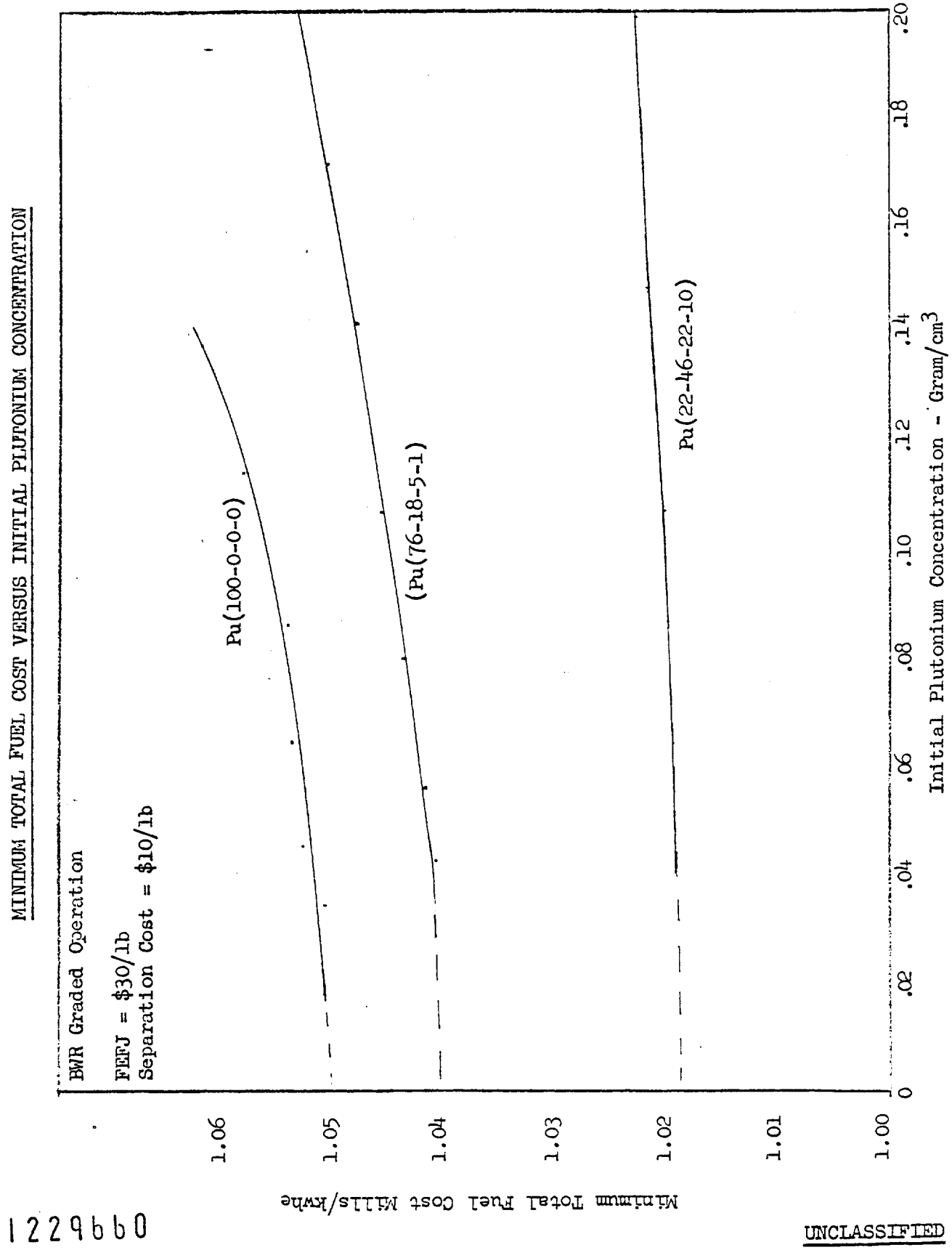


FIGURE 2

Seed-Blanket Studies

A major problem in the design of seed-blanket reactors is the high heat generation rate in the seed. Several preliminary calculations were made to illustrate the influence of "spectral-shift" reactivity control on power sharing between seed and blanket. The cell composition chosen was 30% fuel, 10% zirconium, and 60% moderator. Thus, if the moderator is light water, the neutron spectrum is rather well thermalized; but, if it is heavy water, the neutron spectrum is predominantly epithermal. For these calculations, the blanket was divided into two zones--the outer zone was always moderated with the same mixture of light and heavy water used in the seed as dictated by the reactivity calculation. Early in the life of the seed, most of the thermalization occurs in the outer blanket and the thermal neutrons must diffuse through the inner blanket before they can be absorbed in the seed. Late in the life of the seed after much of the fissile material has been burned, the thermal flux is comparable to, or higher than the flux in the blanket; thus, maintaining the power generation rate in the seed and consuming the plutonium formed in the inner blanket. Figure 3 presents the heat generation rate comparisons for a seed-blanket case using movable seed control and one using spectral shift control. Neither represents an optimized design. Comparative fuel cycle costs are presented in Table I. Costs due to loss or degrading of D_2O are not included.

TABLE I

SEED-BLANKET FUEL COSTS

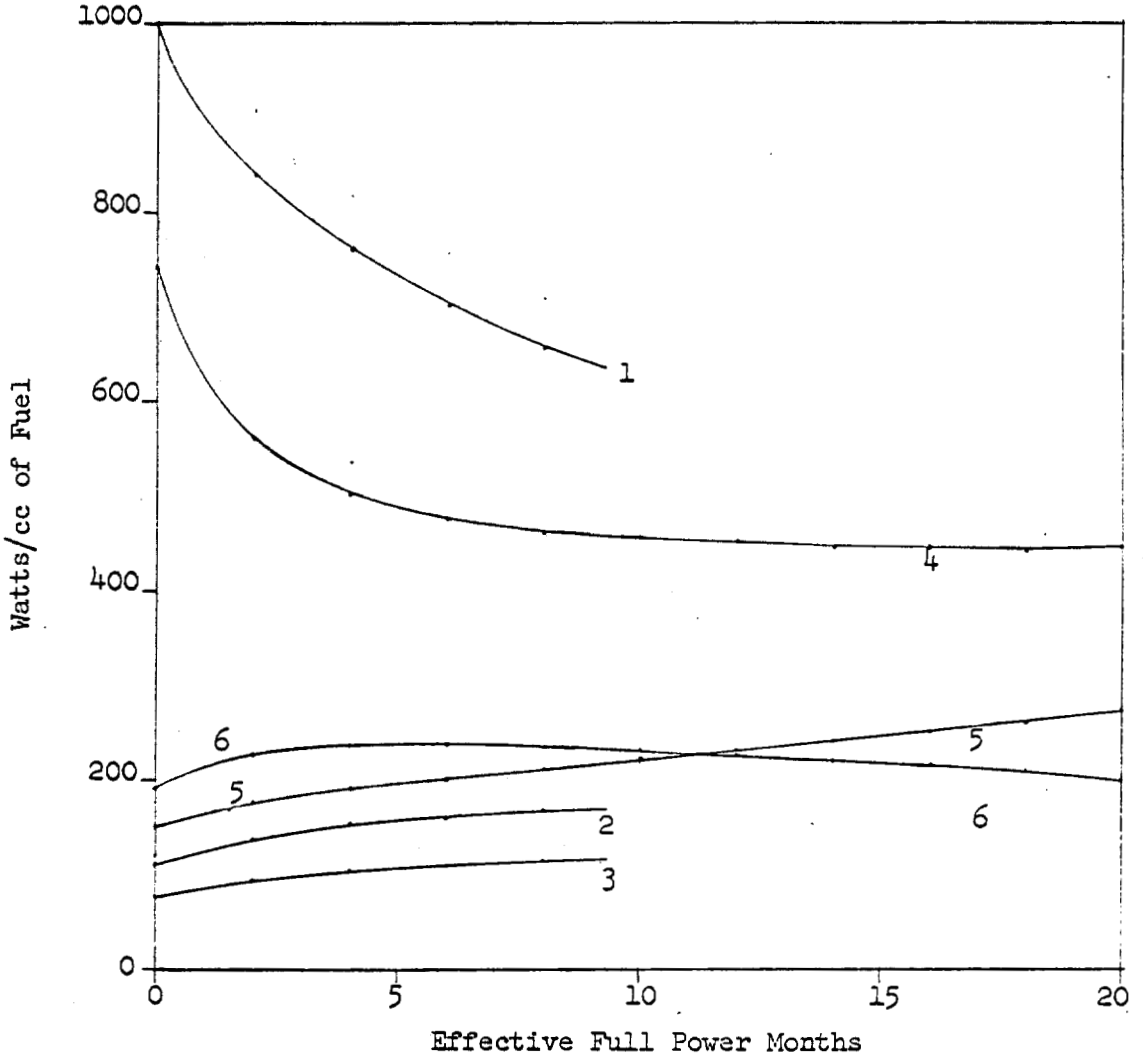
Control Type	Volume Seed	Blanket Power	Cost*	Optimum Number Seeds Per Blanket
Movable seed	15%	46%	1.42 Mills/kwh$_e$	8
Movable seed	20%	43%	1.36 Mills/kwh$_e$	6
Spectral shift	15%	67%	.98 Mills/kwh$_e$	4
Spectral shift	20%	64%	.92 Mills/kwh$_e$	4

* Cost based on \$0.80/cc fuel fabrication cost, plutonium at \$10/gram fissile (50% Pu^{239}, 25% Pu^{240}, 15% Pu^{241}, and 10% Pu^{242}), and uranium at \$23.50/kg.

VESTA - Fuel Utilization Studies

The VESTA fuel utilization code is nearly debugged. This code calculates the electrical generating capacity installed, the electricity generated, and the fuel used by up to seven reactor types as a function of time for projected future economies. Introduction of breeder reactors at various

COMPARISON OF SEED-BLANKET HEAT GENERATION RATES



Legend

1 Seed, movable seed control
2 Inner blanket, movable seed control
3 Outer blanket, movable seed control
4 Seed, spectral shift control
5 Inner blanket, spectral shift control
6 Outer blanket, spectral shift control

FIGURE 3

time and rates can be calculated for these projections and the effect on fuel utilization, or resource conservation, observed. Breeder introduction may be limited by the amount of plutonium available to provide inventories, which in turn is affected by the value of plutonium for recycle in existing thermal reactors.

Simulations of the characteristics of reactors operating in the expected range of plutonium-uranium-fuel composition is nearly complete for the BWR, PWR, and a sodium-cooled plutonium-fueled fast breeder. Work is continuing on advanced converter reactors.

Code Development

QUICK Economics Code

A new table that tabulates the fixed and variable portion of the fabrication and separation fuel charges has been added to the economic summary that the QUICK code writes. This table is written only when a fixed operation cost, in dollars per year, is entered for a fabrication or separations plant.

This mode of operation of the QUICK code is particularly suited to the situation where the fuel element fabrication and separations plant are an integral part of the reactor operation, such as, at Hanford. That is, the fabrications and separations plants are in existence, and fixed operation costs for these plants are available for a given type of fuel and jacketing. Thus, a more realistic value for the fabrication and separations portion of the fuel cost is available than under the normal method of operation.

Indifference Values Code

A new program to compute plutonium indifference values called DAPPER, has been written. Input information includes assigned plutonium prices and minimum total fuel costs are computed by the QUICK economics code. For each assigned plutonium price, DAPPER subtracts the minimum total fuel cost of a plutonium cycle from that of a uranium-only cycle, and curve-fits the differences with a cubic equation. Each of the three roots of the cubic equation are computed so that it can be determined which of the roots is the proper plutonium value. The DAPPER code has been debugged and is presently yielding useful plutonium values.

NEUTRON FLUX MONITOR PROGRAM

One of two U-234 neutron flux detecting regenerating ion chambers being fabricated offsite to Hanford specifications has been received. Delivery

of the other unit is being delayed due to flaking of the U-234 coating. The received chamber is being prepared for in-core tests at KW Reactor.

Final fabrication was completed on one B-11 beta current neutron flux monitor chamber and cable assembly. Extensive vacuum pumping was required to achieve the very high resistance necessary for operation of the assembly. A series of resistance and capacitance measurements were completed to assure that a successful in-core experiment can be conducted. Difficulties were encountered in the assembly from galling of the aluminum portions of the spacers and water jacket, and it appears that a new water jacket tube of slightly larger inside diameter will be required. The assembled cables will be radiographed to check center wire dimensions. Several of the obtained cables will be returned to the vendor for reworking.

No further microwave neutron flux monitor experiments were conducted at the KW Reactor facility; attention was devoted to laboratory experiments instead. A gas tube was designed and fabricated for laboratory testing of the cross-coupling concept. It was determined that electrode temperature could not be maintained at a high enough level to support the plasma; thus, a new capsule design was completed and the unit is being fabricated. Analysis of the data obtained during the last series of KW Reactor irradiation tests was continued; however, the results to date have been inconclusive.

NONDESTRUCTIVE TESTING RESEARCH PROGRAM

Electromagnetic Testing

A series of circuit changes and packaging rearrangement in the multiparameter eddy current tubing test equipment has been completed. Except for the oscillator unit, all circuits are now housed in the original multiparameter tester cabinet rack. These changes incorporated provisions for additional filtering to reduce interchannel harmonic interference, and attenuator networks to prevent overdriving of reference signal amplifiers. The gain of the four main signal channels range from 10,000 at 250 kc to 46,000 at 6 kc with a band pass of 4 kc.

A hydrided region of 300 ppm in a laboratory sample of N Reactor process tubing was detected with a small flat eddy current test coil. This 0.210 inch o.d. test coil is operated at 200 kc. The signal power is coupled to the coil through the recently developed air core transformer with a rotating secondary winding. Mechanical power for scanning is delivered through a flexible drive shaft from a motor located outside the tube.

A method to display the cross section of the tubing under test and to show the relative location of detected defects is being developed. This display will be usable with both the conventional eddy current test and the multiparameter test. However, the significance of this display technique will be more fully realized when used with the multiparameter test which has more defect information available. It is anticipated that this new display technique will be very useful in the further development of the multiparameter testing approach.

Development completed to date has resulted in a display of a circular cathode ray tube scan (J scan) to represent the tubing wall. The beam spot location and movement is determined by the test coil shaft position and movement. When no defect signals are present a circular trace is obtained, representing the outer circumference of the tube being tested. Defect signals modulate the oscilloscope sweep signals which causes a reduction in diameter of the circular sweep. The amount of reduction in sweep diameter is proportional to the defect size and display position shows the relative location of the defect around the periphery of the tube.

The next phase of this development will incorporate a second circle in the display to represent the inner surface of the tube. Means to perform this function have been implemented and breadboard circuitry is ready for test.

Fundamental Ultrasonic Studies

Shear-wave attenuation measurements using obliquely incident longitudinal waves are continuing. Although this method circumvents certain experimental problems, other difficulties have been encountered which require further evaluation. For these measurements it is essential to provide test samples which have opposite surfaces flat to within 50 μin/in. for these tests. This requirement necessitated the relapping of all the previously prepared test samples.

Although the oblique angle method does not require a correction for insertion losses, the effect of beam divergence must be considered. A method for beam divergence correction has been developed. This technique compares a test sample of known attenuation and shear wave velocity to samples having known velocity but unknown attenuation.

Two methods of fabricating test samples for diffraction studies have been investigated. A diffusion bonding technique using aluminum samples was tried initially. It was hoped that two identical samples could be prepared and rejoined by vacuum diffusion to remove the ultrasonic interface. However, initial attempts at this approach were not successful.

As a second approach a contract was negotiated with a private vendor to determine the feasibility of fabricating imperfections in glass samples. The vendor has now developed a technique and supplied one sample having a planer disc defect of 0.15 inches diameter geometrically centered in a glass cube of about two inches in dimension. The exact process which the vendor used for making these samples was not disclosed. However, it appeared that the finished specimen was made by rejoining two parts after the defect had been fabricated in one of the parts. The interface appeared to be optically transparent and a check with ultrasound showed that it was sufficiently transparent for use as a test specimen. Samples having defects of different sizes and shapes are being ordered for use in diffraction studies.

Heat Transfer Testing

Theoretical study of the parameters which govern sensitivities of thermal pulse transducers has continued. The conditions of maximum signal output of a thermal bridge for a given change in thermal diffusivity have been calculated for various transducer, couplant, and sample combinations. For example, a bridge using rubber transducers with a 0.005 inch air couplant layer over an aluminum sample would give a maximum signal at five seconds after application of the heat pulse. Whereas, the same transducer sample combination with water as a couplant would give a maximum signal output--10 milliseconds after pulse application. These calculations indicated that an increase in couplant conductivity would decrease the time delay of maximum signal whereas an increase in transducer diffusivity will increase this delay.

Fatigue Detection

Fatigue specimen preparation is proceeding on schedule. Acceptable techniques have been developed for annealing, electropolishing and fatiguing the aluminum, copper, and stainless steel samples. In addition to these materials, fiberglass plastic has been ordered for inclusion in the forthcoming tests.

It was determined early in this program that precise sample and transducer positioning will be necessary for fatigue detection using both the eddy current and ultrasonic methods. For this purpose, a new mechanical and manipulating system is being fabricated for the ultrasonic work. Although this system is versatile and accurate, the test sample-to-transducer alignment procedure is time consuming. To assist in this function an alignment device consisting of multiple pulse-echo transducers has been developed. By using echo signal amplitude and phase relationships the sample-to-transducer alignment can be rapidly and accurately ascertained.

Preliminary measurements indicate an accuracy of ± 0.0025 inches vertical distance and ± 30 seconds angular rotation can be obtained by this method. These tolerances are an improvement of at least a factor of two over conventional mechanical manipulators.

In conjunction with the alignment work, a technique was developed for using a common pulser for all transducers. By using inductive-resistive coupling, the frequency and signal amplitude of each transducer can be controlled independently. A biased diode on each transducer also provides isolation of received signals so that they can be individually analyzed. This feature may be of further assistance in other multiple transducer applications.

The eddy current electronic equipment has been modified to provide a more flexible bridge balancing needed for the wide range of conductivities of the present fatigue test samples. The gain of the system was increased by a factor of five to provide maximum sensitivity for fatigue detection. Also, the probe coil design was improved by using a larger coil form than was employed for the original hydride test application. These modifications made probe motion compensation more complete.

With the above circuit modifications incorporated, eddy current tests were conducted on fatigued samples of A212-B and 4340 carbon steel, aluminum, and copper. Large signals were obtained from the fatigued regions in the steel samples, even in areas where no visible cracks occurred. However, reliable fatigue signals could not be obtained from the copper and aluminum samples. Further improvements on the mechanical scanning fixture will be necessary before repeatable fatigue signals may be obtained from these higher conductive materials.

Imaging Ultrasound

Previous monthly reports have called attention to experiments in which an ultrasonic beam was imaged by causing it to impinge upon a water surface. The pressure of the sonic beam, modified by an object in the beam, causes a deformation of the water surface which is a shadow image of the object. The object can then be observed by reflecting a collimated beam of light off the water surface and viewing the reflected beam with the aid of a ground glass screen. Some theoretical work has been carried out in order to better understand the physics of this phenomena. In general, the results show that the surface displacement results from the undirectional radiation pressure force and the alternating pressure component is insignificant.

The calculations indicate that the usefulness of this technique will be limited to ultrasonic intensities exceeding 10^{-4} watts/cm^2. Also the

resolution will be degraded by a factor depending upon the surface tension of the liquid. However, the simplicity of this method recommends it for many applications where these above restrictions can be tolerated.

As a continuing effort to exploit all possible ultrasound imaging techniques, several other methods have been evaluated this month. A second method requires two interfering ultrasonic beams as opposed to the single beam used in the experiment described above. The interference fringes, produced at the water surface by the ultrasonic beams, diffract the collimated light beam. If the water surface is viewed using only the first order diffracted light, an image object placed in one of the ultrasonic beams is observed.

Attempts were made to obtain strong diffraction by transmitting light through the region within a media in which two ultrasonic beams interfere. No diffraction was obtained at any angle of incidence indicating that the average density of the water along all possible light paths is constant. Very strong diffraction effects were observed when one ultrasonic beam was traversed perpendicular to its direction of propagation by the collimated light beam. This arrangement was used to observe 10, 20, 30, 50, 60 and 100 megacycle ultrasonic waves in water. These frequencies were generated by driving 10 and 20 Mc crystals at their third and fifth harmonic frequencies.

The great difference in wavelength between light ($\lambda = 0.6\mu$) and ultrasound in water ($\lambda - 100\mu$) has frustrated efforts at wavefront reconstruction. A 100 Mc ultrasound wave ($\lambda = 10\mu$) would be useful if it were not so rapidly dissipated in water. The power output available at this frequency from the equipment on hand did not permit any wavefront reconstruction experiment.

The wavelength difference between the ultrasound and imaging light could be reduced by using infrared ($\lambda = 10\mu$) for viewing the water surface. A recently announced infrared imaging device using liquid crystal detectors may have application to wavefront reconstruction and perhaps even to direct imaging of sound. These liquid crystals are sensitive to small changes in temperature and stress and may have other properties which could be exploited to render ultrasound visible.

Vendors are being contacted to acquire an assortment of these substances and to gain familiarity with their properties.

The possibility of using ultrasound to distort the surface of a thermoplastic film has been considered on a theoretical basis. The concept involved the use of the charge pattern formed by an ultrasonically stressed

piezoelectric crystal. These surface distortions would be converted to an image by optical means. To successfully apply this method the oscillating charge pattern of the crystal must be converted to an undirectional force on the thermoplastic film. At present, no means of successfully accomplishing this conversion has been conceived.

Thermo-sensitive phosphors have been used elsewhere to image ultrasound. This method is described in the literature and appears to have excellent resolution but requires an ultrasonic intensity in the range of 10^{-1} watts/cm^2. The method is relatively simple and inexpensive and may be useful in comparing the resolution of other methods.

The possibility of modulating a dc energized electroluminescent phosphor with the field produced by an ultrasonically stressed piezoelectric crystal has been proposed. This method has not been attempted as far as is known but the expectation is that it will lead to a useful imaging device. However, considerable refinement of the technique would be expected before the sensitivity would approach the desired limit.

Quantum Physics Devices

Possible methods and materials for the construction of piezoelectric semiconducting junction transducers are being investigated. The objective is to create a depletion layer having a width equal to half the wavelength of the desired ultrasonic frequency. A number of II-VI group compounds having piezoelectric as well as semiconducting properties have been ordered. Initial attempts to produce the depletion layer will be made using alloying and diffusion techniques. The use of various forms of radiation will also be investigated as a mechanism for producing n or p type semiconductors from these II-IV compounds.

Some of the more common piezoelectric materials are also being considered for application in the junction-transducer work. Barium titanate and lithium sulfate monohydrate are two common ultrasonic transducer materials which are possible candidates. Various dopants are being considered to find a method of making these materials n or p type semiconductors while still retaining their piezoelectric properties.

Lithium sulfate monohydrate, although widely used as an ultrasonic transducer material, has received very little attention in the literature as to its solid state crystalline properties other than piezoelectric constants and general lattice structure. Some of these unreported properties will be necessary in this work and hence determination of the forbidden band gap width, general exciton structure and defect center properties will be undertaken.

Nondestructive Testing of Isotope Heat Sources

Steady state thermal wave theory shows that the effects of cladding thickness may be eliminated when making nondestructive measurements of thermal properties of finished isotope heat sources. This conclusion was derived from the graphical presentation of the loci of the heat equation solution. This solution was considered for the case of perfect contact between core and outer cladding. It also appears possible to measure the thermal properties of the cladding independently of the core. In addition to measurement of the thermal properties themselves, application of these methods to determining the integrity of the finished heat source is being studied.

Graphical presentation developed thus far is general and can be used to quickly determine the thermal behavior for any cladding-core combination during a test. Sensitivity of the thermal test methods to changes in core properties was calculated by computing the thermal behavior of an isotope heat source with a 0.1 inch Inconel container and a quartz core. The temperature of the outer surface, resulting from a 1 cycle/5.9 minute heat flow having an amplitude of only 1 watt/cm^2 was calculated. A surface temperature change of approximately 2.5°C resulted from a 10% change in core heat capacity or conductivity.

Analytical solutions for the case of variable constant resistance between the cladding and core have been completed. An initial method for graphically representing these solutions has been selected. It is anticipated that these curves will suggest a method for eliminating contact conductance variations. Computer evaluation of the analytical solutions are being conducted to obtain values needed for the graphical representation.

BIOLOGY AND MEDICINE - 06 PROGRAM

Atmospheric Physics

Two field tests with elevated releases from 365 feet were conducted in September. This completes the year's tests planned to investigate the effect of source height in stable atmospheres. In this series, 15 successful experiments were completed from sources of 185 and 365 feet.

Comparison of the 185-foot source data to previous 23-foot data show that, for travel times beyond 20 minutes, both exposure curves asymptotically approach the mean curve for ground-level sources. For short travel times, however, large differences in exposure are noted. In particular,

a. The travel time to the peak ground exposure was several hundred seconds less for the 23-foot release, while

b. The peak ground exposure was one to two orders of magnitude greater.

Over 7,400 raindrops collected at Sunnyside on March 21, 1964, have been sized and the spectra analyzed. Conventional presentation of rain spectra is in the form of space density (number of drops per volume of air per diameter interval) versus drop diameter. In this form, the space density for the 0.7 mm/hr rain shower shows a maximum at 0.46 mm diameter, and an exponential decrease with increasing diameter.

In 1954, L. M. Levin, of Russia, showed that several empirical equations for raindrop sizes are approximated by portions of a log-normal curve, and stated that such a distribution might arise through random combinations of small drops. The idea of collision of drops which are not greatly different in size is not acceptable to most cloud physicists, however, since the collision of two drops depends upon the difference in their fall velocities.

The Sunnyside spectrum is rather close to log-normal throughout the entire range of drop sizes, and corrections for evaporation below-cloud could perfect the agreement. (There are no published spectra with such detail in the small drop portion, and few with such a small rainfall rate, so that comparison to other locations is difficult.)

Kelker's spectra from Indian rains are also fairly well represented by log-normal distributions, and for the same rainfall rate, his spectrum is very close to the Sunnyside spectrum. This is significant because such agreement, if not coincidental, implies that shower rains from different climates arise through the same physical process, and this process may well be the collision of drops of nearly the same size.

The concept of a drop falling within the entrained wake of another drop may be used to explain the collision of drops of the same terminal velocities. Thus, the wake collection theory used to explain the scavenging of particles at Hanford (HW-79382) might also be used to explain the rapid development of showers.

Radiological Physics

Another field trip to Anaktuvuk Pass was completed. The purpose was to measure the peak body burden of the Eskimos before they started eating fresh caribou from their Fall kill. Caribou killed in the Fall have less Cs^{137} than Spring-killed caribou because they have been feeding on fresh plants rather than on lichens. The body burdens were lower than in July because the Eskimos had been eating fresh caribou for several weeks. The average adult body burden was 1100 nCi compared to 1280 nCi measured in July.

A large plastic shield was successfully tested as an anticoincidence shield for the plutonium counter. The shield reduces the background in the whole body counting cave nearly an order of magnitude. The shield reduces the background from K^{40}, Cs^{137} and Zn^{65} a factor of 5 when counting plutonium in people.

R. A. Jalbert, a Summer Professor from the University of Alaska, completed his investigation of a calibration technique for the shadow shield based on Evans' one meter arc method. The technique is not as good as had been anticipated. However, the technique can be very useful in applications where ± 15 to 25 percent absolute calibration accuracy is acceptable. Ten children were counted on the regular shadow shield and on the one meter arc shadow shield. Cs^{137} body burdens determined by the one meter arc counter averaged about 20 percent lower than measurements made on the regular counter.

The helium ion separator being developed by Professor L. W. Seagondollar was operated with beams of 4 MeV alpha particles and intensities of 0.3 microamps. However, the He^{++} beam was contaminated with molecular hydrogen ions. The e/m ratios for HH^{+} and He^{++} ions are the same which make it impossible to eliminate the hydrogen ions with the separator or beam analyzing magnet. Other techniques are being investigated which might eliminate or allow for the unwanted hydrogen beam. The Van de Graaff was converted back to allow normal acceleration of protons and deuterons after being used most of the summer for the ion separator development. Many modifications and techniques developed this past summer have been incorporated into the normal operation of the machine.

The neutron generator and some of the support equipment for the University of Washington spermatogenesis project was moved to the U of W laboratory. Shipment of the neutron shield has been delayed until installation of a fire protection sprinkler system is completed. Washington AEC requested Radiological Physics to review the X-ray dosimetry of the two groups doing spermatogenesis studies here in the Northwest. No gross errors were uncovered in Dr. Paulson's project at the U of W laboratory. The project being done by Pacific Northwest Research Foundation has not been reviewed yet.

The operational characteristics and capabilities of the additional circuits for the Nuclear Data Analyzer to allow determination of local energy deposition have been investigated. The performance is very satisfactory. The circuits can be used in any experiments where pulse height time averaging is required.

The linearity of the He^{3} neutron spectrometer counter was checked with monoenergetic neutrons and found to be very good.

A sampling-storage oscilloscope system was assembled and tested. This system is capable of distinguishing a repetitive signal which is buried in a background of random noise. The system is now ready for application in experiments.

The small calorimeter was assembled and tested. The temperature control for the copper jacket is better than had been expected. A small air leak in the calorimeter was eliminated. However, there remains an unexplained variation in the output of the thermopile between the two cells of the calorimeter.

Instrumentation and System Studies

Fabrication was completed on the final prototype, pocket-size, signaling dosemeter. The instrument includes an extensively-modified "pencil" ion chamber sensor and solid state circuitry, and it is adjusted to provide an audible signal following dose accumulation of about 50 mR. Calibration and field tests are being conducted by Radiological Development and Calibrations, HL.

Noise interference problems were eliminated on the dog counting and scanning system developed for use in biological studies. A modified recorder control method is being incorporated to improve system operation.

To aid in biological inhalation studies with canines, a new sliding valve was developed which reduced the sliding friction by 50% over the initial valve. A new actuation method was devised for use with the valve and the required components were ordered. No electronic instrumentation changes will be required.

Promising results are being achieved with the modified canine masks used in smoke inhalation studies at the Biology Inhalation Toxicology facility. Minor changes are being incorporated to permit easier elimination of the exhaled smoke.

A prototype logarithmic response (1 mR/hr to 10 R/hr) scintillation radiation monitor is being adapted and modified for use in determining dose rates at the Biology fish trough, located at 100-KE Area. The instrumentation will be used to measure the approximate dose rates to the fish.

Fabrication was completed on three regulated power supplies to be used with thermal precipitators at the Biology Inhalation Toxicology facility, and the Biology radiological field monitor and analyzer was completed except for the incorporated NaI (Tl) scintillation detector. The final design of the probe will be completed after the requirements are established.

Promising results were achieved on the fast (1.2 nanosecond rise time) transistor circuits being developed for use in a single electron counting system. Current gain of 10 was obtained for four cascaded amplifiers with 50-ohm input and output impedances. Development of the associated discriminator progressed more slowly with only 50 Mc/sec operation possible to date. Circuit work will be accelerated.

Experiments were initiated using the positive ion Van de Graaff accelerator to provide various energy neutrons on the lithium-foil covered surface barrier diodes contained in 8-inch and 10-inch diameter polyethlene moderators. The development work is directed toward obtaining a wide range neutron energy dosimeter. Results obtained to date are inconclusive.

Testing approaches were outlined for the received blood pressure and respiration rate transducers, which will be incorporated in the experimental animal physiological function and dose telemetry system for use in biological studies. Initial results appear promising.

Because of extensive noise associated with signal pulses, a new approach was initiated for the circuitry development for the peak pulse dosimeter reader instrument, being developed for use in dosimetry studies. In the new circuit, a capacitor is charged to the peak voltage of the input pulse. The capacitor is then discharged in a linear fashion with measurement made of the discharge time using a crystal-controlled 100 kc/sec oscillator. Trigger pulses generated at the start and stop of the linear discharge gate the oscillator into a scaler. As adjusted, a pulse height of 10 V results in 1000 counts in the scaler. Amplifiers are used to amplify linearly the smaller pulses which may be only 0.01 V in magnitude. Logic circuitry selects the proper trigger pulses. Accuracies of better than 1% of full scale are being achieved in laboratory tests.

Development, fabrication, and laboratory testing were completed on a solid state instrument, with recorder readout, to be used in a drinking water monitoring system. The instrument incorporates a scintillation probe to detect and measure concentrations of beta-gamma emitters in the water. Sensitivity and calibration tests were initiated by Radiological Development and Calibrations, HL.

Four of the five remote data stations of the Atmospheric Physics radiotelemetering system have been installed in the field and calibrated. The units are performing correctly. In addition, improvements were incorporated in the central station, and the initial draft of the data station maintenance manual was completed.

A portable, battery-operated, all solid state single channel gamma spectrometer was developed and tested. It was used by Radiological Physics

in dosimetry studies with Alaskan Eskimos. The incorporated circuitry includes a pulse amplifier, single channel analyzer, count-rate-meter, a 5-decade scaler, and a high voltage supply. Operation of the instrument in Alaska was termed fully successful.

Further circuitry refinements were incorporated in the experimental pulse discriminator instrument to be used in dosimetry studies. Limited success was achieved in initial tests of the system for the detection of low energy X-rays from Pu-239 and Fe-55. Noise interference problems are continuing to cause difficulties with the multichannel analyzer.

A study of a meteorology data system was completed and a rough draft report prepared. The report summarizes the routine and experimental data handling requirements at the Hanford weather site. A system was recommended with capacity to handle both routine and experimental data.

A study of methods for digitizing wind component meter data for the Atmospheric Physics Operation is being made. Wind component meter spherical coordinate signals are transformed to rectangular coordinate signals at the analog computer facility. It is desired to digitize this analog rectangular data for use at the digital computer facility. The Meteorology Department of the University of Washington has indicated an interest in making use of our facilities for handling this type of data.

WASHINGTON DESIGNATED PROGRAM

Isotopic Analysis Program

Isotopic analyses were provided on program samples during the month in accordance with current schedules. The mass spectrometer for this program has been put into routine service in its ion-counting mode of operation. Processing of the digital data is greatly facilitated through the use of the new PDP-5 computer. A gratifying comparison of the performance of this spectrometer with the instruments of other major laboratories has been made (see CUSTOMER WORK - Mass Spectrometry).

The new ceramic vacuum-lock sample changer for the mass spectrometer was successfully operated on the ion-optical test bench. Following minor modifications and adjustments testing of this device is being continued under conditions simulating routine mass spectrometer operation. Design of a new voltage divider for this ion-source has been completed.

EXPERIMENTAL REACTOR PHYSICS FACILITIES

PCTR Operation

Operation of the PCTR continued routinely during the month. There were no unscheduled shutdowns. Nine groups of rats were irradiated in essentially an eipthermal neutron spectrum for the Biology Operation.

TTR Operation

Operation of the TTR was on an intermittent basis and there were no unscheduled shutdowns. Four rolls of dimes were irradiated for the Public Relations Operation.

CAF Operation

The Critical Approach Facility was not operated during the month.

PRCF Operation

EBWR-fueled experiments were completed on August 28, 1964. Reactor noise was recorded at 1 watt, 35 watts, and 70 watts for additional kinetics data. Substitution measurements were performed for various poisons (Hf, Eu, Cu) fabricated to fuel rod dimensions. Reactivities of four fuel rods were measured for worth data as a function of fuel composition.

The EBWR fuel rods were removed to storage. The core structure was dismantled and components moth-balled. A new core structure was assembled for experiments with 1/2" fuel rods at a lattice spacing of 0.80", and a core height of 44". The shutdown and control mechanisms were installed and the new core was set up for experiments with 1.8% Pu-Al fuel rods. Fuel loading began September 15, 1964, and the first critical was achieved on September 21, 1964. A power calibration of the flux monitors was performed, and rod calibrations were in progress at month end.

COMPUTER FACILITIES

The General Electric 412 digital control computer was delivered.

The analog computer utilization was as follows:

EASE 1132	EASE 2133	
139	141	Hours Up Time
21	20	Hours Scheduled Down Time
8	7	Hours Unscheduled Down Time
168	168	Hours Total

Problems considered during the month were:

1. N Reactor.
2. N Reactor Sizing Program.
3. Meteorology Wind Turbulence.
4. PRTR Controller Tests.
5. Columbia River Flood Routing.
6. Automatic Parameter Optimization.

Preliminary techniques and equipment configurations were developed for automatic parameter optimization with the analog computer by using a feedback servo-mechanism technique. A generalized approach is being investigated which determines optimum parameter values faster than can be done by the random techniques previously investigated. The preliminary tests indicate that good results can be expected in optimizing the parameters of a system in which the performance function is a quadratic form.

Enrollment for the analog computer class has indicated a strong interest in analog computers by Hanford scientists and engineers. Forty applicants enrolled during the first four days. Since present supplies and facilities will accommodate 15 members for a 10-week class, arrangements were made to conduct two, and possibly three, classes during the 1964-65 academic school year.

CUSTOMER WORK

Weather Forecasting and Meteorological Services

Meteorological and climatological services included: 1) Meteorological data bearing on comfort indices in the 300 Area, 2) cooperation with Chemical Research Laboratory on the design of an I-131 washout experiment, 3) support to Environmental Studies and Evaluation on the processing of river data, 4) cooperation with Chemical Research & Development in the conduct of two dispersion measurements of the Purex plume, and 5) completion of plans to support CPD in the contracted aerial-dusting of Gable Mountain swamp.

Weather Summary

Type of Forecast	Number Made	% Reliability
8-Hour Production	90	86.4
24-Hour General	60	88.1
Special	126	91.3

September marked the continuation of a long cool and dry period. It was the seventh consecutive month with below-normal temperature and the seventh month in the past nine with below-normal precipitation.

Mass Spectrometry

Isotopic analyses were provided on 21 uranium samples in support of HAPO U^{233}-production studies.

A listing was received from the National Bureau of Standards on the isotopic analyses performed by the nine laboratories which participated in analysis of a plutonium sample for use as a NBS isotopic standard of plutonium. The selected analyses produced by the NBS had the highest precision of any of the other data listed and the NBS results were used by the NBS as the basis for a provisional certification of the standard. Of the other eight cooperating laboratories the analyses performed at Hanford Laboratories had the greatest precision, usually by a significant margin, and agreed within confidence limits with the NBS results. The Hanford measurements were made during the first operational tests of the Isotopic Analysis Program mass spectrometer equipped with the new secondary-electron scintillation detector with single-ion pulse counting. These results are taken as evidence of the significant improvement in analysis capability which can be obtained with the new ion-detection system. It is also significant that the Hanford analyses were the only analyses, including those of the NBS, for which no inferred correction for mass ratio discrimination had to be applied.

Instrumentation and System Studies

A battery-operated 115 Vac power supply was designed for use with a solid state multichannel analyzer. In addition, a solid state preamplifier was designed for incorporation in an oscilloscope used with the system. The modified system will be used by Radiological Physics, HL, in Alaskan dosimetry studies.

Engineering advice was rendered to Technical Publications, HL, regarding a proposed data handling system for the typists and report editors.

Chassis and panel layout work was completed for the assault mask monitor being developed for the Laundry Facility at Hanford. Both the inner and outer surface detector probes are completed and tested. Installation of the solid state circuits and system testing remain to be completed.

Design was completed on an ac to dc power supply to be used to replace the batteries in standard HAPO GM portable radiation survey instruments. The work is being done at the request of Radiological Development and Calibrations, HL, in an effort to utilize, for line-powered operation, a number of the instruments.

Required laboratory testing was completed on the scintillation detection and solid state circuitry aerial gamma monitor, which was designed for use by Environmental Monitoring, HL. Field testing was initiated.

A solid state preamplifier was designed and fabricated for use with a scintillation detection and multichannel analyzer system by Geochemical and Geophysical Research, HL.

Circuit modifications and a new assembly were started on a dosemeter obtained from AECL, Chalk River, Canada. The work is being done for Radiological Engineering, IPD.

The analog computer program for a river routing problem which involves the fitting of three parameters of a mathematical model to river flow data was developed for optimizing the parameters manually. A MIDAS program was also developed to check the adequacy of the analog program. In addition a FORTRAN program was developed for performing the routine calculations necessary for converting river flow data into the proper form for inclusion into the analog program. The next phase of the problem is to automatically optimize parameters to obtain the best fit to the river flow data. Performance indication of the parameter fit is by integral-squared-error between measured and computed curves.

Development work on remote displacement measurement of metal specimens in a high temperature oven was started. Optical and other necessary laboratory equipment is being obtained for the bench model.

Optics

During the four-week period covered by this report, the following shop work was performed:

1. Fixtures were fabricated for an ultrasonic tank to be used for a study of fatigue effects in metal sheet.
2. Fatigue specimens were lapped to a #8 surface finish, flat and parallel.
3. An underwater periscope at 105-KW was repaired.
4. A radiometer was fabricated for NRD.
5. Ultrasonic standards of quartz and aluminum were prepared.
6. Mirrors were fabricated for the crane periscopes at U Building.
7. Components were fabricated for a scanning eddy current probe.
8. An alumina furnace fixture was modified.
9. One ruby laser rod was silvered.
10. 114 stainless steel pieces were aluminized.

Physical Testing

Inspection of the tube-to-tube sheet welds on three dissolvers being constructed for Purex has begun with weld qualification coupons. Testing of the tubing and inspection of the welds are to new specifications, with a goal to increase the average life of these dissolvers from a few months to two or three years.

Sonic leak detection methods were used successfully to locate an orifice, of unknown origin, in the portable water supply line to the 100 Area Central Fire Station. Removal of the orifice solved the problem of restricted flow and eliminated the need to remove and replace the pipes buried in the concrete floor.

Fluorescent penetrant examination of over 13,000 end caps for N Fuels detected three caps with cracks completely through the wall of the cap. These cracks could have led to fuel failures, similar to that experienced with the first N fuel failure. Other caps were rejected for miscellaneous machining defects also detected with the penetrant inspection.

An engineering investigation of an induction furnace in the 234-5 Building revealed areas of deficiency in the machine which were corrected. The temperature now attainable is more than adequate, and sufficiently high to cause plating of the graphite crucible at 2300°C. Other grades of graphite are being tested to provide a more suitable crucible.

Engineering assistance is being provided to measure the parameters of both the machine and the material during the impact forging of fissionable oxides for ceramic fuel manufacture. Problems include the measurement of acceleration to 2500 G's, pressures to 300,000 psi, and temperatures to 1200°C, all within a fraction of a second. Results are encouraging.

Canisters, used to transport irradiated N Reactor fuel, are being inspected for poor welds by fluorescent penetrant. This inspection technique reveals those defects that will require repair before use. Included in the program are maneuverability tests on the handles, or bails.

The export water line between 100-B Area and the 1901 Building has been accurately located and staked out. Sonic leak detection survey is nearly complete on the line; again no leaks have been found on the line itself, but some leaks were located on lines attached to the export system.

An ultrasonic test, capable of resolving a crack one-half inch deep, has been applied on the valve stems to determine the condition of the stems in valves to the steam generators at N Reactor. No indications were detected which would indicate any flaws comparable to the notched standard. A service failure prompted this investigation.

Routine tests, involving radiography, magnetic particle, dye penetrant, eddy current, fission fragment tracks, ultrasonic, and metallographic examination were applied during the month on numerous plant problems.

INSTRUMENT EVALUATION

Acceptance tests were completed satisfactorily on all 100 acquired CP-type portable exposure rate measuring instruments, and 10 of 25 purchased Juno portable radiation survey instruments were tested and accepted.

All mercury batteries have been removed from standard HAPO GM portable instruments following investigation into leakage and corrosion problems. Regular batteries are being used in all units until an adequate supply of zinc-alkaline batteries can be obtained.

Using a 0.01-inch thick terphenyl in polyvinyltoluene detector and with 400 Vdc applied to the multiplier photobe, a calibration of 0-4000 R/hr was achieved on a modified HAPO single-range scintillation area radiation monitor. Exposure to a 4000 R/hr rate for one hour produced a temporary -14% calibration shift.

Operation of a 40 liter ionization chamber instrument used for measuring extremely low exposure rates was described in a talk to Environmental Monitoring personnel.

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CHEMICAL LABORATORY

RESEARCH AND ENGINEERING

FISSIONABLE MATERIALS - 02 PROGRAM

IRRADIATION PROCESSES

Electroplating of Nickel on Uranium

Anode current efficiencies were measured for the following nickel plating solutions, all at pH 3.3 and 60 C: A halide-free nickel sulfamate bath; a nickel sulfamate bath containing 0.3 M bromide; and a nickel sulfamate bath containing 0.22 M chloride. The presence of the halide proved necessary for a satisfactory anode current efficiency (A.C.E.), the halide-free bath giving an A.C.E. of only 50 percent. This compares with the A.C.E. of 100 measured for the baths containing chloride and bromide.

SEPARATIONS PROCESSES

U-233 Support Studies

Definition of Pa-233 scavenging conditions for use during the forthcoming "6-ton" plant test was completed, subject to hot-cell verification with short-cooled thorium dissolver solution. Most noteworthy observation during the month was the pronounced adverse effect of aluminum on the carrying capacity of MnO_2 for protactinium. Because of this finding, caustic dejacketing rather than mercury-catalyzed acid aluminum dissolution will be used in the plant.

Other recommended changes in the proposed plant procedure are deletion of sugar denitration of excess feed acidity (to eliminate thorium oxalate precipitation) and backcycle of dissolved MnO_2 to minimize the volume of protactinium-bearing solution (which will be shipped to Hanford Laboratories for storage to allow decay to isotopically pure U-233. At month's end, a short-cooled thorium oxide target element had been dissolved in the B-Cell dissolver to produce feed solution for MnO_2 radiolysis studies. This solution will permit studies at radiation levels up to six-fold greater than those expected in the plant, and will allow the life of MnO_2 scavenging precipitates to be determined as a function of radiation level. Scouting laboratory work is also continuing on processes for isolation and purification of the U-233 which will result from Pa-233 decay.

Thoria Processing

Mini-mixer-settler runs are in progress testing the flowsheets proposed for thoria processing in the Purex plant (HW-83350). A run has been completed simulating thorium recovery and decontamination in the HA and 1C columns. Average steady state thorium loss to the HA raffinate was 1.3 percent (flowsheet value is 1.5 percent). Analytical data on uranium and fission product content of the recovered thorium are not yet available. A method for determining uranium at low concentrations (~ 10 ppm) in thorium was developed and analyses are underway.

Thorium Oxide Dissolution Studies

Studies on the dissolution of thorium oxide prepared by the sol-gel process have now been initiated. In a series of laboratory experiments, dissolution rates for Mallinckrodt sol-gel thoria in a dissolvent initially 12.3 M HNO_3-0.01 M HF-0.1 M $Al(NO_3)_3$ with no agitation other than that provided by the boiling solution were 0.01-0.015 $g/cm^2/min$ based on the macro surface area of the thoria bed. These measurements were made in a vessel four inches in diameter and with a bed depth of three to six inches. Based on these rates, 25 - 37 hours would be required to dissolve one ton of thorium in a pot dissolver eight feet in diameter.

The dissolution rate obtained for a sample of -6 +8 mesh arc fused thoria was significantly lower than that obtained for a sample of Mallinckrodt sol-gel thoria of the same particle size range and in the same dissolvent. The narrow size range was chosen to show differences in particle penetration rate for the two oxides.

Plant studies were also performed in a 1:20 scale annular dissolver simulator. Highlights of an initial run with a 150-pound charge of aluminum-clad Mallinckrodt Chemical Company prepared thoria and 13 M HNO_3-0.025 M fluoride-0.1 M aluminum as the dissolution agent are as follows:

1. Caustic-nitrate coating removal proceeds without difficulty but burial of thick aluminum end caps in the thoria bed prevents complete aluminum dissolution.

2. During jet out of the coating waste and subsequent dissolver rinses, low drainage rates through the thoria bed result in slow and incomplete removal of coating waste. Thoria losses to the coating waste were on the order of 3 percent; however, the percentage would be expected to decrease in large systems.

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3. Observed thoria dissolution rates indicate that existing plant dissolvers may be limited to less than 1 ton thorium per day per dissolver.

Studies are continuing to define dissolver operating conditions and possible modifications for minimizing the time cycle.

Polonium Chemistry

In preliminary experiments, polonium-210 was found to distill readily from 0.25 molar nitric acid solutions containing bismuth and diphenylcarbazone or diphenylcarbazide. Although material balances were not good, it is believed that at least 95 percent of the polonium distilled in the first five milliliters distilled from 25 milliliter samples. The bismuth concentration may be limited to 0.25 molar to prevent precipitation of bismuthyl nitrate and the acidity from 0.25 to 0.5 molar nitric acid. The lower limit is imposed by precipitation of hydrolyzed species and the upper by the adverse effect of increased acidity on the distillation.

Cerium-Rare Earth Partition

Work in support of Semiworks use of the silver persulfate-D2EHPA process was reported last month. This led to recommendation and successful use of a high-purity hydrocarbon diluent instead of soltrol. Another problem has now been revealed, the high apparent plant losses of rare earths. This phenomenon was investigated and found to be due to precipitation of rare earth sulfates by excess sulfate ion which results from decomposition of persulfate. It was found possible to prevent this precipitation by addition of suitable complexing agents and pH control. HEDTA and citric acid were both effective in preventing the precipitation while still allowing efficient D2EHPA extraction of Ce(IV). EDTA and DTPA are not recommended due to poor cerium extraction.

Sodium Formaldehyde Sulfoxalate as Plutonium Partitioning Agent

It was previously reported that sodium formaldehyde sulfoxalate (SFS) solutions are corrosive to 304-L stainless steel under some conditions proposed for use of this reagent as plutonium reductant in the Purex plant. Further studies show the product obtained when SFS is used as a reducing agent (an addition complex of formaldehyde and sulfurous acid) is also corrosive to 304-L under comparable conditions. Current laboratory emphasis is on possible preparation of U(IV) by SFS, destruction of the SFS reaction products and subsequent use of the U(IV) as plutonium reducing agent.

Stability of Trilaurylamine Solvents

As yet unidentified white solids were precipitated from 0.3 M TLA-Soltrol 170 or -dodecane solvents during continuous contact with either simulated Purex 1WW or 4M HNO_3 for 50-60 hours at 40-50 C, while subjected to 6 x 10^5 r/hr Co-60 radiation. Neptunium extraction capacity and amine titer of the residual solvent was significantly reduced as compared to the original solvent. White solids were also precipitated from 0.3 M TLA-Soltrol 170 contacted with simulated 1WW for one week at 29 C with no radiation exposure.

Corrosion of 304-L and HAPO-20 During Thoria Processing

Determination of corrosion rates for 304-L stainless steel and HAPO-20 alloy under thoria dissolution and feed preparation conditions was continued. Tests were made under heat transfer conditions and at boiling temperatures. The most severely corrosive environments to these alloys occur during the feed boildown step. Chemical destruction of the nitric acid in the dissolver solution prior to the boildown step would reduce corrosion in the dissolvers. Galvanic currents observed with 304-L to HAPO-20 couples in solutions simulating thoria dissolution and feed boildown were insignificant; coupling of these two alloys in a dissolver should introduce no galvanic corrosion problems.

Disposal to Ground

A fluorescein dye was added to the inlet of the Gable Mountain Swamp, and its progress was followed by aerial photography to determine the uniformity of infiltration over the bottom area. Resulting dye patterns indicated relatively uniform distribution and infiltration of the water. The test served as a basis for the recommendation to spread bentonite clay uniformly on the swamp to decrease the infiltration rate (raise the water level) and thereby increase the inundation of near-shoreline mud contamination.

The minimum travel time for water to move from the 1301-N Crib to the Columbia River was estimated, prior to crib use, to be about 96 days based on information from a comparable study using radioiodine tracer at 100-H Area. Initial evaluation, based on recent sampling of wells down-gradient of the in-use 1301-N Crib, indicates an actual travel time of 100-150 days. Additional information will be collected and evaluated to define more accurately the local flow system.

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WASTE MANAGEMENT AND FISSION PRODUCT RECOVERY

Zeolite-Cation Selectivity Studies

An examination into the basic causes of cation selectivity in zeolites was continued. As reported earlier, there is an inverse relationship between the zeolite silica to alumina ratio and strontium selectivity in the presence of sodium. The relationship between zeolite cesium selectivity in the presence of sodium and silica to alumina ratio is a direct one. Since the above relationships included the variable of crystal structure as well as silica to alumina ratio, an effort was made to obtain zeolites with variable silica to alumina ratios within a given crystal structure. The zeolites Type X (13X) and Type A (4A) were found to have such variable ratios. Samples of Type X with a 2.4 silica to alumina ratio and Type Y with a 4.6 silica to alumina ratio were obtained from the Linde Company. Both Type X and Y zeolites have a faujasite crystal structure. The Type X gave a thermodynamic equilibrium constant at 25 C of 0.355 for cesium removal from a cesium-sodium system and 19.9 for strontium removal from a strontium-sodium system. Higher silica Type Y, on the other hand, gave constants of 6.46 and 21.9 for cesium and strontium removal, respectively, from cesium-sodium and strontium-sodium systems. The increase in the equilibrium constant for cesium removal was expected at the higher silica to alumina ratio of zeolite Type Y. The unchanged strontium removal constant indicates that there are three types of cation sites on the synthetic faujasite crystal structure, and that cation site depopulation occurs mostly by removal of the sodium-selective sites. Work is underway on a similar study of a silica-rich Type A zeolite sample.

Cesium Removal from Purex Alkaline Waste

The presence of TBP-Soltrol in synthetic Purex supernatant waste was found to have little or no effect in laboratory studies of the cesium exchange capacity or loading kinetics on Linde AW-500 zeolite. A Cs-137 spiked synthetic waste saturated with 30 to 70 volume percent TBP-Soltrol was passed through the exchanger for seven load-wash-elute-regenerate cycles. The results obtained were compared with results from runs with the same waste, but organic free, on the same exchanger. Variations in the 50 percent breakthrough point were within experimental error in nine of the ten experimental runs. The shapes of the breakthrough curves were generally similar. Cesium elution rates from the exchanger were about the same in all runs.

Technetium Chemistry

Precipitation of ammonium pertechnetate (NH_4TcO_4) has been widely utilized in the isolation and purification of technetium; however, literature

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data are apparently not available on the solubility of the material. The solubility of ammonium pertechnetate has accordingly been measured, as a function of temperature, using ultra-high purity NH_4TcO_4 prepared by a series of four recrystallizations. Similar solubility measurements are being extended to the other alkali pertechnetates, some of which have apparently not been previously prepared. Solubility of NH_4TcO_4 in re-distilled water ranged from 0.222 M at 0 C to 1.04 M at 50 C. Solubilities of $KTcO_4$, $RbTcO_4$, $CsTcO_4$, $TlTcO_4$ and tetrapropyl ammonium pertechnetate were 0.110, 0.057, 0.018, 0.0031 and 0.0068 M, respectively (at 23 C). Low solubility of some of these compounds may have valuable process application. The measurements are being extended and additional compounds prepared.

In other work, laboratory assistance was given to the plant in defining conditions for the current (second kilogram-scale) recovery demonstration. Major departures from the first campaign are (1) use of sugar denitration, vice distillation, for removal of excess nitric acid from the large volume of STT eluate, and (2) installation of an anion exchange column in the Strontium Semiworks for purification and concentration of the recovered technetium. Potential advantages of the sugar denitration include greatly reduced corrosion and hence much less iron impurity than was present in the product of the first run. Results from the field indicate excellent confirmation of laboratory denitration results. Operation has been extremely smooth and stable, efficiency (moles of acid destroyed per mole of sugar consumed) has been high (ca. 30), and recovered acid is suitable for re-use, suggesting that future chemical costs might be significantly reduced by acid recycle.

EQUIPMENT AND MATERIALS

New Dissolver for NPRF

A glass mockup of the new Plutonium Reclamation Facility dissolver was constructed and utilized to demonstrate operability on simulated slag and crucible material. The new design provides recirculation of the solids by means of thermal effects as well as the air lift effect provided by purge gas. A deliberate effort was made to plug the dissolver with unagitated solids from four cans. The new dissolver proved to be capable of providing by-pass flow around the plug and of restoring normal circulation within a matter of minutes. Further observation of the "cold" solids during actual dissolution with 70 C, 2 molar nitric acid indicated fairly rapid dissolution capability.

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PROCESS CONTROL DEVELOPMENT

Purex Instrumentation

Laboratory studies have been made to evaluate the applicability of recently developed in-line plutonium monitors to the detection of U-233. The results of these studies indicate that both the alpha scintillating glass and thin sodium iodide crystal for X-ray detection can be used just as they are being used for plutonium concentration measurements. The alpha detector is approximately a factor of 10 less sensitive in grams per liter because of the reduced activity of U-233, making a detection limit of approximately 0.001 gm/l of U-233.

The X-ray (17 kev) cell was installed at Purex plant in the L-8 sampler and has been working satisfactorily since installation. The monitor measures the plutonium concentration of the combined ion exchange waste streams from N cell and has followed expected changes in concentrations caused by process operations.

AC Column Facility

The 1CF tri-split uranium photometer was calibrated with a series of 35 organic-phase uranium solutions. The solutions represented five levels of uranium concentrations (0 to 80 gm U per liter), five levels of organic solvent color and ten replicate solutions. The calibration data is currently being processed to determine the calibration equation for the instrument. Following the calibration procedure, the instrument was installed in the 1CF feed line of the experimental pulse column facility.

REACTOR-DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Salt Cycle Process Engineering Development

Approximately 15 pounds of mixed oxide were removed by vibratory decladding from five 4 ft. x 1/2 in. diameter Zircaloy-clad, cold-swaged half rods irradiated to 5000 Mwd/ton in the Plutonium Recycle Test Reactor. No evidence of cladding brittleness or radioactive powder release to the cell atmosphere was found.

RADIOACTIVE RESIDUE PROCESSING DEVELOPMENT

Calcine Melter

The chemicals required to form "glasses" from high level wastes can be added to the waste by either blending in the waste liquid feed to the spray calciner, or by separate addition (simultaneously with the waste) to the melter. To date, the blended feed technique has been quite successful when colemanite is used as the "glass" former. Limited work is now underway to evaluate a separate stream addition technique.

Two runs using a dry, powdered glass frit as one feed stream and spray calcined powder as the other have been made. Approximately 1.9 pounds of glass frit were fed per pound of spray calcined Purex waste at an operating rate equivalent to 1.4 tons of uranium per day. The runs were successful except for some foaming in the melter and some porosity in the glass product.

Coupled Spray Calcine Melter

A 40-hour continuous run was completed using simulated sulfate-free Purex waste which also contained mercury and colemanite. In the absence of a draft tube within the calciner, there was no wall deposition problem. Filter operation was good and there was no evidence of mercury causing a problem in the system. The run was terminated when excessive corrosion of the 310 stainless steel melter became evident after the production of 87 pounds of glass. Replacement of the 310 stainless steel melter with a platinum unit is planned.

Spray Calciner

A reduction in the quantity of borax additive to wastes was studied to determine its effect on the operability of the calciner. Reducing the quantity from 500 to less than 100 grams per liter eliminated any calciner wall deposit problem. The resulting powder melted near 900 C.

Glass Forming Processes

The system calcined Purex 1WW - sodium oxide - silica is being studied for potentially useful glasses in the spray calciner-continuous melter development program. Promising glasses containing greater than 30 weight percent calcined 1WW were produced but fusion points for these mixtures were all higher than 900 C.

Laboratory-scale studies were performed simulating continuous concentration of phosphate-containing Purex 1WW waste (first step in the BNL phosphate glass process). Under steady-state conditions nitrate concentrations in the evaporator bottoms decreased from 4 M to 0.8 M as the boiling point increased from 135 C to 180 C when the mol ratio of phosphorous to total metal ion equivalents in the feed was 0.9. When this mol ratio was 1.15, steady-state nitrate concentrations were slightly lower. Viscosity, boiling point and density measurements were made on the evaporator bottoms.

Corrosion rates for HAPO-24 alloy (similar to HAPO-20 but with cobalt substituted for half of the nickel) and Uranus 5 alloy in a calcined Purex 1WW (sulfate free)-borax melt at 900 C were 25 and greater than 100 mils/mo, respectively.

Continuous Phosphate Glass Experiment

The first hot cell test of the Brookhaven continuous phosphate glass process was performed late in the month in A-Cell of the High Level Radiochemistry Facility. Although analytical results are not yet available, the run was operationally successful and radiologically uneventful. Run duration was about 30 hours.

Start-up of the runs was with a cold synthetic feed. When steady-state operation was established, this was switched to full-level Purex 1WW (to which a 10 mole percent excess of H_3PO_4 had been added) and operation continued until the feed was exhausted. Samples of the nitric acid and sulfuric acid condensate streams and of the off-gas were taken periodically for analysis to determine the extent to which fission products are volatilized and their distribution among the various secondary streams. (Because the temperature of the melter, 1200-1400 C, is substantially higher than in previous spray and pot calcination and the chemical environment is also different, it is conceivable that fission product behavior may be substantially different from in earlier pilot plant calcination studies.) The pot of solidified glass is being sectioned for "metallographic" examination and for the cutting of geometric samples for stability and leaching experiments. Further "hot" runs are planned.

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Supporting laboratory phosphate glass composition studies continued. Highlights of the month's laboratory work included (1) indication that certain phosphate glasses are susceptible to marked deterioration in leach resistance when annealed, and (2) further indication of the critical importance of the metal oxide to phosphate ratio. Details of these studies, and of the hot glass experiment, will be included in the July-September Waste Fixation Quarterly Report.

Intermediate Level Waste Treatment

A three-cell electrodeionization unit was continuously operated with a synthetic feed for a 25-day period, at a membrane current density of 10 ma/cm^2 and a flow rate of 0.5 column volume per minute through the resin filled compartments. Feed to the dilution and concentration compartments was 10^{-3} and 10^{-1} M $NaNO_3$, respectively. Decontamination factors of 20-27 were obtained for the first 10 days of operation and decreased to 2 after 25 days. Chemical degradation of the resins accounts for the poor decontamination factors. The permselective membranes, although bowed slightly, appeared to be in good physical condition.

The same electrodeionizing unit is currently in operation, using Purex Tank Farm condensate as feed (pH, 10; 10^{-3} M NH_4^+). After six days' operation equivalent to 2500 column volumes through the resin filled dilution chamber, ruthenium and cesium decontamination factors are approximately 50 and 400, respectively.

The results of bacteria counts on Purex Tank Farm condensate samples from the 417 tank after hypochlorite treatment show that bacterial activity has been substantially reduced. Hypochlorite was added to the 417 tank on four successive days at concentrations to give about 2 ppm free chlorine in the condensate. Samples were taken after a four-day waiting period following the treatment. Only the one sample showed any bacterial activity (500-1000 cells/ml); however, this may have been caused by contamination since succeeding sample counts were zero. The clarity of the steam-stripped condensate following the hypochlorite treatment appears to be satisfactory for ion exchange work.

Distribution coefficients (K_d) were determined for pyrolusite, activated carbon and Dicalite, using Purex A-10 acid condensate waste adjusted to pH values from 2 to 12. All three materials exhibited maximum K_d values throughout the pH range of 5 to 9. Pyrolusite showed a high capacity (K_d = 4040 ml/g at pH 4.9), while activated carbon had a lesser capacity (K_d = 1600 ml/g at pH 5.0). The K_d value for Dicalite was 40 ml/g at pH 5.0.

Columbia River Studies

Electrodialysis of Columbia River bottom sediments from McNary reservoir indicated that most of the Co-60, Zn-65 and Mn- 4 could be removed from the sediment as cationic species. Only about one percent of the Cr-51 and Sc-46 could be removed even when the Cr-51 had only been associated with the sediment for three days. In a reaction rate study of Cr-51 with Columbia River sediments trivalent chromium ions were sorbed very rapidly. Hexavalent chromium, however, required about 36 hours for 98 percent sorption. In a sediment sample which had been oxidized with hydrogen peroxide the reaction with hexavalent chromium was only 60 percent complete at 180 hours. It may be that uptake of hexavalent chromium by sediment proceeds through reduction to trivalent chromium by reducing constituents of the sediment.

CONTAINMENT SYSTEMS EXPERIMENT

Major Facilities and Equipment

Detailed design of the auxiliary equipment and piping for the Containment Systems Experiment is currently receiving the major emphasis. First priority is being placed on locating equipment in the crane cab gallery prior to the start of installation of the major vessels. Installation is still expected to begin in October.

The award of the contract for the simulator is being held up pending the receipt of requested clarifying information from the vendor. The information that has been requested primarily is concerned with inspection details and procedures.

Fission Product Simulation

A series of tests was made to evaluate the suitability of various high temperature resistant materials as a container for molten UO_2. Ten stainless steel clad uranium oxide specimens were heated in air for periods up to 20 minutes. In all cases, the combustion boats were penetrated due to a combination of combustion, melting and reaction with the molten metal and oxide. Boat materials tested were zirconium oxide, zirconium silicate, aluminum oxide, graphite, zirconia coated graphite, alumina coated graphite and alumina coated tantalum.

Instrumentation Development

Detailed instrumentation requirements have been determined, and an instrumentation scope report is being assembled. The report describes the work to be done and proposed methods of approach, as well as time scheduling and cost estimates.

[redacted] [redacted]

Latest tests on the gamma water depth monitor for the reactor simulator indicate that a 3-decade change in count rate occurs for a 4 foot change in water depth. Spaced detectors and gamma sources will be necessary to monitor the whole 17 ft. depth of the reactor simulator.

Protective Coatings for CSE Vessels

Testing of protective coatings for the Containment Systems Experiment vessels is 75 percent complete. Tests under dry well and wet well conditions are completed; tests under main vessel conditions are in progress. Seven different protective coating systems are being evaluated.

BIOLOGY AND MEDICINE - 06 PROGRAM

TERRESTRIAL ECOLOGY - EARTH SCIENCES

Hydrology and Geology

Results from a study of transient, linear, partially-saturated flow show that the general partial differential equation does a good job of predicting flow. The difference between calculated and experimental results can be explained and is mainly caused by experimental problems. These results emphasize the necessity for accurate measurements of the soil parameters of permeability, capillary pressure, saturation and porosity.

A numerical integration scheme for unequally-spaced points was programmed to integrate the moisture content of soil in polar and spherical coordinates. This sub-routine will solve for the fluid content in a wetting sphere or cylinder when used with the extension of Phillip's Method to these coordinate systems. An obvious application is the analysis of the flow system development from a leaking buried tank.

Piezometer tube installations, to permit measurement of piezometric heads, in well 699-37-82B were unsatisfactory due to the apparent collapse of several of the plastic tubes. Also, the heads measured in that well were not in agreement with heads measured in an immediately adjacent well which has cement-separated (vice sand-packed) tubes. Cleanout of the sand and tubes from well 37-82B was accomplished to a depth of 560 feet, and the perforated zones are being checked with the straddle packer to assure correct perforation depth. The shape-charge perforator will be used, if needed, prior to reinstallation of new tubes.

Soil Chemistry

Laboratory experiments were initiated in an effort to determine anion-soil relationships. Soil columns are used to determine the rate of As-76, P-32 and Cr-51 movement relative to flow rate. Flow rates are measured directly by effluent volume and indirectly by Cl-36 breakthrough. Initial Cl-36 breakthrough studies show that 50 percent breakthrough occurs at one pore volume.

A study is underway to separate effects of self-diffusion, flow rate and hydraulic dispersion on the shape of the Cl-36 breakthrough curve. Diffusion coefficients for chloride in a Hanford soil matrix have been obtained. These values range from 1.00×10^{-6} to 1.6×10^{-6} $cm^2 sec^{-1}$ at volumetric moisture contents of 0.27 and 0.30, respectively.

Apparently, Mackie's diffusion coefficient equation can be used as an approximation. This equation,

$$De = D\, f^2/2 - f$$

where De = diffusivity in matrix
f = fractional pore volume
D = diffusivity in bulk water,

considers only geometrical tortuosity factors and assumes no chemical or physical interaction.

RADIOLOGICAL AND HEALTH CHEMISTRY

Bioassay Procedures

The direct measurement of radionuclides in urine samples by newly developed multidimensional gamma-ray spectrometric techniques has proven to be an extremely sensitive method for estimating radionuclide body burdens. The interference from natural radioactive potassium is eliminated for most radionuclides which decay by emission of two or more gamma-rays in cascade. The method is far more sensitive than present whole body counting methods for the determination of body burdens of many radionuclides. Cu-64, Na-24, As-76, Sc-46, Zn-65 and Co-60 have been measured in ashed urine samples from Richland, Washington, residents. In addition, the radionuclides Na-22, Cs-134 and Cs-137 were measurable in urine samples taken both locally and from other locations.

Radionuclides in Hair

A monthly hair sampling program was initiated for 12 male Alaskan Eskimos for the purpose of correlating Cs-137 body burdens and hair concentrations. The subjects will be whole body counted over a period of time where their Cs-137 body concentrations are changing by factors of 2-3. These data should provide valuable information as to the use of hair analysis as a method for estimating radioisotope concentrations in the body. Sr-90 analyses will also be made on the hair samples.

The Determination of Tc-99 in Urine

Tests were made on a bioassay procedure for Tc-99 in urine for use by the Internal Dosimetry Operation. This procedure was developed at Argonne National Laboratory but had not been tested on urine containing metabolized Tc-99. It was found that metabolized Tc-99 did not carry in the co-precipitation steps using alkaline earth phosphate and cupric sulfide, thus implying that the technetium is in a chemical form different from that used in developing the method. Further studies are planned to provide a satisfactory procedure.

Radiation Chemistry

In joint studies with the Radiological Development and Calibrations Unit, it was determined that the 2 mev electron Van de Graaff accelerator could be converted by the High Voltage Engineering Corporation into a high current pulsing unit. This machine could give pulses of 0.3, 1 and 3 microseconds at currents up to 0.5 amps per pulse, and could be pulsed from 1 to about 200 times per second. If operated at about 1 mev a one-microsecond pulse is estimated to give about 1000 rads per burst. Such an instrument could be a valuable tool in studies of the chemical kinetics of radiation reactions.

ATMOSPHERIC RADIOACTIVITY AND FALLOUT

Aerosol Sampling Study

A computer program was finalized for calculating particle size distributions from data obtained in seven particle size increments. An iterative technique is used to obtain a least squares fit of a quadratic or cubic equation. In most size distributions examined using both the cubic and quadratic fitted curves, no case could be made for the cubic over the quadratic insofar as improved consistency in the final subisokinetic sampling error was concerned. The results are interpreted to mean that uncertainties in establishing the true size distributions of particles on the collected filters are dominant in determining anisokinetic errors.

Aerosol Generation and Characterization

Dye-traced monodisperse particles generated from colloidal silica using the spinning disc were found to have a density of 1.14 g/cm^3. The classical, but tedious and time-consuming Millikan oil-drop experiment apparatus was used. The density obtained was much lower than the theoretical density, but agreed reasonably well with the 1.24 g/cm^3 obtained with gravity settling in a horizontal tube.

A locally designed parallel plate charge spectrometer was used to determine the charge of 5 μ dye particles produced by the spinning disc. The mobility spectrum showed a peak at -0.03 cm^2/sec volt, which corresponds to about 100 electrons per particle. Although a large fraction had this negative charge, the plate analysis showed that some were positively charged. These may be particles introduced in the sheath air required for the spectrometer. This possibility will be eliminated.

ISOTOPES DEVELOPMENT - 08 PROGRAM

Isotopic Composition of Promethium

To resolve the question of the promethium-146 content of the promethium which will be produced in future power reactor fuels, analyses are being performed on samples of typical high-burnup fuels. Three UO_2 pellets from the VBWR have been dissolved in the Analytical Hot Cells and the burnup checked by Cs-137 determination. Results were approximately 5,000, 10,500 and 14,800 Mwd/t, very close to the expected values. The rare earths have been separated as a group from each sample and the promethium is being purified by chromatographic ion exchange. Four UO_2 samples from the Yankee reactor have been received and are now being dissolved.

Besides determining promethium isotopic content, it is planned to analyze the samples for most of the other significant fission product and transuranic isotopes as a verification of the validity of computational techniques.

Promethium Compatibility and Re-entry Studies

Metallographic examinations have been completed on the pneumatically impacted high-temperature cladding material compatibility test samples. These had been heated for 1000 hours at 1100 C, the Nd_2O_3 serving as a stand-in for Pm_2O_3. No attack whatever was detected on the samples of 310 stainless, molybdenum, Hastalloy-N, Hastalloy-X, Hastalloy-C, or Haynes-25. Platinum showed a diffusional attack to a depth of about 0.06 inch.

Plasma jet runs on neodymium and samarium metals (stand-ins for promethium metal) with 80 percent argon, 20 percent oxygen showed that both melt readily (with considerable oxidation) and form fairly fluid melts. Implication is that promethium metal will behave predictably on re-entry. A similar test of stainless-clad neodymium oxide did not succeed in melting either the stainless can or the contained neodymium oxide (before failure of the quartz tube surrounding the jet). These results indicate that stainless-clad rare earth oxides will be difficult to burn up on re-entry. Alternately, they should be good candidates for intact re-entry.

In laboratory synthesis work, high purity SmF_3, NdF_3 and SrF_2 were prepared for compaction and compatibility studies. Strontium borate ($Sr_2B_2O_5$) was also prepared for use in irradiation "needle" fabrication experiments. An alternate route to the synthesis of di-strontium

[redacted] [redacted]

silicide was explored which should be more suitable for hot-cell use than the hydride reaction. Proposed synthesis is the high-temperature reaction of SrF_2 with elemental silicon. Advantage is taken of the volatility of SiF_4.

M. T. Walling, Jr.

Manager
Chemical Laboratory

MT Walling:cf

BIOLOGY LABORATORY

A. ORGANIZATION AND PERSONNEL

J. D. Berlin joined the Biological Analyses Operation as a Biological Scientist on September 1, 1964.

J. R. McKenney, Biological Scientist at the Experimental Animal Farm, returned from an Educational Leave of Absence at the University of Washington on September 4, 1964.

F. A. Demers, Biological Technologist, transferred from Analytical Laboratories to Radioecology Operation on September 7.

A. M. Harty, Biological Technologist in Biological Analyses Operation, returned from illness absence on September 8.

Employees resigning to return to school:

J. K. Lund, Biological Analyst, Biological Analyses, Sept. 4.
W. B. Aitkens, Biological Technologist, Metabolism, Sept. 11.
C. M. Jones, Biological Technologist, Biological Analyses, Sept. 11.

Employees completing temporary summer assignment and returning to school:

H. H. Jones, Jr. Scientist, Radioecology Operation, Sept. 8.
I. L. Jacques, Jr. Scientist, Exptl. Animal Farm, Sept. 18.
S. C. Rall, Technician, Inhalation Toxicology, Sept. 11.

R. R. Adee transferred from Metabolism Operation to Biological Analyses on September 28.

R. C. Erickson, AEC Fellow, completed his assignment with Aquatic Biology on September 15.

B. TECHNICAL ACTIVITIES

FISSIONABLE MATERIALS - 02 PROGRAM

Columnaris

A total of 82 jack chinooks, precocious males, trapped at Priest Rapids Dam during September 23-28 is being held in our hatchery as test animals for columnaris and water temperature studies. The practical problem of holding mature salmon in a healthy state is difficult, but the fish in its second week in our tanks appear well and only two fish have been lost. Blood samples from 17 adult chinooks captured on September 10 and tested for columnaris antibody titer showed 16 negative and one positive. Adult salmon apparently have an immune response mechanism to columnaris. Some fish, during their upstream migration, may not have been challenged by columnaris.

Following a series of ten injections of heat-killed columnaris organisms into fish, active antibody production was observed by the agglutination test. All strains of columnaris isolated from scrap fish, salmon, and trout produce antibodies when injected into a test fish and all antibodies are apparently of a common type.

BIOLOGY AND MEDICINE - 06 PROGRAM

METABOLISM, TOXICITY AND TRANSFER OF RADIOACTIVE MATERIALS

Zinc

Trout fed 0.1 μCi/g daily for 17 weeks retained 13% of the total administered dose of 1300 μCi four months following the last feeding. Deposition in the gastrointestinal tract is consistently high and amounted to 47% of body burden. The bone contained the highest concentration of 2.1 μCi/g. Peak accumulation in the bone of 4.3 μCi/g occurred during the fifth week after the last feeding.

Strontium

A three-year-old female miniature pig that had ingested 625 μCi Sr^{90}/day since nine months of age was killed when her clinical condition deteriorated rapidly. Three other animals fed 625 μCi Sr^{90}/day had died earlier, approximately nine months after initiation of Sr^{90} feeding at nine months of age.

The three early deaths resulted from hematological changes with severe thrombocytopenia, neutropenia, and anemia being the most prominent changes. Osseous changes, per se, did not contribute to the death of these earlier animals.

In contrast, in the recent case the animal had severe "radiation osteitis" with fractures of the femur and the mandible which necessitated killing the animal. Although this animal had a moderate thrombocytopenia, neutropenia, and anemia, these hematological changes did not seriously affect the animal's health.

Cesium

Rumen studies are presently underway to establish the biological factors responsible for the concentration of Cs^{137} in the rumen exceeding the concentration of the feed (both on a dry weight basis). This phenomena was previously discussed in the August 1964 Biology Report. Two rumen fistulated ewes are being fed 25 μCi Cs^{137} with 500 g chopped alfalfa hay twice daily at 12-hour intervals. The left parotid duct of one ewe has been surgically exteriorized to ascertain the role that saliva contributes to the concentration of Cs^{137} in the rumen.

Cerium-praseodymium

Rats were injected with Ce^{144}-Pr^{144} 2, 24, 48, and 240 hours following partial hepatectomy. Radionuclide distribution was determined 24 hours post-injection. Animals injected up to 48 hours post-hepatectomy retained less Ce^{144}-Pr^{144} in their livers and more in kidney, spleen, femur, and blood, as compared to controls. Animals injected 240 hours following partial hepatectomy did not differ from controls.

Neptunium

The enzyme liver tryptophan pyrrolase was induced in rats by intraperitoneal administration of L-tryptophan. Two-hour prior injection of Np^{237} in female rats reduced the level of induced enzyme. Similar pre-treatment with Np^{237} did not effect incorporation of C^{14}-labeled leucine into liver or plasma proteins.

Plutonium

Six white miniature swine were injected subcutaneously on each foreleg with $Pu^{239}O_2$ to determine the translocation of the Pu^{239} from the site. The animals will be sacrificed 1, 7, 30, 60, 90, and 365 days after $Pu^{239}O_2$ administration. No results are available on the Pu^{239} concentrations in the tissues sampled. However, external monitoring of the injection sites suggests that $Pu^{239}O_2$ moves from the site at the same rate as Pu^{239} nitrate.

Seven miniature swine were also injected subcutaneously with $Pu^{239}O_2$ and then were given Na_3Ca DTPA intravenously either one or six hours later. No data are available on the concentrations of Pu^{239} in the tissues sampled.

Inhalation Studies

One dog died 56 months after a single inhalation exposure to $Pu^{239}O_2$. The body burden at death was 1.2 μCi Pu^{239}; 49% in lungs, 27% in bronchial and mediastinal lymph nodes, 15% in liver, and 5% in skeleton. Translocation to liver and skeleton was the highest observed in this study. Previous high levels were 10% for liver and 4% for skeleton. Cardiopulmonary insufficiency and lymphopenia were the primary clinical signs prior to death. Primary pulmonary neoplasia was confirmed histologically after being visible radiographically for 8 to 14 months before death. In all of our studies a total of 36 dogs have died following inhalation of plutonium and pulmonary neoplasia was seen in six. In the surviving 26 dogs lymphopenia continues to be the major clinical sign. Several dogs show increased respiratory rates and one shows radiographic evidence of a lung tumor.

Plutonium dioxide was injected into the lymphatic vessels of the hind legs of two dogs to determine whether Pu^{239} in lymphatic tissue will alter the level of circulating lymphocytes, such as is seen after plutonium inhalation.

Preliminary work is being done to determine the possible action of dimethylsulfoxide (DMSO) on radionuclides deposited in lungs. Tests on skin indicate that DMSO may increase the rate of skin absorption of I^{131}.

Secondary Disease Studies

Host and donor cell populations were assessed in radiation chimeras using the newly developed cytolytic antibody technique. Red blood cells, peritoneal cells, lymph node cells, and spleen cells were studied. Mice irradiated with 700 r and protected with 2×10^7 rat bone marrow cells showed cells of exclusively host origin three months after treatment. Mixed cell populations were observed in mice irradiated with 950 r and protected with 2×10^7 rat bone marrow cells. Red blood cells and peritoneal cells were of predominantly donor origin. Lymph node cells were about equally donor and host in origin and spleen cells showed a 3 to 1 host-donor cell population. The significance of this mixed-up situation remains to be interpreted.

Effects of X ray on Fish

Groups of cichlids given 2000 r X-irradiation and reared in three different temperatures of 20, 25 and 30 C, all indicate growth depression compared to the controls at three months post-administration. The most marked growth depression is observed in the 30 C group in which the mean body weights are 12.4 and 9.3 g for controls and irradiated groups, respectively.

Effects of Water Temperature on Fish

Tissue respiration studies indicate the overall physiological capability of trout. Tissues from trout acclimated at 18 C have a $Q_{O_2}(N)$ of 1.24 for red muscle and 0.824 for white muscle. When 18 C tissues are measured at 8 C, they have a $Q_{O_2}(N)$ of 0.48 and 0.21, respectively. This depression in oxygen consumption at lower temperatures is expected. When tissues acclimated at one temperature are measured at a higher temperature, levels of consumption generally increase. However, when fish tissues acclimated at 18 C are measured at 28 C, the $Q_{O_2}(N)$ is 1.19 for red muscle and 0.73 for white. This depression in oxygen consumption is indicative of a temperature level beyond the physiological capacity of the organism.

Plant Nutrition

Continuing studies of the uptake of rubidium and iodide ions by plants show that the partially expanded leaf is the site of greatest deposition of these ions. The ratio of I to Rb is about six for plants held in the light and about eight for plants in the dark. Rubidium uptake is markedly decreased during periods of darkness, while iodine uptake is little changed. Treatment of the nutrient solution with chloramphenicol during the period of uptake enhanced the uptake of iodide, while rubidium uptake was suppressed. During darkness both ions are held up in stems and petioles and transport to leaves is suppressed.

Microbiology

Indolepyruvic acid has been clearly shown to satisfy the growth requirements of tryptophan requiring mutants of Neurospora crassa. Indolepyruvic acid is converted to tryptophan by a transaminase of non-specific origin in the cells. The pathway of conversion does not appear to be through the intermediate indole. Cell-free extracts of mycelia grown either in the presence or absence of tryptophan will catalyze the reversible reaction: tryptophan + pyruvate reversibly converted to indolepyruvate + alanine in the presence of pyridoxal phosphate.

Radiation Effects on Insects

The amount of energy from 4.6 Mev fast neutrons required to produce 50% dominant lethals in flour beetles was two to threefold less than from 250 KVP X-rays. Because of non-linearity of the X-ray dose response curve, this relative biological dose was used as a basis for comparison rather than the usual RBD. Experiments showed that pre-meiotic and meiotic cells were susceptible to adverse effects from X-ray and fast neutron radiation. This is of concern from the hazard viewpoint because these cells are more liable to be repeatedly irradiated compared to post-meiotic cells which do not remain in the body for long periods of time.

Columbia River Limnology

Preliminary attempts to fractionate plankton into the net and nanno components have been temporarily stopped because of lack of sensitivity in the counting equipment available within Biology.

Likewise, continuing difficulties are being encountered in finding a suitable technique for counting C^{14} in algae in connection with studies of primary productivity in the Columbia River. Neither dry combustion nor direct counting of the algae in a liquid scintillator has been completely satisfactory. The Van-Slyke liquid combustion technique appears to be the best potential method, but the assembly and perfection of the apparatus have been slow.

Terrestrial Ecology

The gamma emitters associated with cheatgrass harvested from an abandoned field on Hanford Reservation were reduced in total about fourfold on a concentration basis when compared with the 1963 harvest. Cesium-137 concentration was essentially the same in both years, although the amount/m^2 of harvested area was about tenfold lower in 1964 than in 1963 because of a reduced yield of cheatgrass in the later year. The concentrations of cerium-144 and ruthenium-106 were reduced very nearly in accord with their expected decay, and there is no apparent reduction in the rate of deposition even though most fallout predictions have indicated a near 50% reduction in fallout during 1964 as compared with 1963. The lack of such an apparent reduction is probably due to local conditions which have modified deposition rate.

Normal local sandy soil was mixed in various proportions with the saline soil typical of areas inhabited by greasewood and the uptake of Cs^{137}, Sr^{85}, and Ca^{45} measured by the Neubauer technique. Higher proportions of the saline soil produced slight reductions of Cs^{137} and Ca^{45} uptake, and somewhat more extensive reduction of the uptake of Sr^{85}, the latter being about a fourfold reduction. This observation will be checked by tests on pot culture to determine both the extent and differential reduction of uptake of Sr^{85} and Ca^{45}.

Alaskan Studies

Radioactivity in 82 residents of Anaktuvuk Pass was measured on September 9-11. The average and maximum body burdens of Cs^{137} were approximately 10% lower than measured last July. This decrease resulted from a change in diet from spring-killed to fall-killed caribou. This measurement also indicates that the body burden measured in July must have been near maximal and stayed at a plateau during the remainder of the summer.

Earlier in the summer Sr^{85} and Cs^{134} were applied to individual Thalli of lichens and to areas of lichen fields. Samples since that time have been taken on the day of application, the first day following application, and the 22nd day following application. In this short period of time there is little if any evidence of loss of either radionuclide from the lichens. Sampling is expected to continue through the year.

Special Problems

Enhancement of an autoradiographic image was found to be optimum with 12-14 mg of P7-920B zinc sulphide phosphor/cm^2. The phosphor was mixed with 2% gelatine and deposited on aluminum coated mylar. Using this material, samples from the bicassay laboratory containing 0.03 d/m of alpha could be distinguished from the samples containing 0.05 d/m or more. One sample did not check well between the autoradiographic and the direct microscopic examination, and on recheck by the autoradiographic technique again failed to check closely with the microscopic evaluation.

H A Kornberg

Manager
BIOLOGY LABORATORY

HA Kornberg:es

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TECHNICAL INTERCHANGE DATA
BIOLOGY LABORATORY

I. Speeches Presented

a. Papers Presented at Society Meetings and Symposia

Bair, W. J. Deposition, retention, and excretion of inhaled particles. Pacific Northwest American Industrial Hygiene Assoc., Richland, Washington. August 28, 1964.

Park, J. F. Biological effects of inhaled aerosols. Pacific Northwest American Industrial Hygiene Association, Richland, Washington. August 28, 1964.

Hungate, F. P. Radionuclides in Alaskan Eskimos. 15th Alaskan Science Conference, Fairbanks, Alaska (AAS). September 1-4, 1964.

b. Seminars (Off-Site and Local)

Hanson, W. C. Whole-body counting of Eskimos in Alaska. Hanford Laboratories Technical Activities Meeting, 300 Area. September 2, 1964.

Stuart, B. O. Effects of radiation on living tissue. Refresher Course for Radiation Monitors - 325 Building, 300 Area. September 22 and 25, 1964.

c. Seminars (Biology

None

d. Miscellaneous

None

II. Articles Published

a. Open Literature

Dean, John Mark and Clarence J. Goodnight. 1964. A comparative study of carbohydrate metabolism in fish as affected by temperature and exercise. Physiological Zoology 37: 289-299. (Work done elsewhere.)

b. Documents

None

III. Visits and Visitors

a. Visits to Hanford

About 40 Tech Grads from Hanford toured Biology on 9/17/64.

Ten AEC Trainees toured Biology on 9/18/64.

C. W. Fort, Jr., Graduate Student at the University of Washington, Seattle, Washington, discuss possible research to be done at Hanford with R. E. Nakatani.

John Stout and William Chobotar of Walla Walla College discussed research with L. Eberhardt on 9/22/64.

James Dilley of the University of Chicago toured facilities on 9/23/64 and discussed research with L. K. Bustad, R. C. Thompson, and W. J. Bair.

Osman Uzman, an International Farm Youth Exchange Program Associate with the Washington State University Extension Service (from Izmir, Turkey) toured the facilities and discussed research with J. F. Cline.

H. Hollister, Division of Biology and Medicine, U. S. AEC, Washington, D.C. Discuss mutual problems with L. Eberhardt.

Dr. Adolph Waller, Professor Emeritus, Ohio State University and Consultant to Battelle, Columbus, discussed ecological research with Dr. Hungate and staff and toured the facilities with Dr. Kornberg.

b. Visits Off-Site

8/3-4 - T. G. Tombropoulos visited the National Institute of Health, Bethesda, Maryland, to discuss problems of lipid biosynthesis and methods with Drs. R. O. Brady and Bier's group.

9/1-3 - F. P. Hungate attended and presented a paper at the 15th Alaskan Science Conference in Fairbanks, Alaska.

9/8 - F. P. Hungate attended a meeting of the Federal Radiation Council in Washington, D.C.

9/8-17 - W. C. Hanson conducted whole-body counting studies in Alaska.

9/9-10 - C. E. Cushing discussed sampling program with Dr. W. Hepworth at University of Wyoming, Wamsutter, Wyo.

9/11-10/11 - D. G. Watson presented a paper at the Symposium on Radioactivity in Scandinavia in Riso, Denmark and toured other European laboratories to discuss research.

9/4 - V. G. Horstman inspected feed at Pendleton Grain Growers, Hermiston, Oregon.

9/17 - L. K. Bustad discussed jointly authored paper with editor and performed library research at University of Washington, Seattle.

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b. Visits Off-Site (continued)

9/23-28 - M. P. Fujihara attended a meeting on Viral Diseases of Poikilothermic Vertebraes at the Eastern Fish Disease Laboratory and New York Academy of Sciences in New York City.

9/22 - V. G. Horstman transported two swine to Northwest Airlines in Spokane for shipment to SPAL, Washington, D. C.

9/23-24 - C. E. Cushing and W. H. Rickard collected fallout samples in the Cascades near Packwood, Washington.

9/28 - F. P. Hungate visited Portland, Oregon for the Commissioning of the Oceanographic Vessel "Yaquina", Oregon State Univ.

9/29 - L. K. Bustad and H. A. Kornberg served on the Thesis Committee at Washington State University in Pullman for the final oral examinations of Pat Hackett and Bea McClanahan.

9/30 - L. L. Eberhardt collected fallout samples in the Blue Mountains, Dayton, Washington.

IV. Achievements

None

V. Honors and Recognitions

P. L. Hackett and B. J. McClanahan passed their final oral examinations on September 29 for doctor of Philosophy degrees in animal science at Washington State University. The degrees will be awarded in February 1965. Members of their thesis committees included Dr. H. A. Kornberg and Dr. L. K. Bustad.

VI. Professional Group or Organization Assignments

None

APPLIED MATHEMATICS OPERATION

MONTHLY REPORT - SEPTEMBER, 1964

ORGANIZATION AND PERSONNEL

Ross J. Wood has been named Acting Manager of Statistics. R. C. Burke transferred to IPD on September 14, 1964. K. B. Stewart transferred to Vallecitos Atomic Laboratories on September 4, 1964. R. L. Hooper joined the section as a statistician on September 1, 1964.

ACTIVITIES FOR OTHER HAPO COMPONENTS

Chemical Processing Department

Closed form solutions were obtained to several mathematical models of the chemical processes which occur in the recovery of aluminum nitrate nonahydrate from Redox acid waste.

Irradiation Processing Department

The power curve was developed for a two-stage acceptance sampling plan embodied in a purchasing specification for Resistance Temperature Detectors (RTD).

An analysis was performed on post-irradiation data relative to distortion of dimensional characteristics of AlSi and HDS fuel elements.

The study of the validity of in-reactor sector gauge measurements of wall thickness of process tubes was completed.

A study was initiated of probolog measurements of wall thickness of process tubes. The aim of this study is the development of an optimal in-reactor tube sampling procedure for the Alternate Tube Corrosion Monitor Program.

A reliability study was initiated of reactor pressure monitoring systems.

N Reactor Department

A preliminary analysis of data was completed to estimate the p.p.m. of uranium in "inserts" which will be employed as scaling standards for fuel end-weld measurements.

A sampling plan and procedure appropriate to estimating the fractions of 1/4" stainless steel tubes having cracks at the initial outage period was developed.

A sampling procedure was formulated to facilitate an assessment of the change in the fuel I.D. due to rewelding.

A model and associated procedures appropriate to the evaluation of different pre-extrusion lubricating treatments of uranium billets were determined.

A study of pre-irradiation fuel weights obtained in air and under water was initiated. The object of this study is to prevent "laggard" and "outlier" data from being used in a post irradiation swelling study.

ACTIVITIES WITHIN HANFORD LABORATORIES

2000 Program

Flow System Models

Modifications of some of the "shoe box" EDPM programs have been completed. Although minor, these modifications make it possible to study more general flow systems and to examine computational errors with statistical techniques.

The statistical study to measure the errors in the computational sequence for determining the in-place permeability distribution for heterogeneous soils was continued.

C-Column Computer Control

The GE 412 process control computer is being installed in the Hanford van which is located next to the 321 Building. The computer will be used initially to control the operation of the C-column test facility. A number of 412 functional programs were assembled on the GE 225 system, and reliable paper tape output punched. The GE 412 computer operates on paper tape input routines. Desk type debugging is still in progress on other functional programs. The general diagnostic (equipment failure and peripheral failure routines) is now being written.

The calibration experiment for the organic photometer was completed. The photometer will be used to monitor the organic uranium stream concentrations of the A-column test facility. Experimental data is now available on punched cards, and the statistical analysis necessary for the establishment of the calibration function is in progress.

4000 Program

Sonic Transmission in Visco-elastic Materials

An EDPM program has been completed which will aid in the investigation of attenuation of ultrasound. The program produces the frequency spectrum of an initial pulse and the rebounding pulses from a plane boundary separating dissimilar media together with the frequency spectra of the rebounding pulses. A first draft of the mathematical model used as a basis for the program has been written.

Other

Mathematical assistance was provided Ceramics Research and Development in determining precision lattice constants of hexagonal crystals once these crystals were indexed. An EDPM program was written and debugged which employs the Nelson-Riley extrapolation functions to determine a weighted least-squares fit of the data.

Mathematical models are being investigated, and EDPM programs are being written to study the flow of heat in layered media. This investigation is concerned with non-destructive testing by thermal methods.

A regression analysis was performed on radiation measurements from the PRTR.

Work on the mass spectrometer simulation study relative to propogation of measurement errors was continued.

5000 Program

Computation and Statistical Analysis

Data for the BLU analytical file is being prepared both for debugging of the system and for the final input to the completed system.

Work continued on the hypothesis testing problem associated with deciding between the two alternatives that a set of random times between successive counts arose from the decay of a pure nuclide, and that the times were generated from a uniform intensity background. Uniformly most powerful similar region tests, based on random time and on fixed time counting procedures, have been worked out. Current efforts are directed toward a composite procedure based on random time with a fixed time truncation point. Programming for the digital computer calculation of critical points for the above tests is now in progress.

A number of statistical analyses of program data are in progress in anticipation of a program meeting here at Hanford during the week of October 19.

Radiochemical Analysis

Several extensive modifications to the IRA master file have been specified and the necessary programming completed. Specification of a channel summing pass for the multidimensional analyzer system MUL was completed. Card output for this program will be input to the latest version of the GEM program which now appears to be debugged.

Other

Data was analyzed relative to a graphite research and development study.

6000 Program

Biology

The analysis of data from a study to investigate the effect of physical and biological conditions on deposition and retention of I^{131} on plants was completed.

The method of evaluation of particle-size data from inhalation toxicity experiments is being studied.

Carl A. Bennett

Manager
APPLIED MATHEMATICS

CA Bennett:lg

RADIATION PROTECTION OPERATION REPORT FOR THE MONTH OF SEPTEMBER 1964

A. ORGANIZATION AND PERSONNEL

The Nuclear Health & Safety function, formerly in Programming, was transferred to the Radiation Protection Operation on September 1 under the continued direction of R. L. Junkins. R. W. Hardie completed his rotational assignment in RDCO effective September 30. Myrtle Ghent and Ina Lierman terminated from EDO on September 30. J. A. Gile and L. W. Hankel transferred from RMO to IPD effective September 28. A. W. Norwood and R. W. Switzer transferred from IPD to RMO effective the same date. C. A. Tompkins transferred into IDO effective September 14, replacing D. L. Silver who terminated September 9 in order to return to school.

B. ACTIVITIES

Occupational Exposure Experience

There were three new plutonium deposition cases confirmed by a special bioassay analysis during the month. The evaluation of additional urinalysis data resulted in the reclassification of one employee who was formerly considered to be a deposition case. The total number of individuals who have received internal depositions of plutonium at Hanford is 347, of which 246 are currently employed at Hanford.

In September there were six incidents involving twelve employees which required special bioassay sampling for plutonium analysis. None of the incidents resulted in any detectable deposition. In addition to the incidents involving plutonium, there were four incidents involving four persons that required evaluation for possible intake of other radioisotopes. None of these incidents resulted in any significant deposition.

There were two items of special interest involving exposures of personnel. Brief descriptions are:

> Two Hanford Laboratories personnel working in the Plutonium Fabrication Pilot Plant (308 Building) received hand exposures, based on finger ring film, that appear to exceed the operational control limit of 8 rem/month. Evaluation is not yet complete, but it does not appear that either will exceed the occupational exposure standard of 25 rem/13 week period.
>
> Analysis of a bioassay sample submitted by a Hanford Laboratories employee, following work in the Plutonium Recycle Test Reactor (309 Building) indicated a concentration of 127 μc of tritium per liter. Based on the results of this and subsequent samples, the whole body dose received through the badge period ending 9-25-64

by the employee is estimated to be 0.8 rem and the total whole body dose resulting from this exposure is expected to be 1 rem.

Experimental work on fuel elements in A cell in the 327 Building resulted in a maximum weekly I^{131} stack emission of 55 mc. Pressure drop measurements across the charcoal filter indicated satisfactory filter seating and the filter, which was just newly installed in July, was left in operation for subsequent observation. Stack emissions returned to normal and replacement of the charcoal filter was not required. The A cell absolute filter box radiation level suddenly increased from 5 R/hour to 80 R/hour during the same work in A cell. The filter was replaced at a maximum personnel dose rate of 10 rads/hour and with good contamination control. A two-inch lead shielded box was used for transfer to the burial ground.

At the request of the Commission, and in coordination with the Administrative Manager of Vitro Engineering Company, arrangements are in progress to establish, maintain, consolidate and summarize radiation exposure records for employees of that company.

At the request of the Commission, a summary of the 1963 Hanford Exposure Experience was prepared for their annual report. This included the total number of employees covered by the film badge dosimeter system, the number of employees receiving penetrating doses in excess of 1 rem and the percent of work force receiving less than 1 percent of the maximum permissible dose. Summaries of the number of plutonium deposition cases that have occurred through 1963 and the number and description of radiation incidents in which an NCRP limit were exceeded, were also included.

Environmental Experience

On June 12, 1964 the swamps that receive cooling water from the Purex plant became grossly contaminated as a result of a leak in the cooling coils of a process tank. Backfilling of the inlets to the swamps and some of the shore line, increased depth of water in the swamps, and time for fixation of the contamination in the bottom of the swamps have virtually corrected the conditions. The status of "B" Swamp has been satisfactory since August.

Efforts to eliminate the radiation problems still remaining at the Gable Mountain Swamp continued through September. The contamination in the water is on the order of 5×10^{-5} μc/cc and is no longer a problem. The mud in the bottom of the swamp is still highly contaminated and the major efforts have been directed at raising the level of the water so that the mud will be less accessible to ducks.

Evaluation of the effects of the fuel element failure at 105-F Reactor on August 31, 1964 indicated that the total fission product release was

about 1000 curies including about 15 curies of I^{131}. Samples of river water indicated a maximum concentration of I^{131} of about 100 pc/l at the Richland Water Plant.

Concentrations of fallout materials in the air of eastern Washington averaged 0.4 pc/m^3 during September, the lowest monthly average since the fall of 1961. These concentrations have been steadily decreasing from the peak values of 2 pc/m^3 noted in May and June of this year.

Nuclear Safety

The hazards review, "Plutonium Reclamation Facility, Miscellaneous Treatment Room, Glove Boxes 1 and 2", was completed by the HAPO review group and a report issued on September 1, 1964. The group concurred with the recommendations in the hazards evaluation. The over-all nuclear safety margin appears adequate.

Document HW-82259 REV, "Nuclear Safety Guidance in the Use of Water to Fight Fires in CPD Facilities", was revised to update the categorization of plant areas for fire fighting purposes.

Hanford Laboratories personnel are working on a draft of a nuclear safeguards policy which will be recommended to Battelle-Northwest for adoption. The recommended policy will be based on the current contractual requirements for nuclear safety as well as the current practices in the Laboratories.

There were no meetings with the General Electric Technological Hazards Council or the Advisory Committee on Reactor Safeguards during this reporting period.

Status of Action Items

Hanford Nuclear Health and Safety Study

Action Item Number 7: Prepare and start discussion with the AEC of Operating Safety Limits for the PCTR, CML, TTR, and PRCF.

Drafts for discussion with RLOO-AEC have been revised and resubmitted for PCTR, TTR, and PRCF. Informal agreement has been achieved on control of the Operating Safety Limits for PRCF.

Action Item Number 8: Prepare and start discussion with the AEC of Operating Safety Limits for Hanford Test Reactor.

No change during this reporting period.

Action Items
Number 16,
17, and 18: Implementation of desirable Hanford capability in the event of a serious radiation incident.

No change during this reporting period.

Consultations

At the request of Biology Operation personnel, thermoluminescent dosimeters and silicon neutron dosimeters were used to measure the gamma and neutron dose in the PCTR core prior to a Biology experiment. The thermoluminescent dosimeters were calibrated with radium gamma radiation for doses up to 30 R. Glass rod dosimeters were also calibrated and used in this same experiment to confirm the gamma dosimetry results. The results compared favorably. The silicon diode neutron dosimeters indicated neutron doses between 330 and 410 rads for a five-minute reactor operating time. The average neutron dose was determined to be 369 rads ±40 rads.

Several thermoluminescent dosimeters that were implanted in sheep to determine the dose rate to various organs were evaluated for Biology personnel.

A number of thermoluminescent dosimeters, previously exposed in Alaska by the Biology personnel, were evaluated. In general, these dosimeters read unexpectedly high.

Methods of protecting glass rod dosimeters from damage during insertion in fish tissue and during retrieval were reviewed with Biology personnel. The shielding effect of a small diameter polyethylene surgical tube was evaluated. Recommendations for sealing the glass dosimeter rods in this tubing prior to insertion were made. The tubing should be effective in reducing glass chipping and may also reduce the migration of the glass in the tissue. Four glass rods which were exposed to fish on Zn^{65} diets were evaluated.

Neutron and gamma dose rates were measured for experimental exposures of rats at the accelerator facilities. The rats were exposed to a dose of 175 R at a dose rate of about 1,000 R/hr at the electron Van de Graaff accelerator.

Consultations were provided to Materials and Process Chemistry personnel on the use of silver phosphate glass dosimeters for Co^{60} irradiations in the dose range from 10^4 to 3×10^6 R. The discussions included methods to evaluate, anneal and reuse the glass dosimeters after exposure.

Discussions relating to pulsed radiation sources, particularly those available from the Van de Graaff and the Flash X-ray machine, were held

with a member of the Radiological Chemistry staff. Possible use of this equipment for the study of chemical reaction rates after exposure to high intensity, short duration dose rates is being considered.

Shielding calculations were performed for Reactor Materials Research Operation to determine the maximum quantity of irradiated samples that could be safety handled in a proposed reactor material facility. Other radiation protection aspects of the proposed facility, including its location, were discussed.

Studies and Improvements

A report from DuPont laboratories substantiated the wide range of readings of blank film reported last month. Their representative plans to visit soon to discuss the problem further. A new lot of film was received and about five thousand pieces of film were sampled. Sampling consisted of taking the top and bottom five film from each tube of 150 film and developing according to standard procedures. Only film from tubes whose tested film ranged between 95 and 120 mv in darkening were used in personnel film dosimeters. The current lot of film is generally superior to the previous lot. Blank film reading frequency histograms are being prepared.

The new automatic densitometer designed and fabricated by Radiological Development and Calibrations Operation was first used for production purposes September 29, 1964. The performance of this equipment was flawless and marks a significant improvement in external dosimetry processing technique.

A meeting was held with 308 Building personnel to formulate a plan of action to identify the source of and eliminate contamination from the building air exhaust system. Contamination has been detected downstream of two absolute filters in the hood exhaust system. A six-point plan of action was agreed upon.

The fission fragment neutron detectors with U^{235} fission foils were exposed to 1 Mev neutrons. The fission tracks observed were easily distinguished and about equal to the number expected from theoretical calculations. The exposures conducted with U^{238} as the fission material did not produce fission fragment tracks. These results were anticipated and conducted merely to confirm the threshold fission data for U^{238}. Neutron energies above 1 Mev are required for fission of U^{238}.

The G.I. Tract Dose Monitor installed at the Richland Water Plant was removed from service for several days to permit coating the water-exposed surfaces of the scintillator with special silicon compounds to reduce radionuclide deposition and buildup. This treatment was partially effective but has not fully eliminated background buildup.

Studies are continuing on modifications to the electron Van de Graaff accelerator to provide variable, short duration radiation pulses. The

High Voltage Engineering Company now offers a pulsing unit which can be attached to our accelerator to provide pulses in the region from 1/2 to 3 μsec. Pulse equipment designed at Hanford and now installed on the equipment provides pulse durations from 10 msec to many hours in duration.

A new Field Emission electron-emitting tube suitable for use on the Flash X-ray machine is now available commercially. This equipment, which has a pulse duration of 0.03 μsec will provide an electron dose of 10^6 rads per pulse. Equipment of this type is being considered to provide improved capabilities within the Calibration Operation. Personnel from the Radiological Chemistry group are currently interested in performing chemical experiments in these short duration pulsed fields.

All portable instruments routinely used at Hanford were tested for response under photon radiation pulses of 0.1 μsec duration. With the exception of the G.M. and BFQ monitoring instruments, a clear response was noted for each pulse. The results of these studies were documented in HW-84067, "Single X-ray Pulse Response of Radiation Monitoring Instruments".

LiF dosimeters filled with hydrogenous material to enhance their neutron sensitivity were irradiated. In general, the results of these studies were inconclusive. Further study is being conducted to define parameters that control the LiF sensitivity to fast neutrons. In some experiments, detection limits of 5 to 10 rads were noted, but it has not been possible to dependably reproduce these exposures. Possible variations now under study include variations in the LiF powder size, possible interaction of the fluoride powder with sunlight or fluorescent lighting and possible triboluminescence which may go unnoticed in many laboratory experiments where the dosimeters are carefully handled but may contribute extraneous readings when dosimeters are used under field conditions.

Research Studies

Effect of Reactor Effluent on the Quality of Columbia River Water

A study is in progress of the effects of reactor effluent on Columbia River water quality with emphasis on temperature effects. Spot dye releases from B, K, and N Area outfalls were made for determination of travel times in the river flow range of 100,000 - 120,000 cfs. The lag between river channel and shoreline arrival times at downstream locations was somewhat greater in this set of runs than expected. Installation of the portable meteorological station at White Bluffs was completed.

Mechanisms of Environmental Exposure

Columbia River whitefish were used in a study utilizing a P^{32} whole-body counting technique. Initial results with one subject indicate an effective half-life of P^{32} in blood of 10.7 days. The instrument gave a measurable response to P^{32} ingestions as low as 58 nc. When laboratory analyses are completed the instrument response to various total body burdens of P^{32} can

be ascertained to permit interpretation of whole-body counting data.

A cooperative effort with Washington State Game Department personnel is in progress to contact the most avid Columbia River fishermen and invite their cooperation to obtain data concerning fishing practice and the resulting radioisotope ingestion. These fishermen are invited to the whole-body counter for P^{32} and Zn^{65} analyses. The first two such counts completed revealed a maximum Zn^{65} body burden of 8.5 nc. The study will continue in an attempt to obtain a statistical sample of this group.

Nuclear Facilities Monitoring Guide

Work continued on preparing a first draft. The material already written was reorganized into a sequence of subjects which makes the text more usable as a guide and not so much a collection of facts. The sequence of major subject categories is now (1) objectives, (2) requirements, (3) methods and procedures, (4) equipment, and (5) data interpretation and handling. The first two categories are nearly completed.

C. TRAINING

Radiation protection orientations and training lectures on the general radiation work procedure were presented to 308 Building personnel. Orientation lectures were given to 12 Transportation personnel in the 384 Building.

The course "Radiation Protection Training for Exempt Personnel" was started on September 16 with an enrollment of about 25 persons. A refresher training course for radiation monitors was also started on September 15.

Two lectures on the Columbia River Emergency Plan were presented to 40 RPO exempt personnel. Four evening emergency training sessions on simulated problems were attended by 35 RPO exempt personnel.

A four-hour "Fallout Shelter Meeting", presented by the University of Washington for the Department of Defense, was attended by K. R. Heid.

D. SIGNIFICANT REPORTS

HW-80991, "Evaluating Radiological Conditions in the Vicinity of Hanford for 1963", R. H. Wilson, Editor.

HW-80892-8, "Radiological Status of the Hanford Environs for August 1964", R. F. Foster.

HW-83047, "Single X-ray Pulse Response of Radiation Monitoring Instruments", P. E. Bramson, September 2, 1964.

HW-84335, "Radiation Monitoring Monthly Report, August 1964", A. J. Stevens.

HW-83970, "Review of 300 Area Emergency Plans", C. L. Brown, K. R. Heid and and R. L. Junkins.

Radiological Development and Calibrations Summary of Technical Activities Report for CY 1963, C. M. Unruh.

Operating Instructions for the Flash X-ray, P. E. Bramson.

Manager
RADIATION PROTECTION

AR Keene:np

FINANCE AND ADMINISTRATION OPERATION

ACCOUNTING

Cost Accounting

A firm financial plan was received by RLOO-AEC for FY 1965. Following is a summary of program funds included for Hanford Laboratories:

(Amounts in thousands)

04 Program	
R&D	$16 076
Equipment	1 090
IU's	2 653
05 Program	
R&D	1 694
Equipment	300
IU's	4
06 Program	
R&D	3 570
Equipment	275
08 Program	
R&D	500
Equipment	40

Details of the above amounts have been furnished Hanford Laboratories' management.

Control budgets for September were adjusted to reflect the firm financial plan.

Control budgets will also be adjusted to reflect the transfer of mail and duplicating functions from IPD.

The following 04 Program codes were established during the month:

.11 Microwave Detection of Coolant Impurities
.24 Phoenix Fuel
.28 Pu and U-233 Fueling

Additional authorizations were received for the following special requests:

.1V	PRDC Graphite Irradiations	$30 000
.3N	Basic Cermet Studies (NASA)	50 000
.3F	Fog Cooling of Fuel Elements (AEC/AECL)	25 000

General Accounting

The following letters were approved by the Atomic Energy Commission:

Approval No. AT-361	Assistance to Washington State University - Dr. Archie S. Wilson	Approved 9-18-64
Approval No. AT-362	UO_2 Compaction Work for General Electric Company	Approved 10-1-64

OPG 3.5.2, Tuition Refund Program, was revised and issued during the month.

Hanford Laboratories' net material investment at September 1, 1964 totaled $27.7 million as detailed below:

		(In thousands)
SS Material		$26 464
Reactor & Other Special Materials		954
Spare Parts		345
Yttrium		26
Subtotal		27 789
Reserve: Spare Parts	$88	
Yttrium	26	(114)
Net Inventory Investment		$27 675

The cumulative value of nuclear material consumed in research by Hanford Laboratories during FY 1965 (at September 1, 1964) is shown below:

02 Program	$ (1 852)
03 Program	74 447
04 Program	(273 043)
Total	$(200 448)

The credit in the nuclear material consumed in research account is due primarily to return of material to Redox at full value during the month of August.

Arrangements were completed for the quarterly inventory of reactor and other special material in custody of Hanford Laboratories as of the end of September, 1964. This will be a "certification" type inventory except for an inventory of materials within the Chemical Laboratory (7600) component, which was "witnessed" on September 30, 1964. The primary difference between the two inventories is the active participation, or lack of it, by Financial personnel. Upon receipt of the requested information and reconciliation with Hanford Laboratories' financial records, a report of results will be issued.

The physical inventory of movable catalogued equipment in the custody of Radiation Protection and Biology Laboratory was started during the month of September. The physical count of Radiation Protection equipment is complete and the reconciliation is in progress. The physical count of Biology Laboratory equipment started on September 28 and will extend through October 20, 1964.

The status of Hanford Laboratories' heavy water inventory at September 30, 1964 is as follows:

	Current Month		FY to Date	
	Pounds	Value	Pounds	Value
Beginning Balance	31 596	$421 644	32 762	$447 572
Acquisitions	27 438	376 998	27 438	376 998
Scrap Returns (SROO)				
Consumption -1)				
PRTR: Loss	(1 300)	(17 979)	(2 466)	(34 103)
Scrap		(4 375)		(14 179)
Ending Balance -2)	57 734	$776 288	57 734	$776 288

(1- Consumption - Scrap reflects amount charged to Cost only.

(2- Includes 14,039 pounds of heavy water scrap valued at $134,760.

The loss and scrap amounts shown above under current month are estimated in absence of a physical inventory at September 30, 1964. The tentative plans by PRTR are to take a physical inventory around October 12 when the reactor is scheduled to be down.

Savannah River Operations Office's calculation on the last heavy water shipment made in June indicated receipt of 126.60 pounds higher than the HAPO computed weight, consequently, a credit to Cost of $869 was made during September.

Laboratory Storage Pool activity is summarized as follows:

	Current Month		FY to Date	
	Quantity	Value	Quantity	Value
Beginning Balance	1 884	$1 531 546	2 027	$1 493 571
Items Received	168	45 073	397	166 869
Items Reclaimed by Custodians	(24)	(13 035)	(210)	(22 879)
Equipment Transfers	(53)	(5 552)	(110)	(47 770)
Items Disposed by PDR	(29)	(1 392)	(31)	(5 849)
Items Disposed by Excessing			(127)	(27 302)
Ending Balance	1 946	$1 556 640	1 946	$1 556 640 -1

(1- Includes 171 items valued at $119,589 on loan at September 30, 1964.

Loans & Transfers in Lieu of Purchases	Current Month		FY to Date	
	Quantity	Value	Quantity	Value
Loans	12	$ 3 248	45	$ 24 998
Transfers	53	5 552	110	47 770
Total	65	$ 8 800	155	$ 72 768
Operating Costs (8-30-64)		$ 1 488		$ 2 972

Laboratory Storage Pool material and equipment at September 30, 1964 totaled $2.6 million as detailed below:

Equipment	$1 556 640
Reactor & Other Special Materials	262 491
SS Material	154 800
Other Material	541 026
Exotic Material	56 063
Total	$2 571 020

A value of 25% ($56,063) was established for materials received from the Boeing Company during the month of September. This material classified as Exotic Material consisting of Columbium, Molybdenum, Inconel, and Hastelloy, is physically located and controlled by the Laboratory Storage Pool. A journal entry was prepared during the month establishing this amount ($56,063) in the inventory account (0417) with an offsetting entry to 2790 - Cost - Prior Month's Operation.

New money was authorized General Electric on projects as follows:

CAH-100	High Temperature Lattice Test Reactor	Additional $30,000; making a total of $50,000.
CAH-153	Plutonium Recycle Critical Facility Irradiated EBWR Fuel Handling	$19,500.

The following contracts were processed in September:

DDR-192	Wah Chang Corporation
SA-360	Turco Products, Inc.
MRO- 78	RCA Service Company
MRO- 79	Philips Electronics and Pharmaceutical Industries Corp., Philips Electronics Instruments Division

Personnel Accounting

Effective September 1, 1964, responsibility for the administration of the Employee Payroll Status Change forms in conformance with the Company salary plan was transferred from Personnel Accounting to Technical Compensation.

Patent awards were made to the following employees:

L. R. Vancott (transferred)	HWIR 1390	Rectangular Wire Pressure Roll Assembly
D. T. Aase	HWIR 1685	Nuclear Reactor Fuel Element
R. J. Hennig	"	" " " "
J. A. Christensen (resigned)	HWIR 1597	Direct Energy Conversion
J. O. McPartland	"	" " "
L. A. Pember	"	" " "

Suggestion awards in the total amount of $2,165 were paid to 21 employees. There is a balance of $406 remaining from the $11,000 authorized for Hanford Laboratories' Suggestion Awards for the calendar year of 1964.

W. J. Flicek, M. S. Ghent, and I. Lierman retired effective October 1, 1964.

Personnel statistics follow:

Employee Changes	Total	Exempt	Nonexempt
Employees at beginning of month	1 841	810	1 031
Additions and transfers in	41	16	25
Removals and transfers out	71	36	35
Employees at end of month	1 811	790	1 021

Overtime Payments During Month	September	August
Exempt	$ 4 183	$ 5 500
Nonexempt	32 152	30 183
Total	$ 36 335	$ 35 683

Gross Payroll Paid During Month		
Exempt	$ 816 549	$ 819 612
Nonexempt	726 187	592 679
Total	$1 542 736	$1 412 291

Participation in Employee Benefit Plans at Month End	September		August	
	Number	Percent	Number	Percent
Pension	1 706	99.3	1 702	99.4
Insurance Plan - Personal	384		391	
- Dependent	1 419	99.7	1 420	99.7
U. S. Savings Bonds				
Stock Bonus Plan	158	34.5	153	34.5
Savings Plan	70	3.9	71	3.9
Savings & Security Plan	1 185	87.5	1 213	86.8
Good Neighbor Fund	1 297	71.5	1 325	71.9

Insurance Claims	September		August	
	Number	Amount	Number	Amount
Employee Benefits				
Life Insurance	1	$15 502		$ -0-
Weekly Sickness & Accident	10	835	8	621
Comprehensive	45	3 486	54	3 481
Dependent Benefits				
Comprehensive Medical	90	8 863	98	9 988
Total	146	$28 686	160	$14 090

TECHNICAL ADMINISTRATION

Sixteen nonexempt employment requisitions were filled; 89 remain to be filled.

Suggestion Plan activity:

Suggestions received	36
Suggestions adopted	20
Suggestions rejected	16
Suggestions in process	108

Visitors Center activity:

September attendance	1 443	
Average attendance per day open	55	
Cumulative attendance since 6-13-62	79 538	
Conducted groups	1	(totaling 1 person)

Plant tour activity:

	Number	Total People
General Public Relations Tours	1	18
Special Tours	7	120

Overall recruiting results for September are as follows:

Offers extended	4
Offers accepted	3
Offers rejected	5
Added to roll	7

Advanced Degree - Two Ph.D. applicants visited HAPO for employment interviews. Two offers were extended; two acceptances and five rejections were received. Four offers are currently open.

BS/MS (Direct Placement) - Two offers were extended. There were no rejections and one acceptance; one offer is currently open.

BS/MS (Program) - No offers were extended. No offers were accepted and no offers were rejected. There is one offer currently open.

Technical Graduate Program - Four Technical Graduates were placed on permanent assignment. Two new members were added to the roll and one terminated from the roll. Current Program numbers 39.

H. A. Paulsen attended the annual Research Personnel Compensation Survey meeting at Columbus, Ohio.

FACILITIES ENGINEERING

At month end, Facilities Engineering Operation was responsible for 13 active projects having total authorized funds in the amount of $10,729,000. The total estimated cost of these projects is $11,880,000. Expenditures through August 31, 1964 were $4,640,000.

The following summarizes project activity in August:

Authorized projects at month end ---------- 13

New projects authorized ---------- 1
- CAH-153, Pu Recycle Critical Facility - Irradiated EBWR Fuel Handling

Projects completed ---------- 0

New projects submitted to the AEC in August ---------- 1
- CAH-155, Services for Biology Laboratory Facilities - 300 Area

New projects awaiting AEC approval ---------- 2
- CAH-123, Laboratory Fire Protection System
- CAH-155, Services for Biology Laboratory Facilities - 300 Area

Project proposals being prepared ---------- 6
- Geological and Hydrological Wells - FY 1965
- Power Supply - Million Amp Welder
- PRTR Increased Power Level
- Shielded Creep Test Facility - 3707-C Building
- Variable Spectrum Test Reactor
- 309 Building - Experimental Facility Addition

The status of active projects follows:

CAH-100 High Temperature Lattice Test Reactor

Design is 86 percent complete compared to a scheduled 94 percent. An addendum to the Phase I bid package was issued on September 15. The addendum included 31 drawing changes, one new drawing, some language changes, and an extension of the bid opening date to September 30, 1964. In order to reduce

costs the Commission removed the ground cover, underground sprinkler system, and exposed aggregate building exterior from the Phase I package. Bids were opened September 30. The apparent successful low bidder with a bid of $782,000 was George A. Grant Construction Company. The Government Fair Cost Estimate was $905,000. Phase II equipment and construction drawings are now being received by the Company for review and comment. The first step of a two-step bidding procedure for procurement of the PMARS equipment was issued to prospective bidders on September 1. Replies are to be received by October 15. They are to contain complete technical proposals but are not to include price information.

A Work Authority revision was received authorizing the Company $50,000 for performance of all assigned functions. Our most recent request was for $75,000. Eliminated was our technical guidance of design and project field service during construction and fabrication of graphite.

CAH-114 Critical Mass Laboratory Addition

The project proposal submitted to the Commission on November 4, 1963 was returned unapproved by the AEC on September 28, 1964.

CAH-116 PRTR Decontamination and D_2O Cleanup

Design is complete. The detailed design drawings were approved by the Company on September 9. Project funds in the amount of $136,000, to cover the cost of the D_2O cleanup system, were authorized on September 8. A revised Work Authority authorized Vitro an increase in design funds from $43,500 to $50,000. It also states the CPFF Construction Service Contractor will procure and install the D_2O cleanup system.

CAH-119 PRTR Storage Basin and Experimental Facilities Modifications

Design is about 96 percent complete. It was scheduled to be completed on June 15, 1964. Vitro is performing detailed design of the heating and ventilating system.

Construction is 8 percent complete. A construction schedule has not been issued. Work was slowed considerably by the pipefitters' strike and delayed receipt from Vitro of an approved method of excavating and shoring the basin area.

CAH-123 Laboratory Fire Protection System

The project proposal was transmitted to the Commission on March 3, 1964. No action has been taken by the Commission.

CAH-126 Waste Transport System

Design is 63 percent complete compared to a scheduled 68 percent. Design of the loading and unloading facilities and railroad is progressing. Three information drawings have been received on the loadout facilities.

CAH-136 Service Addition - 327 Building

Design is 89 percent complete compared to a scheduled 95 percent. Information drawings of the general architectural features and furniture locations have been received.

CAH-137 Temporary Physical Sciences Center

Design is 60 percent complete. There is no design schedule. J. A. Jones has initiated procurement of materials and equipment. No project work has been performed at the building site.

CAH-146 Atmospheric Physics Building

The design criteria document was reviewed with the Commission on September 15, preparatory to negotiating a contract with an architect-engineering firm. The criteria need to be revised by the Company. It is anticipated a contract will be awarded before the end of October.

CAH-151 Office Addition - 308 Building

Design is 91 percent complete compared to a scheduled 94 percent. Thirteen information drawings have been received for comment.

CAH-153 Plutonium Recycle Critical Facility, Irradiated EBWR Fuel Handling System

A directive dated September 8 authorized the project with total funds in the amount of $40,000. A Work Authority dated September 15 authorizes the Company $19,500 for total design and for procurement of the on-site cask.

CAH-155 Services for Biology Laboratory Facilities - 300 Area

The design criteria document and project proposal were transmitted to the Commission for review and approval on September 18 and September 23, respectively.

CAH-916 Fuels Recycle Pilot Plant

Construction is 77 percent complete compared to a scheduled 65 percent. The pipefitters' strike slowed construction progress. The contractor poured

concrete in the Metallurgical and Hot Pilot Cells walls. The elevator door frames and Pyrochemical Cell stainless steel liner were installed. The painters are applying topping cement on the interior concrete block walls and are continuing to apply paint throughout the building. The plasterers are constructing partitions throughout the administrative and change room areas.

CAH-962 Low Level Radiochemistry Building

Construction is 23 percent complete compared to a scheduled 26 percent. All of the precast, exposed aggregate wall panels have been poured and are currently being erected. Erection of the structural steel frame was completed. Electrical and sheetmetal work is continuing in the basement area. The pipefitters' strike delayed progress and caused changes in work schedules.

CAH-977 Facilities for Radioactive Inhalation Studies and
CAH-982 Additional Radionuclide Facilities

The revised project proposals were issued by the Commission. A separate proposal (CAH-155) was prepared to provide temporary utilities to the two facilities. The Commission is integrating these two projects and project proposal CAH-155.

Engineering Services and Plant Engineering

Engineering work was performed in support of design and construction on active projects, project proposals, preliminary planning, and design criteria for new projects. Principal work items included: (1) field consultation and review of vendor drawings for projects CAH-916, Fuels Recycle Pilot Plant, CAH-962, Low Level Radiochemistry Building, and CAH-151, Office Addition, 308 Building; (2) reviewed the high temperature filter specification for project CAH-100, the High Temperature Lattice Test Reactor; (3) prepared a second draft of the functional specification for use in procuring underwater inspection and cutting equipment for project CAH-119, PRTR Storage Basin and Experimental Facilities Modification; and (4) rewrote the design criteria for project CAH-146, Atmospheric Physics Building.

Facility planning and budget study work included: (1) preparation of a study to develop more usable space for the operating groups in the 314 building; (2) completion of a study for additional raw water supply to the 324 building; and (3) assistance given in the preparation of two additional construction data sheets for a total of five proposals for the Poodle Thruster test facilities.

Engineering and consulting work was provided to research and development personnel as requested. Major work items included: (1) a specification was written to procure an annunciator for process monitoring in the 325 building; (2) an off-site trip was made to the vendor's plant to confer on design problems concerning the 321 building Computer Trailer; (3) planning of a mobile facility for air monitoring equipment for on- and off-site use, including locating an excess Army four-wheel flat bed trailer; (4) designing an extended reach sample holder for use in the 324 building Waste Calcine Demonstration; (5) study of a proposed modification to the 325 building to accommodate promethium; and (6) review of a sample glove box design for use with the low bay cell in the 324 building.

Plant engineering work during the month included: (1) revision of the control circuitry for 325 building diesel generator to provide more reliable starting and switching operations for the unit; (2) circuitry changes were developed to provide a method of initiating the 306 civil defense evacuation system from the 306 building, in addition to control from patrol headquarters; (3) electrical changes were suggested to reduce the cost of the A-E's detail design for the 3718 building addition; (4) a layout of partitions and room lights was provided for the maintenance work on the 3201 building; and (5) comments were made on a Vitro drawing of the 300 Area classified scrap incinerator.

Consulting services for other departments included assistance on: preparation on an authorization request for a proposed electron microscope installation in the 326 building and a letter was written to NRD indicating recommended changes to the 109-N building ventilation systems to alleviate high temperature conditions in the cells.

Pressure Systems

Field work and costs are on schedule and within the estimated amount for the Containment Systems Experiment. Section 1 and the head end of the 221-T building are now in a condition wherein no SWP clothes are required. The Chicago Bridge and Iron shop drawings were reviewed and comments submitted. Two meetings were held with CB&I representatives to clarify questions on the stress calculations. Negotiations between J. A. Jones and Struthers-Wells concerning the simulator vessel are still pending. Clarification of technical questions has not been received from Struthers-Wells. The design effort for systems associated with the vessels is being conducted by Vitro. Piping flow diagrams have been reviewed and comments are being incorporated by Vitro.

On September 17 the High Temperature Gas Loop in the 314 building was placed in operation at temperatures to 2050° F. A large leak developed in the primary piping and the loop was shut down. Due to new materials used in this loop, it has not received third-party approval.

Design has been completed for the High Pressure Furnace Prototype in the 308 building and bids will be opened on October 15.

The drawings for the Liquid Sodium Loop in the 314 building have been commented upon. The loop design will be submitted for third-party approval on October 14.

Eleven vessels were inspected by the third-party inspector during the month. All vessels were found to be satisfactory for service.

Facilities Operation

Costs for the month of August were $140,447, which is 88 percent of the forecast for the month. The costs for the first two months of FY 1965 were $279,245, which is 77 percent of the predicted year-to-date. The increase in maintenance activity is raising the actual cost level toward the predicted. The impact of the 3201 building improvement maintenance should be seen in the next few months. Electricity predictions are being lowered, and appropriate rental reductions are being made. This change reflects the actual Bonneville power billing as compared with the Richland Power and Light rate schedule which had been anticipated as being in effect this year for the laboratories.

Safety corrections have been made to all entrances at 329 building.

A second 80 R/hr filter was removed from 327 building. A study has been initiated to simplify removal of the highly radioactive filters from this building.

New telephone pairs have been added to 328 building.

Waste Disposal

The following table summarizes the Waste Disposal Operation:

Item	July	August
Concrete waste barrels disposed to 300-wye burial ground	0	10
Concrete waste barrels disposed to 200-W burial ground	9	0
Loadluggers of dry waste disposed to 300-wye burial ground from 300 Area sites other than the 325 building	33	47

Item	July	August
Loadluggers of dry waste disposed to 300-wye burial ground from the 325 building	7	7
Loadluggers of dry waste disposed to 200-W burial ground from 300 Area sites	7	6
Containers of high level dry waste disposed to 300-wye burial ground waste tanks	96	75
Crib waste volume, gallons	300 000	245 000

No unusual incidents occurred during the month.

The large dry waste disposal tanks at the 300-wye burial ground are now in use. To date we have had no problem in getting the waste boxes to travel to the bottom of the tanks.

There was some Beryllium waste from the 306 building deposited in the regular Beta-Gamma burial trench at the 300-wye burial ground during the month. Permission was granted by the Safety Engineer for this operation.

None of the retention basins exceeded the Class II activity levels during the month.

All components of the retention waste monitoring systems which have failed are being returned to the vendor. Return of the alpha detectors has been delayed by the pipefitters' strike.

Building Operations

Many preventative maintenance procedures were accomplished during a recent reactor shutdown in the 312 and 315 buildings. Revisions are being made to the microphotometers to improve their accuracy at the filter plant.

Leaks in the reheat coils of #1 and 3 units at 306 building and in the 306 building roof units were repaired. Excessive noise from the supply and exhaust units of 306 building has required shutting these units down during recent tours.

In 325 building the precision water still was repaired and cleaned, all major steam valves were repacked, and a faulty 1" nipple was renewed on the base of the lab vacuum tank.

The diesel emergency generator is being tested each week on a routine basis.

A new office supply motor was installed in the 328 building.

A new expansion valve and control were installed on "C" section refrigeration in the 329 building.

In 3760 building temporary repairs were completed to #9 booster coil pending receipt of a new coil. No. 1 supply for wash pump and motor was overhauled. No. 2 will be overhauled during October.

All HL buildings normally serviced by this group were checked for winter operation.

Drafting

The equivalent of 161 drawings was produced during the month for an average of 26 man-hours per drawing.

Major designs completed or in progress are: (1) a powder processing glove box line; (2) a high temperature furnace for the NASA program; (3) FRPP service piping to waste solidification equipment; (4) underwater measuring equipment for calibrating elements in N Area; (5) electrical work for waste solidification equipment in FRPP; (6) mock-up of equipment in FRPP pyrochemical cell; (7) scope work for equipment layout for PRTR increased power level; (8) a sodium pump test facility in PRTR; (9) a critical mass expansion tank for building 209-E; and (10) a scope design for the polonium hood complex.

Drafting service was also supplied in support of other laboratory engineering programs.

Construction

	Unexpended Balance
Orders outstanding beginning of month	$724 515
Issued during the month (incl. suppl. & adj.)	178 869
J. A. Jones expenditures during month (includes C.O. cost)	151 719
Balance at month end	751 665
Orders closed during month	91 075

Maintenance Work Orders active - 6, Face Value - $18,764.

Major nonproject jobs in progress during the month were: (1) in the 100 Areas - an electron microscope room in the 108-F building, men's and women's rest rooms for the 141-M building, remodeling of dog pens and runs in the 141-F building, an intercom system for the 141-F building, testing of new fire detection systems in five buildings in the 100-F Area, completion of modifications to a dark room in the 1706-KEL building, and minor work to stairway and electrical services in the 189-D building; and (2) in the 300 Area - electrical bus work has been installed for a new rectifier for the arc melt furnace in the 306 building, work is progressing during reactor shutdown periods on hydraulic snubbers, access manholes and a corrosion film loop for the 309 building, 80 percent of the repair and recoating work for the exterior of the containment vessel is completed, a computer trailer has been delivered and positioned by the 321 building, two offices in the control room have been enlarged in the 325 building, in the 325 building a stairway has been constructed in corridor number 5 to the basement, three offices were modified in the 328 building, the entrances to the 329 building have been modified and enlargement of the gas bottle dock is 50 percent complete, a personnel change and survey building is being erected next to the 340 building, partitions and change doors are being constructed in the 3717-B building, and an addition has been completed in the 3718-C warehouse.

Construction work is completed for installation of magnetic flow and radiation meters. Six alpha detectors, one Texas recorder, and one count-rate meter are being returned to the vendor because of malfunction.

Well Drilling Program

The design criteria for the FY 1965 program is being routed for approval and the project proposal rough drafted.

Waste Solidification Engineering Prototype

As the pipefitters were on strike, there was no progress this month on this program.

GENERAL

There were no reports of invention or discovery during the month.

DS Parsley

Acting Manager
Finance and Administration

DS Parsley:RDT:whm

REACTOR DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Plutonium Recycle Test Reactor

Operation

Reactor output for September was 1,587 MWD for an experimental time efficiency of 83% and a plant efficiency of 76%. There were eleven operating periods during the month, eight of which were terminated manually, two were terminated by scrams and one operating period lasted through month-end. A summary of the fuel irradiation program as of September 30, 1964, follows:

	Al-Pu		UO_2		PuO_2-UO_2		Other		Program Totals	
	No.	MWD	No.	MWD	No.	MWD	No.	MWD	No.	MWD
In-Core	0		7	1842.1	77	13426.5			84	15268.6
Maximum				338.0		355.8				
Average				263.1		174.4				
In Basin	7	572.5	26	2687.1	46	5334.5			79	8594.1
Buried							1	7.3	1	7.3
Chem. Process.	68	5465.8	35	1965.8					103	7431.6
Program Totals	75	6038.3	68	6495.0	123	18761.0	1	7.3	267	31301.6

(Note: MWD/Element x 20 $\simeq$ MWD/TU for UO_2 and PuO_2-UO_2.)

Estimated heavy water loss and indicated helium loss for the month were 1300 pounds and 154,781 scf., respectively.

Equipment Experience

A total of 55 outage hours were charged to repair work. All outages were directed to emergency repairs with minimum reactor downtime. Valves constituted the main repair items.

Preventive maintenance required 116 manhours, or 2.4% of the total maintenance effort.

Initial demonstration tests of the mocked-up PRTR Pneumatic Irradiation Facility were made. A sample capsule was transmitted through the simulated out of reactor piping at the designed 50 feet per second.

Improvement Work Status (Significant Items)

Work Completed

Gamma Scanner Modifications
Revision of PRTR Exhaust Fan to Emergency Power
Storage Basin Alarm

Work Partially Completed

Corrosion Loop Installation
Primary Water Sample Station
Shim Rod Shroud to Top Cap Modification
Repair and Recoating of PRTR Containment Vessel Roofing
Air Lock Door Operators
Modification to PRTR Warehouse 3718-C
Vibration Snubbers for Earthquake Protection
Supplemental Emergency Water Addition
Voltage Off Normal Detection and Alarm for 24-Volt Battery System
PRTR Steam Utilization
Additional Fuel Storage and Examination Facility
Mark III Shim Prototype
Creep Test Facility
Flux Wire Scanning System
C Cell Instrument Tubing Penetration

Design Work Completed

Bypass for LWI Flow Switches
Alarm Annunciator - High Helium Flow to RLT-1
Thermal Barrier Seal and Hoist Improvements

Design Work Partially Completed

Decontamination Building and D_2O Cleanup Facility
Pneumatic Irradiation Facility
PRTR Experimental and Building Facility Addition
PRTR Increased Power Level

Process Engineering and Reactor Physics

Studies in support of the high power density core are continuing. Moderator Level Coefficients have been computed for the normal operating range (90 - 106 inches) with both clean and borated D_2O. The computed coefficients are compatible with the requirements of the PRTR control system. The feasibility of using H_2O coolant in the small core is under study.

Previous studies have shown that the existing light water injection system would be inadequate for the proposed high density core. A study was completed on the criteria for the light water injection system and presented several alternatives for providing an adequate light water injection system for the high density core.

Experimental Reactor Services

The status of the various test elements at the end of September 1964, is shown below. Those elements which had reached their assigned goal exposure or had been permanently discharged for other reasons prior to September 1, 1964, have been deleted from this table.

Test No.	Channel Location	Element Number	Description	Date Initial Charge	Date Discharged	Approximate Accumulated MWD
14	1956	5097	Moxtyl-Swaged	4/2/62	--	219.3
14	1352	5098	Moxtyl-Vipac	5/8/62	--	326.8
14	1758	5099	Moxtyl-Vipac	5/8/62	--	229.0
48	1156	5150	Moxtyl ($\frac{1}{2}$" x $\frac{1}{2}$" pads)	8/1/62	--	226.9
54	1542	5116	Moxtyl (clip on pads)	5/8/62	--	240.9
54	1554	5118	Moxtyl (clip on pads)	5/8/62	--	355.8
61	1249	5185	Moxtyl-Physics	5/28/63	--	238.7
61	1354	5186	Moxtyl-Physics	5/28/63	--	232.2
61	1445	5192	Moxtyl-Physics	6/13/63	--	234.6
67	1047	5117	Moxtyl (Repaired Wire)	10/20/63	--	194.2
80	1746	5214	Moxtyl (1% PuO_2, Swaged)	11/18/63	--	191.9
85	1855	5230	Moxtyl (1% PuO_2, Vipac)	1/30/64	--	129.2
37	1548	1098	UO_2-Physics	5/12/62	--	220.5
37	1550	1097	UO_2-Physics	5/12/62	--	236.2
37	1552	1099	UO_2-Physics	5/12/62	--	201.0

Examination of the band from Fuel Element 5118 (6728 MWD/TU) showed crevice corrosion between the bands and between the band and the fuel rods.

A temporary counting system was set up in the FERTF Annex Control Area to scan the irradiated wires from PRTR Test 89. Relative activity profiles of the wires were obtained over their lengths. Samples of the wires were sent to 200 Area for absolute counting in order to obtain absolute flux values from the activations.

Process Tube 6084 was examined in the Gamma Scanning Facility, cut up, and five sections shipped to Radiometallurgy for testing.

Fuel Element Rupture Testing Facility

FERTF Test #7, Irradiation of Longitudinal Slit Defected UO_2, continued through September 7. During this period in September, the fuel element was cycled through five critical periods including three in which the reactor power exceeded 60 MW. The fuel element was subjected to one scram from 63 MW. The test element was discharged from the loop on September 7, after a scram caused by the failure of the pressure control valve. Because of the increasing number of control valve and small line failures caused by vibration problems, the loop was taken out of service until the necessary changes could be made to decrease the frequency of these failures.

TECHNICAL SHOPS OPERATION

Total productive time for the period was 20,782 hours. This includes 12,764 hours performed in the Technical Shops, 4,785 hours assigned to J. A. Jones Company, and 3,233 hours assigned to off-site vendors. Total shop backlog is 20,255 hours, of which 90% is required in the current month with the remaining hours distributed over a three-month period. Overtime worked during the month totaled 578 hours or 3.4% of the total available hours.

Distribution of time was as follows:

	Man Hours	% of Total
N Reactor Department	3 084	14.8
Irradiation Processing Department	3 805	18.3
Chemical Processing Department	310	1.5
Hanford Laboratories	13 583	65.4

LABORATORY MAINTENANCE OPERATION

Total productive time was 17,200 hours of 18,800 potentially available. Of the total productive time, 95% was expended in support of Hanford Laboratories components, with the remaining 5% directed toward providing service for other HAPO organizations. Craft overtime worked during September was 650 hours or 3.5% of total available hours.

Manpower utilization (in hours) for September was as follows:

A.	Shop Work		2 000
B.	Maintenance		5 900
	1. Preventive Maintenance	2 400	
	2. Emergency or Unscheduled Maintenance	1 300	
	3. Normal Scheduled Maintenance	2 200	
C.	R&D Assistance		9 300

WD Richmond:bk

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
C. A. Ratcliffe	Count Rate or Frequency Meter Circuit (HWIR-1758)

R S Paul

Acting Manager, Hanford Laboratories

[redacted]

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