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HANFORD LABORATORIES
MONTHLY ACTIVITIES REPORT
NOVEMBER 1964

DECEMBER 15, 1964

[redacted]

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

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HANFORD LABORATORIES MONTHLY ACTIVITIES REPORT NOVEMBER 1964

Compiled by
Section Managers

December 15, 1964

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

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Table I - Hanford Laboratories Force Report

Date: November 30, 1964

	At Beginning of Month		At Close of Month		
	Exempt	Salaried	Exempt	Salaried	Total
Chemical Laboratory	158	133	157	139	296
Reactor & Fuels Laboratory	208	200	209	204	413
Physics & Instruments Laboratory	130	80	134	80	214
Biology Laboratory	44	63	45	63	108
Applied Mathematics Operation	16	7	16	6	22
Radiation Protection Operation	49	86	51	81	132
Finance & Administration Operation	127	168	117	168	285
Programming Operation	5	2	5	2	7
Test Reactor & Auxiliaries Operation	62	303	62	305	367
General	2	5	2	5	7
Total	801	1047	798	1053	1851

BUDGET AND COST SUMMARY

November operating costs totaled $2,799,000, a decrease of $252,000 from the previous month. Fiscal year-to-date costs aggregate $13,844,000 or 38% of the current control budget for FY 1965.

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

(Dollars in thousands)	COST Current Month	COST Previous Month	COST To Date	Budget	% Spent
HL Programs					
02	$ 33	$ 52	$ 258	$ 542	48
04	1 195	1 416	6 030	16 076	38
05	120	152	605	1 694	36
06	260	312	1 458	3 570	41
07			7		
08	33	47	199	500	40
	1 641	1 979	8 557	22 382	38
Sponsored By					
NRD	103	123	647	1 594	41
IPD	16	21	91	425	21
CPD	151	200	896	2 207	41
	$1 911	$2 323	$10 191	$26 608	38

RESEARCH AND DEVELOPMENT

1. Reactor and Fuels

Metallographic examination of several irradiated (~2460 Mwd/ton) N-Reactor fuel pieces verified the presence of ultrasonically detected longitudinal cracks in the fuel material near the end region. The cracks could not be clearly ascribed to handling damage.

Extensive clad-core reaction was found when Zircaloy-clad aluminum-lithium alloy was heated to 1100 C for 5 min.

Target elements containing $LiAlO_2$ and Li_2SiO_3 have been irradiated for 58 days in the KER loop to obtain data on gas composition and tritium release from ceramic core targets.

Ball Channel No. 60 at N-Reactor has been charged with 19 large graphite bars to monitor graphite changes due to irradiation.

Laboratory experiments were completed that permit the temperatures of N-Reactor fuel elements to be predicted for 10 to 15 sec following the gross rupture of an inlet riser supply line; differences between the laboratory test section and the reactor fuel column prevent prediction past that time.

Laboratory experiments were started with a second electrically heated test section representing the downstream half of an N-Reactor fuel column to determine the effects of the interjunction flow on hydraulic stability and heat transfer characteristics of the three flow channels, especially when one channel is receiving a greater than normal amount of heat.

In-reactor tests simulating off-standard primary coolant conditions in N-Reactor show that neutral pH, O_2 addition, or reduced purification rate will increase crud levels and corrosion rates. Short-term tests indicate that minor variations in pH or O_2 concentration will not increase crud levels or corrosion rates significantly.

Examination of carbon steel jumpers and tubing in N-Reactor graphite cooling system revealed a thick crud film with many pits in the underlying carbon steel. Most of the pits were 1 to 2 mils deep although a few deep pits (10 to 15 mils) were found at a tubing flare.

Nickel-plated aluminum coupons exposed 20 days in 330 C water, pH-10 NH_4OH at 25 ft/sec flow rate showed no sign of the plate loss such as occurred during similar tests in pH-10 lithiated water.

Based on the burst test of a deliberately defected section of N-process tubing, it appears possible to predict the rupture pressure (without bursting the specimen) from an analysis of the sound produced by the growing defect.

[redacted]

The first vibrationally compacted UO_2-2 wt% PuO_2 high power density fuel element was successfully irradiated in the PRTR to a burnup of 680 Mwd/ton_U.

The first batch of impacted, UO_2-PuO_2 using U_3O_8 to control the O:U ratio was successfully processed.

The PRTR swage-compacted UO_2 element defected with a 3-in. longitudinal slit in one of the rods has successfully completed about 19 days of operation in the rupture loop.

A prototypic recycle element (2 wt% PuO_2) using salt cycle material, specially designed hot cell fabrication equipment, and segmented Zircaloy-2 tubes, is being fabricated.

A fuel element designed to demonstrate the feasibility of rejuvenating fuel elements with plutonium alloy wire was shipped to MTR for irradiation.

A fuel element designed to investigate the effect of heterogeneous enrichment and the homogenizing effect of irradiation on the heterogeneous portions of the fuel was fabricated and shipped to the MTR for irradiation.

The document outlining transition plans for converting the PRTR to the High Power Density Core is being revised in the final draft.

A second out-of-reactor fretting test of a PRTR High Power Density fuel element revealed no significant fretting after 500 hr at 1050 psig, 530 F, and 165 gpm, the expected tube flow in the proposed short core.

Continued tests on irradiated PRTR fuel elements have confirmed previous results showing that the core materials (physical mixtures of UO_2 and PuO_2) are very resistant to washout by 300 C water. Tests up to 3-1/2 weeks in duration have resulted in undetectable loss of material.

The effectiveness of pressure in inhibiting the swelling of high purity uranium (as well as alloy specimens) was observed in specimens from a controlled pressure-temperature capsule which operated at 450 C and 1000 psi

to 0.13 at.% burnup. Comparable data from previous general swelling capsules revealed swelling in high purity uranium of 70%; whereas, samples in the pressurized capsule showed swelling of about 1%.

Physically mixed and impacted PuO_2-UO_2 powders were shown to possess the small particle sizes and uniformity of plutonium distribution necessary for fast reactor fuel.

Arc melted plutonium-boron compositions between 10 and 90% boron, quenched from 1500 C, or annealed at 900 C and slow cooled, showed PuB, PuB_4, and PuB_6 to be high temperature stable phases. Incongruent melting points observed for these compounds were 1750, 1990, and 2190 C, respectively.

Stainless steel clad, stainless steel-UO_2 fueled cermet fuel pins were successfully extruded with minimum fuel particle stringering by using impacted extrusion billets.

The first stress-to-rupture tests on irradiated nickel base alloys show that the time-to-rupture is reduced markedly by irradiation to 1.8×10^{20} nvt. Underaged Inconel X-750 specimens irradiated and tested in an attempt to explain the reduction of time to rupture failed, contrary to expectations, upon application of initial load.

A prototype instrument to continuously detect total gas impurities in the ATR gas loop helium coolant was successfully tested at a lower detection limit of 1 ppm.

A scope design has been prepared for the ATR gas loop analytical instrumentation, sampling system, calibration system, and panel layouts.

Comparison of Hanford and United Kingdom graphite irradiations shows good agreement for the 450 C irradiations, but poor agreement at 650 C, with the United Kingdom graphites apparently contracting at a much lower rate at 650 C. The discrepancy is probably due to differences in test conditions or

problems in converting to a common exposure basis rather than differences in materials.

The integrated exposure of three thorium-uranium fuel elements in the ETR has reached 10,000 Mwd/ton (3.3×10^{20} fissions/cm^3).

The first irradiated tensile specimens were successfully tested in vacuum at temperatures up to 650 C in the new equipment in H Cell of the Radiometallurgy Laboratory.

UO_2 single crystals were characterized and shipped to ORNL, University of Michigan, and Northwestern University for research studies.

Ultrasonic examination has resulted in rejection of 486 of the 1350 EBWR rods shipped to ANL because of cracks near the weld zone of the end closures.

Fabrication of fuel for the Saxton Reactor plutonium loading is under way.

Coolant channel hydraulic demand data for ATR shutdown and emergency cooling conditions were obtained from an electrically heated test section. High power experiments were suspended when failure of electrical insulation rendered the test section unusable.

2. Physics and Instruments

N-Reactor Phase III fuel cycle studies are being extended to include PuO_2-UO_2 fuel. Previous studies were on UO_2, ThO_2, and uranium metal fuels.

Boron enriched in B^{10} is being considered as a replacement for natural boron in the N-Reactor control rods to increase their worth. The worth of samples of both types will be measured in the PCTR. The PCTR is also being used to measure physics parameters of a coproduct fuel element.

[redacted]

Several reactor physics computer codes (ZODIAC, HRG, COMBO, and TEMPEST) were modified to improve their efficiency and versatility.

Preliminary analyses of foil activation measurements taken on the graphite lattice (8-3/8 in. pitch) fueled with PuO_2-UO_2 are complete. The results are being used to calculate the average absorption rates in the cell components. Plans are being made for the second experiment, which will have a lattice pitch of 6-1/2 in.

Amplifier and other circuit modules were completed for use in the N-Reactor subcritical neutron flux monitor, and specifications were completed for instrumentation to be used in the prototype irradiated reactor fuel cooling age measuring system.

The N-Reactor three surge tank analog model programming was completed. Input data for the system were obtained from results of the N-Reactor plant simulation. A method for control of the three tank system was proposed.

Initial experiments were performed to eliminate the effects of Am^{241} in the Pu^{239} liquid sample counting system now in test operation at a separations plant. In addition, detector and circuitry development progressed on the Am^{241} monitor that will measure distribution of Am^{241} in a process column.

A prototype ultrasonic test to measure the degree of bondedness between the jacket and core of lithium-aluminum target elements is being operated to inspect preproduction samples of these fuel elements for N-Reactor fuels.

The X-ray fluorescence tester, which was designed to detect uranium contamination in the end cap braze closure, has been returned to the laboratory for further development before this tester is evaluated at the step-cut stage.

A prototype ultrasonic test has been developed to measure braze wire melting for the TIG braze end closure process.

Fabrication of the mechanical portions of the irradiated N-Reactor fuel tester is about 80% complete. Electronic upgrading of this equipment has been completed. Metallographic confirmation of two small cracks that had been previously detected by the instrument was obtained.

Laboratory attempts to measure enrichment of N-Reactor fuel have been favorable. Possible use of the test will be made to confirm fuel confirm fuel enrichment immediately before reactor charging.

Exponential and neutron multiplication experiments have provided further data on the criticality of enriched N-Reactor fuels in light water. During the month, measurements were performed with two different fuel assemblies in a third lattice.

Calculations show that Pu^{240} will have a maximum effect on criticality in an intermediate neutron spectrum; a new series of critical experiments was begun with plutonium containing 8 wt% Pu^{240} in PuO_2-plastic mixtures to provide data for evaluating this effect. Criticality was achieved in an unreflected cubic assembly about 40% larger than a similar critical assembly that contained plutonium of 2.2 wt% Pu^{240}.

Neutron multiplication experiments performed with 64 PR cans positioned in a planar array (containing 113 kg Pu) showed the critical number of these to be less than for the SN cans measured previously, but still $\geq$ 280. As a result of these experiments, a considerable relaxation can be expected in future handling procedures as the current nuclear safety limit is only 15 cans per storage array.

Encouraging results have been obtained with multigroup diffusion theory for computing criticality of plutonium nitrate solutions in spherical geometry. The criticality factor was calculated to within 10 mk for 12 different cases of measured criticality with plutonium solutions in the concentration range from 33 to 268 g Pu/ℓ.

[redacted]

The Class I HL-designed shipping container for fissile materials that successfully passed drop tests last month has satisfactorily passed the standard 1 hr fire test conducted by Underwriters Laboratories.

Performance testing of the slow-neutron time-of-flight spectrometer was continued and included measurements of the scattering of 0.15 ev neutrons from vanadium. Multiple-scattering and absorption corrections for these measurements were successfully calculated using Program S.

The results of the 3- to 15-Mev total cross section measurements in the last two series both yielded incorrect values in the region of 8- to 10-Mev. Extensive investigation has failed to reveal as yet the cause of these anomalous results.

Experiments continued on the PuAl-H_2O core in the PRCF. Reactivity measurements by substitution were made on PuO_2-UO_2 (EBWR) fuel rods, various poison rods, and samples of materials used in constructing critical assemblies. Other measurements were made on void and moderator level coefficients and flux and spectrum measurements.

Preparation for the first Phoenix fuel experiment in the PCTR is essentially complete. The experiment has been rescheduled to begin before the middle of December.

A 1000-hr, 1100 C test of samples of a matrix of UO_2 in graphite has been successfully completed. This material is to be used in the horizontal control rods of the HTLTR. The temperature of the HTLTR mockup continues to be increased. The heater elements were at 700 C, and the stack at 300 C at the end of month. Graphite corrosion up to this point appears to be very small.

Plutonium values have been calculated under the private ownership situation to guide AEC in setting the plutonium buy-back price until 1971. Values were determined using recent 1000 Mw_e designs for PWR, BWR, D_2O, and SGR reactors. Results of this study are consistent with the $10/g

[redacted]

buy-back price now in use. Values were also calculated for a proposed future price of \$6/lb for U_3O_8 instead of the present \$8/lb U_3O_8 price. This resulted in lower plutonium values which were proportional to the change in the fully enriched uranium price.

Uranium requirements have been calculated for the hypothesized power economy as projected in the "Report to the President, 1962," Initial runs with the VESTA code assume that unimproved light water reactors will initially supply the nuclear portion of the electrical generation requirement and that breeder reactors will be introduced after 1975 or 1990 as rapidly as there is plutonium to feed them. By 2060, cumulative uranium requirements for this projection will be 22 million tons if no breeders are developed; about 6 million tons if a long doubler (20 yr) is used; and about 2.5 million tons if a short doubler (7 yr) is used. The date of introduction seems much less critical from a conservation viewpoint than does the doubling time. These results support the view that the USA should have a concurrent fast reactor development program aimed at (1) development of public acceptance with prudently safe fast reactors as may appear financially justified in the near future, and (2) development of truly advanced fast breeders with very short doubling times on a long term basis.

The underwater fuel element gamma scanner at PRTR was improved through changes in the pulse height analysis instrumentation circuitry and design was started on a new slit collimator assembly.

Satisfactory in-core performance at KW-Reactor is being achieved with the two regenerating neutron flux detectors, which use coatings of 90% U^{234} and 10% U^{235}. Signals in the milliampere range are being obtained; data are recorded without preamplifiers.

The prototype B^{11} neutron flux detector and five cables (all in an assembly) were irradiated in a facility at KW-Reactor with the test covering

[redacted]

both a reactor shutdown and startup. Valuable information was obtained regarding noise generation by various types and sizes of cables, and promising short time performance was achieved for the B^{11} detector.

Analog computer runs were completed in an investigation of possible hazards at increased power PRTR levels. Transients were observed under the conditions of shim failure, control rod malfunction, and experiment failure.

Ability of the multiparameter eddy current test to separate signals due to flaws opening onto each side of a metal test sheet was demonstrated. The relative location of these fabricated flaws was successfully displayed on the cathode ray tube.

Ultrasonic shear-wave attenuation measurements on stainless steel are complete. Sampling techniques are being used to measure broad-frequency band pulse shape changes suitable for experimentally testing the validity of theoretical wave models.

A stainless steel sample has been fatigued in steps of 200,000 cycles to a total of 1,200,000 cycles. Eddy current tests after each step have been encouraging, but the ultrasonic results are not conclusive. The fatiguing of the sample will be continued until failure occurs.

The recently developed ultrasonic imaging unit has been used to study the transmission of ultrasound through a plate. Several luminescent phosphors and liquid crystals and two new techniques using chemiluminescent compounds of piezo-optic properties of piezoelectric materials also were investigated for potential use in ultrasonic imaging.

The electrostatic ultrasonic transducer has been successfully used to generate and detect ultrasound with a single transducer. Mica and ceramic materials are being evaluated for the dielectric.

Ultrasonic test equipment (400 kc) has been developed to test isotope core materials for cracking. Initial tests indicate ultrasound penetration is sufficient for inspection purposes.

[redacted]

Testing was initiated on the blood pressure measuring transducer and design was initiated on the signal conditioning circuits to be used in the animal physiological function and radionuclide uptake telemetry system. Other channels for telemetering temperature, pulse rate, and radionuclide uptake have now been laboratory tested.

The Biology dog counter was further improved through the installation of a new detector support for the two lateral detectors. The change permitted more accurate positioning adjustment, and thereby improved scanning accuracy.

The solid state peak pulse reading instrument, used to provide readout of small ionization chambers used in radiation dosimetry studies, was completed.

The analog computer program for the radioisotope distribution in bodies was further developed for Te^{132} and I^{132} in "standard man." The results of computer runs for ingestion were compared with experimental data to determine the constants which define the biological processes. Good agreement was obtained in some cases; however, more investigative work is required.

Sonic energy released from propagating defects in stressed pressure vessels is being monitored by three pickup transducers whose outputs are recorded on magnetic tape. Early warning of vessel failure is thus provided.

An 11-in.-long liquid level probe, which measures the transit time of an electrical pulse, reflected at the liquid surface, was developed and used successfully to measure the level of liquid glass at 1000 C. A 7.5-ft-long probe is now being designed for another similar application in waste solidification work.

A new controlled switching device has been developed for the capacitor discharge machine in Plutonium Metallurgy. The new switch, which explodes a copper wire imbedded in the insulation between two plates,

[redacted]

reduces the inductive effect from previous switches and achieves control to within plus or minus 1 μsec.

In a joint effort, Atmospheric Physics and Radiological Chemistry measured the washout of gaseous radioactive iodine by natural rain on November 3. The quantity of scavenged iodine in the collected rainwater was a hundred times the detection limit, and was of the magnitude predicted theoretically. This is the only known atmospheric iodine washout experiment to be conducted. The simplicity of the design and the sensitivity of the detection methods show promise of providing high quality washout data in future experiments.

An Eskimo from Anaktuvuk Pass, Alaska, who has a Cs^{137} body burden of 1300 nCi, spent 2 weeks at the laboratory. His cooperation enabled completion of several significant whole body counting experiments: intercomparison of the three Hanford whole body counters, improvement of Na^{22} and Fe^{55} counting techniques, and improved calibration of the simplified whole body counting method to be used in Alaska to measure whole body burdens of Cs^{137}.

3. Chemistry

Additional understanding was achieved of the unexpected exothermic chemical combination of metals contained in N-Reactor "target" elements when cycled through temperature conditions which might prevail in a reactor overheating incident. The observations were compatible with the assumption that a barrier to diffusion exists initially but is breached under certain conditions.

No significant changes were observed in the gross beta activity levels in the ground water beneath 200 Area disposal sites during this month.

Recent analytical results of samples from piezometer tubes installed in wells southeast of 200 East Area confirm previous analyses which showed the presence of low-level contaminants in the lowermost aquifer (of six) near the river.

[redacted]

The carrying of polonium by $BiONO_3 \cdot H_2O$ precipitates tends to follow the logarithmic distribution law.

Full-level, B-cell experiments on the absorption of Pa^{233} on unfired Vycor have continued to give poorer loadings than reported by ORNL. Presence of an "unabsorbable" protactinium species is suspected.

Sufficient spray-calcined thoria has been prepared for fabrication of three cold-pressed 8-in. target elements.

Increased thoria dissolution rates were achieved in a series of experiments incorporating several process and equipment improvements. The major beneficial factors were the adoption of an acid codissolution process for the aluminum jacket and thoria target material, and the use of small air lift circulators in the dissolver to promote solids-liquid contact.

Several factors appear to be involved in high Strontium Semiworks losses of promethium in the "A" contact: substitution of DTPA for the HEDTA which was used in earlier successful plant runs; use of a pulse column contactor in place of batch extraction; and the presence of solids in the feed.

Examination of samples of IRA-401 resin from the two plant 1-kg Tc recovery campaigns revealed no evidence of degradation or loss of capacity.

Development and testing of a new slag and crucible dissolver were completed for the unit to be installed in the Plutonium Reclamation Facility. Several improvements in process conditions, equipment configurations, and operational procedures were made as a result of extensive round-the-clock testing of the dissolver system.

A computing system was devised to provide the accurate measurement of pulse column static pressure required for automatic column control. The system corrects the observed pressure signals for errors contributed

by variations in new flow and pulse velocity. Performance testing of the system was completed successfully.

Three blocks of shielding glass of a type used for FRPP shielding windows were irradiated to about 1×10^8 r, at a rate of 7×10^4 r per hour. One of the blocks, a 6-in. cube, discharged after removal from the source. The other two blocks, with dimensions corresponding to FRPP cell side window thicknesses, did not discharge. These results provide added confirmation of the decision to install thin glass sections in FRPP high level cell windows.

Uranium and plutonium losses during the mechanical decladding of PRTR mixed oxide fuel elements were quantitatively determined. Results of these studies indicate higher waste losses (about 0.5%) with irradiated fuel than with unirradiated elements (less than 0.1%).

Rare earth earth and uranium decontamination factors as high as 110 and 700, respectively, have been obtained with quantitative two-stage precipitation of PuO_2 from salt cycle melts.

Equipment has been developed and work is well along in developing techniques for the analysis of O:U ratios in mixed oxides and UO_2-containing cermets.

Two waste solidification runs were completed with prototype pot calcination equipment. Simulated Purex waste was processed at an average rate of 26 liters per hr; calcination time for a standard pot (8-in. diam, 8-ft long) was 35 hr.

A platinum melter was coupled to the 14-in. spray calciner to achieve an allowable operating temperature in the range 1000 to 1200 C; initial operation using an external overflow weir was successful. In related laboratory studies melting points and leach rates in distilled water were determined for several compositions of glasses or polycrystalline solids in Purex 1WW, phosphate, plumbate, and borate systems.

[redacted]

Two additional continuous glass experiments were attempted in the High Level Radiochemistry Facility. The first was plagued with repeated plugging; the second ran smoothly and produced a true glass.

A scheme for extensive treatment of intermediate level laboratory-type wastes (including removal of ruthenium) is being developed, employing scavenging, ion exchange, and adsorption. The treatment is sufficient to reduce all radio-nuclide concentrations in the 300 Area cribbed laboratory waste to below MPC.

Experimental evidence was obtained this month indicating that sediment scouring occurs from the McNary Reservoir during high water flow periods.

Design and procurement activities for the Containment Systems Experiment were continued actively. Erection of the containment vessel was begun on November 16. Aerosol development studies included runs comparing the behavior of molecular iodine released in the presence of and in the absence of molten stainless steel-UO_2. These tests were possible because a suitable technique was found to contain the melt, that of mounting the specimen on UO_2 powder inside a water-cooled quartz tube.

An initial calculation of predicted flow paths, travel times, and soil transmissibility (permeability) distribution in the ground-water regime was made using several recently developed computer programs and limited field data. Reasonably good agreement was obtained in comparing the computed results with those deduced from ground-water contamination observations.

Concentrations of radionuclides on Alaskan lichens and on euphausids (krill) taken from the Pacific Ocean were found to be readily measurable by low level multidimensional spectrometry.

Use of low level multidimensional analysis techniques in activation analysis of sea water allows the measurement without chemical separation

of Na, Sr, Rb, Fe, Zn, U, Th, Co, Cs, Sb, Ag, and Sc. Many of these elements are present in sea water at less than ppb concentrations.

Air and rain samples collected after the Chinese bomb test on October 16, 1964, were analyzed using the multidimensional gamma ray spectrometer. Ba^{140}-La^{140}, Te^{132}-I^{132}, Mo^{99}, and Np^{239} were readily measurable.

A joint program with the Atmospheric Physics Operation was begun to determine the washout coefficient of airborne gasses and particulate materials by rain. The first measurements of I_2 washout agreed well with theoretical calculations.

Chemical analysis (for Pm^{146}) of the four samples of high burnup Yankee pressurized water reactor fuel was completed. The Pm^{146}/Pm^{147} ratio was essentially constant and independent of fuel burnup.

The computer program for predicting the reentry characteristics of cylindrical isotopic fuel capsules has been debugged.

Measurements of the thermal diffusivity of high-energy-rate impacted Sm_2O_3 (stand-in for Pm_2O_3) have permitted calculations showing that the central temperature, and temperature drop from center to surface, will not be excessive, even with very large Pm_2O_3 sources.

Compatibility studies have shown the advisability of using nickel-free alloys or materials for containment of Pm_2O_3 heat sources.

A new high energy impaction machine (Dynapak) has been received and is now being set up for cold mock-up and process studies before installation in a Fuels Recycle Pilot Plant high level cell. The 200,000 ft-lb machine, largest now on site at Hanford, will be used for encapsulation studies of isotopic process sources.

4. Biology

On November 3, a roof fire at the Aquatic Biology Laboratory resulted in an estimated $250,000 building and equipment damage, in addition to loss of experimental fish. More than 90% of the valuable research records were saved. No radiation was involved and no personnel injuries resulted. As a result of the fire, studies on Zn^{65}, X-ray and temperature effects in fish are temporarily suspended. Emphasis on the columnaris problem has been shifted from laboratory to field studies. Radioecology fallout samples are being processed, temporarily, in 700 Area laboratories while more permanent facilities are being constructed in the undeveloped portion of the third floor of the 108-F Building.

Glutathione, in conjunction with chelating agents (DFAB and DTPA), was shown to be effective in accelerating the excretion of Ru^{106} from rats.

Pulmonary clearance of inhaled $Cr_2^{51}O_3$ particles was not altered in dogs following 11 months of smoking up to 20 cigarettes per day, 5 days per week. This experiment was one of several preliminary tests to determine whether cigarrete smoking alters the capability of the respiratory tract to remove inhaled particles.

Indolepyruvic acid was isolated from Neurospora culture medium filtrates and positively identified. This adds significantly to our understanding of the tryptophan cycle and will provide a new basis for studies of feedback mechanisms.

A total of 1443 salmon nests was observed in aerial surveys of the Columbia River between Richland and Priest Rapids Dam. This is the second highest number observed during the past 18 years. Manipulation of river levels by the upstream dams resulted in the exposure of some salmon nests.

[redacted]

Whole-body counts were made on practically the entire population of Anaktuvuk Pass on November 15-17. Equipment trouble required operation at reduced voltage, which will delay results pending calibration studies.

TECHNICAL AND OTHER SERVICES

Surveillance of the Purex cooling swamps that had become highly contaminated in June continued. The soil sterilization program that was undertaken by CPD personnel is complete. Most of the wild grains (millet) near the swamp have been burned or covered. Wild fowl that were sampled near the end of November showed no detectable external contamination. At present all radiation problems associated with the incident are well controlled.

Closed form solutions were obtained for a mathematical model which was developed to explain and quantify the apparent exchange of materials between two supposedly closed systems.

A study was carried out to operate several alternate single stage attribute sampling plans equivalent to two-stage plans now being used.

Both transient and steady-state solutions were obtained to mathematical models describing the application electromagnetic wave guide theory to thermal neutron detection.

A study of air propagation relative to the mass spectrometric analysis of a four-component gas is being extended to a 12-component gas.

A program was completed for the calculation of critical points of a test designed to distinguish the presence of a decaying radionuclide from power background in the analysis of a program where the power function is now being coded.

SUPPORTING FUNCTIONS

Plutonium Recycle Test Reactor output for November was 1477 Mwd for an experimental time efficiency of 83% and a plant efficiency of 70%.

[redacted]

There were five operating periods during the month; two of which were terminated manually; two that were terminated by scrams; and one that continued through month-end. A summary of the fuel irradiation program as of November 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	1953.1	77	14680.5			84	16633.6
Maximum				364.3		397.2				
Average				279.0		190.6				
In-Basin	7	572.5	26	2769.0	51	6671.6			84	10013.1
Buried							1	7.3	1	7.3
Chemical Processing	68	5465.8	35	1965.8					103	7431.6
Program Totals	75	6038.3	68	6687.9	128	21352.1	1	7.3	272	34085.6

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

Heavy water loss and indicated helium loss for the month were 815 lb and 114,290 scf, respectively.

Installation of the prototype Second Generation Shim Control Rod was completed during the month. Features of this assembly include: packaged drive assembly (using gearing) located above the top shield and detachable from the lower assembly, zirconium lead screws, swivel calandria gas seal, accurate synchro readout, and rotary limit switches. Some sticking has been experienced that is attributed to the nonprototype 1/16 in. lead screw balls.

The irradiation in the Fuel Element Rupture Testing Facility of swage compacted UO_2 fuel element 1039 with the 3 in. longitudinal slit was completed on November 15, 1964. The test element had endured 447.25 hr of operation, including three startup-shutdown cycles in which full power was achieved, and accumulated 7.87 Mwd or 129 Mwd/ton exposure for a

[redacted]

total exposure of 133 Mwd. The test element was inspected and photographed in the storage basin. No evidence of defect propagation or of fuel release was apparent.

Arrangements were made with Redox Operation of CPD to conduct a chemical processing campaign in March of 1965. Approximately 14 UO_2, 4 Al-Pu, and 20 UO_2-0.5 wt% PuO_2 PRTR fuel elements will be processed along with 208 I&E depleted uranium fuel slugs from Production Test 231-A to produce 7 kg of plutonium containing 20% Pu^{240} isotope.

Total productive time in Technical Shops Operation for the period was 21,558 hr. Distribution of time was:

	Manhours	% of Total
N-Reactor Department	2 495	11.6
Irradiation Processing Department	2 951	13.7
Chemical Processing Department	377	1.7
Hanford Laboratories	15 735	73.0

Total productive time in Laboratory Maintenance Operation was 14,600 hr of 16,000 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 November was:

A. Shop Work		1900
B. Maintenance		4700
1. Preventive Maintenance	1300	
2. Emergency or Unscheduled Maintenance	1000	
3. Normal Scheduled Maintenance	2400	
C. R&D Assistance		8000

The heavy water inventory for the PRTR at the end of November 1964 showed a loss of 815 lb valued at $11,263. Heavy water scrap generated during the month amounted to 449 lb, resulting in a $435 charge to operating costs. Total scrap on hand at November 30, 1964 amounted to 15,847 lb valued at $196,064.

[redacted]

Cumulative data of Hanford visitations:

	Number of Visitors	
	In November	Since 6-13-62
Visitors Center	1259	82,366
Plant Tours	130	---

HAPO professional recruiting activity for November:

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

Six Technical Graduates were placed on permanent assignment. Ten members transferred to the plant General Electric Technical Graduate Program. The current Laboratories' Technical Graduate Program numbers 19.

Hanford Laboratories hosted a meeting of the Weapon Contractors Classification Conference on November 18 and 19. Representatives of 16 weapon sites attended.

Authorized funds for 13 active projects total $10,729,000. Total estimated cost of these projects is $11,899,000. Expenditures through October 31, 1964 were $5,301,000.

H M Parker

Manager, Hanford Laboratories

HM Parker:JEB:dh

[redacted]

CHEMICAL LABORATORY

RESEARCH AND ENGINEERING

FISSIONABLE MATERIALS - 02 PROGRAM

IRRADIATION PROCESSES

Overheated N-Reactor Fuel Study

Seven unirradiated prototype N-Reactor "target" elements were heated individually throughout the length of the element to 1100 C and cooled in helium at differing rates. One element was similarly heated in a steam atmosphere and cooled. The purpose of these tests was to establish the behavior of the elements under the severe temperature conditions which might prevail in a reactor overheating incident. The current unirradiated-element tests were preliminary to similar tests to follow using fully irradiated target elements. Observed behavior was not as anticipated, yet could be explained with reasonable assumptions. The observations of particular interest are the following:

1. The end areas swelled to about 1-1/2 times the original diameter and the element as a whole distorted and swelled.

2. Some elements failed with oozing and flowing of the aluminum alloy. If the element survived the first minute or so of the goal temperature of 1100 C, rupture with flow of metal did not occur in subsequent heating.

3. An exothermic chemical combination of the metals present can occur under conditions not yet completely defined. In the first element tested, the temperature rise from this energy resulted in not only failure of the element but local melting through the wall of the steel tube in which the element was supported. The reaction occurs after heating to 1100 C, holding for a short period, then cooling to around 870 C. When held at temperature for as long as 30 minutes, the element did not undergo this reaction on cooling. The reaction results in the formation on cooling of lustrous black crystals whose composition corresponds to $ZrAl_3$.

The observations are compatible with the assumption that a barrier to diffusion exists initially which could well be the continuous anodized layer on the inside surfaces of the Zircaloy tube. Slow diffusion of aluminum through this film occurs and a second barrier, $ZrAl_3$, forms. If the $ZrAl_3$ layer retains continuity during the expansion of the

unalloyed Zircaloy upon cooling through the β to α transformation, the exothermic reaction between the molten core and Zircaloy will not occur. If a break develops, the exothermic reaction between zirconium and aluminum occurs. Similarly, if a break appears in the anodized film soon after heating, allowing direct contact between the aluminum alloy and the Zircaloy, probability of rapid diffusion is high and jacket failure may follow.

Although these suppositions seem tenable, the results indicate the need for a detailed metallurgical study of the metals involved at these temperatures.

SEPARATIONS PROCESSES

Disposal to Ground

No significant changes were observed in the gross beta activity levels in the ground water beneath 200 Area disposal sites during this month.

There are six confined or partly confined aquifers beneath the project which can potentially become contaminated with wastes discharged to ground in the 200 East Area. Three wells southeast of 200 East Area, 699-15-15, 20-E12 and 10-E12 intercept and monitor the uppermost five aquifers. Recent analytical results of samples from piezometer tubes installed in these wells confirm previous analyses which showed the presence of low-level contaminants in the lowermost aquifer near the river. This is indicative that wastes entering the aquifer move at a faster rate or are diluted to a lesser degree than the bulk of the radiocontaminants which are contained in the uppermost free ground-water zone. Four additional wells are planned to be installed soon southeast of 200 East Area to provide monitoring access to all six aquifers.

Polonium Chemistry

As mentioned previously polonium is effectively coprecipitated when Bi(III) is precipitated as $BiONO_3 \cdot H_2O$. Effort this month has been directed toward determination of the limiting distribution law for the incorporation of polonium into bismuthyl nitrate.

Precipitation of the desired amount of $BiONO_3 \cdot H_2O$ was accomplished by the addition of a suitable volume of water to a 1M Bi(III) - 1M HNO_3 solution. The amount of bismuth precipitated and the fraction of polonium coprecipitated were determined.

When rapid precipitations are carried out, as was the case in these experiments, the logarithmic distribution law is usually obeyed:

[redacted] [redacted]

REACTOR AND FUELS LABORATORY MONTHLY REPORT

NOVEMBER 1964

TECHNICAL ACTIVITIES

A. FISSIONABLE MATERIALS - 02 PROGRAM

1. Metallic Fuel Development

Correlation of Postirradiation Nondestructive Test Indications on "N" Fuels. Defect indications have been obtained on some irradiated N-fuel components using ultrasonic techniques. Selected components have been examined in Radiometallurgy to correlate the ultrasonic test indications with the condition of the pieces. In one instance, in which a defective cap or closure was indicated, a damaged closure was revealed by metallographic examination. The damage was, therefore, attributed to postirradiation handling. In several other instances in which large longitudinal cracks in the fuel in the end closure region were indicated, cracks were disclosed by the metallographic examinations. Although these cracks may be the result of postirradiation handling, attempts to produce such cracks by intentional rough handling of fuel components were not successful.

Thermal Expansion of "N" Fuels. Measurements of the diametric thermal expansion of NOE's and N-Driver tube elements are being made to provide data needed in the design of support hardware. In the temperature range 20-300 C, the diametric thermal expansion coefficient for both the NOE and N-Driver fuel is 15.5 ± 0.5 in./in./°C. This compares with a longitudinal thermal expansion coefficient for NOE and NIE components of about 13.0, thus indicating that the Zircaloy-2 cladding is less effective in restraining the radial expansion of the fuel than it is in restraining the axial expansion.

Comparative Swelling of Uranium Alloy Fuels. Two KSE-5 fuel elements which were irradiated in KER loop 1 to approximately 2700 MWD/T have been examined in Radiometallurgy. Fuel swelling in the element containing N-fuel (140 ppm Fe and 120 ppm Si) was 2.2 vol.% while fuel swelling in the element containing 400 ppm Fe and 800 ppm Al was 1.2 vol.%. Optical metallography and fuel density measurements made in Radiometallurgy confirm the swelling data. A small amount of grain-boundary tearing is evident in the cooler regions of both fuels. In the hotter regions of the "N" fuel the microstructure is heavily twinned and contains clusteres porosity while the Fe-Al bearing fuel appears to be free of this latter type of porosity. Postirradiation annealing studies will be conducted on samples of each fuel element to determine the influence of the alloy additions on the formation and growth of gas porosity.

[redacted]

Alternate Uranium Composition. Studies are in progress to determine the effects of altered fuel compositions upon fuel element fabrication, fuel material properties, and irradiation swelling resistance.

Material coextruded to NOE stock and containing 179 ppm Fe - 250 ppm Si (Billet No. 2036385-extrusion X-92) and 159 ppm Fe - 418 ppm Si (Billet No. 2036389-extrusion X-93) was obtained for study of the structural effects of heat treatment and determination of recrystallization behavior. Sections of the material as extruded, beta heat treated, and gamma heat treated were cold worked to 21.4% area reduction and heated at temperatures from 400 to 625 C for 20 hours. Hardness measurements were made and the microstructure was examined for extent of recrystallization and observation of the intermetallic compound distribution. The temperatures at which 50% recrystallization was observed in the structure and 50% decrease in hardness measured are shown in Table I.

It is seen that increases in recovery and recrystallization temperature are produced by increasing silicon content and by heat treatment.

TABLE I

Recrystallization Temperature* of Uranium Containing Iron and Silicon Additions

	179 Fe - 250 Si			159 Fe - 148 Si		
Prior Treatment	Ext	BHT	γHT	Ext	BHT	γHT
Recrystallization Temp. °C	475	490	500	475	510	535
50% Hardness Decrease	430	465	455	435	455	500

* 21.4% cold work, 20 hour anneal, 50% recrystallization estimated from microstructure.

Metallographic examination of samples after the annealing treatments showed that for both materials, the gamma heat treatment was more effective in obtaining complete solution of Fe and Si compounds than the beta heat treatment, and that for both treatments and materials, progressive precipitation and growth of intermetallic compounds occurred at annealing temperatures above 425 C.

Tension and tension stress cycling tests were made at 400 C on samples prepared from beta heat treated U - 150 Fe - 100 Si and U - 400 Fe - 800 Al material used in KSE5 fuel element tests. The purpose of the tests are to study the structural effects of cyclic deformation and to determine differences in mechanical behavior of the two materials. Standard tensile properties of the materials at 400 C are shown in Table II.

[redacted]

TABLE II

Tensile Properties of U-150 Fe - 100 Si and U - 400 Fe - 800 Al at 400 C

Material	0.2% Yield Strength 1000 psi	Ultimate Strength 1000 psi	Elongation % in 1-inch
U - 150 Fe - 100 Si	33.3	40.2	19.8
U - 400 Fe - 800 Al	42.3	51.0	14.2

Cyclic tests were run at 25,000 ± 5000 psi, 27,500 ± 5000 psi, and 30,000 ± 5000 psi at 400 C at a cyclic rate of 6-7 cpm to a maximum of 300 cycles. The 150 Fe - 100 Si material at 30,000 ± 5000 psi was strained high enough into the plastic range that after 14 cycles it was continuing to yield just below 35,000 psi and the test was terminated. Total deformation as a result of cycling is indicated below.

	No. of Cycles	Nominal Stress 1000 psi	Total Strain % in 1-inch
U + 150 Fe - 100 Si	300	35.0	0.5
"	300	27.5	0.8
"	14*	30.0	6.7
U + 400 Fe - 800 Al	300	25.0	0.2
"	300	27.5	0.2
"	300	30.0	0.2

* Test Terminated.

The density and structure of the material in the gage section is being determined, specifically looking for evidence of void formation.

Target Element Development. As part of the continuing program of support for the N-Reactor multi-product target element, several studies are being conducted on the target materials and target element components.

To obtain data on the gas composition and tritium release during irradiation of ceramic core targets, two elements of $LiAlO_2$ and two of Li_2SiO_3 were irradiated for a period of approximately 58 days in the KER loop. During fabrication, careful control was

exerted to assure that the target cores were free of moisture. These elements have been discharged and will be shipped to Radiometallurgy for examination.

A series of experiments was conducted to explore the behavior of target element components under various conditions:

a. A short length of Al-clad Al-0.8% Li was filed bright and enclosed by electron-beam welding in a bright-etched Zircaloy jacket. It was then induction heated slowly to about 1100 C, held 5 minutes, and cooled slowly. It was found to be swollen and ruptured with a bulged area near the end; a large cavity occupied most of the internal volume. Microscopic examination of the longitudinal section showed the presence of a considerable number of aluminum-zirconium alloy platelets dispersed throughout the Al-Li matrix. Except at the ruptured zone, the jacket showed only light attack by the Al-Li.

b. A short length of C-64 aluminum rod was similarly brightened and enclosed in a bright-etched Zircaloy jacket. It was heated similarly to the previous sample but was cooled rapidly. It was found to be bulged uniformly throughout its length except at the end-cap zones. Longitudinal sectioning revealed a small internal cavity encrusted on the inner surface with the lustrous platelets of zirconium-aluminum compound (presumably $Zr-Al_3$), and metallographic examination showed a heavy dispersion of such platelets throughout the Al-Li matrix.

c. Another short length of Al-clad Al-08% Li rod was encased in a Zircaloy jacket similarly to the first experiment, except that the core was burnished with graphite before inserting in the jacket. It had been intended to apply the same heating-cooling cycle as for "a", but when the specimen reached about 900 C, large bulges appeared near the ends and the power was shut off. Sectioning revealed a large internal cavity, highly encrusted with the $ZrAl_3$ crystals, and the Al-Li matrix was heavily charged with smaller block-like crystals assumed to be ZrC formed by reaction of graphite with the jacket. The jacket had been thinned to 0.008" thickness from an original 0.030", by reaction with the graphite.

From these observations the following tentative conclusions are drawn:

a. Induction heating causes a hotter zone near the ends of the specimens.

[redacted] [redacted]

b. The tendency to bulge or rupture is aggravated by erosion and dissolution of the jacket wall in the core material.

c. Reaction of the core metal with the jacket is speeded by clean, unoxidized contact surfaces. Reaction is delayed by the presence of oxidized interfacial surfaces.

d. Graphite reacts rapidly and uniformly with Zr-2 at temperatures below 900 C.

2. Corrosion and Water Quality Studies

Crevice Corrosion at Heated Surfaces. Internally heated Zircaloy clad rods with suitcase handle supports forming crevices are being exposed in the TF-3 Loop as part of a program to evaluate effects of concentration of LiOH at the heated crevices. In comparative tests, deposition and corrosion were much more severe in lithiated water (pH 10) than in ammoniated water (pH 10). In one test in lithiated water at 200,000 Btu/(hr)(ft^2) after 135 days, the oxide films varied from 0.0005 to 0.002 inches and covered about one-half of the length of one of the crevices. No white oxide was found at any location away from the heated crevice. In ammoniated water no thick films were formed.

One test in lithiated water at 550,000 Btu/(hr)(ft^2) continued for 45 days until the heater element failed. Oxide formation was slight except for one crevice where a oxide film, ~ 0.0005-inch was formed on the heating element surface at a crevice. One test is continuing: an element with suitcase handle supports at 300,000 Btu/(hr)(ft^2).

Effects of Off-Standard Conditions. The testing program in the K-1 Loop to evaluate off-standard water conditions in N-Reactor primary coolant was completed this month. During various stages of the test, the pH had been controlled at values between neutral and 10; the water quality had been controlled by feed and bleed at the normal rate of 1.0 gpm or at a reduced rate of 0.5 gpm; the feed water had been either deoxygenated or air saturated. The conditions during different portions of the test are shown below:

[redacted]

	pH	Feed Rate	Feed Water	Dates
1.	10	1 gpm	deoxygenated	9/8 - 9/24
2.	Neutral	1 gpm	deoxygenated	9/24 - 9/30
3.	10	1 gpm	deoxygenated	9/30 - 10/1
4.	10	1 gpm	air-saturated	10/1 - 10/6
5.	10	1 gpm	deoxygenated	10/7 - 10/13
6.	Neutral	1 gpm	air-saturated	10/24 - 10/25
7.	Neutral	0.5 gpm	air-saturated	10/25 - 11/3
8.	Neutral	1 gpm	deoxygenated	11/3 - 11/10
9.	10	1 gpm	deoxygenated	11/10 - 11/15

Previous results (Parts 1-5) had shown that crud and activity problems increase as pH is reduced from 10 to 7 and/or oxygen content of the feedwater is increased. A trend toward increased in-reactor pressure drop and fuel element temperature was observed during the testing with neutral pH and deoxygenated water (9/24 - 9/30); however, both crud levels and activity levels returned to normal when pH was increased to 10 and deoxygenated water was used as feed (period (9/30 - 10/1).

The results during this month are in agreement with previous results. With oxygen-saturated feedwater, solution activity and iron concentrations in the water were higher than normal indicating higher corrosion rates and/or higher crud release rates; however, there was no indication of increased pressure drop or fuel temperature during any time that this type of feed was used. There was no accumulation of O_2 in the water even when air-saturated feed was used.

Some crud release occurred during thermal cycling (primarily during loop shutdown and startup operations), but this release had no significant permanent effect on pressure drop or fuel element surface temperature. There was no significant effect on coolant quality or system activity when the coolant purification rate was decreased from 1.0 gpm to 0.5 gpm. This is an encouraging indication that N-Reactor may be able to operate with reduced feed and bleed rates. However, some pilot plant tests in N-Reactor are required before this can be recommended.

In summary, the results indicate that short term (1-2 weeks) deviations from water quality at N-Reactor may cause minor increases in crud and activity levels, but if the water quality is brought back to normal conditions, these crud and activity levels will decrease to normal values. However, the results are not sufficient to indicate the effects of long periods of continued operation at lower pH (~ 7) or higher oxygen levels.

[redacted]

Pitting Corrosion in N-Reactor Graphite Cooling System. An outlet N-Reactor graphite cooling system jumper (tube 0999) was inspected to determine if the high oxygen level caused by radiolytic breakdown of the cooling water is causing excessive corrosion. The carbon steel tubing and tee were covered with thick, light-chocolate colored film. After descaling, hundreds of pits 1 to 2 mils in diameter were found on the internal surfaces at the non-crevice areas. A few larger pits 10 to 15 mils in diameter by approximately 5 mils deep were found at the crevice formed at the tubing flare. The tubing is approximately 40 mils thick.

Stress Cracking of N-Reactor Valve Stems. Several large 17-4 pH stainless steel valve stems in the N-Reactor primary system have failed due to stress-corrosion cracking. The valve stems were ordered to a H 1025 condition but hardness measurements correspond to a somewhat lower temperature aging heat treatment. Numerous components in N-Reactor contain 17-4 pH stainless steel; therefore a program is being initiated to test this material at secondary and graphite cooling system conditions. Of particular concern is the high oxygen content of the graphite cooling system, which may accelerate the stress-cracking corrosion.

Nickel-Plated Aluminum. Nickel-plated aluminum coupons have been exposed for 20 days in 330 C water, pH-10 NH_4OH, at 25 ft/sec flow rate. Weight changes after 20 days were + 10 to -12 mg/dm^2. By comparison, weight losses in water at 25 ft/sec, 330 C, pH 6 to 7 were 15 to 75 mg/dm^2, depending on heat treatment of the nickel plate. Coupons in the NH_4OH test with prior exposure only in NH_4OH retained bright interference colors formed in heat treatment and showed no evidence of pitting or plate loss. In similar tests in LiOH, considerable plate loss occurred after 17 days.

Nickel-plated fuel elements exposed 30 days in the C-1 loop are undergoing postirradiation examination in Radiometallurgy Laboratory.

3. Gas-Atmosphere Studies

Graphite-Zirconium Compatibility Loop Experiment. One objective of this experiment is to determine the rate of oxidation of a large graphite bar exposed to the loop gases. Test No. 9 has now been completed, which essentially duplicated Test No. 8 conditions of 4000 ppm of water vapor at 820°C. Similar results were found. Modifications made to the computer program now permit a calculation of oxidation rate as a function of depth from the surface of the bar. The calculations show that the relative increase in

oxidation rate of the interior of the bar found in the last two tests must be due to an increase in the effective diffusion coefficient for water vapor in the graphite bar. Oxidation has probably opened up more surface in the porous graphite making the interior more accessible to gases than it was prior to oxidation.

4. Process Tube Development

Fracture Studies. Previous attempts to record growth of internal flaws in a metallic specimen using microphones to hear noises generated by energy release were hampered by low frequency background noises. At the suggestion of Aerojet-General Corporation personnel, accelerometers were substituted for microphones. According to A.G.N., as stress is increased in a specimen under test, acoustic transducers affixed to the surface detect and record sonic and ultrasonic signals originating from flaws or other areas of incipient failure. Sporadic signals from the earliest developing microcracks have been detected at stresses as low as 20 percent of ultimate, and occur with increasing frequency as stress is increased. As experience is gained with a given material, the imminence of failure can be deduced from the frequency with which the signals occur and the test stopped just short of destruction of the specimen.

If the method can be successfully applied to a flawed section of Zircaloy pressure tubing, it should be possible to "grow" the flaw by low cycle fatigue and stop the test just short of critical crack length. In this way a point on the curve for stress vs critical crack length can be determined without destroying the test piece. Repeating the test at successively lower cyclic pressures should allow construction of the entire curve with a single specimen. This is an inviting prospect when considering work on very scarce irradiated material.

The method has tentatively been applied to a section of N-Reactor pressure tubing deliberately flawed and then pressurized to failure. Although the tape recorded signals have not yet been fully analyzed, it appears that strong acoustic burst at 10 MC emanated from the growing defect. The frequency of occurrence of these signals increased as the stress in the tube approached ultimate.

5. Thermal Hydraulic Studies

Heat Transfer Experiments for N-Reactor. Conclusions were made from laboratory experiments conducted to determine the thermal

and hydraulic conditions in a column of N-Reactor fuel elements following a gross rupture of an inlet riser supply line. These experiments were performed with a full-scale, electrically heated model of the downstream half of a fuel column with prototypic hydraulic connectors and fittings. Following a detailed analysis of the results, it was concluded that

(1) The heat removal rate following the rupture would be adequate to prevent any temperature rise in the fuel for at least 1.5 seconds.

(2) At the end of this period, the heat removal rate would decrease very rapidly and essentially all of the heat generated in the fuel would remain in the fuel. This condition would cause the fuel temperature to increase and would last for perhaps 5 to 10 seconds.

(3) It is not practical to apply the laboratory results to the reactor following this period. The test section was vented to drain during the experiment and had no source of backup cooling. On the other hand, the reactor would have water trapped in various piping components that could be available to the fuel for further cooling in many cases.

The results of these experiments will be used in the analytical study of the whole problem of reactor cooling and containment following the possible rupture of an inlet riser.

In other programs for N-Reactor, laboratory studies were started to refine the knowledge of thermal hydraulic characteristics of the tube-in-tube fuel elements. A second electrically heated test section representing the downstream half of an N-Reactor fuel column is being used in these studies. This test section differs from the one used previously in that provision was made to allow interchannel mixing as could occur at each junction of the fuel elements in the reactor. One of the main purposes of the present tests is to determine the effects of interjunction flow on hydraulic stability and heat transfer characteristics of the three flow channels, especially for cases of flow or heat imbalance between the three channels.

Heat Transfer Experiments for Co-Producer

Fuel Elements in N-Reactor. Plans were made for the laboratory experiments necessary to define the heat transfer limits of a co-

[redacted] [redacted]

producer fuel element. This element will consist of a hollow uranium cylinder containing a solid rod of some target material. The element will contain two flow paths -- one between the uranium cylinder and the pressure tube and the other between the uranium cylinder and the target rod.

Experiments with three electrically heated test sections were planned to provide information on the boiling burnout characteristics of the heated surface facing the target rod. Two of these test sections will be short (about two feet long) and will provide information on burnout at high heat fluxes in the subcooled region for two different annulus thicknesses. The third test section will be about eight feet long to determine any length effect and to investigate burnout conditions when the outlet coolant is a steam-water mixture.

Hydraulic Tests for the Present Production Reactors. Tests were conducted in the hydraulics laboratory to determine the effects of using the top inlet port of the extruded K ribbed nozzle instead of the bottom inlet port as is used now. The use of the top inlet port would be an advantage on spline tubes because of less interference between the coolant stream and the spline. It was found that use of the top port would reduce the pressure drop between the front header and the beginning of the fuel column by 25 to 30 psi and increase the flow rate by 4-1/2 to 5 percent.

6. Shielding Studies

NPR Shield Analysis. Analysis of the NPR shield experimentation has been completed. Agreement for neutron fluxes and gamma dose rates are generally within a factor of 2 throughout the reflector and shield, on the basis of absolute measurements and on calculated core parameters and power level. Some of the important items observed were: (1) input neutron spectrum for MAC should be taken as the spectrum calculated (a unit cell calculation) at a fuel-moderator interface; (2) $\frac{1}{E}$ weighted cross section produce better agreement for thermal neutrons in strong slowing down regions such as the reflector; (3) shield homogenization should emphasize those sections of the shield which shows up at a dose point, and (4) MAC and MAC-RAD calculate essentially identical numbers (based on limited experience).

Current calculations for the full power reactor will be completed by month end.

7. Graphite Studies

N-Reactor Graphite Test. Ball channel No. 60 and rod channel No. 74 at N-Reactor were recently converted into graphite testing facilities. The ball channel has been charged with samples, and samples for the rod channel are in preparation. The samples for the ball channel are large blocks with dimensions of 4 x 5-3/8 x 18 in. long. The long axis of the blocks lie in the vertical plane of the reactor. Nineteen of these blocks were charged. Initial dimensions were measured at three locations on the sides and at each corner on the ends. Some of the blocks contain holes for small samples (0.43-in. diam x 4-in. long). Comparison of the results with the long-term tests on small samples in the GETR will give insight into the sample-size effect and will also provide a check on the extrapolations of GETR data to N-Reactor conditions.

Some of the large blocks contain 7/8-in. diameter holes that extend to 1-3/8 in. from the bottom of the block. In the holes are graphite rods that extend above the top of the block and support the weight of the other blocks in the ball channel. This arrangement permits the sample blocks to be irradiated in an unloaded condition.

In addition to the long sample blocks, the ball channel was also charged with nine short sample blocks (4 x 5-3/8 x 6 in.). These blocks contain no center support rods and no holes for small specimens. They are arranged in the ball channel so that the vertical axis (6 in.) is perpendicular to the extrusion axis of the graphite bar from which the blocks were fabricated.

The nineteen long sample blocks and the nine short sample blocks were annealed at 950°C for 2 to 3 hours and then weighed and measured. Purity measurements were also obtained in the Hanford 305 Test Reactor so that the extent of impurity burnout can be determined at some future time.

N-Reactor Graphite Irradiations. The series of long-term irradiations of N-Reactor graphite continues to progress satisfactorily.

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

A summary report on Ceramic Research and Development Operation achievements in plutonium utilization for the period 1956-1964 was approved for publication. This report briefly outlines accomplishments in fuel materials research, development of fuel element fabrication techniques, and irradiation testing in the PRTR and other test reactors.

PRTR High Power Density Core Fuel Element. The first vibrationally compacted UO_2-2 wt% PuO_2 high power density (short core) PRTR fuel element was successfully irradiated in the PRTR to a burnup of 690 Mwd/ton_U. Estimated maximum fuel temperatures during irradiation were 2450 C at the maximum tube power of 1000 kw. Interim examination of the element in the PRTR basin revealed that its general appearance is excellent. The element was moved to a higher flux position where the maximum estimated operating temperature will exceed melting during further irradiation.

PRTR Fuel Fabrication. A second high power density, 2% PuO_2 enriched, 5-foot long PRTR fuel element having a cobalt-Zircaloy flux wire adjacent to the center rod was fabricated and charged to reactor on November 19, 1964.

Four 1%, 8-foot PRTR elements were delivered to the PRTR. Two were charged to reactor.

Sufficient swaged and Vipac rods were in process to assemble two Vipac and one swaged, 2% PuO_2 enriched, 5-foot long elements; and three swaged, 1% PuO_2 enriched, 8-foot long elements.

A change from horizontal to vertical excitation of the horizontal beam to which the tube is top-coupled during vibrational compaction resulted in a decrease in tube breakage rate. No cladding failure has occurred with this method, compared to a 2% failure rate previously experienced with 8-foot rods and 30% rate with 5-foot rods.

The enrichment of uranium dioxide fuel elements containing sintered UO_2 pellets enriched with plutonium-zirconium alloy wires is being developed. The extrusion of delta plutonium-zirconium alloy wire was successfully accomplished this month. The pressure required was six to seven tons at 520 $\pm$ 20 C acting on a 0.260-inch diameter

billet. A reduction ratio of twenty to one was used. The required process conditions are very close to the yield strength of the tooling. The limited quantities of wire fabricated are of good quality and are being used to fabricate test rods for the MTR (one rod) and PRTR (one rod).

PRTR fuel (2.0 PuO_2-UO_2) was successfully processed using arc-fused UO_2 blended with U_3O_8 to control the O/U ratio. The high temperature (1150 C) achieved during Nupac preheat diffuses the excess oxygen throughout the powder. More uniform and consistent results were obtained in density and gas content control.

Hydriding of PRTR Fuel Element Components. Six Zircaloy-2 test capsules were hydrided in an ultra-pure hydrogen atmosphere at temperatures between 300-410 C. The hydrogen had a reported moisture content of 9 ppm water.

Conventional vipac end closure capsules and modified capsules were included in the test. All of the capsules which were hydrided between 335 C and 300 C failed in the crevice region near or in the weld zone. One capsule hydrided at 360 C failed just outside the crevice, while a capsule hydrided at 410 C failed midway between the two end caps. Capsule modifications appeared to have little effect on changing the point of failure.

Slit-Defect Fuel Element Performance. The PRTR swage-compacted UO_2 element deliberately defected with a 3-inch longitudinal slit in one of the rods successfully completed 18.7 days of operation in the rupture loop. Steady state activity release rates were approximately the same as for the earlier 5/8-inch long slit on the same rod. No significant activity release bursts occurred during power level increases with the slit defects. The activity release rates showed a strong power dependence that reflects fuel temperature. This type of release (diffusion controlled) is characteristic of defects that are large enough to provide good communication between the fuel and coolant. Post-irradiation examination in the PRTR basin showed no indications of swelling or fuel washout and no evidence of water-logging. Another swage compacted UO_2 element (FE-1030) was defected with a 6-inch long slit for irradiation testing in the rupture loop.

PRTR Recycle Element. Fabrication of a prototypic recycle element (2 wt% PuO_2) is under way utilizing salt cycle material, specially designed hot cell fabrication equipment, and segmented Zircaloy-2 tubes.

A high power density PRTR fuel element (2% PuO_2) is being fabricated with six of the outer fuel rods to contain recycled plutonium fuel made by salt cycle electrodeposition from solutions of mixed oxide from fuel elements irradiated to approximately 5000 Mwd/ton in the PRTR. Six hundred grams of additional PuO_2 were provided as enrichment for the spent 1/2 wt% PuO_2-UO_2 fuel rods being recycled. Approximately 16 pounds of electrodeposited 0.68 wt% PuO_2-UO_2 were produced; however, the first attempt to make 2% PuO_2-UO_2 material failed. Control of the Pu/U ratio was lost by the reducing action of graphite which flaked off from the salt bath vessel liner and dissolved in the melt. A second run is under way in a quartz lined vessel.

Special fabrication equipment for remote, low head-room, hot cell use is being developed. A pneumatic vibrator unit for vibrational compaction and two remote welding chambers were designed and fabricated.

Specifications for Salt Cycle, Compactible UO_2-PuO_2 Powder. Specifications were written for internal quality control of chemical and physical properties required of high density UO_2 particles enriched with PuO_2 by the salt cycle process. This compactible grade powder is to be used in studies of packed particle fuel elements made by contact or remote vibrational compaction methods.

Fuel Element Rejuvenation. A fuel element designed to demonstrate the feasibility of rejuvenating fuel elements with Pu alloy wire was shipped to MTR for irradiation. Following one irradiation cycle in the GEH-4 facility, the 4-rod cluster will be returned to Hanford. Rejuvenation will be accomplished remotely by placing a 9-inch long, 0.040-inch diameter Pu-15 wt% Zr wire into the 0.063-inch diameter hole in the center of the cored, natural UO_2 pellets.

Heterogeneous Enrichment. Three methods of enriching ceramic fuels with plutonium are being compared in a fuel element shipped to the MTR for irradiation in December. The one-foot long, 4-rod cluster consists of one rod of Nupac UO_2-1 wt% PuO_2, one rod of Pu-Zr alloy wire enriched pellets, and two rods of pellets peripherally enriched with UO_2-PuO_2. The mixed oxide enrichment is a sized blend of UO_2 containing calcined PuO_2 as the fine fraction. The principal advantages of the "hot-wire" and "hot-wall" Heterogeneous enrichment methods are simplicity--small amounts of enrichment material can be handled separately until the final steps in the fabrication process--and potentially increased thermal efficiency.

Corrosion and Water Quality Studies

PRTR Pressure Tube Monitoring. Ten pressure tubes were visually examined this month. These examinations disclosed no new fretting of any significance even though one of the process channels had operated with a UO_2 fuel element which was found to have a broken wire wrap.

Since PRTR startup, ID measurements have shown that there has been little or no creep of the pressure tubes under PRTR operating conditions. Since, from these data, creep is not a significant factor, ID measurements will no longer be obtained. Therefore, the ID gage has been removed from the inspection probe and stored for future use if the need arises.

Ceramic Washout Tests. Mixed oxide core elements irradiated in PRTR have been very resistant to washout (release of core material) by high temperature water in ex-reactor tests. A Vipac-physical mixture element clad in Zr-2 with a core of UO_2-1/2 wt% PuO_2 and a slitted defect 1-1/2" long by 1/16" wide released no activity to the water after 3-1/2 weeks of testing in 300 C, 13 fps water in the IRP. The size of the defect was increased to 6" long by 1/16" wide and in the present test no activity has been released after 1-1/2 weeks of testing. This element had been irradiated to 5000 Mwd/ton in the PRTR prior to testing.

A second element which had been irradiated to 4100 Mwd/ton and which was defected with a slit 6" long by 1/16" wide released no activity to the water after 3-1/2 weeks. The element was a swaged physical mixture with a UO_2-1/2 wt% PuO_2 core and Zr-2 cladding.

Dissolution of PuO_2 by Bromide and Iodide Solutions. Tests were conducted to determine whether HBr and/or HI could be used to dissolve and remove sintered PuO_2 from reactor systems. The only reagent which appears effective is 9 M HBr at high temperatures. In four hours at 100 C, 9 M HBr dissolved about 1.2% of the PuO_2. This is more effective than the OPG solutions but is slow for effective removal of sintered PuO_2 from a reactor system.

Decontamination of PRTR Jumpers. Some PRTR jumpers are being decontaminated to evaluate different procedures for removing long-term films as may be present in the PRTR. Both the APACE and APBIS procedures are effective if cycling and longer exposure times are used. For example, utilizing jumpers which had been in PRTR for 22 months, two cycles of the AP-Bisulfate procedure (alkaline permanganate at 105 C for 3 hours and bisulfate at 70 C for 3 hours) gave a DF of 75; substituting ammonium citrate for the bisulfate resulted in a DF of 30.

Chloride in PRTR Gaskets. Spiral wound SS-asbestos gaskets have been removed from PRTR tubes as leaks develop or as part of a periodic replacement program. Many of these gaskets have been cracked, presumably by stress corrosion cracking. The gaskets were analyzed and found to contain an average ~400 ppm Cl^-. Some gaskets which had shown extensive cracking also had a concentration gradient for Cl^- from the inner to the outer ring (280 to 1430 ppm). Two additional gaskets which did not show extensive cracking had 200-300 ppm Cl^- with no definite concentration gradient. Additional samples were being analyzed to determine if the concentration or gradient can be correlated with the cracking or leaking.

One new nozzle was leached with water at 300 C. After two hours, 400 ppm Cl^- had leached out; additional exposure did not leach out any additional Cl^-.

Automated Continuous Analysis of Borate. Boric acid has been proposed as a shim control for the PRTR during the high power density core test. It will be necessary during all in-reactor tests and operation to have some procedure for analyzing and controlling the concentration of boron in the water. Work was continued to develop a suitable procedure to use with the Technicon Autoanalyzer to measure the small amounts (<200 ppm) of boron continuously. Most procedures tested to date employ concentrated acid reagents and are either unsatisfactory from the standpoint of sensitivity or reproducibility, or introduce potential problems of safety to personnel and/or damage to the analysis equipment. However, an original procedure based on decolorization of a buffered solution (pH ~10) of carminic acid by H_3BO_3 has been developed and appears to be well suited for the PRTR application. This procedure is currently being checked to determine the effect of possible interfering agents.

Examination of PRTR Crud Films. A crud film, observed on the inside of some PRTR pressure tubes during routine borescopic examination, was sufficiently thick and nonreflective to hamper the fretting examination. Selected portions of a tube were decrudded with 6 M HCl. After the decrudding was completed, the inside of the tube was a dull black rather than shiny appearance of ZrO_2 normally observed on coupon specimens. The decrudding solution was analyzed for cations and radionuclides. The major cations were Al, Fe, Zr, Cr, Cu and Mg; the major radionuclides were Cr-51, Ba-La-140, Zr-Cb-95, Ce-144, Ru-103, and Co-60.

Reactor Engineering Studies

Second Generation Mechanical Shim Rod for PRTR. The modification of the lower assembly of the second generation mechanical shim rod to

accept the newly developed gasket was completed. Installation of the complete assembly in the PRTR is currently in progress.

High Power Density Core Chemical Shim. The environmental shim rod test facility used for corrosion and operational tests of the second generation mechanical shim rods is undergoing modifications for use in the chemical shim studies. The facility will contain an actual mechanical shim rod assembly with the moderator system materials (stainless steel, aluminum, Inconel, Haynes 25) and calandria aluminum shim well. The entire unit will be contained in an aluminum housing of perhaps a prototype shroud tube. Most of the major equipment to be used in reactor performance testing, except for the boron removal ion exchanger, will be employed for operation of this 314 Building facility. Since laboratory tests will have been made to determine the ion removal capacities, prototype testing of this exchanger is not considered necessary. However, a coolant quality control ion exchanger to be operated in parallel with boron removing exchanger will be tested. This testing program will provide corrosion information in environment and conditions similar to actual PRTR conditions except for the nuclear flux, and performance evaluation of individual pieces of equipment.

Fretting Corrosion Investigation. A high power density (HPD) fuel element has been tested for fretting characteristics for 500 hours at 530 F, 1050 psig, and 165 gpm flow in an ex-reactor facility (EDEL-I). Subsequent tube inspection showed three marks caused by support pads and one mark caused by a rod wrap. Two of the support pad marks correspond to the lower fuel element bracket; one corresponds to the upper bracket, and was the first upper bracket mark produced by the HPD fuel element. The three pad marks are of unmeasurably slight depth and appear as lightly burnished areas. The rod wrap mark was less than 0.25 mil deep. The only area of noticeable wear on the fuel element was located on the rod wrap approximately one-third the length of the fuel element from the upper bracket. The bundle bands welds were intact.

The HPD fuel element has been recharged and loop flow conditions established at 530 F, 1050 psig, and 185 gpm flow. These conditions will be maintained for 500 hours to determine if a flow-dependent threshold for fretting exists in the range of expected flow rates.

Previous tests to evaluate the effect of pad width on fretting tendencies showed anomalous results when wide pads resulted in greater fretting than sharpened pads. It was suspected that fuel pad orientation was a prime variable. Additional tests were run with the fuel element installed so that unsharpened (1/16-inch wide) end bracket pads contacted the south "side" of the tube liner,

i.e., the plane of vibration. Results of the recent test are compared to those results where the fuel element was installed so that sharpened end bracket pads contacted the south "side" of the liner.

Contact Location	Location-Type of Centering Pads[a]: Sharpened Pads at South Orientation	Location-Type of Centering Pads[a]: Unsharpened Pads at South Orientation	Liner Penetration (inch): Sharpened Pads at South Orientation	Liner Penetration (inch): Unsharpened Pads at South Orientation
South	T - S	T - NS	0.002	<0.001
South	B - S	B - NS[b]	0.001 - 0.002	0
NW	T - NS	T - S	0	0
NW	B - NS[b]	B - NS	0.001 - 0.002	0
NE	T - S	T - S	0	Shiny area
NE	B - NS	B - S	<0.001	0

(a) T denotes top (end bracket), B-bottom, S-sharpened (centering pad), NS-unsharpened.

(b) This centering pad is less than 1/16-inch wide but is not sharpened to a knife edge.

The results indicate that (a) the end bracket pads do not always contact the tube-liner wall over their entire area, and (b) sharpened centering feet result in deeper penetration. Temperature (530 F), flow rate (123 gpm), and amplitude and frequency of tube vibration (4-5 mils at 27 cps) were the same in both the initial (27-day) test and the second (23-day) test. These data and previous tests support the conclusion that orientation effects can "override" effects of fretting caused by varying pad area.

The stiffness of the PRTR Mark I (HPD) fuel element has been statically measured. This value, the product of the moment of inertia and Youngs Modulus, was calculated to be $546.8(10^3)$ lb-in^2, compared to $461(10^3)$ lb-in^2 for the present fuel element. The vibrational characteristics of the two fuel elements may then be expected to differ by a small amount.

PRTR-HPD Core. Comments were received on the rough draft issue of HW-84449, "Transition Schedules - PRTR High Power Density Core," and revisions are being made for the final issue of this document.

Because the greater neutron flux depression recently calculated for the 2% enriched 19-rod cluster PRTR fuel will cause greater local power peaking in the fuel, a detailed analysis of fuel temperature has been made. The results show that, for the local peaking factors assumed and a nominal peak tube power of 1570 kw, the pins in the 12-rod ring will operate with about 30-40% of their cross section molten. Fuel temperatures should slightly exceed the melting point at the average tube power of 1270 kw in the HPD core. These analyses are based on adequately conservative local peaking factors but do not include allowance for power measurement error or operating margins. It appears, therefore, that a greater percentage of fuel rods in the HPD core will operate with molten cores than was originally intended, and that it may be desirable to reduce the power density in the core to compensate for the higher local peaking factors.

The status of chemical shim tests and nuclear analyses for the HPD core was reviewed, and some of the completed work is being documented for more convenient reference.

The first 58-inch, 19-rod cluster (containing UO_2-2 wt% PuO_2 fuel) was charged into PRTR channel 1255, and demonstration irradiations commenced on October 27. The coolant flow rate through the channel was retained at nominal 110 gpm for the operation. The inlet jumper vibration measuring instrument system failed at startup precluding any correlation between vibration characteristics of short and long fuel elements. Visual inspection after the November 15 shutdown revealed no pressure tube damage attributable to short fuel element performance.

Safety of Mixed PuO_2-UO_2 Fuels. A paper summarizing the analyses carried out with respect to the Doppler delay problem in mixed PuO_2-UO_2 fuels has been written for presentation at the ANS winter meeting next month. Further consideration is being given to generalizing the exponential burst approximation to include a prompt positive Doppler contribution from plutonium in addition to the delayed negative coefficient from U-238. This extension appears essential to obtaining a realistic approximation for the energy release in highly enriched fuels.

Thermal Hydraulics Studies. Calculations determining the maximum tube powers for the PRTR High Power Density Core based on boiling burnout were modified as new information concerning the core became available. The latest calculations show that with a 450 F inlet temperature, maximum tube powers of 1760 and 2030 kw would be possible for flow rates of 138 and 165 gpm, respectively.

The salient assumptions which were used in these calculations were that the reactor was operating without mechanical shims, that the heat flux on the outer surface of the outside rods was 136% of the average fuel element heat flux, that the axial power level was that calculated for 106 inches of moderator containing 150 ppm natural boron.

The maximum tube powers calculated for these conditions would vary approximately linearly with inlet temperature. At 138 gpm flow, the maximum tube power varied from 1500 kw at 494 F inlet temperature to 2100 kw at 339 F. At 165 gpm flow, the corresponding power levels would be 1500 kw at 518 F and 2100 kw at 402 F inlet temperatures. It may be noted that the inlet temperatures for both flow rates at 1500 kw tube power would be greater than would be permitted by the requirement of an outlet temperature of 540 F. The reactor power level would be limited by the outlet temperature limit for these inlet temperatures.

It is thought that the use of mechanical shims in the reactor would decrease the permissible tube powers. The extent of the decrease would depend upon how much the mechanical shims would skew the axial flux distribution and upon how well the skewing is known.

2. Plutonium Ceramics Research

Fast Reactor UO_2-PuO_2 Fuel. Physically mixed and impacted powders were shown to possess the small particle sizes and uniformity of plutonium distribution deemed necessary for a fast reactor fuel. These results support previously obtained electron microprobe data, alpha-autoradiographs, and ceramographic observations. As inferred from the autoradiographs and the microprobe analyses, the particle sizes of the ball-milled mixtures measured with the Coulter counter are quite small. The average particle size for the 64-hour ball-milled mixture was one micron with 99% of the particles being less than six microns in diameter.

The Plutonium-Boron System. Arc melted specimens of plutonium and boron at 10% composition intervals were quenched from 1500 C or annealed at 900 C with subsequent slow cooling. X-ray analyses of quenched specimens indicate that PuB, PuB_4, and PuB_6 are the stable high temperature phases. Regions of stability were tentatively outlined. Transformations occur between 1000 C to 1400 C. The following incongruent melting points were measured: PuB ~1750 C, PuB_4 1990 C ± 10°, PuB_6 2190 C ± 20°. Additional heat treatments are in progress.

UN-20 wt% PuN Irradiation Study. X-ray diffraction analyses of UN-20 wt% PuN pellets irradiated to 2.5 x 10^{20} fissions/cm^3 show no change in the solid-solution lattice parameter. The MgO guard pellets adjacent to the fuel pellets also showed no lattice

Fuel Relocation. For the study of fuel relocation, another tungsten wire assembly has been made with $UO_{2.006}$ vibrationally compacted to 84% TD in a stainless steel tube. The assembly was designed to provide enough cooling of the ends of the central wire to prevent its burning out at temperatures at which UO_2 becomes conductive. Center void formation will be observed by gamma radiography using an image intensifier.

Materials and Information Exchange. UO_2 single crystals were characterized and shipped to ORNL, the University of Michigan, and Northwestern University for research studies.

A request was received from ANL to prepare approximately 3 kilograms of pneumatically impacted PuO_2. In addition, a request was received from ORNL to prepare 1 kilogram of high surface area UO_2 powder from ORNL for use in HL cermet studies.

4. Basic Swelling Studies

Irradiation Program. The second controlled pressure-temperature swelling capsule is operating successfully at goal conditions of pressure and temperature, i.e., 1000 psi and 575 C. It contains specimens of high purity uranium, U + Fe - Al and U + Fe - Si and will provide greater insight into the effect of pressure on "growth" induced, crystallographically aligned tearing. A sister capsule to the previous two pressurized capsules for operation in reactor at 1000 psi and 625 C is being assembled.

Postirradiation Examination. Electron microscope examination of replicas made from high purity uranium irradiated to 0.05 a/o B.U. at 700 C is in progress. A solid cylinder, one-half inch in diameter, portions of which operated in the alpha and in the beta region, has been studied in some detail. The region which operated in the alpha phase revealed the original, small equiaxed grains. Pores with diameters from 0.2 to 1 micron are located at the grain boundaries. There is no porosity within these small grains. The bulk of the samples which operated in the beta phase now consists of alpha grains much larger than the original alpha grains. Small pores having diameters of 0.05 to 0.08 microns are uniformly scattered throughout these grains. The large grains adjacent to that portion of the samples which operated in the alpha range shows a network of porosity which resembles the original grain boundary network. Replicas of two other samples, split tubes with 0.030-inch thick walls, irradiated at lower temperatures in this same capsule, have also been examined. Both specimens show large alpha grains with uniformly scattered pores having diameters in the range of 0.05 to 0.1 micron. Examination of other specimens from this capsule is in progress.

The first controlled pressure-temperature capsule which operated at 1000 psi and 450 C to 0.13 a/o B.U. was opened in Radiometallurgy Laboratory. The capsule contained six high purity uranium specimens, two U + Fe - Al specimens, and two U + Fe - Si specimens which had undergone several different heat treatments prior to irradiation. Post-irradiation photomacrography and density measurements of each specimen are complete. Preliminary analysis of the density data shows very markedly the effectiveness with which pressure inhibited the swelling of the high purity and alloy specimens in this capsulle. For example, data from high purity uranium specimens irradiated at about 450 C in general swelling capsules reveal swelling of 52% and 85% for calculated "R" values of 320 and 770, respectively, whereas high purity uranium specimens irradiated at 450 C in the pressurized capsule show swelling of about one percent for calculated "R" values of about 8. Following metallography on the pressurized capsule specimens, their annealing characteristics will be studied.

A paper, entitled "Basic Swelling Studies," was prepared and presented at the 19th High Temperature Fuels Meeting held at North American Aviation Science Center, California, on November 16, 17, and 18, 1964.

A blue cover document, HW-79559, entitled "Irradiation Behavior of High Purity Uranium," was issued. The report describes the behavior of small, high purity uranium specimens irradiated under controlled conditions. A conclusion arrived at in the report is that fission gases play only a minor role in the irradiation behavior of these uranium specimens.

5. Irradiation Damage to Reactor Metals

Alloy Selection. Several nickel base alloys are being studied to determine the effect of irradiation and environment upon their mechanical properties. Development of test equipment to perform high temperature tensile tests upon irradiated specimens of these alloys is currently underway. Three partially successful tests at 650 C were performed on Inconel 625 specimens irradiated at 50 C, 280 C, and 740 C to an exposure of about 1×10^{20} nvt. Results of these tests show a marked decrease in ductility as compared to similar specimens tested at room temperature. Six additional specimens are scheduled for testing at 650 C during the next month.

Chromium Alloy Investigation. A chromium alloy (Cr-0.7 Y-0.7 Ti-1.4 Zr) is currently being studied as a possible high temperature reactor structural material. The microstructure of this alloy in the as-received condition has been examined, revealing what appears

to be a carbide dispersion that is preferentially located in certain grains. Using an annealing treatment, the as-received hardness of the alloy has been reduced approximately twelve percent. Utilizing small wafers, various heat treatments have been applied in an effort to define a solutioning treatment for the alloying constituents. The principal problem with this alloy is its extreme brittleness.

In-Reactor Measurements of Mechanical Properties. An in-reactor creep test of annealed 304 stainless steel at 650 C and 20,000 psi stress was completed during the past month. This test exhibited a rate of 5.7×10^{-4} after 60 hours of testing at which time the reactor shut down. During the reactor outage the rate decreased to a minimum of about 3.6×10^{-4} at 120 hours. The specimen failed after 145 hours with an elongation of about nine percent. The ex-reactor test at these conditions exhibited creep rates of 7.8×10^{-4}/hr at 60 hours and 3.9×10^{-4}/hr at 380 hours. The specimen failed at about thirty percent elongation after 480 hours.

High Temperature Creep-Rupture Tests. Five additional tests have been run using the high temperature creep-rupture apparatus, described in the October 1964 monthly report, with the following results:

Material	Temperature	Stress	Minimum Creep Rate	Percent Elongation	Time to Rupture
Haynes 25	2100 F	1500 psi	7.0×10^{-3}/hr	11.7	12.0 hr
Haynes 25	"	1000 psi	1.5×10^{-3}/hr	8.4	33.25 hr
Hastelloy X	"	3000 psi	4.0×10^{-1}/hr	21.9	0.46 hr
Hastelloy X	"	2200 psi	1.4×10^{-1}/hr	18.5	1.07 hr
Hastelloy X	"	1800 psi	1.02×10^{-1}/hr	21.3	1.85 hr

The new Haynes 25 data combined with the previous data show a more pessimistic rupture life at low stresses than was predicted from earlier work using a dead weight loading system and inducting heating. Additional tests at low stresses are planned to see if this observation is correct.

A review of the literature shows stress-rupture data for Hastelloy X only up to temperatures of 1800 F. Tests are planned to determine the creep-rupture properties of Hastelloy X in the range 1800 to 2200 F.

An additional high temperature creep-rupture unit has been built. This unit will be further adapted for remote operation in order to test irradiated specimens.

Irradiation Effects in Structural Materials. A cleavage specimen of Zircaloy-2 has been successfully tested. This specimen is of such design as to allow a large amount of fracture toughness data to be obtained from a single specimen. Preliminary investigation of the data has shown behavior similar to that observed on the fatigue-cracked notch bend tests. This was found to be particularly true at low temperatures (-190 C) where the material behaved in a brittle fashion.

Irradiation Effects on Nickel-Base Alloys. Stress-to-rupture tests on experimentally heat treated Inconel X-750 - a precipitation-hardened alloy - have continued at conditions of 4800 psi and 1350 F. As shown below, irradiation at 50 C to 1.8×10^{20} nvt (E > 1 Mev) reduces the rupture life of specimens given a standard double aging treatment (heat treatment #1). Experimental treatments which under-age the specimens reduce rupture lives of unirradiated ones and appear (on the basis of only one test, however) to also drastically reduce rupture lives of irradiated specimens.

	Controls		Irradiated	
Heat Treatment	Speciman No.	Hours to Rupture	Speciman No.	Hours to Rupture
1. 2150 F/2 hrs, AC, 1550 F/24 hrs, AC, 1300 F/20 hrs, AC	A007	175.2	A001 A003	9.5 12.0
2. 2150 F/2 hrs, AC, 1200 F/50 hrs, AC	A009 A010	20.5 18.3		
3. 2150 F/2 hrs, AC	A023	5.0	A019	0.0 (broke 20 sec. after loading)

Another control specimen in heat treatment #1 was found to have a markedly reduced rupture life compared with manufacturer's data. This is suspected to be the result of a specimen defect.

Metallography shows the fracture of specimen in heat treatment #1 to be of an intergranular nature.

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 α -iron is currently being investigated.

The first phase of this investigation has been concerned with identification of the origin of the defects responsible for the changes in mechanical properties. The application of the theory of thermally activated flow to this problem has shown conclusively that these defects are lattice imperfections produced by the neutron bombardment and are not just a redistribution of impurities or precipitates formed as a result of the accelerated diffusion in irradiated samples. The latter effects are indeed present and at low exposures may be relatively important in describing the effects of irradiation on the mechanical properties, but at practical operating exposures they are of less importance. The observations and conclusions of this study have been submitted to Applied Physics Letters as a paper.

After establishing the importance of the lattice imperfections produced by neutron bombardment in modifying the mechanical properties, it is necessary to identify and characterize them. Past experience has shown that their configuration depends to a large extent on the relationship between the irradiation temperature and the temperatures at which point defects become mobile and that their configuration, in turn, dictates the type of interaction with moving dislocations and hence the mechanical properties. Methods of accomplishing this latter objective are presently under study.

ATR Gas Loop Studies

Model Gas Loop Testing. The following tests are scheduled for the next model gas loop operating period:

(1) Pressure drop across a tensile specimen holder which is one-fourth the total length planned for the ATR gas loop.

(2) General operation of the tensile specimen holder design with stainless steel substituted for the refractory metals planned for future model loop and ATR usage.

(3) Relative general operating characteristics of Platinel, chromel/alumel, platinum/platinum-rhodium thermocouples in the flowing high temperature helium.

(4) Operating characteristics of a bypass partial cleanup system.

(5) Continued operational evaluation of loop components, i.e., compressor, regenerative heat exchanger, test section, heater and instrumentation.

Thermal conductivity determination of metallic foil type insulation with prototypical ATR type joints will be made when the test foil piece is supplied by Solar Aircraft Co.

Heater Design. Design of the second generation helium gas heater for the model loop is approximately 50% complete. The heater is being designed to incorporate and investigate salient design details of the compact two-stage heater presently considered for the ATR gas loop. This heater will use 12 Ni-Cr tubes of 0.51-inch inside diameter to heat the gas to 1800 F with a second stage section of six Mo tubes of 0.535-inch inside diameter to produce the 2100 F outlet temperature. Alumina surrounds all tubes to act as combination electrical insulator and flow block to force the majority of the gas through the inside of the heated tubes.

High Temperature Oxidation of Candidate ATR Materials. Haynes Alloy 25 has been thermally cycled nine times from room temperature to 1120 C, the total time at maximum temperature being 450 hours. Through the first five cycles oxidation in 25 torr oxygen was comparable to that in a single cycle oxidation test. The rate started to increase during the sixth cycle, essentially doubling during the seventh cycle and redoubling during the eighth. Spalling occurred after each cycle. Gross spalling, especially after the eighth and ninth cycles, accounted for a total metal weight loss of 0.84 gram or 60 mg/cm^2 of the sample coupon. The coupon still retains an oxide layer showing colonies of oxide crystals which were not accounted for in the above mentioned weight loss.

The thermal cycling test of this Haynes Alloy 25 sample was ended after the ninth cycle. A similar test using Hastelloy X-280 has been started.

ATR Analytical System. A scope design has been prepared for the ATR gas loop analytical instrumentation, sampling system, calibration system, and panel layouts. Specific instruments have been recommended. Contacts have been made with three vendors for procurement of the ATR automatic chromatograph and total impurity analyzer.

Total Impurity Analyzer. A working model of a total impurity analyzer has been constructed to demonstrate the concept for an ATR gas loop instrument. The model was successful and indicates the basic principle to be sound, with a lower detection limit below 1 ppm possible. Since this instrument is similar to the CMO gas chromatograph, the previous chromatograph improvements are applicable to the total impurity analyzer and will be included in the procurement specification.

Neutron Spectrometry

An in-core experiment to determine fast neutron spectra has been performed in the ETR Critical Facility (ETRC) using a Li^6 spectrometer system (see HW-SA-3330). The purpose of the experiment was to detect and measure the spectral shift between mid-core positions and positions near the core boundary, and also to measure the effect of a boron-stainless steel thermal-neutron absorber. Spectra were measured at reactor mid-plane and 17 inches above mid-plane near the core boundary in positions F6 and M6 presently being used for Hanford irradiations.

Preliminary analysis of the data indicates that neutron spectroscopy is a useful method for determining neutron spectra in sufficient detail for use in monitor activation and damage correlation studies. Spectral detail can also be measured in positions where the geometry makes transport calculations difficult. However, the need for better resolution of spectra was indicated by these tests. The detector has since been modified by reducing the thickness of the Li^6F layer, thereby reducing the self-shielding. Increased resolution of the detector should be obtained, enabling a more detailed analysis of the spectra between 0.5 and 1 Mev.

6. Nuclear Graphite Studies

US-UK Neutron Exposure Correlation. Correlation of neutron exposures reported for graphite irradiation experiments conducted by Hanford Laboratories and by United Kingdom investigators is essential if the data are to be correctly interpreted and used. Recently, spectral calculations of a number of UK test facilities were made available, which enabled us to convert exposures reported in UK units (nickel dose) to integrated flux of energies greater than 0.18 Mev. The conversion technique has been applied to compare observed dimensional changes of PGA graphite with those of CSF and EGCR, and to the dimensional stability of graphites at different temperatures. Data for PGA contraction have been reported for irradiations at 450 C and 650 C. In order to compare these data with the Hanford CSF and EGCR graphites it was necessary to convert exposures to common units. This was accomplished by calculating effective cross sections for the nickel monitor used Ni^{58} (n,p) Co^{58} according to

$$\bar{\sigma}_{Ni} = \frac{\int_0^{\infty} \sigma(E) \quad \phi(E)\, dE}{\int_{0.18}^{\infty} \phi\,(E)\, dE}$$

where $\sigma(E)$ is the differential activation cross section and $\phi(E)$ is the neutron spectrum of the UK test facility.

Since nickel was assumed to have an effective cross section of 107 mb in the calculation of UK nickel-dose unit, exposure per integrated flux above 0.18 Mev was obtained simply from the relationship:

$$\Phi_{0.18} = \Phi_{Ni} \frac{107}{\bar{\sigma}_{Ni}}$$

where $\Phi_{0.18}$ is the integrated flux of neutrons with energies exceeding 0.18 Mev and Φ_{Ni} is the flux in units of nickel dose.

Dimensional changes of PGA were then compared with changes in CSF and EGCR graphites at the calculated exposures.

Good correlation was obtained for the graphites irradiated at 450 C. Dimensional changes of PGA are nearly the same as those of CSF and EGCR agreeing with observations reported in UK AEA Graphite Newsletter No. 11 for experiments in which CSF and PGA were irradiated together. However, the agreement is poor for the 650 C irradiations. The reported temperature sensitivity of PGA is extreme compared to CSF or EGCR. A decrease in contraction of a factor 5 is noted between the 450 and 650 irradiations for PGA samples with transverse orientation and a factor of three for parallel samples. CSF and EGCR graphites have only about a 50% decrease in contraction in the temperature range. It is unlikely that this is due to differences in materials, but probably is attributed to some undiscovered differences in test conditions or problems still remaining in converting to a common exposure basis.

EGCR Graphite Irradiation. The ninth capsule, H-3-9. in the series of long-term irradiations of EGCR graphite has completed two cycles of operation and continues to function satisfactorily. Thermocouple 5 which had become erratic was successfully rewelded by passing a small current through it.

Kinetics of the Reaction of Carbon Dioxide with Hydrogen. The investigation of the kinetics of the reaction, $CO_2 + H_2 = CO_2 + H_2O$, was continued. Two distinct reaction paths which contribute to the over-all rate of the reaction were previously described. The rate expression for the high activation-energy process (78 kcal/mole) is:

$$\frac{-d[CO_2]}{dt} = k\,[H_2]^{1/2}\,[CO_2].$$

We now wish to report the results for the low activation-energy process that predominates below 800 C. The rate of carbon monoxide and water-vapor formation was determined at 775 C as a function of carbon dioxide concentration. The results show that, in the partial-pressure range from 200 to 600 torr, the reaction is first order in carbon dioxide. The rate of the reaction as a function of the hydrogen pressure was also investigated and found to be 0.3 order in hydrogen in the range of 16 to 500 torr partial pressure. The activation energy is 39.2 kcal/mole.

The rate for the low temperature process can therefore be expressed as:

$$\frac{-d[CO_2]}{dt} = k\,[H_2]^{0.3}\,[CO_2].$$

It has been suggested previously that oxygen affects the rate of the reaction of carbon dioxide with hydrogen; however, no quantitative experimental data were reported. The oxygen concentration in the present experiments was maintained at 5 ppm or less by passing the reactants over copper turnings at 300 C. When the copper turnings were cooled to room temperature, the oxygen content increased slightly to 11 ppm and the rate of the reaction increased to 20 times its original value. These results suggest that the differences in the reaction rate reported by various authors may be due to slight differences in oxygen content.

Oxidation Inhibitor Studies. Graphite manufactured for the Experimental Gas-Cooled Reactor has provided the majority of samples for study of the inhibiting effect of CF_2Cl_2 on graphite oxidation. The reason for this choice was that gas-phase oxidation inhibitors have been considered for the safety of gas-cooled reactors such as the EGCR in the event of air entry into the coolant.

The particular impurity content of EGCR graphite produced complex effects which obscured the general significance of the tests for more typical nuclear graphites. Consequently, other graphites were studied, none of which displayed the activation of impurity catalysis found for EGCR graphite.

The catalytic effect of impurities on oxidation rate was confirmed independently of other characteristics, by selecting samples two inches apart from the same cross section of a bar of TSGBF graphite. Spectrochemical analyses identified an impurity gradient which for iron was from 5 ppm to greater than 100 ppm. X-ray fluorescence analyses indicated from 8 ppm to 64 ppm iron. The less pure graphite oxidized at a greater rate at 570 C both in air and air with 1/2% CF_2Cl_2. The rates with 1/2% CF_2Cl_2 were a factor of four less than in air alone. Comparison with rates for other graphites in this same range of purity, however, shows greater variations than result from impurity differences. The selection and analysis of graphite samples demonstrated that graphite characteristics such as type of filler, binder, purification process and graphitizing temperature can have a greater effect on air oxidation rates than typical impurity variations between different nuclear graphites.

The Effect of Graphitization Temperature on Thermal Expansion. The thermal expansions and particle orientations of molded graphite samples with the same composition but graphitization temperatures of 1370, 1800, 2100, 2300, 2570, and 2700 C were studied. The thermal expansion tests were made from 25 to 1250 C in argon, and the particle orientations of sections taken from the samples were investigated by x-ray transmission.

The x-ray analysis indicated that the average relative concentrations of c axes are 0.36 and 0.32 parallel and transverse with the molding pressure, respectively.

The bulk thermal expansion measurements, $\frac{\Delta L}{L}$, related best to the crystallite thermal expansions, $\frac{\Delta L_c}{L_c}$ and $\frac{\Delta L_a}{L_a}$ in the c and a axis directions, respectively, by

$$\frac{\Delta L}{L} = \frac{\Delta L_c}{L_c} + (1 - \theta\gamma) \frac{\Delta L_a}{L_a} \qquad (1)$$

where θ is the orientation factor and γ measures the transmission of the crystallite thermal expansion to the bulk material.

The porosity can be estimated either by calculating γ from equation (1) after substituting in the x-ray orientation and thermal expansion data or by calculating the ratio, R, of the bulk-to-crystallite thermal expansion.

$$R = \frac{\left(1 + \frac{\Delta L}{L_{\parallel 1}}\right)\left(1 + \frac{\Delta L}{L_{\parallel 2}}\right)\left(1 + \frac{\Delta L}{L_{\perp}}\right) - 1}{\left(\frac{\Delta L}{L_a}\right)\left(\frac{\Delta L}{L_c}\right) - 1} \qquad (2)$$

where $\parallel_1$, $\parallel_2$, and $\perp$ represent the two parallel and single transverse directions. The porosity estimates are about the same from either method and indicate that the porosity decreases with increasing temperature at a decreasing rate. The transmission of the crystallite thermal expansion to the bulk material for the samples graphitized at 1370 C is also significantly greater than that of the samples graphitized at 1800 C and above, even though the densities are about the same.

7. Boronated-Graphite Studies

2-C Irradiation Tests. A small, glovebox-enclosed jewelers lathe was used to remove material at various radial depths from samples of three irradiated boronated graphite specimens. The machined samples were collected and are presently being prepared for spectroscopic analysis of the B^{10}/B^{11} ratio. Results of the isotopic measurements, if successful, will yield quantitative information concerning boron burnout as a function of depth and will allow comparison of theoretical calculations with experimental data.

Prior to and after machining the samples, length measurements were made on each boronated specimen. No significant length changes due to removal of material was observed.

Further machining was done in order to obtain samples for measurement of thermal conductivity, compressive strength, and crystallite thermal expansion. Tests are under way to determine the values of these properties. The thermal conductivity of a 5 wt% black sample after approximately 2×10^{20} nvt was the same as at 1×10^{20} nvt. A 7 wt % grey sample showed a further decrease from 0.020 to 0.015 cal/sec-cm-°C. Thermal conductivities of a number of samples will be determined following the present irradiation of the 2C-3 capsule.

8. 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 outlet temperature of the loop coolant was increased 40 C so that the fuel

elements are currently operating at a maximum temperature of 500 C. The surface heat flux is 52 cal/sec-cm^2 (7.0 x 10^5 BTU/hr-ft^2), and the specific power is 47 watts/gm (143 kw/ft). The integrated exposure is now 3.3 x 10^{20} fissions/cm^3 (10,100 Mwd/ton).

Irradiation of Metallic Uranium with Sub-micron Uranium Carbide Dispersions. The irradiation performance of fuel rods containing a submicron 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 micron 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 are still being irradiated. The exposure at the end of the fourth cycle in these two capsules was 0.24 at%.

In the discharged capsule, the maximum temperature at the center of the uranium rod with the submicron carbide particles was 500 C and on the rod with 2-5 micron-sized carbide particles was 450 C. Optical and electron microscopy has been completed on samples from both rods in both the as-irradiated condition and after a 100-hour anneal at 630 C. As reported last month, the 100-hour anneal caused the density of the coarse carbide containing uranium to decrease 3.2% but caused no change in the density of the fine carbide-containing fuel. This is confirmed qualitatively in the results from the electron microscopy examination. The observed porosity in the coarse carbide uranium is much greater than in the as-irradiated condition. Little, if any, change can be observed in the fine carbide-containing specimen. Examination of these fuel rods is continuing.

9. Advanced Reactor Concepts

Heavy Water Organic Cooled Reactor Program. At the request of the AEC, a study was made to determine the feasibility of installing an organic loop in the PRTR in support of the HWOCR program. The request specified that maximum use of the EOCR Fuel Technology Loop (FTL) was to be made. The desired operating and design conditions were:

1. A 3.25-inch ID Zircaloy-2 pressure tube (PRTR size).
2. In-core test length of about 10 ft.
3. Available experimental length of about 15 ft.
4. Carbon steel piping system.

5. Heat removal of 2500 kw.
6. Coolant temperature of 430 C.
7. Coolant pressure of 600 psi.
8. Unperturbed thermal flux of 2 x 10^{14} n/cm^2-sec.
9. Axial flux ratio of about 1.6 peak-to-average.
10. Variable flow rate from 75 to 600 US GPM.

It was found that the EOCR Fuel Technology Loop, installed with the necessary rearrangements but avoiding significant equipment modification would provide operating capabilities in the PRTR which should generally meet the need of the D_2O organic testing program. The specific operating conditions which would be somewhat lower than the desired values include in-core test length, power, flow rate, and unperturbed thermal flux, but these factors do not appear to be major deterrents to achieving the program objectives.

It is expected that such an organic loop installation would cause little interference with the Plutonium Recycle Program operations and its objectives. The proposed transition from the present 85-tube core to the high power density, 55-tube core will make test channels available. The radial position could thus be selected so that the location would satisfy the organic program objectives and at the same time minimize perturbations from the organic loop to the basic fuel testing core.

Nitride Fuel Cycle for Fast Reactors. A brief conceptual description of a possible process for preparation of uranium and plutonium nitrides by nitridation of the chlorides has been issued for comment, together with supporting data from chemical equilibrium calculations. If such a process appears feasible and economically advantageous, it will be incorporated in a forthcoming design study of a nuclear power plant embodying an integrated fuel cycle.

10. Critical Flow at High Pressures and Temperatures

Earlier, data were obtained on the critical flow of steam-water mixtures being discharged to the atmosphere through a 1/2-inch pipe elbow and through branch side of a 1/2-inch tee. During the experiments an attempt was made to determine the "critical pressure" for each data point. The critical pressure is defined for uniform flow passages as the pressure at the discharge plane of the flow passage during choked flow conditions. This quantity is of interest for fittings because it will furnish a method to evaluate the effects of turbulence induced by the fitting on the thermodynamic equilibrium of the flashing steam-water mixtures critical flow.

The method used to obtain the critical pressure was to place pressure taps close to the discharge of the fitting and determine the pressure profile for the fitting at each flow condition. Unfortunately, the data provided by these downstream wall taps were erratic, and data were inconclusive. Therefore, to obtain the desired information, experiments were performed to determine the critical pressure by the alternate "rise-of-back-pressure" method. This method involves the gradual increase of back pressure during critical discharge from the flow passage. At some sufficiently high back pressure, changes in back pressure will be reflected by small changes in the upstream pressures and the flow rate. The back pressure at which this behavior commences is indicative of the "critical pressure." This method seemed successful although the data have not yet been completely analyzed.

11. Phoenix Fuel Program

MTR Experiment. Preliminary engineering calculations and analyses concerning Phoenix-type experiments in the MTR are completed. It is concluded from the study that a high exposure plutonium core design for the MTR would be feasible. To meet all of the physics objectives and to employ fuel alloy which is considered fabricable without a significant R&D program, it is necessary to employ the full core of 45 fuel element positions, reduce the coolant channel thickness and flow velocity, and decrease the number of fuel plates in each fuel element assembly.

12. Plutonium and U-233 Fueling of a Fast Compact Reactor

Discussions were held at GE-NMPO on November 10-11 to compare assumptions and analytical methods to be used in this study. Plans for the study were subsequently reviewed with AEC personnel. It was determined that the major topics of interest in the study would be core size and control span and reactivity endurance; and that lesser interests would be study of more dilute fuel and zoning of fissile isotopes for power flattening.

The above information was factored into a comparison calculation. For clad and coolant temperatures agreement is within 50 F at maximum clad temperature. However, total pressure loss is 15-20% greater than calculated by NMPO.

13. Nuclear Rocket Fuels Studies

Research and development in the field of nuclear fuels and alloy development in support of NASA programs continued. Details of these activities are reported separately via distribution directly to the sponsors.

[redacted]

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.

Foils of molybdenum containing <10 ppm and 450 ppm carbon which were irradiated to 10^{20} nvt and annealed at 750 C for two hours have been examined by transmission electron microscopy. Both specimens revealed small defect clusters, dislocation loops of varying sizes, and irregular dislocation networks. An estimate of the number of small clusters is approximately 10^{15}/cc, an order of magnitude less than observed in the "as irradiated" state. The larger loops are irregular in shape, which indicates that they were formed by coalescence of smaller loops. The large loops present in the molybdenum which contains carbon have been identified as being interstitial in character and lie on $\{321\}$. Prior to annealing the loops were observed on $\{111\}$ planes. Dislocation reactions which would result in loops being present on $\{321\}$ are being considered. The irregular dislocation networks present have $\{100\}$ and $\frac{a}{2}\{111\}$ Burgers vectors. These dislocations may result from interaction of loops having different $\frac{a}{2}\langle 111\rangle$ Burgers vectors.

Similar foils will be annealed at higher temperatures to determine the effect of carbon as a stabilizing agent of defect structures in molybdenum.

Four single-crystal samples for length-change and lattice parameter measurements were received after an integrated exposure of 7×10^{18} nvt ($E > 1$ Mev). The lengths and lattice parameters of the samples had been precisely determined prior to irradiation, and the same measurements, made in the same manner, are being repeated to determine the magnitude of irradiation-induced changes.

Three of the four crystals showed an increase in length of 0.023 to 0.024 percent. The fourth crystal was found to have a black or dark brown deposit on one end when removed from the capsule. The deposit was readily removed by immersing in an NaOH solution. The measured increase in length, however, was 0.009 percent, less than half that observed for the other three crystals.

Lattice parameter measurements are in progress. Tentative results indicate a lattice parameter increase due to irradiation of 0.020 to 0.024 percent - the same increase, within experimental error, as the measured length changes. Earlier work on irradiated polycrystalline molybdenum indicated that a lattice parameter increase of about this magnitude would be expected after this exposure.

Characterization of nickel foils by X-ray diffraction prior to irradiation has been completed. Nickel samples consisted of Johnson-Matthey high purity nickel, 99.97 percent pure nickel, "A" nickel, and 99.6 percent pure nickel. All were annealed at 700 C for one hour. Lattice parameters varied with impurity content, from 3.5238A for the Johnson-Matthey material to 3.5262A for the 99.6 percent nickel. Samples of these foils are now being encapsulated for irradiation.

Studies of thermally-activated deformation are being conducted with high purity polycrystalline molybdenum. Specimens were irradiated to 1×10^{17} and 1×10^{18} nvt ($E > 1$ Mev), and a series of post-irradiation annels were performed at 460, 540, and 875°K. Room temperature tests have shown the effective activation volume, V*, to be very sensitive to irradiation at low strain values. At 5 percent strain, V* increased from $70b^3$ in the unirradiated condition to $80b^3$ after 1×10^{17} nvt and to $96b^3$ after 1×10^{18} nvt. At 20 percent strain the corresponding values of V* were $84b^3$, $89b^3$, and $91b^3$. The decrease in V* with strain at 1×10^{18} nvt is obviously a manifestation of the dislocation channeling process. The behavior of V* in the irradiated and annealed molybdenum is somewhat complex. Annealing for two hours at 460°K resulted in 18 and 2.5 percent increases in the lower yield stress at 1×10^{17} and 1×10^{18} nvt, respectively. At 5 percent strain, the activation volumes for both exposures were approximately $76b^3$, but at 20 percent strain V* increased to $92b^3$ for 1×10^{17} nvt and only to $85b^3$ for 1×10^{18} nvt. Two-hour anneals at 540 and 875°K both resulted in V* versus strain curves which coincided with that for the unirradiated condition. Thus, the importance of the reaction occurring at 460°K in affecting the nature of the short range stresses on dislocations has been demonstrated. It is of note that this temperature coincides with the temperature of the peak recovery rate of electrical resistivity in irradiated molybdenum. The exact nature of the dislocation mechanism at 460°K cannot be determined without enthalpy determinations and extension of testing to lower temperatures, both of which are now in progress.

An unirradiated molybdenum single crystal, bent in an identical manner and to the same degree as the irradiated crystal reported previously, was sectioned and examined in the electron microscope. Isolated dislocation tangles were observed, though a distinct cell

structure had not yet formed. The dislocation tangles were distributed fairly uniformly and there was no evidence that dislocation motion was restricted to well-defined channels, as in the irradiated crystal.

A second set of irradiated crystals with a (001) specimen axis and containing approximately 500 ppm carbon has been deformed by bending. There is evidence that the (112) and/or ($11\bar{2}$) are serving as the initial slip planes and the resolved shear stress is highest on these planes. However, several major slip systems become operative after only a slight amount of deformation. As in the previous crystals with the (001) axis, straight lines and wavy lines appear on the same surface. In several instances, the wavy slip lines are observed to "flow" around the carbide particles present in the material, illustrating the barrier effect of the carbides. The density of the slip lines is also greater in the crystal containing the carbides, but it is not known whether this is due solely to the carbide or to the different initial orientation of the crystal.

The equations for the "two beam dynamical theory" of electron diffraction have been programmed. The program calculates the transmitted and diffracted intensities for electron beams transmitted through thin foils with defects. The defect structure of a straight dislocation with arbitrary Burgers vector and inclination to the foil surface has been programmed. The output of the program is a tabulation and graphical representation of the diffracted and transmitted intensities as a function of the distance from the dislocation.

An initial numberical technique based on difference equations was unstable in the regions near the dislocation. The present numerical technique is based upon the assumption that the displacement terms in the equations can be averaged over increments of foil thickness and the resulting differential equations are solved analytically. The development has been made using matrix techniques which will allow future extensions to a multibeam diffraction theory. Test cases for edge and screw dislocations have been run on cases reported in the literature and the results have checked. A writeup of the program and its operation is completed.

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.

Studies on the effect of plastic deformation of beta phase plutonium on the kinetics of the beta to alpha transformation have been completed. The results show that beta plastic defsormation decreases the beta to alpha transformation rate and that the rates are lower the higher the deformation temperature.

The application of compressive stresses to plutonium during the beta to alpha transformation, which in the absence of external stresses normally results in a 10 percent volume decrease, does not lead to extensive transformation creep. In fact, the unit length change of a specimen under compressive stress undergoing the beta to alpha transformation is independent of the transformation rate. These observations support the contention that the beta to alpha transformation of plutonium is essentially diffusionless.

Deformation of gamma phase plutonium by compression at 220 C increases the rate of the gamma to beta transformation at 155 C. The unit length change of specimens which are under a compressive stress of 2000 psi and are undergoing transformation from gamma to beta is a function of transformation rate; the slower the transformation, the greater the unit length changes. The data show that (1) plastic deformation of gamma prior to transformation and (2) applied compressive stress during the gamma to beta transformation have an effect which is opposite to that observed for the beta phase and subsequent beta to alpha transformation. The data indicate that diffusion mechanisms are important for the gamma to beta transformation.

The development and refinement of techniques and facilities for elevated temperature metallography of plutonium have continued. Preliminary experiments indicate that plutonium in the beta phase can be polished at temperature.

The elevated temperature specimen holder for use with X-ray diffractometer has been successfully rebuilt to afford the uniformity of sample temperature required for the work with plutonium. Installation in the glovebox was completed and the initial investigatory runs have been made with a plutonium sample.

For this first run a transverse section of a columnar grained specimen was employed. The initial pattern indicated the high degree of texture as evidenced by the prominence of the (020) reflection. The feasibility of following the transformation from alpha to beta, beta to gamma and the reverse of each has been demonstrated. The results to date, though inconclusive as yet, suggest that the original alpha texture is not seriously altered after an excursion into the gamma phase and return.

There is also reason to believe that the beta formed from alpha differs in orientation at least from that formed from gamma. These matters together with an anomaly noted in the beta to alpha transformation process must be studied in detail before definite statements can safetly be made concerning their validity.

Further work with the columnar grained material indicates that the fiber axis is the {020} direction, but the degree of texturing in the samples available to date is not sufficiently high to yield precise information with regard to other texture details. The structural complexity of alpha plutonium greatly increases the problem areas.

E. CUSTOMER WORK

1. Radiometallurgy Laboratory

Examinations

During the period October 23 to November 19, 1964, sample examination and testing at Radiometallurgy included the following:

Microphotography	44
Photomosaics	4
Autoradiography	18
Replication	9
Fission Gas	7
Density	26
Dissolution	23
Rockwell Hardness	29
Micro-Hardness	17
Tensile Testing (650°C)	14
X-ray	10

High-Temperature Tensile Testing - H Cell. The first irradiated tensile specimens were successfully tested in the new Tinius Olsen machine in H cell. A dozen unirradiated control samples were tested previously to verify the accuracy of the results and to eliminate any bugs in the system. All tests were made in vacuum at temperatures up to 650°C.

An Instron load cell was incorporated in the machine along with a remote dual extensometer to record stress-strain data on Instron console

Uranium Attack-Polish Technique. An attack-polish procedure was adapted for use on irradiated uranium. Normal grinding and polishing techniques down through one micron diamond are followed by attack-polish steps with Linde "A" and then Linde "B", both in a 2% chromic acid medium. This technique removes almost all of the worked metal and scratches, and allows examination of the grain structure with polarized light in the as-polished state.

Equipment

Project CAH-136, Service Addition - 327 Building. A copy of "HWS-8307, Specification for Service Addition-Building 327," was received from Vitro Engineering for comment. Vitro continued work on revision of detailed drawings to comply with comments submitted by Radiometallurgy.

Project CGH-857, Physical & Mechanical Properties Testing Cell Remote Impact Tester. Calibration of the remote impact tester to Watertown Arsenal testing standards was successfully accomplished at Testing Machines Inc. plant. The tester was shipped by vendor and is schedule to arrive in December.

"E" Cell Metallographic Facilities. The remote metallograph has been tested and aligned. Installation in the "E" cell blister is in progress. Testing of the orbital grinder is still in progress. A vacuum storage unit for metallographic samples was designed and fabrication was started.

"B" Cell Modification. The large lead-glass viewing windows for "B" cell were received and shipped to 100-H area for fitting in the openings which are being machined in the cast-iron cell door sections.

Remote Belt Sander. Fabrication of the remote belt sander hood was completed. Final alignment and testing was started.

Strain Gage Spot Welder. Preliminary tests of a remote spot welding head designed for spot welding strain gages on the surfaces of irradiated zircaloy process tubing were successful. Final tests will include spot welding strain gages on a non-irradiated zircaloy tube and then burst testing the tube section in the underwater burst test facility.

Zeolite Ion Exchange Capsule Test Equipment. A vacuum leak testing chamber, heli-arc welding jig, and capsule testing furnace were designed and are being fabricated for use in testing the reliability of the cartridge for retaining Strontium 90.

Remote Machining. A summary of a report titled, "A Survey of Remote Machining and Component Disassembly Methods Used in the U.S.," was accepted for oral presentation at the Euratom Hot Laboratory meeting.

2. Metallography Laboratories

During the report month, 474 samples were processed, a total of 836 micrographs and macrographs taken, 2579 negatives printed, and 8649 prints processed.

Part of a valve stem from an NPR control valve was examined to determine the cause of failure. The steam was fabricated from type 304 stainless steel with an overlay of stellite-6 in the region of the valve packing. The break occurred just beyond the region of the packing at the point where the stem had been reduced in diameter by about 1/2-inch. The broken surface exhibited typical fatigue rings which indicated approximately half the surface parted at the time of initiation. The balance of the stem parted in a series of small increments each of which left its own fatigue ring. A deep scratch or galling mark along the stem in the region of the packing may also have been caused by the initial overload which initiated this break. No evidence of corrosion was found, and no defective material was found in the section of the stem submitted for examination.

During cathodic etching of two low-melting alloys, it was demonstrated that the ion-bombarded surfaces reached temperatures in the range of 124 to 150°C. The test specimens were etched with standard operating conditions of 3000 volts and 0.3 milliamps at 1×10^{-4} torr krypton gas pressure. The lower limit was determined with a bismuth-lead eutectic alloy (55.5% Bi - 44.5% Pb) specimen with a melting point of 124°C. A ten-minute etch at standard conditions resulted in melting of the bombarded surface. The upper limit was determined with a bismuth-tin alloy (52% Bi - 48% Sn) specimen with a melting temperature of approximately 150°C. A three-hour etch at standard conditions did not melt the bombarded surface of this specimen. Since the only method employed to dissipate heat from the specimen during etching is by positioning it on the water-cooled cathode, specimen geometry and the thermal conductivity of the specimen will influence the temperature of the ion-bombarded surface.

3. High Temperature Lattice Test Reactor (HTLTR)

Environmental Test in HTLTR Materials. A test to evaluate the compatibility of TD Nickel with the UO_2-graphite compact intended for use in the control mechanism was completed. In this test the graphite

compacts, contained in sealed and unsealed TD Nickel containers, were exposed in a nitrogen-graphite environment at 1100 C for 1000 hours. The TD Nickel cladding was free of distortion and had no visible reaction with the UO_2-graphite matrix. Metallographic examination of the cladding is in progress. A similar test for an evaluation of possible B_4C interactions with TD Nickel and K-23 insulating brick continue to run at 1100 C. Preparations were started for another environmental test of fuel element components. The materials of interest in this application are UO_2, Al_2O_3, and Gd_2O_3 with TD Nickel containers.

HTLTR Mockup. Operation of the High Temperature Lattice Test Reactor mockup containued.

System temperatures have been increased to 1350 F and 800 F for heater elements and graphite stack, respectively. A greater than normal gas flow through the mockup may account for the larger than predicted temperature difference between the stack and heater. To date, slightly less than 10 gallons of water have been removed from the mockup.

One graphite sample has been removed from the mockup after being exposed to the mockup atmosphere at a temperature of 500 F for 72 hours. A weight loss of 0.003 grams was noted in the sample which originally weighed 13.3665 grams.

Testing of the horizontal control rod was started with several cycles of travel in, and scram out, completed. Disassembly of the control rod was started. Modifications to be incorporated include replacement of the scram holding solenoid and modification of the connection between the stainless steel and TD nickel shafts to allow for a larger thermal expansion than originally anticipated.

4. EBWR Fuel Elements

EBWR Fuel Fabrication. The ultrasonic thin wall tubing tester was improved to detect circumferential microcracks in the end cap weld zone of Zircaloy-2 clad, UO_2-PuO_2 fuel rods. Dur to the curvature at the weld, previous placement of the nonfocusing transducer prohibited detection of defects in this area. Utilization of a focusing transducer allowed the crystal to be placed at such an angle to detect flaws in the end cap zone. Defects less than 0.001 inch deep were detected using this technique, and verified by destructive microscopic examination. Good correlation was found between the ultrasonic signal amplitude and the severity of the defects.

Prior to the development of the new ultrasonic testing technique,

1350 EBWR UO_2-1.5 wt% PuO_2 fuel rods were fabricated and shipped to Argonne National Laboratory. The end cap weld zones of these fuel rods were subsequently tested ultrasonically at ANL by Hanford personnel. The 486 rods showing ultrasonic indications that may be microcracks or end cap discontinuities will be returned to Hanford for further inspection and subsequent repair or replacement. Causes of the weld zone defects are being investigated.

Twenty-five special EBWR fuel rods are being fabricated for physics tests in the PRCF and for subsequent power operations. The fuel loadings for these fuel rods will comprise normal UO_2 (five rods), UO_2-1.5 wt% PuO_2 (five rods each of 20 and 26 percent Pu^{240} content). The oxide fuel is currently being prepared, while the Al-Pu alloy fuel rods have been fabricated and are ready for final processing.

Irradiation Testing of Prototypic EBWR Fuel Rods. A maximum exposure of 4.2×10^{20} fission/cm^3 was achieved for the eleven capsules still under irradiation. Fission gas release values to 84% were obtained on plenum-equipped specimens which operated at high rod power (1000 w/cm) and underwent fuel-pellet-spring interaction. A fuel element bundle, filled with 21 dummy EBWR rods, was flow tested in a PRTR pressure tube. The pressure drop was 1.14 gm/cm^2 (2.34 psig) with a water temperature of 20 C and a flow of 6.75 l/sec (107 gpm). From calculations, a pressure drop of about 6 psig was anticipated. Of the 61 EBWR rods selected for irradiation, 38 have defect indications in the end cap region.

5. Other Customer Work

PRCF Fuel Fabrication. Two hundred PRCF rods (16.5 wt% Pu^{240}) were completed and made ready for shipment the last of October. These rods are now being held for ultrasonic testing of cladding integrity in the end cap region. Testing is scheduled to be completed by mid-December. The remaining 16.5 wt% $Pu^{240}O_2$ powder, sufficient for 30 to 35 rods, is of low density (96.5%). If this powder cannot be satisfactorily vibrationally compacted because of density, higher $Pu^{240}O_2$ powder will be down blended with lower concentration material to produce the amount of fuel needed.

Blended powder for 100 PRCF rods (8 wt% Pu^{240}) is ready for Nupac. The tubing and other hardware to fabricate these rods have been prepared.

Saxton Fuel Fabrication. More than eight kilograms of PuO_2 were prepared for use in the Saxton fuel program. The metallic Pu was oxidized to PuO_2, and the oxide calcined at 950 C for two hours to remove moisture and volatiles. The oxide was then screened (-325 mesh) and blended to obtain a uniform Pu^{240} content. A total of three hundred

pounds of arc-fused UO_2 are being heat treaded to remove moisture and other volatiles and then crushed to -65 mesh. Two hundred pounds of this material were prepared this month.

The UO_2-PuO_2 powders will be ready for blending as soon as analytical results are received from our laboratories, and information on the desired Pu concentration is obtained from Westinghouse.

A nuclear safety review was initiated for the Saxton process. This will be completed by mid-December.

Drawings of all fabrication hardware and parts to be used in the development of welding were completed. Vipac loading techniques are now being developed.

PuO_2-NiCr Compatibility Studies. Eight PuO_2-NiCr sintered cores were enclosed in NiCr cans (right circular cylinders - 0.6 cm x 0.6 cm x 0.086 cm wall thickness). One end of these cans is closed by electron-beam welding a 0.012 cm NiCr foil to the can wall. The other end is closed by a 0.32 cm end plug (TIG welded). The cans will be pneumatically impacted at 1200 C to achieve a core-clad meta metallurgical bond suitable for extended (400 hours) isothermal testing in moving air at 1100 C.

Phoenix Project. Cast 8001 Al-20 Wt% Pu alloy clad in 6061 aluminum alloy is recommended as the reference core material for the proposed MTR Phoenix plate fuel on the basis of a survey made of the irradiation data on aluminum matrix fuel systems. If it becomes necessary to add burnable poison to the fuel, an alternative core material of $PuAl_4$, and B_4C in a powder compact 8001 aluminum matrix is recommended.

Phase III Fuel Cycles - N Reactor. A rough draft report of fuel fabrication processes and economics for Phase III operation of N-Reactor was prepared for N-Reactor Department.

Boiling Burnout Studies for the Advanced Test Reactor (ATR). Installation and initial operation of the ATR-1 test section were carried out during this report period. This test section is a full-length simulation of the 49-1/2 inch long coolant channels of the Advanced Test Reactor located at the National Reactor Testing Station in Idaho. The test section coolant channel was 2.00-inch wide by 0.070-inch thick. Sides of the coolant channel of ATR-1 test section were flat plates, whereas the ATR will have fuel plates with a lateral curvature with radii of 2-1/2 to 5-1/2 inches. This was the only departure from exact geometric simulation of a typical ATR coolant channel.

The ATR-1 test section used resistance heating by dc current in Cu-Ni bars to simulate nuclear heat generation. The Cu-Ni bars were each machined with a special axial profile along the back side to achieve an axial chopped cosine heat input pattern with a peak-to-average value of 1.41:1. Both sides of the coolant passage were heated. The collant passage was formed by brazing 0.010-inch thick stainless steel sheet to the inside surfaces of the Cu-Ni heater bars and then brazing minute strips of Hastelloy to the stainless steel sheet to form the rectangular flow channel edges.

Heat transfer experiments were conducted by establishing coolant inlet temperature, flow rate, and outlet pressure at a selected power input rate. The test section pressure drop was then recorded as the flow rate was reduced by small steps with other parameters being held constant. Flow reductions were continued until the channel pressure drop increased appreciably due to boiling and two-phase flow conditions.

Hydraulic demand curves were obtained at an inlet temperature of 128 F and an outlet pressure of 25 psig for power inputs of 15.2, 23.5, and 30.6 kilowatts. These represent "fuel plate average" heat fluxes of 39,000 to 79,000 Btu/(hr)(sq ft), or peak heat fluxes of 54,000 to 110,000 Btu/(hr)(sq ft). The data show that a pressure drop of 1.0 psi across the simulated coolant channel would provide adequate cooling for 23.5 kw heat input but not for 30.6 kw.

After obtaining the low power hydraulic demand data, the power input was increased to about 300 kw and the axial power distribution along the test section was determined. This was done by measuring incremental voltage drop along known lengths of the test section with a constant power input. It was found that the axial power distribution matched the desired chopped cosine curve quite closely. The maximum deviation from the desired durve was only 3 percent. This corresponds to a heater bar thickness deviation of less than 0.002-inch from the desired thickness.

The power input to the test sect on was then increased to 550 kilowatts. This corresponds to a peak heat flux of nearly 2×10^6 Btu/(hr)(sq ft). Hydraulic demand data were obtained for this power level with inlet temperature of 126 F, an outlet pressure of 240 psig, and flow rates from 20.0 to 17.6 gpm without difficulty. The experiments were terminated because of mechanical failure of the test section. Breakdown of the electrical insulation near the inlet end of the test section allowed shunting of the electrical current to the test section support structure.

DOD Support. Development of special fabrication methods for DOD programs continued. Details of these activities are reported separately via distribution directly to the sponsors.

For Manager
Reactor and Fuels Laboratory

PHYSICS AND INSTRUMENTS LABORATORY

MONTHLY REPORT

NOVEMBER 1964

FISSIONABLE MATERIALS - 02 PROGRAM

REACTOR

NPR Utilization Studies

NPR Phase III fuel cycle analyses of PuO_2 enriched UO_2 have begun. Plutonium and uranium of currently available isotopic content are being used in the study (76 a/o Pu-239, 18 a/o Pu-240, 5 a/o Pu-241, 1 a/o Pu-242 plutonium and .253 w/o U-235 uranium). The calculational scheme (ZODIAC-2) used is the same as in previously reported Phase III studies with some exceptions:

The Wigner-Wilkins light moderator approximation is used to generate thermal spectra in the regions containing fuel and coolant. The Wilkins approximation is used for the graphite region.

Self-shielding factors for the large 1 eV Pu-240 resonance are calculated, using the NRIA approximation. These factors are then introduced into the ZODIAC routine by means of a numerical fit.

The following PuO_2 enrichments are being considered: 0.3 w/o, 0.6 w/o, 1.0 w/o, 1.5 w/o, 2.0 w/o, and 3.0 w/o. The burnup behavior of all cases except the 0.3 w/o case is being investigated. At present the 1.5 w/o and the 3.0 w/o burnup cases are about 95% complete.

In conjunction with this study, an auxiliary study is being carried out to compare thermal spectra generated in TEMPEST (Wilkins and Wigner-Wilkins) with more accurate water spectra. So far, the Nelkin scattering kernel at the right water temperature has been generated using the code GAKER, but the THERMOS run for the complete NPR cell has not been set up yet. Additional work is also in progress on a more realistic treatment of NPR lattice geometries.

Preliminary results of a 9-ANGIE two-dimensional analysis of the NPR lattice indicated that the arithmetic averaging of cell reactivities to obtain reactor multiplication is surprisingly accurate, at least for a two-batch loading. For a specific case, using a two cell lattice with "Green" and

"Exposed" (~ 40,000 MWd/t) ThO_2 with initial enrichment of 4.0 w/o $U^{235}O_2$, the error in the average k was only 1.2%. At present a four-batch loading of ThO_2 is being investigated.

NPR - Control Rod Enhancement Studies

Simulated N-Reactor control rod samples and "enhanced" samples are soon to be tested in the N-Reactor spectral environment in PCTR experiments. The Metal Fabrication Development Operation has started fabrication of a natural B_4C rod and an amphorous B^{10} rod. The rods will be 24" long, 2" O.D., with an 0.38 cm annulus of absorbing material between concentric aluminum cores having nominal wall thicknesses of 0.050". The rods are to be vibrationally compacted to approximately 60% theoretical density. The B_4C rods are totally black up to approximately 1 eV while the B^{10} rods are expected to extend this total blackness up to 10 to 100 eV. B^{10} is extremely expensive ($3/gram), in the quantities required in the NPR (2400 pounds), hence, other materials are being considered.

In theoretical studies the IBM code THERMOS has been applied to the NPR control rod super cell with little success to date. The possibility of applying the IBM Program S-4 (HW-65031) is being studied, concurrently.

NPR - Coproduct Block Test

The analysis of the 21-tube block test of the 1.95 coproduct fuel, proposed for the NPR, has continued and is approximately 25% complete. Flux peaking (power density distribution) and reactivity effects are to be evaluated for cold unexposed and hot unexposed conditions with the block on the reactor axis and at a peripheral location.

Completed analyses of the axial block for the cold unexposed conditions indicated an unacceptable power density peak with a "bare" block. However, surrounding the block with approximately 40 natural columns will return the power density to its present, relatively flat, condition.

Coproduct Experiments for NPR

Experiments are in progress to measure the infinite medium multiplication factor k_∞ and conversion ratios in both driver fuel tube and target rod of the coproduct lattice. All experimental work has been completed in the PCTR to determine cadmium ratios, thermal utilization, k_∞, conversion ratios, and spline worths in the wet lattice. The data reduction and analyses of these tests are to be continued while experiments are in progress on the dry lattice.

Subcritical Experiments with Enriched N-Fuels for Nuclear Safety Guidance

Exponential and neutron multiplication experiments have provided further data on the criticality of enriched N fuels in light water. Measurements have now been completed with two fuel assemblies in each of three lattices. The fuel assemblies are the 1.25 wt% enriched outer tube (2.4 in. o.d., 1.8 in. i.d.), and the tube-in-tube assembly comprised of the outer tube and a 0.95 wt% enriched inner tube (1.25 in. o.d., 0.44 in. i.d.). The length of the zirconium clad fuel elements is 26 in. The cylindrical arrays used in these experiments are 52 in. in height with each fuel column comprised of two fuel elements. Results of the latest measurements are presented below.

Tube-in-Tube Assembly
(1.25 wt% outer tube; 0.95 wt% inner tube)

Lattice Spacing	H_2O/U Volume Ratio	Critical Buckling	Computed Critical No. of 52 in. Assemblies from Buckling	Computed Critical No. of 26 in. Assemblies in Cylindrical Array
3.4 in.	2.47	2785 μB	90.3	185.1 (~8,541 lbs U)

Outer Tube Only
(1.25 wt%)

3.4 in.	4.27	2180 μB	124.8	360.1 (~11,080 lbs U)

Measurements are now being performed on a close packed array of the 1.25 wt% outer tubes in water. The results will provide data for nuclear safety guidance in handling bundles of such fuel elements under water, and in storage and shipment.

Instrumentation

Amplifier and other circuit modules were prepared for use in the N Reactor subcritical neutron flux monitor. Noise interference problems of the system were investigated. Work was started on improving the performance of the period amplifier.

Specifications and basic design features were completed for a prototype instrumentation system which measures the cooling age of irradiated fuel.

Work was initiated on testing new multiplier phototubes to achieve scintillation detectors with better stability for use in fuel rupture monitors.

System Studies

The N Reactor three surge tank analog model programming was completed. Input data for the three tank model are determined from the results of the N Reactor plant simulation. A proposed method of control of the system was forwarded to NRD and a MIDAS program was written for the simulation.

Initial N Reactor primary coolant pump controller output and flow recordings were made to update the N Reactor plant simulation.

SEPARATIONS

Criticality Experiments with PuO_2-Polystyrene Mixtures

New series of critical experiments were begun with PuO_2-polystyrene compacts and the Remote Split-Table Machine. Because modifications had been made to the control and safety rod system since last used, and because a "known" critical assembly was desired on which to check a newly installed on-line reactor noise analysis system, criticality was redetermined for a bare cubic assembly previously measured. The corrected critical mass of the bare cube (12" x 12" x 12.3") was 34.7 kg Pu (Pu conc. 1.12 g/cc, H/Pu atomic ratio 15). This value is in excellent agreement with the previous determination (within about 0.6% in mass or about 40 cents in reactivity).

The decay constant α, $\left| \frac{1-k_{eff}(1-\beta)}{\ell} \right|$, determined from a power spectral density curve obtained with the on-line noise analysis system, was in fair agreement with the value obtained from pulsed neutron source experiments. Although some further adjustments and modifications are indicated, the on-line reactor noise analysis system (the first installed at Hanford) appears to be functioning properly.

Calculations show that Pu^{240} will have a maximum effect on criticality in an intermediate neutron spectrum. Experiments were begun with plutonium containing $\sim 8\%$ Pu^{240} in intermediate spectrum critical assemblies to provide data needed for evaluating the effect of Pu^{240} on criticality. The first assembly consisted of a bare rectangular parallelopiped with base dimensions of 14.4 x 14.4 in. The average plutonium density in the array was ~ 0.9 g/cc (H/Pu atomic ratio ~ 16). Enough PuO_2-polystyrene compacts were available to form a stack 13.4 in. in height, but the resultant assembly was subcritical. The estimated critical height from the neutron multiplication curves was about 20 in. with the critical mass being roughly 66 kg Pu (the assembly was too far subcritical to obtain other than rough estimates). A composite bare cubic assembly comprised of alternate 2-in.

fuel cubes and 2-in. Lucite blocks was then built that had an H/Pu ratio of ~ 39. Criticality was achieved in this assembly. The dimensions were 14.4 x 14.4 x 17.4 in. The critical mass of Pu^{239} was 25.6 kg. This value is about 40% larger than that measured for a similar assembly (of same cross sectional dimensions but of different length) containing plutonium with 2.2 wt% Pu^{240}.

Neutron Multiplication Measurements on Large Arrays of Fissile Material

Slight differences exist between the SN and PR cans used for storage of plutonium solutions at Hanford. The principal difference is that the inner cylindrical container (5.8 in. i.d., 10 ℓ volume) of the PR can is surrounded by a lead-cadmium alloy layer about 1/2 in. thick, whereas the SN can does not have this feature. Previous neutron multiplication measurements had shown the critical number of SN cans for a planar array to be $\geq$ 350, but replacement measurements had indicated PR cans to be slightly more reactive. Neutron multiplication experiments performed during the month with 64 PR cans positioned in a planar array (containing 113 kg Pu) showed the critical number of these to be less than for the SN cans but still $\geq$ 280. Since existing nuclear safety specifications have limited the number of SN and PR cans of Pu solution that may be stored together to 15, it is apparent that a considerable relaxation can be expected in the number of such units that may be safely handled together in the future as a result of the experiments.

Critical Mass Theory and Analysis

Encouraging results were recently obtained with multi-group diffusion theory for computing criticality of plutonium nitrate solutions in spherical geometry. The solutions studied ranged in concentration from 33-268 g Pu/ℓ. Criticality was calculated for ten critical solutions in the 11.5 and 14.0 in. water reflected spheres, and for two critical solutions in a bare 15.2 in. sphere. Multi-group diffusion theory (18 groups) was used in the calculations with the multi-group constants being obtained from the GAMTEC II code utilizing the Sher normalized thermal cross sections. The calculated multiplication factors, k_{eff}, were within 10 mk of unity for each experiment with the average k_{eff} being 1.004. (To be in agreement with experiment, the calculated k_{eff} should have been unity.)

Critical Mass Laboratory Instrumentation

The second reactor hood in the critical assembly room of the Critical Mass Laboratory has now been equipped with separate neutron detectors. The addition of the new detectors materially reduces the time required to change over from solution to solid assembly experiments.

The frequency response of the existing linear count rate meter used in noise analysis experiments was found to be insufficient for use in the analysis of reactor noise in the intermediate neutron spectrum critical assemblies that are now under study. To overcome this problem, a simple diode pump circuit was built and incorporated with a variable gain operational amplifier. The amplitude versus frequency response of the diode pump circuit is -3 db at 4000 cps, which is well above the useful range of the noise analyzer. The output of the count rate circuit is essentially linear from 100 cps to approximately 1 Mc.

Consulting Services on Nuclear Safety--Criticality Hazards

1. Nuclear Safety in HL

Specification K-9 which covers 2.0-2.6 wt% PuO_2-UO_2 fuel elements was reviewed for PRTR.

The storage and handling of a 5 in. i.d. birdcage containing 8.74 kg of highly enriched UNH solution in the 325 Building was reviewed for Ceramic Research and Development. Nuclear safety controls to cover the processing (reduction) of this UNH to uranium oxide powder were recommended.

2. Nuclear Safety in NRD

A study is being made for Reactor Physics to evaluate the nuclear safety of a Stanray Corporation fuel cask for shipping N reactor fuel to New York. Fuel enrichments of 0.95 wt%, 1.25 wt%, and 1.95 wt% are to be evaluated. The cask has capacity for about 480 fuel elements or 13.5 tons of uranium.

3. Nuclear Safety in Shipment of Fissionable Materials

Three shipments were reviewed and approved for the AEC-RLOO. These shipments were: 23 kg of plutonium metal to the Westinghouse Corporation, Pittsburgh, Pa.; 5 kg of 8 wt% enriched UO_2 to General Electric, San Jose, Calif.; and 216 kg of plutonium metal to the Nuclear Materials and Equipment Corporation, Apollo, Pa.

Comments on the nuclear safety aspects of modifications to railway car ATMX 3472 were submitted to the AEC-RLOO. The modifications permit the shipment of two isotope casks on the car, together with several birdcages of plutonium metal.

The Class I HL-designed shipping container for fissile materials that successfully passed drop tests last month has now been tested for fire resistance by Underwriter Laboratories. The cask was subjected to temperatures up to 1725°F during a standard one-hour fire test; the temperature inside the container within the heat shield reached only 116°F during this time. Word received from Underwriters indicates the cask to have satisfactorily passed the test. The cask will now be submerged in water as a test for leak tightness.

4. Nuclear Safety Training and Education

A four-hour lecture on criticality and nuclear safety was presented to the personnel from IPD, HL and NRD who are taking the course in Radiation Protection.

Separations Instrumentation and System Studies

Initial experiments were performed to eliminate the effects of Am^{241} in the Pu^{239} liquid sample counting system, now being operated on a test basis. The objective is to isolate signals arising from trace quantities of Am^{241} which are otherwise indistinguishable from Pu^{239}.

Detector and circuitry development progressed on the Am^{241} column distribution monitor. A series of spaced detectors plus appropriate solid state circuitry will be used. Both meter and recorder readouts will be employed.

Engineering assistance was rendered on BF_3 proportional counters used in a 234-5 Building neutron counting system.

METALLURGY - Nondestructive Testing

N Fuels Testing

A prototype ultrasonic test to measure the bonding of lithium-aluminum cored target elements is being used to inspect pre-production samples of these fuel elements. Early extrusion runs exhibited heavily striated interface surfaces which hampered testing efforts; however, recent process improvements have apparently eliminated the striation problem and subsequent test results have been satisfactory.

The X-ray fluorescence tester, which was designed to detect uranium contamination in the end cap braze closure, has been returned to the laboratory for further development. This tester will be modified for potential application at the step-cut stage to reduce the number of fuels requiring autoradiography. Over-all performance of mechanical and electronic portions of this unit has been substantially improved.

Fabrication of a fuel handling system for use with the surface contamination tester is about 75% complete. Fabrication of the o.d. detecting heads has been temporarily discontinued pending approval of a supplemental AR. Delays in the delivery of the carriage motor have been encountered.

A test is required to determine whether or not the braze wire was actually melted during the welding on the TIG braze and closure process. A prototype ultrasonic test has been developed for use in performing this inspection. To save time transducers were fabricated on site. Thus far, only two pieces have been available for inspection; test effectiveness has therefore not been determined.

Fabrication of the mechanical portions of the 105-N irradiated N fuel tester is approximately 80% complete. Upgrading of the electronic equipment is essentially completed. Final modifications will be done on site at 105-N. A cap defect ultrasonically detected with this equipment several months ago was confirmed to be two small cracks located in the outer clad interface which extended into the cap. The cracks were apparently a result of a sharp impact--as might occur during normal fuel discharge. Another irradiated element is currently being sectioned by Radiometallurgy for confirmation of core cracks located at the unnumbered end.

Development has been initiated on an eddy current tester to detect the presence of striations on irradiated N fuels. When completed, this unit will be incorporated into the remotely operated UT-10B tester system in the fuel examination basin at N Reactor. Efforts this month were devoted to procuring suitable test standards and assembling a basic eddy current chassis with which to conduct initial tests. An unused Model IV penetration tester is being renovated to provide a 20 kc test frequency and the basic balance and amplifier circuits.

Possible measurement of fuel enrichment immediately prior to reactor loading is being evaluated at the request of Research and Engineering, NRD. A tester, patterned after the billet test that was developed for N Fuels, was breadboarded and evaluated in the laboratory.

Results indicated an 8% change in readings between 0.72% and 0.95% enrichments with the test head positioned directly on the fuel surface, and a 5-1/2% change when the measurements were made from the outside of a magazine tube in which the same samples were inserted.

The direct measurements were made with the fuel element positioned over a detector mounted in a lead cylinder, while the attenuated measurement was

made with a 1/8 inch sheet of stainless steel inserted between the detector and the wall of the fuel element.

IPD Fuels Testing

A feasibility study was initiated to determine the most promising non-destructive testing technique for measuring the wall thickness of aluminum process tubes in older Hanford reactors. Objectives are to identify and characterize various defect types such as groove corrosion, pit corrosion, external corrosion, etc. Results of the study will provide technical and economic bases for development of working inspection equipment.

HL - Test Engineering Support

The feasibility of applying NDT techniques to obtain high accuracy measurements of the thickness of sputter-formed plutonium coatings on substrates of beryllium, steel, or uranium is being investigated. Both eddy current and ultrasonic techniques will be evaluated, in addition to other potentially applicable methods. Efforts thus far have been restricted to formulating an engineering definition of the problem.

A study is being conducted to determine the feasibility of nondestructively measuring the thickness of ZrO_2 films on Zircaloy corrosion coupons. Measurements over a range of 0.00002 to 0.0005 inch with ± 20% accuracy are required for current corrosion study programs. A literature search is being conducted and equipment assembled for laboratory tests.

An instrument is required to measure the core-to-can spacing of developmental fuel elements which utilize a Pu-Al alloy core. Fuel design does not require a metallurgical bond, but a tight mechanical fit must be guaranteed. Instrumentation is also needed to ensure that the space between the can and core is not greater than 1 mil. Preliminary investigations indicate that this should be possible with eddy current techniques. The resistivity of the Pu-Al alloy was determined empirically, and a dummy fuel element with standard spacings designed for continued testing.

A study was initiated to investigate the feasibility of remotely measuring creep on Zircaloy-2 process tube samples at 300°C and 15,000 psi. Requirements are an accuracy of ± .03% of circumferential measurement with a range of 1 inch. The most promising method appears to be an ultrasonic pulse-echo Sing-Around system. A pulse reflected from the opposite wall of the water-filled tube is used to trigger the transmitter, thus controlling the pulse repetition rate. This frequency is then counted to provide a very accurate diameter measurement. Problems of propagation through water at this temperature and pressure remain to be studied along with development

of a high-temperature transducer.

Development of nondestructive testing techniques and hardware for the waste storage pot testing program was resumed. These pots are cylindrical containers approximately 8 inches in diameter and 10 feet long with 1/2 inch wall. Main emphasis is currently on the development of tests for ensuring wall thickness. A mechanical system which rotates the pot in its vertical position and translates the ultrasonic test head over the pot length is being designed. The unit will fit into the present decontamination tank which will be filled with water during the test. Pot rotation will be synchronized with an Alden recorder to provide contour plots showing wall thickness variations on the intensity modulated trace.

NEUTRON CROSS SECTION PROGRAM - 02/04 PROGRAM

Triple-Axis Spectrometer

The study of systematic effects in the determination of absolute differential scattering cross sections has been continued. It has been determined that the response of the analyzing spectrometer is significantly sensitive to the spatial distribution of neutrons incident on the scattering sample. A new detector system for this spectrometer is being designed and built to accommodate a larger detector with more uniform spatial response. Scattering law measurements were made for H_2O at 22°C and 95°C at a value of scattered neutron energy for which the systematic effects were minimized.

Time-of-Flight Spectroscopy for Slow Neutrons

Measurements of the performance characteristics of the Time-of-Flight spectrometer have continued. Analysis of the measurements used to separate the various resolution components indicates that some of the measured elements are in good agreement with calculated values and substantial discrepancies occur with others. Experiments are being performed to attempt to understand these discrepancies. A test run was made of the scattering of neutrons of initial energy of 0.15 eV from a 3/32-inch-thick vanadium sample. The computer program to reduce these data to cross-section values has not yet operated successfully. The transport Program S has been used to calculate the multiple scattering and absorption corrections for the case of a vanadium sample inclined at 45 degrees to the incident neutron beam direction as used in these measurements. In this calculation all of the scattering is treated as elastic and isotropic. The results of this calculation have not yet been compared with the experimental results.

Fast-Neutron Cross Sections

The results of the 3- to 15-MeV total cross section measurements made during October were analyzed. The results indicated that the anomalous behavior in the region of 8- to 10-MeV was still present. It appears that the results obtained outside this anomalous region are valid. Extensive investigation of the components of the time-of-flight system has failed to reveal the cause of the anomalous results which are obtained in the 8- to 10-MeV region. This investigation is continuing. Modifications have been made in the instrumentation to reduce RF pickup in the building and to measure the total current in the deflected ion-beam. All of the FORTRAN II programs associated with the data reduction are undergoing conversion to FORTRAN IV.

REACTOR DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Data-Theory Correlation

1. Monte Carlo Studies of Homogeneous Plutonium Nitrate Systems

   Two of the critical plutonium nitrate solution filled spheres, experiments 2218 and 1258, reported in the Physics Research Quarterly Report, April-June, 1964, were run with the RBU code. Analysis of the results is continuing. One problem in the analysis of the results is determining the reliability of the values derived from the Monte Carlo. The critical experiment, No. 2243, is being run with special treatment to determine the reliability of different parameters as a function of running time.

2. Analysis of Thermal Neutron Spectra in Pu Poisoned Light Water Systems

   The thermal spectra measured at Harwell (AERE-R 4668) for several aqueous plutonium poisoned systems are being compared with the Nelkin, Wilkins, and Wigner-Wilkins scattering models. Group averaged cross sections for the plutonium isotopes will be compared as a measure of the adequacy of the scattering models.

Code Development

1. ZODIAC

   The criticality search in ZODIAC has been debugged. The operability of this section allows "just critical" burnup studies to be run. The normal mode of operation consists of adjusting the poison content of

the whole core (soluble poison), or of a core region (rod bank), so that a k_{eff} of unity is achieved. In many cases the spectrum of a just critical reactor will be markedly different from an unpoisoned core. This spectral change may have a large effect on the burnup characteristics of the core. Code users are urged to make use of this option as standard procedure. A detailed write-up on the use of the critical search will be distributed to all ZODIAC users.

2. HRG

The punch option in HRG has been extended to punch broad group macroscopic cross sections in LISTIN format for input to HFN. Since additional cross section values will also be needed, the punched cards leave blank the storage location of the first word; this location must be supplied by the user. Also left blank is the value of the perpendicular buckling for each group. Appropriate identifying and sequencing information is given in columns 73-78 of each card. According to HFN users, this additional flexibility in HRG will significantly reduce input preparation time for certain HFN applications which are not conveniently adaptable to PHYSICS CHAIN usage.

3. COMBO

A revised version of COMBO, a data handling component of the PHYSICS CHAIN tape, has been written and run successfully in several test cases. COMBO prepares input for both TEMPEST and HRG from a single set of data, thereby reducing the work of preparing input for these codes when they are run together on the PHYSICS CHAIN. The most significant improvement of the revised version is in its treatment of TEMPEST input. Missing cross sections for materials not appearing explicitly in the TEMPEST Library are now synthesized for use in calculating the spectrum; this synthesis is done by use of appropriate multipliers applied to fictitious materials of unit cross section already present in the TEMPEST Library. Although the SIGMA-3 component of PHYSICS CHAIN does a similar synthesis of missing cross sections in processing TEMPEST output, the missing cross sections were not previously included in calculating the spectrum. The input requirements for COMBO are unchanged from those described in HW-80968, "User's Manual for HFN and CALX Chain."

4. TEMPEST

One of the output options of TEMPEST is the averaging of flux weighted microscopic cross sections. Since some runs of TEMPEST, particularly when using the PHYSICS CHAIN, use this option many times, the procedure for averaging was inspected for possible means of speeding up the cal-

culation. When numerical integration of constant cross sections was eliminated, it was found that, in a typical case requesting averaging of all cross sections in the library, that the total execution time was reduced by 50%. For the heavy gas and light gas calculations, the averages agreed to the full eight figures with previous results. For the Maxwellian weighted cross sections, in which the neutron flux can now be integrated analytically instead of numerically, the averages agree to six figures with previous results.

PuO_2-UO_2 Graphite Lattice Studies

Preliminary analysis of foil activation measurements which were taken on the 8-3/8" lattice is complete. The results are being used to calculate the average, absorption rates in the cell components. A detailed three-dimensional traverse, using 26 copper foils, was employed to determine the absorption in the poison. Similar traverses were made in the fuel and graphite with copper, uranium-aluminum, and plutonium-aluminum foils. The THERMOS computer code is being used to generate the neutron density as a function of velocity and position in the cell. The THERMOS code also calculates cross sections averaged over the neutron density spectrum. Cross section ratios for plutonium, uranium, and copper are being compared with the experimental values to check the validity of the THERMOS calculation. Drawings for a similar lattice with a 6-1/2" square pitch have been completed, and the fabrication work has been scheduled by the graphite shop.

PRCF - Experiments on Pu-Al-H_2O Core - 0.80" Lattice

1. Substitution and Importance Measurements in the PRCF

Reactivity worths of PuO_2-UO_2(EBWR) fuel rods located at the same radius as the control rods were measured in the 1.8 w/o Pu-Al core. These measurements indicate that replacing the twelve mixed oxide fuel-follower rods by twelve 1.8 w/o Pu-Al rods would increase the number of Pu-Al fuel rods needed for criticality by about 0.5 rods.

Measurements were made of the reactivity effect resulting from the substitution of various poison rods (hafnium, europium, copper, and aluminum) in the center of the PRCF. The worth of the copper rod was measured also at other radii in the reactor.

Samples of aluminum, "Lexan", "Teflon", "Lucite", and polyethylene shaped to resemble a hexagonal template with 19 fuel rod holes was used to determine what effects these materials would have on the critical mass of the L_x fuel if these materials were used in the construction of

the core. All the reactivity values were negative except for the polyethylene.

2. Void Traverse and Moderator Level Coefficient

A traverse, vertically through an empty fuel channel, was completed. This void was 8" long and 0.585" in diameter. The curve formed by plotting Δk against void position was cosine in shape with the peak value slightly positive. The moderator was lowered 8" below the top of the fuel. This changed the reactivity by -11 mk.

3. Flux and Spectrum Measurements

Bare and cadmium covered Lu_2O_3-Al_2O_3 pins were exposed in separate irradiations. They were positioned radially in a cell and vertically in the core. The vertical traverse used pins attached to the central fuel rod. "Lucite" holders were used to position the pins. The bare lutetium pins have been counted and the data are being analyzed. The cadmium covered lutetium pins are being counted.

An additional radial flux distribution was measured near the vertical center of the core using bare copper wire. In order to compare this with the lutetium on the top template some copper pins were irradiated in the same positions. Copper cadmium ratios were also obtained for two positions near the radial center.

Since a comparison of the effective resonance integral of lutetium pins and foils is needed, bare and cadmium covered foils and pins were irradiated on the rotator in the TTR core. In the same irradiation lutetium pins were exposed in the TTR thermal column for spectral normalization. Lutetium pins covered with a gadolinium filter were also irradiated on the rotator in the TTR core. Two covers were 0.020" thick and one was 0.040" thick. This was a test of homogeneity of the alloy and a relative comparison to the cadmium filter.

Isotopic Analysis of PRTR Samples

Isotopic analyses were performed on 5 plutonium-burnup samples from the mixed oxide fuel element number 5187.

Instrumentation and System Studies

The underwater fuel element gamma scanning facility was improved by engineering changes in the pulse height analysis portion of the circuitry. Considerably improved system performance was achieved following the changes.

Failure of a limit switch during a scanning run damaged the collimator and a redesign was initiated to provide a new collimator head with better safeguards and slit positioning ability.

Engineering assistance was provided regarding difficulties with the PRCF log-N channels and regarding shielding problems associated with leakage through specific FRPP "trench" covers.

The pressure transducer installed last month for the PRTR automatic controller test was calibrated during startup and shutdown transients. The transducer was installed for use in providing a moderator level indication to the analog simulation of the PRTR kinetic equations. Calibration tests indicated that the air pressure to the bubbler supply is a critical parameter in the calibration. During the forthcoming test, an adequate flow of the bubbler supply must be assured to produce a signal proportional to moderator level at the pressure transducer. The test, which was scheduled for November, was postponed until the first quarter of 1965.

Analyses were started on eighteen filters designed for use in the spectrum analysis of tape recorded information concerned with process tube vibration at the PRTR. The analyses will yield the normalization factors which will permit correct interpretation of the power density spectrum of data recorded on magnetic tape.

A study of the PRTR transient behavior was made on the analog computer to investigate possible hazards with increased power level. Runs were made to simulate startup accidents and power level accidents including shim failure, control system malfunction, and experiment failure. The computer runs were satisfactorily completed.

EBWR PROGRAM

PRCF 0.71" Lattice Temperature Coefficient

A calculation of the over-all (moderator and Doppler) temperature coefficient for the 0.71" EBWR-fueled PRCF lattice has been made. The calculated coefficients change continuously with cell temperature, varying from + 1.05 mk/°C at 20°C to 0.0 mk/°C at ~ 29°C to -1.28 mk/°C at 70°C.

Shipping Cask

Agreement to use the Yankee Single Element Cask for shipping irradiated fuel rods from EBWR to Hanford has been reached with ANL personnel. Studies of possible changes in handling equipment at each site, required to handle the cask, are in progress.

[redacted]

arise due to motion (partial insertion) of the shim rods. Whereas the above document reports a successful computation of the beginning-of-life multiplication for the cores tested, the calculation of the reactivity transient during burnup is not well reproduced due to inadequacies of the burnup model used thus far. Improved models to describe shim rod effectiveness are being investigated.

Plutonium-Beryllium Systems

The possibility of performing critical experiments for Pu-Be systems is of interest in connection with the Phoenix Program. As part of the planning for such experiments, the dimensions of bare critical cubes were determined for various moderator-to-fissile ratios using plutonium at three exposure levels. Search routines in HFN were used with GAM and TEMPEST cross sections. Pu-240 cross sections generated in GAM were corrected to NRIA approximation values by the introduction of suitable self-shielding factors. For low exposure plutonium, 11 to 22 kg appears sufficient to cover the range of 500 to 1200 moderator-to-fissile ratio. Plutonium requirements for critical experiments with intermediate and high exposure materials are so high that the use of reflected geometries will probably be necessary. Calculations on reflected systems are now being performed.

Experiments utilizing PuO_2/BeO composites are also of interest. The formalism used by L. W. Nordheim in calculating the effect of lumping fuel material in small grains embedded in a moderating medium is contained in the resonance absorption code ZUT. Published results for the homogeneous thorium oxide graphite system have been duplicated. Extension of these calculations to PuO_2 grain-beryllium oxide moderator systems is planned.

Pu-Al Light Water Experiments in the PCTR

Preparation for the first Pu-Al experiment is essentially complete. It's scheduled to begin during December and will employ disks of 20 w/o Pu in Al. The Pu contains 67 w/o Pu-239, 27 w/o Pu-240, 5 w/o Pu-241, and 1 w/o Pu-242. The disks have a diameter of 1.96" and a thickness of 0.040". Data supplied by the manufacturer include for each disk the Pu concentration, the diameter and its variation, and the thickness and its variation. More than 100 disks have been weighed and 56 disks which contain the same mass of Pu within a range of ± 2% have been selected. These 56 disks will be used in the central region of the lattice for comparison with a "void" reactivity measurement. There are 2543 disks of this Pu-240 content.

This lattice will have a H/Pu ≅ 200 (atom/atom). Measurements of the concentration of boron necessary to reduce k_∞ to unity, Cd-ratios for Au, Mn, and BF_3, and the ratio of the effective fission cross section of Pu to U-235 in the lattice spectrum will be made.

COMPACT FAST REACTOR STUDIES

Reactor physics studies concerning the use of Pu^{239} or U^{233} in fast spectrum cermet reactors are continuing. A complete survey of reactor size as a function of void fraction, fuel-cermet ratio, and fissile material is in preparation. This survey will use the HFN code with the 16-group Hansen-Roach cross sections. In order to check the accuracy of the HFN survey, a few transport theory calculations were performed using LASL's DTK code. All calculations were for a cylindrical core (L/D = 1) with a void fraction of 0.35 and a 50-50 fuel-tungsten volume ratio. A 15 cm beryllium reflector was used for all cases. The critical core volume of the PuN core was about 1/8 compared to the $U^{235}O_2$ fueled core. The $U^{233}O_2$ core resulted in a volume reduction of about 4 compared to $U^{235}O_2$.

The reactivity effect of neon (a possible closed cycle coolant) and hydrogen (open cycle coolant) in various cermet reactors was also analyzed using the DTK code. Characteristic results are summarized in the table below. It is clear from this table that neither coolant appears to pose a very serious nuclear problem. Note that plutonium reactors are significantly less sensitive in k to changes in hydrogen density than uranium reactors.

WORTH OF COOLANT GAS AT 1000°K AND 50 ATM

	H_2		Ne*	
	δk	¢	δk	¢
U^{235}(β = .0064	.0037090	57.95	.0005098	7.96
U^{233}(β = .0026)	.0029149	112.11	.0004637	17.83
Pu^{239}(β = .0021)	.0010427	49.60	.0003129	14.90

* Fluorine cross sections

HIGH TEMPERATURE REACTOR PHYSICS PROGRAM

A review was made of the design of several of those features of the HTLTR that bear most directly on its experimental use. Items covered were the special penetrations through the gas containment envelope of the reactor, the light duty and heavy duty oscillators, the collimator for the neutron spectrometer, and the flux wire monitors. Some modifications in design were required. With the incorporation of the changes all of the functions of these components listed in the criteria will be achievable.

A change in design has been made to an instrumentation and control system for the HTLTR that is almost completely computer based. The change has both

economic and functional benefits. A procurement specification for the new system has been written.

A 1000 hour 1100°C test of samples of a matrix of UO_2 in graphite has been completed. Some samples were canned in T.D.-nickel and others not. Weight losses are small enough, even for the uncanned samples, not to interfere with performance as a control rod material. Off-site preparations have a compressive strength up to 18000 psi at 1000°C--sufficiently strong for use as a component material in the horizontal control rod as presently designed. A set of matrix cylinders for the prototype control rod has been fabricated on-site. Although less strong than the off-site material the cylinders will be adequate for prototype testing, particularly since a modification of the design will considerably lessen the maximum stress to which they will be subjected.

The HTLTR mockup at present contains four full scale graphite heaters, a 2 x 2 x 10-foot stack of graphite, about 1000 cubic feet of insulating brick, several thermocouples of various types, and test samples of metal and ceramics. The heaters have been raised steadily to about 700°C and the stack to about 300°C.. In the process about 40 liters of water have been taken from the system. The water content of the nitrogen atmosphere at that time was 1000 ppm. As indicated by an extracted sample, graphite corrosion up to this time has been very small.

Methods of fabricating TD-nickel cans for the HTLTR driver fuel are under study. This will be followed by the construction and testing of a prototype fuel element.

A study is being made of the application of pulsed neutron methods to reactivity measurements in the type of fuel moderator systems to be met with in the HTLTR.

Design was started on the graphite lattice for the first experimental core to be placed in the HTLTR. This is to be a square lattice of natural uranium rods on a 7-1/2 inch pitch.

FUEL CYCLE ANALYSIS PROGRAM

Plutonium Value Determined Under Private Ownership for 1000 Mw_e Reactor Designs

The value of plutonium as a substitute fuel for slightly enriched uranium is determined by recycling the plutonium formed in a uranium fuel cycle and solving for the price which would make the costs equal. Because the value is a function of composition which changes with each recycle, the

best values are found by recycling the plutonium until near equilibrium composition is reached. Under equilibrium conditions, the value charged and discharged from a reactor can be set equal and an exact solution obtained.

In this study, four 1000 Mw_e reactor designs were investigated--the D_2O, BWR, PWR, and SGR. Variations in interest rate and the cost of U_3O_8 feed to the uranium cascade were made for each reactor type.

Figure 1 shows the results plotted against cumulative fuel exposure using \$8/lb U_3O_8, which is the cost presently used in the uranium cascade. The SGR has the highest value largely because the fuel is clad in stainless steel. The high plutonium cross section increases the thermal utilization when compared to U^{235} fissile enrichment. Conversely, the D_2O reactor, with zirconium cladding, has the lowest value because the thermal utilization is already very high and plutonium can not add much improvement. The PWR and BWR use zirconium cladding and light water moderation which represent an intermediate thermal utilization.

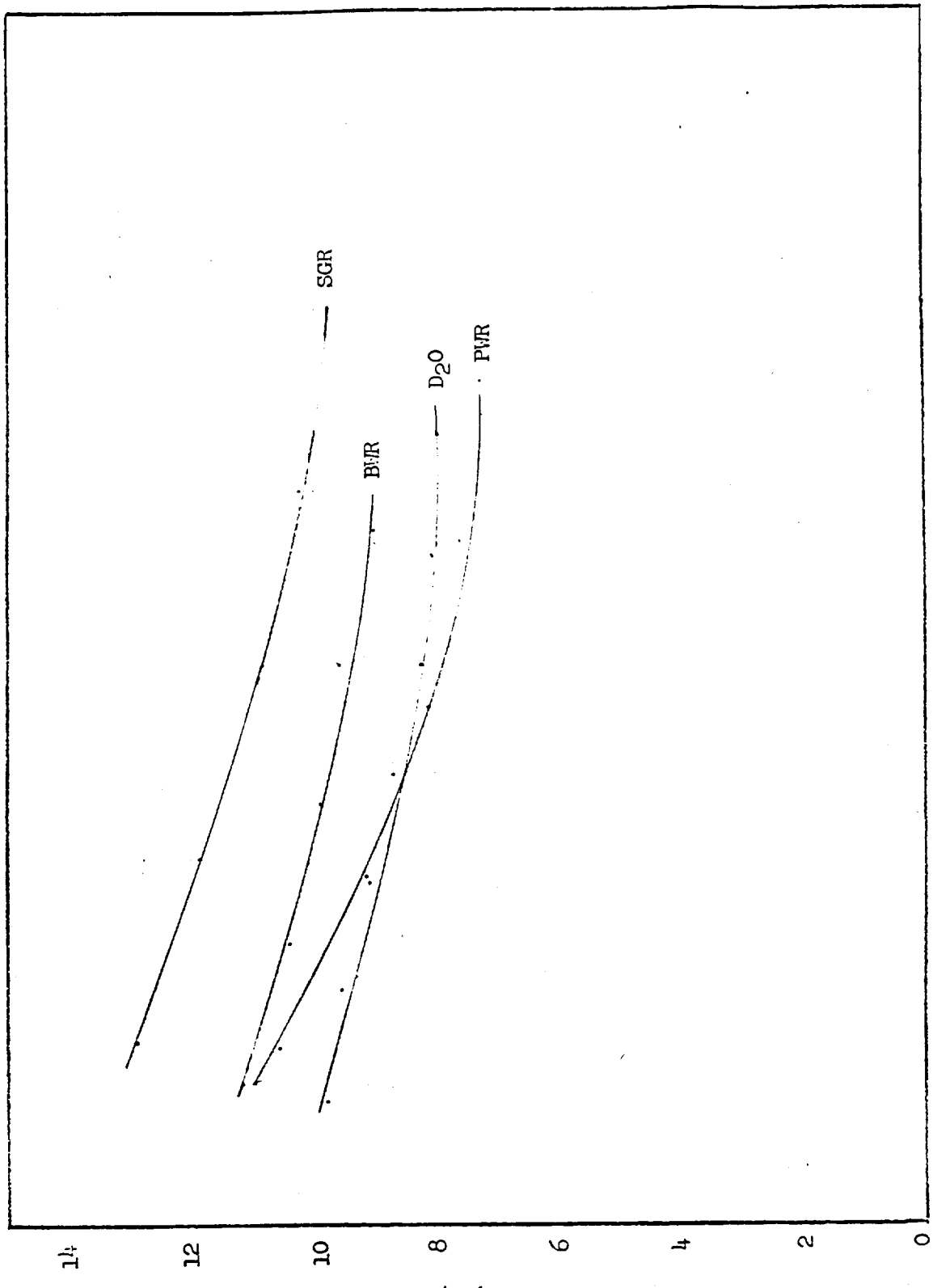
Thermal utilization is not the only factor affecting plutonium value. The relative optimization of the reactor spectrum for U^{235} and plutonium has a strong effect on value. These 1000 Mw_e reactors were all designed for operation with a slightly enriched uranium fuel, and the value would increase if the lattice were adjusted for plutonium fuels.

Figure 2 shows the same reactor types but with the U_3O_8 feed price set at \$6/lb which may represent a future uranium price. The values are lower and proportional to the change in fully enriched uranium price. Table I shows the ratio of values for \$8/lb and \$6/lb U_3O_8, which demonstrates that the plutonium value is proportional to the price of fully enriched uranium. The SGR ratio does not agree as well as the other reactors because a technological exposure limit of 30,000 MWd/MT used during this study perturbed the results of only the SGR.

TABLE I

PLUTONIUM VALUES FOR \$8/LB AND \$6/LB U_3O_8

	Fully Enriched Uranium	PWR	BWR	D_2O	SGR
(1) U_3O_8 at \$8/lb	12.05	10.60	11.20	9.80	12.90
(2) U_3O_8 at \$6/lb	10.60	9.40	9.80	8.40	10.90
(3) Ratio (2)/(1)	.88	.885	.875	.86	.84



PLUTONIUM VALUES FOR VARIOUS REACTOR TYPES USING $8/lb U_3O_8, AND 10 PERCENT WORKING CAPITAL, 10% REAL RATE

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FIGURE 1

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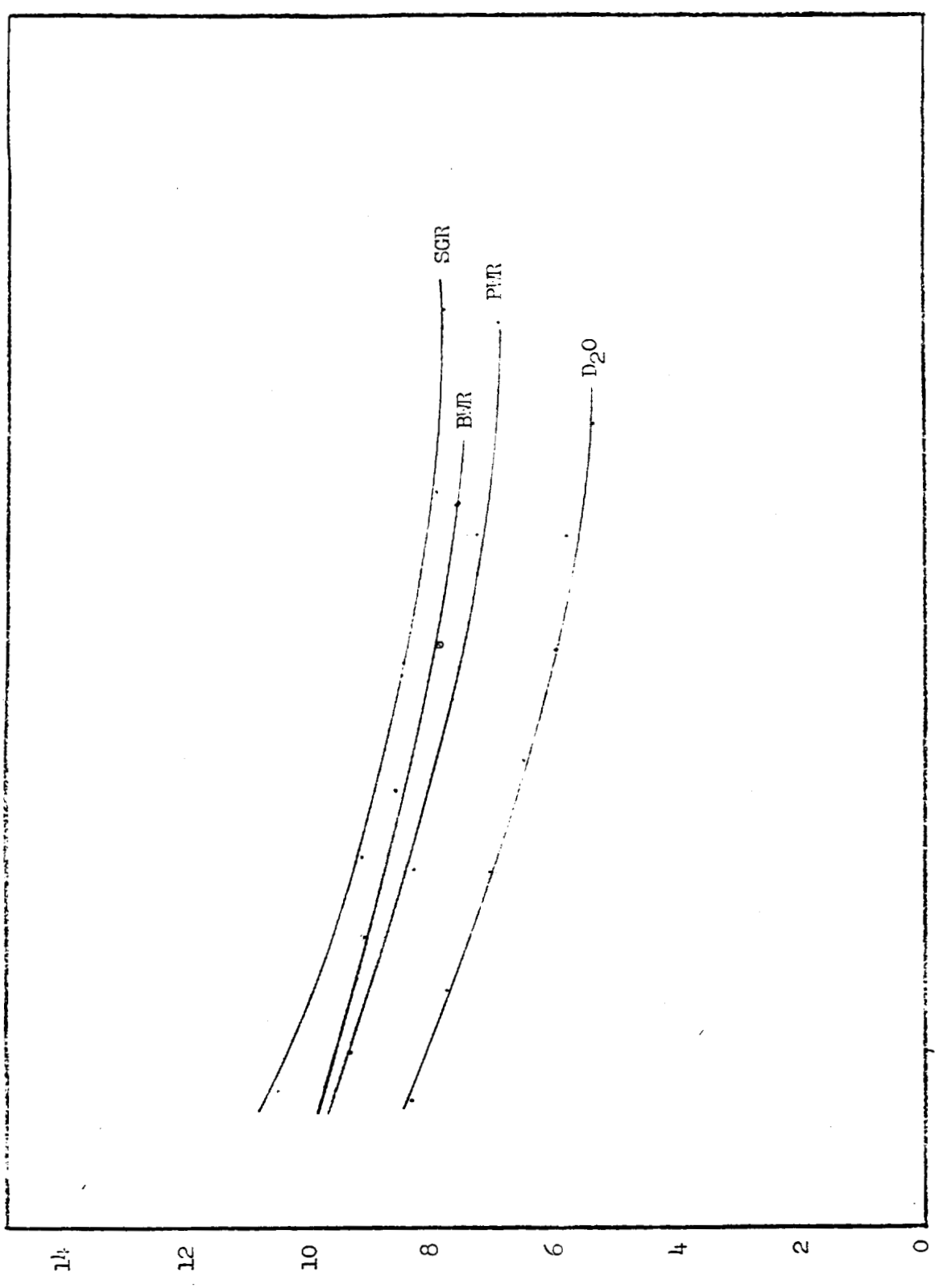


INCREMENTAL VALUES FOR VARIOUS REACTOR TYPES USING $6/lb U_3O_8 AND 10 PERCENT WORKING CAPITAL INTEREST RATE

1234673

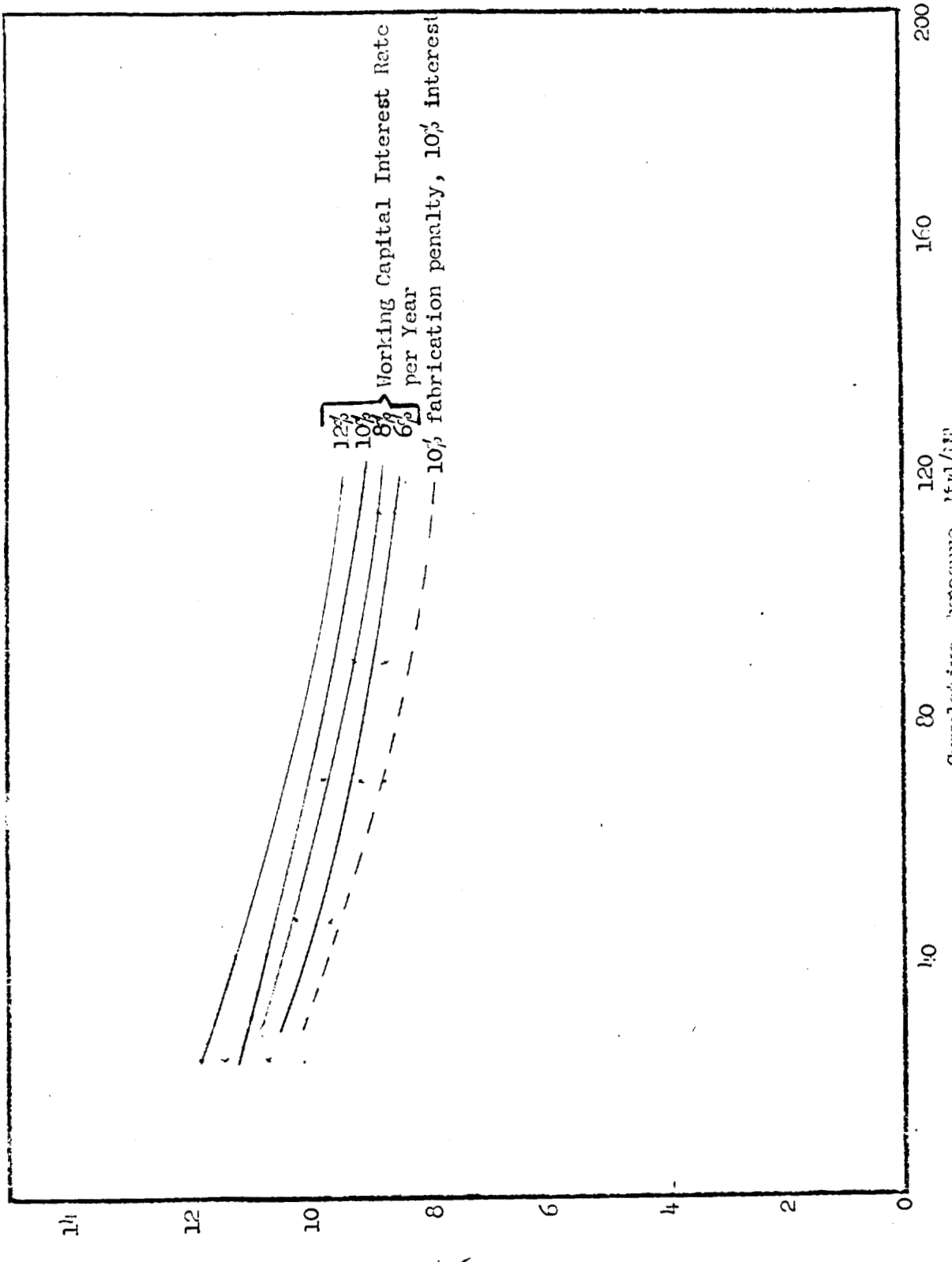
FIGURE 2

Plutonium value is also a function of interest rate and fabrication cost penalties for plutonium fuels. Figure 3 shows the values as a function of interest rate and the effect of a 10 percent fabrication cost increase, all for the BWR. The value increases with interest rate because plutonium in this reactor is worth more in terms of reactivity per dollar than U^{235}. This is not necessarily true for all reactor types--in the PWR reactor where Pu^{239} alpha is high, the reverse is true. The 10 percent fabrication penalty reduced the value about $1 per gram fissile. Fuel elements containing plutonium only made up 40% of the core. The amount of plutonium in each plutonium fuel element is controlled by the initial heat transfer rates.

Plutonium^{242} is formed as plutonium fuel is burned; this isotope is treated as a poison and is formed at different rates in each reactor. A remarkable correlation (linear) between percent Pu^{242} concentration and value in $/gram total was found to exist. Figure 4 shows this correlation for each reactor type. This knowledge made it possible to obtain precise values without reaching equilibrium compositions because the value at discharge can be predicted from the Pu^{242} concentration.

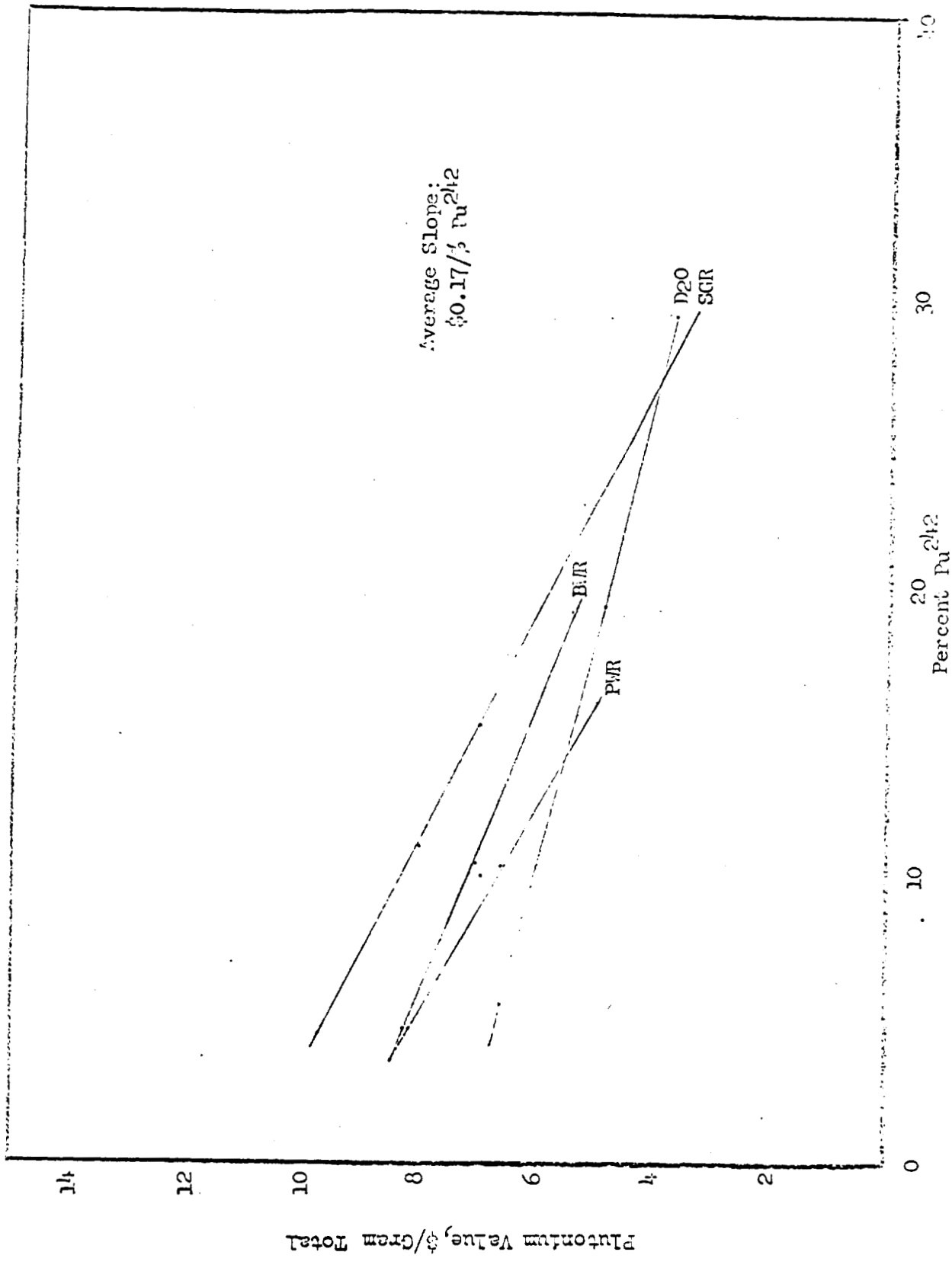
VESTA Fuel Utilization Code

This code, which calculates the uranium requirements for hypothesized future nuclear power growth rates, is essentially debugged and some cases have been run using it. The economy projected shown in Figure 5 is published in "A Report to the President - 1962." The dashed curve shows another estimate of the nuclear power business which considers development of nuclear power to be "sooner," that is, higher, during the present century than shown in "A Report to the President - 1962." The cases that have been run assume that light water reactors will supply the nuclear portion of the electrical generation requirements and that breeder reactors will be introduced after 1975 or 1990 as rapidly as there is plutonium to feed them. Breeders which double the fissile inventory in 7 and 20 years are considered. The results indicate that by the year 2060, the cumulative uranium requirements for this projection will be 22 million tons if no breeders are developed; about 6 million tons if the long doubler is used and about 2.5 million tons if the short doubler is used. As seen in Figure 6 the date of introduction seems much less critical from a conservation viewpoint than does the doubling time. The development of short doubling time breeders is much more important than the early introduction of breeders. Even late introduction of fast reactors having higher specific power and shorter doubling times than are considered here can result in substantial savings in the uranium requirements of the next hundred years. Within the limitations of this study, it appears that we can introduce economical, long doubling time breeders in the near future which allow



PLUTONIUM VALUES IN A BOILING WATER REACTOR WITH $8/lb U_3O_8

FIGURE 3



PLUTONIUM VALUES FOR VARIOUS REACTOR TYPES USING $3/lb U_3O_8 AND 10 PERCENT POWER CAPTIAL INTEREST RATE

FIGURE 4

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ELECTRICAL GENERATION RATE PROJECTION

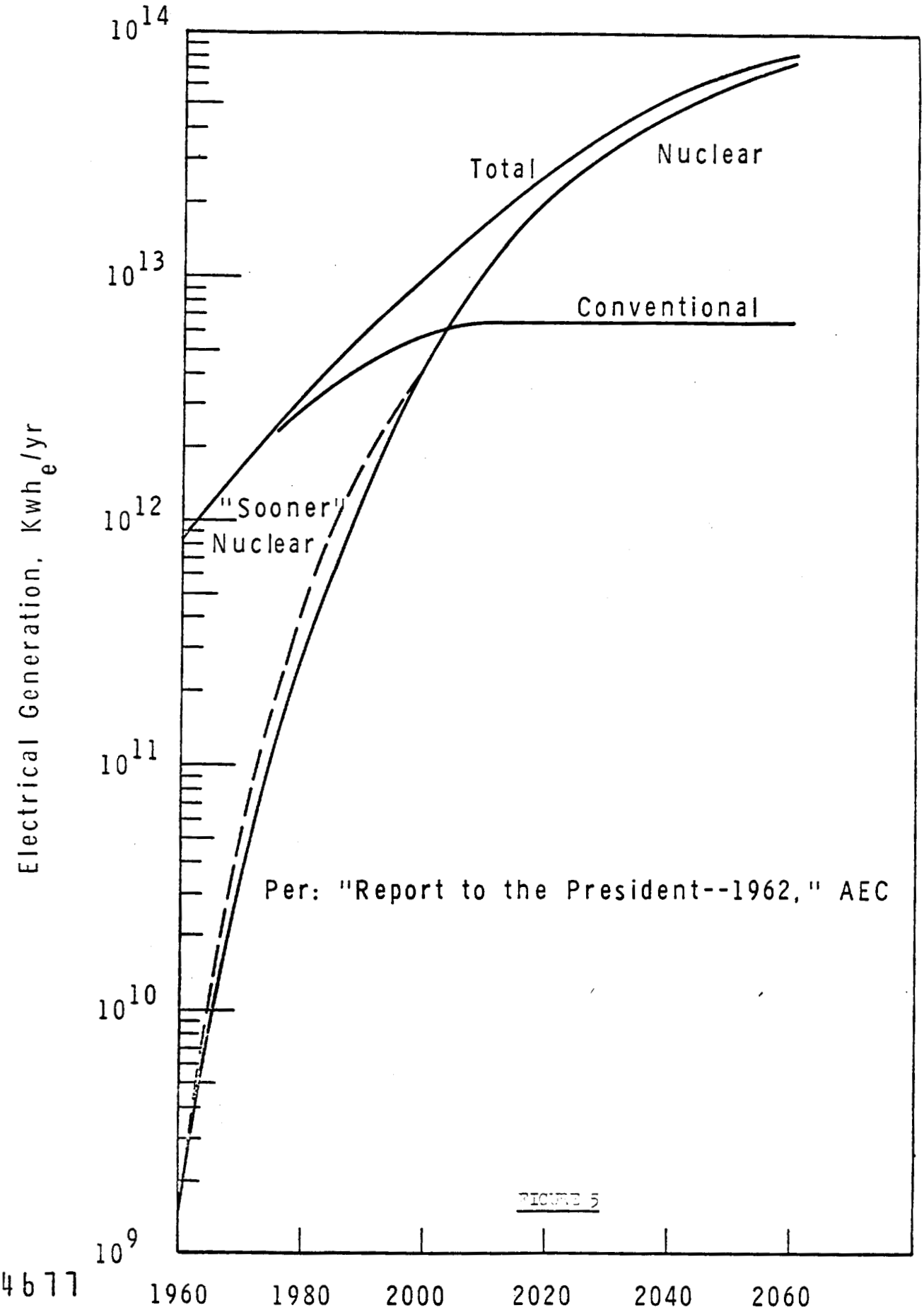

FIGURE 5

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RELATIVE URANIUM USAGE FOR VARIOUS BREEDER INTRODUCTION DATES

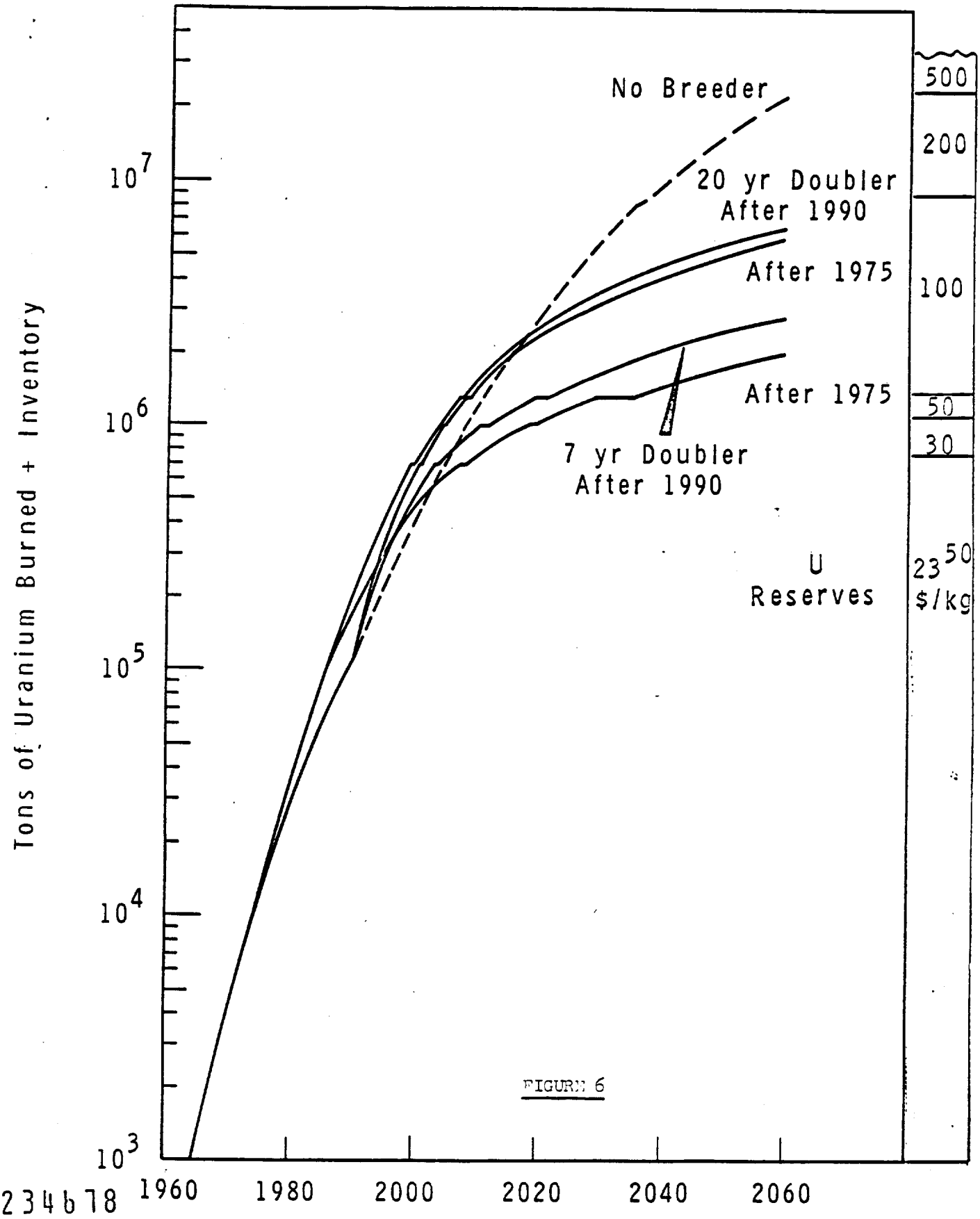


FIGURE 6

1 2 3 4 5 6 7 8

orderly development of fast breeder reactors while maintaining a nearly maximum potential for conservation of our energy resources. In the meantime, continuing development work will lead to further improvements in the conservation performance of thermal and fast reactors--performance which can still be utilized in the future.

A Comparison of Plutonium^{239} Alpha Values

The value of α, the ratio of capture-to-fission cross sections, for Pu^{239} as a function of neutron spectrum and plutonium concentration during burnup is very important. For this reason the THERMOS code is being used to determine values of α at various moderator-to-fuel ratios and plutonium concentrations. Table II and Figure 7 present the results that have been obtained. The temperature of the fuel and moderator for these particular cases was 20°C.

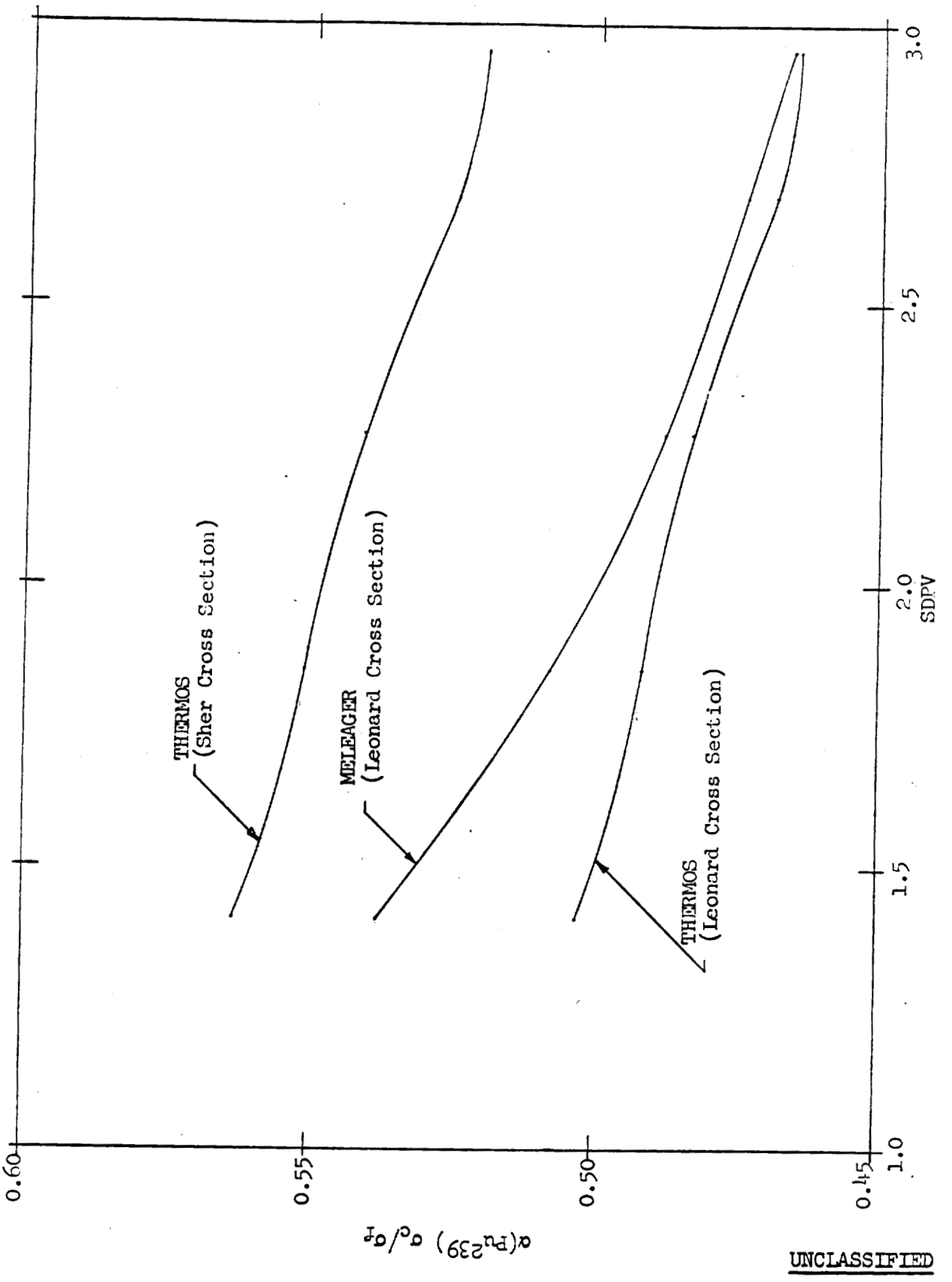
TABLE II

COMPARISON OF ALPHA (α) VALUES FOR PLUTONIUM^{239} FOR VARIOUS DEGREES OF MODERATION

SDPV	V_{mod}/V_{fuel}	Pu^{239} $(G/cc)_{fuel}$	THERMOS α_{Sher}	THERMOS $\alpha_{Leonard}$	MELEAGER $\alpha_{Leonard}$
1.41	1.456	0.04611	0.563	0.503	0.538
1.85	1.904	0.04611	0.551	0.492	0.508
2.27	2.341	0.04611	0.541	0.484	0.488
2.69	2.771	0.04611	0.525	0.469	0.474
2.95	3.045	0.04611	0.520	0.465	0.466

The MELEAGER burnup code uses Leonard's values from the RBU data tape as converted by program GANDS for the absorption and fission cross section of Pu^{239} to determine the value of α, and the values listed are at time zero. Because the MELEAGER code uses Leonard's cross section values, one would expect the THERMOS and MELEAGER values for α to be in close agreement since both codes use the same base cross section. Figure 7 shows that this premise is true for soft spectra, but indicated need for revision of the shielding model for hard spectra. The reason for the apparent large difference in the Sher and Leonard values of α is not known at this time.

Other systems containing varying amounts of Pu^{239} will be investigated for the concentration effect on α, and a new library tape is planned with an elevated water temperature to determine this effect on α.



COMPARISON OF α (Pu^{239}) VALUES BETWEEN THERMOS AND MELEAGER AT 20°C

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FIGURE 7

Reduced Density Fuels

A comparison of minimum fuel costs was made using fuel fabrication costs in the $100/kg range and fuel density reductions to 95%, 85%, 75%, and 65% of theoretical density in a PRTR reactor simulation.

The curves plotted in Figure 8 from these data show that minimum fuel cost is the same for a situation where fabrication cost is $114/kg* and fuel density is 95%, and a situation where fabrication cost is $110/kg* and density is reduced to 65%. In other words, the density reduction penalty is about $4/kg of fuel which possibly can be offset by lower fabrication costs at lower densities. Both situations assume a 4.75% fuel rental rate (AEC Interest). An increase in fuel rental rate would reduce this delta.

Data in the $45/$55/kg* fuel fabrication range shows smaller penalties and possible savings for certain cases.

NEUTRON FLUX MONITOR PROGRAM

Satisfactory in-core performance at KW Reactor is being achieved with the two uranium regenerating neutron flux detectors (90% U^{234} and 10% U^{235} coatings). Data are now being assembled for the reporting of the initial operating characteristics. It is planned to include such information as the initial dynamic range, the dynamic range after specific neutron flux exposure, saturation curves, gamma sensitivity, background levels, and the estimated neutron sensitivity. Since the output signals from the chambers are in the milliampere range, it was not necessary to use amplifiers prior to the recorders. Initial difficulties with leakage currents within the floating power supplies were eliminated, and long-term testing of the chambers was initiated.

The prototype B-11 neutron flux detector and five cables were irradiated in a KW Reactor facility to obtain specific performance information. The tests included operation during a reactor shutdown and a startup. Improved data measurement and recording methods provided considerable information, which is now being studied to learn the mechanisms responsible for generation of the cable background current. The cable insulation material is now being examined to determine the constituents. During the irradiation testing, the operational characteristics of the B-11 chamber changed abruptly, indicating that vacuum was lost. A new chamber will be designed to eliminate this problem and new cables of a particular type and size will be procured.

New gas capsules for the cavities in the microwave neutron flux monitoring system were designed and are being fabricated. Plans were established to resume reactor in-core tests next month.

* At full density.

MINIMUM FUEL COST AS A FUNCTION OF DENSITY
FOR VARIOUS FABRICATION COSTS

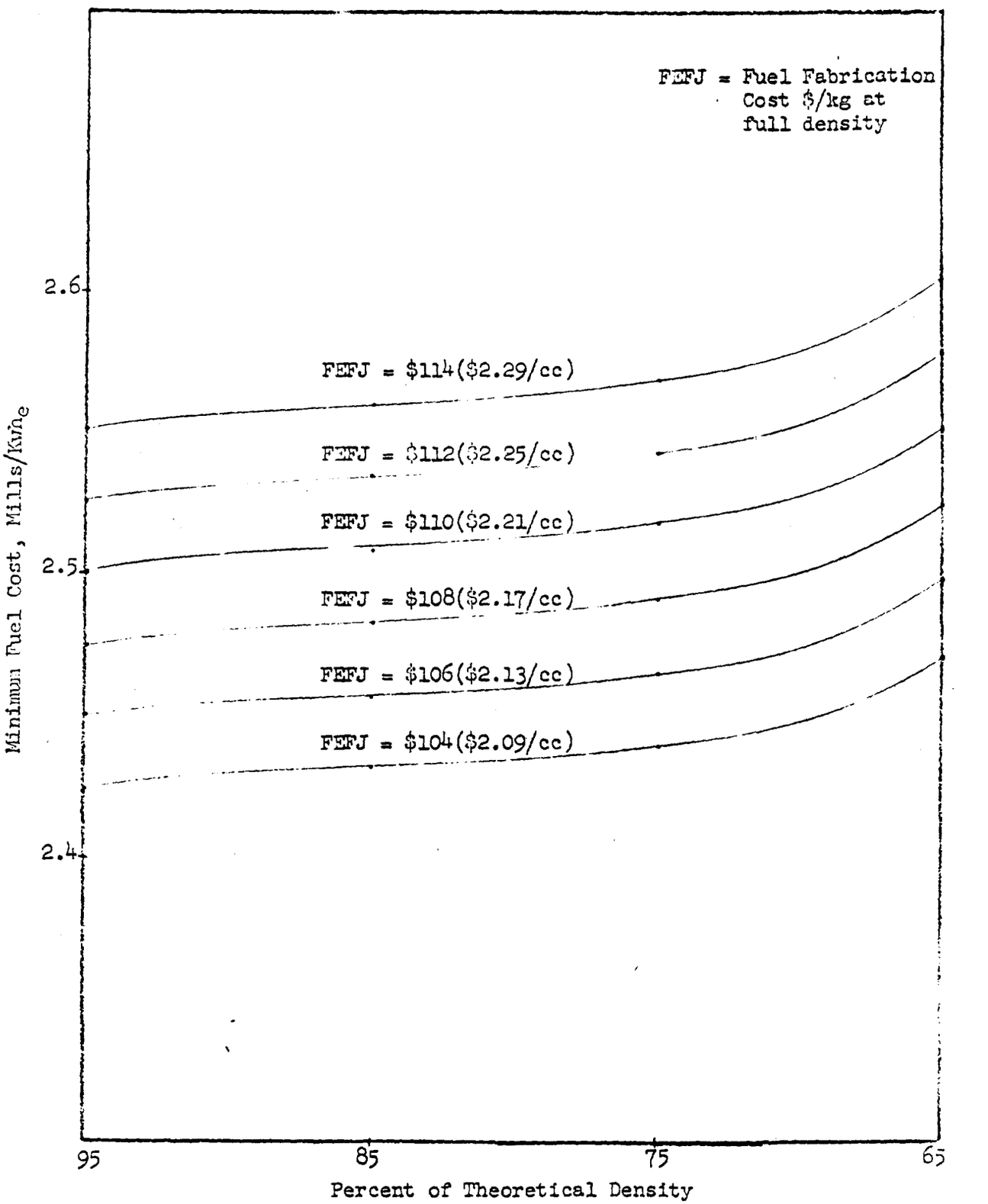

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FIGURE 8

NONDESTRUCTIVE TESTING RESEARCH PROGRAM

Electromagnetic Testing

Signals from 1/8 inch diameter drilled flat bottom holes on two sides of a flat stainless steel plate 0.60 inches thick were separated using the multiparameter tester. The plate, having holes .002, .004 and .009 inch deep on the test coil side, and .014, .020 and .031 inch deep on the opposite side, were rotated past the coil to give a simulation of a scanning type tube test. This technique has been adopted for exploratory tests because of the ease with which the fabricated flaws may be made in the sheet.

The separated signals were used to drive the cathode ray tube system being developed to display the cross section of tubing being tested. The resulting display scanned the cross section of the simulated tube with the flaw signals in their relative position on the test sample and location within the steel sheet. Signals from a .007 inch deep hole on the test coil side of the sheet and those from a .020 inch deep hole drilled from the opposite side of the sheet at the same position were separated and displayed in their proper relative location. For these tests, the multiparameter tester was operated using two frequencies; 70 kc and 250 kc. By using both in-phase and quadrature signal components at each frequency, the test possessed four parameter capability.

A series of eddy current test model measurements are planned from which a family of eddy current test design charts can be made. To facilitate taking data, further refinements were made in mechanical accessories for manipulation of test coils. A mechanical arrangement was assembled to position test coils in vertical and horizontal directions with an accuracy of .005 inches. The equipment consists of a rigid steel support upon which a milling machine crossfeed and vertical feed assembly is mounted. The test coil is connected in a bridge circuit driven by a variable frequency oscillator. The output of the bridge circuit is amplified and displayed on a vector impedance plotter and recorded on an X-Y plotter.

Fundamental Ultrasonic Studies

Efforts to determine the validity of the recently developed ultrasonic wave propagation model continued. Attenuation measurements on 304-L stainless steel are complete and the results were fitted to curves for use in the analytical studies.

Difficulty was experienced with shear-wave attenuation measurements in aluminum and Zircaloy-2. For reasons not understood, signals transmitted through as-worked material varied widely in amplitude. All shear-wave

attenuation was measured using the oblique-incident-angle techique. This method compares the transmission through a test sample of known acoustic parameters to an unknown test sample. Insertion loss corrections are eliminated by using two thicknesses of the test samples. Beam spreading correction factors were obtained by using a specified ultrasound incident angle for a given ultrasound velocity and sample thickness. These incident angles were calculated using an approximation to the diffraction theory. A more complete study of beam spreading has been hampered by the inability to express test parameters in an analytically explicit form.

To facilitate calculations, a computer program is being written which will provide future correction factors and will check the previous approximations. Beam spread correction must also be provided for experiments conducted to test the validity of the theoretical wave model. Pending completion of the beam spread study, the attenuation model is being tested using broad-frequency-band pulses. Pulse shape changes which are due to attenuation losses must be accurately measured for these studies.

Fatigue Detection

Fatigue-to-failure cycling and nondestructive testing of a 304-L stainless steel sample stressed in units of 200,000 cycles revealed surface "dimpling" which became progressively severe with continued cycling. Optical examination of the sample suggested the imperfections were 0.5×10^{-3} inches in diameter and extended an indeterminable depth.

Eddy current testing of the sample performed after each 200,000 cycles revealed readily detected changes at the first examination. The observed changes have persisted through the 1,200,000 total cycles applied to date, and appear to correspond to regions of maximum stress along the sample surface. Ultrasonic tests applied to the sample concurrently with the eddy current tests have revealed no changes.

Heat Transfer Testing

Gas coupling between a thermal transducer and sample is desirable because:

1) A thin gas gap has low heat capacity and a reasonably high heat conductance;

2) The temperature may vary over a large range without a phase change in thermal impedance; and

3) Such a couplant is easily fabricated and maintained.

However, thermal conductivity of a gas is temperature dependent and unless special measures are taken, the gap conductance will be non-linear. Such non-linearity would introduce undesirable distortion in the thermal wave and make measurement of the thermal impedance more difficult.

A possible method for linearizing (as a function of temperature) thermal conductivity of a gas gap by varying the gap thickness with temperature has been conceived. This technique is based on the known behavior of conductance of a thin helium gap during variable temperature conditions. The initial thermal transducer, however, will be fabricated without the linearization feature in order to obtain some experimental back-up prior to further theoretical work.

Ultrasound Imaging Research

The recently developed ultrasonic imaging unit has been used to study the transmission of ultrasound through plates of aluminum and glass. This unit uses light reflection from the water surface to visually image the ultrasound transmitted through an object. Transmission through plates is characterized by maximums which occur at angles of incidence which are regularly spaced about the position where the beam is normal to the plate. These angles at which maximum transmission occurs depend upon the material and thickness of the plate. The self interference of the ultrasound in the plate causes a characteristic set of interference fringes similar to those seen in thin glass plates under monochromatic light.

One aluminum plate had a 0.01 inch deep by 1/8 inch wide defect milled into it on one side. This defect was readily detected, although irregularities in the ultrasound beam pattern make distinct imaging difficult. A screen placed beneath a 1/8 inch thick plate of aluminum was also distinctfully imaged with this unit.

A series of pictures were taken of light diffracted by ultrasonic beams in water. Under some conditions as many as five diffraction orders on each side of zero order were observed. At ultrasonic frequencies of 10 Mc and higher, the mercury spectrum is clearly split into its component yellow, green, and violet lines in each diffraction order. Pictures of this clearly separated spectrum were taken using a 20 Mc sound beam as the diffracting medium. Diffraction was observed from ultrasonic beams up to 65 Mc. In previous experiments 100 Mc beams had been observed when a 20 Mc crystal was used at its fifth harmonic.

Further experimentation with electroluminescent phosphor materials have been completed. Efforts to develop a satisfactory electroluminescent cell are continuing. A straightforward approach of evaporating a thin layer of

the material upon a transparent conductive substrate proved inadequate. The material used was zinc sulfide with copper activation which emits green light under excitation. The thin layer formed by the evaporation process was virtually colorless and without luminescent properties. The crystalline properties of this layer have not been determined.

Several samples of the cholesterol compounds which change color with temperature, stress, etc., have been obtained and investigated. An experiment was conducted to determine if there were any direct effects of ultrasonic energy upon their observable properties. A crystal layer, approximately one-half of an ultrasonic wavelength thick, was subjected to an intense ultrasonic beam. There were no observable changes in the appearance of the material.

Experiments were conducted to determine the utility of two new methods of ultrasonic imaging. The first method made use of the chemi-luminescence of amino-phthalhydrizide (Luminol). The sodium salt of this organic compound is soluble in water and, when oxidized, energy is released as light in the visible region of the spectrum.

The ultrasonic cavitation of water causes the release of hydrogen peroxide (H_2O_2) and free oxygen which may then oxidize this organic component. Thus, an object placed in the path of an ultrasonic beam in an aqueous solution of this compound would be "shadow imaged" in the luminous intensity. Initial experiments showed that the technique was feasible; however, the only equipment available with enough power to appreciably cavitate the solution was "ultrasonic cleaners" operating at approximately 20 kilocycles. The long wavelength of this low frequency made resolution poor.

The second new ultrasonic imaging technique investigated makes use of the piezo-optic and electro-optic properties of piezoelectric materials. An ultrasonic image could be constructed from such a material by placing a transducer between crossed polarizers and allowing an ultrasonic beam to impinge on it. If the stress in the crystal produced by the ultrasonic beam is sufficient to cause an appreciable rotation of the plane of polarization, then the light passing through the second polarizer would be a "shadow image" of any object in the ultrasonic beam. Experiments on quartz and barium titrate crystals showed that the rotation in these materials was not sufficient to be used in any practical device.

Quantum Physics Devices

Radiation damage studies of Ld_2SO_4-H_2O were continued. Single crystals were bombarded with 1 MeV protons. Initial attempts were hampered by heating due to the intense proton beam and the resulting decomposition of

Li_2SO_4-H_2O to Li_2SO_4. Further attempts will be made using liquid nitrogen cooled samples bombarded with both electrons and protons.

Single crystals of CdS (pure and indium doped) CdSe, ZnS and SnSe were received and are being studied for their properties.

Ultrasonic Transducer Development

The ability to ultrasonically inspect high temperature materials continues to look favorable with further evaluation of the electrostatic transducer. Both mica and ceramic material have been evaluated for use in this device. These two dielectrics are comparable as to efficiency of generating and detecting ultrasound; however, each possesses characteristics which would make its use advantageous for specific applications. The mica is more pliable and readily obtained with the desired thickness but has a more limited operating temperature range than does the ceramic materials. The operating temperature of the components is of particular interest since one significant application of this device is to measure the elastic moduli of metals at high temperature.

The ability to generate and detect ultrasound with the same capacitor transducer has been demonstrated. This feature will make the device applicable to making ultrasonic measurements on objects with only one surface available. Measurements were taken on the outside surface of a cylindrical tube having a 1/4 inch thick wall. For this test a fast rise and slow decay voltage pulse was applied to the single capacitor. The transmitted ultrasound is generated by the fast rise portion and the return pulse is detected by the charge which remains on the capacitor during the slowly decaying portion of the voltage pulse.

A pulse superposition technique was used to obtain an accurate and automatic measure of ultrasonic wave velocity in rod samples. For this method, the transmitter pulse rate is synchronized with the time between transmission and receiving of a reflected pulse. In this way the transmitted pulse is reinforced by the reflected pulses from previous periods and a maximum amplitude results. Thus, by adjusting the transmitted pulse rate until a maximum pulse amplitude is achieved, the ultrasonic wave velocity may be calculated directly from the distance of the rod and period of the transmitted pulse.

Nondestructive Testing of Isotope Heat Sources

Design of a mechanical system for inspection of isotope heat sources is near completion and a prototype system suitable for installation in the hot cell facility should be fabricated within one month.

The low frequency ultrasonic test equipment has been set up for inspection of the core material in the isotope heat cells. Initial tests indicate that this low frequency sound (400 kilocycles) penetrates entirely through the core with sufficient test signal to measure. As more prototype cells become available, a detailed study of this test will be conducted to determine the extent of information available from this test. Grades within the core material and the extent of any molten core condition should be detectable with this test.

Several 5 megacycle transducers which are highly damped have been fabricated for use in making wall thickness and wall integrity measurements. These units use a ceramic piezoelectric element and are constructed with a radiation resistant epoxy resin. Ultrasonic beam profiles for these units show a more uniform sound wave than would be available from commercial transducers. These special characteristics are needed to perform accurate wall integrity measurements on the isotope cells.

Experiments are being designed which will provide test evaluation of both the steady state sinusoidal and transient thermal test methods proposed earlier. A high temperature water soluble coating has been sprayed on the outer surfaces of initial test samples in an attempt to minimize the possible effects of surface emissivity differences in the samples. Automatic emissivity compensation could be incorporated in future equipment, but the added complexity is not warranted at the present stage of the problem.

A simulated isotope heat source having a defect in the core to cladding heat conductance was fabricated by slumping a glass cylinder into a 310 stainless steel can. An iron shim was placed against the inside can wall on one side. This shim will be etched away to produce a simulated defect. Thermal tests on this sample will give indications as to the applicability of thermal test methods of detecting cracks in the core material. Although a few cracks would not be too detrimental, a large number (particularly if they completely encircle the core) could cause a molten center during operation.

A simple thermal testing experiment has been set up for an initial attempt at testing the simulated heat source. The sources are to be heated to 450°C and then externally cooled by an air blast while being rotated in a scanning lathe. An infrared radiometer has been set up to view the surface during the scan. Differences in the core to cladding heat conductivity should cause transient differences in the surface temperature during cooling. Although this thermal testing method is not as sophisticated as the sinusoidal steady state method, it is simple to implement and is worthwhile to ivestigate.

BIOLOGY AND MEDICINE - 06 PROGRAM

Atmospheric Physics

Field testing of the atmospheric tracer detection system and turbulence instrumentation on the Cessna 01A aircraft continued. Daytime in-flight tests, using zinc sulfide particulate released from the Meteorology Tower and sampled at 100 feet above ground to distances of eight miles, demonstrated that both the real-time detection system and the bulk sampling systems were operational. Improvement in recorder dependability and further calibration of the turbulence sensor against the wind component meter on the portable mast will be attempted prior to full scale field use of the aircraft system.

The Hanford diffusion-deposition model currently used for evaluating the consequences of reactor accidents was programmed for the IBM 7090 to prepare "Aids to Computation" for inclusion in the Second Edition of "Meteorology and Atomic Energy."

In precipitation scavenging research, measurements of the washout of radioactive iodine from a plant off-gas stack were obtained during the rain of November 3, demonstrating that the experimental methods were feasible. Total rain samples obtained at ground level contained activity proportional to the total iodine release from the stack during the sample period, since the raindrops sampled the plume in the vertical dimension and the total rain samples were collected across the width of the plume. The proportionality constant is the "washout coefficient."

The washout coefficient for gaseous iodine, determined from the data collected, was very close to the theoretical value determined from molecular diffusion theory for that rate of rainfall. The coefficient for the organic iodide fraction was considerably lower than for gaseous iodine, quite in accord with its lower solubility. The raindrop size spectra were estimated from earlier measurements obtained during similar type rain. Because of the very high sensitivity of the detection methods, washout data can be obtained from a very modest source strength, and may be extended to other isotopes.

Radiological Physics

an Eskimo from Anaktuvuk Pass, Alaska, spent two weeks at the laboratory helping us study his 1300 nCi body burden of Cs-137. The following studies were conducted:

1. The results from the 3 whole body counters at Hanford (shadow shield, the mobile counter and the iron room) were compared. They were in close

agreement giving 1300, 1290, and 1290 nCi, respectively.

2. A differential body scan showed the body sections of the shoulders, liver, thighs, and calves to have much more Cs-137 than the head, pelvic region, knees and ankles.

3. Na-22 was detected in his arms by coincidence counting between two large crystals. This isotope was not detectable in a regular whole body count. The Na-22 present was probably the small fraction deposited in the bones which has a relatively long residence time when compared to the 11 day half life of the isotope in soft tissues.

4. Fe-55 was detected in a blood sample. An estimate of a total body burden of 25 nCi was made from the data. This estimate may be off a factor of two or more due to self-absorption of the 5.9 keV X-ray. To the best of our knowledge, this is the first time this isotope has been detected in man from fallout sources.

5. Using Cs-137 body burden, it was possible to make a better calibration of the portable counter using a 3 x 3 NaI crystal which will be used in Alaska.

6. Daily regular whole body counts were used to determine a biological half life for Cs-137 of 75 days. The body burden decreased from 1310 nCi to 1160 nCi over a 14-day period.

7. An estimate of the Cs-137 interference in the background of the plutonium counter was determined. The barium X-ray resulting from the decay of Cs-137 was easily detected.

8. Dose rates at the body surface were determined with sensitive ion chambers. Using the low background in the counting cave, a dose rate of .005 mr/hr was determined. Unfortunately, the statistical uncertainty in these data makes it impractical to draw any significant conclusions from this experiment.

One of the dogs previously counted on the plutonium counter has developed an unexpected tumor. Previous data indicated this dog should not have developed a tumor; however, recent data taken with a dog phantom and 13 control dogs which were counted with a known Pu source in their trachea have established a correlation between Pu body burden and body weight. This correlation would raise the estimated body burden of the dog that prompted this experiment from .6 μCi to 1.2 μCi. This body burden is in the range of other dogs which have died from inhaled plutonium.

The old gas filling (He^3, CO_2, Kr, and Xe) was removed from the He^3, CO_2, and Kr. The resolution of the thermal neutron peak improved from 17.5% to 5.7%. The obvious conclusion to be drawn is that Xe is not a good counter gas at high pressures. General development of the spectrometer system is continuing.

A technique has been developed for the fast pulse averaging system which will average pulses randomly spaced in time. The previously reported technique could be used on regularly spaced pulses only.

Instrumentation and System Studies

The Biology Laboratory fire destroyed the experimental logarithmic-response fish trough monitor, which was being used to measure gamma dose rates. In addition, the original Biology field analyzer and monitor was destroyed; however, a later model was being used in a different building and thus escaped damage. A new fish trough monitor will be fabricated.

Testing was initiated on the blood pressure transducer and design started on the signal conditioning circuits for the animal physiological function and radionuclide uptake telemetering system. The conditioning circuits will operate a voltage-controlled oscillator. The transducers employ two temperature compensated strain gages which measure pressure. The two gages plus the input circuit of the signal conditioning unit operate as a bridge circuit. Output voltages are in the microvolt range. The blood pressure measuring channel is the last of the channels remaining to be finished. The other channels of temperature, pulse rate, and radionuclide uptake have all operated successfully in laboratory tests.

Satisfactory operation of the canine smoke inhalation control system is being achieved at the Inhalation Toxicology Laboratory. In addition, two radionuclide aerosol inhalation experiments involving six dogs were successfully completed following correction of several minor mechanical difficulties. A second inhalation control system will be designed and fabricated for use in another glove box. This system will include all valve control electronics and a lung tidal volume monitor.

Development commenced on a rodent whole body monitoring system to be used at the Biology Laboratory. The system requirements were established in a series of discussions and preliminary sketches were made of the detection assembly. The complete system will be prepared in mockup form for use in defining the operational characteristics.

The lateral detector support trays for the Biology dog counter were replaced with improved models to permit more accurate adjustment and position-

ing during scanning. Operation appeared to be fully satisfactory.

Design was started on a solid state preamplifier and probe housing to be used with the Pu^{239} wound monitor being developed for use by Hanford medical personnel during removal of Pu^{239} from wounds. Initial tests of the bare probe indicated that successful operation could be achieved.

Minor modifications were incorporated in the completed experimental ion chamber peak pulse reading instrument and the required high current power supply was completed and installed. The instrument is being used in radiation dosimetry studies, and operation to date appears acceptable.

Development of the low noise preamplifier was completed for use in the neutron-gamma mixed field dose rate measuring instrument, and most of the tests of the neutron detector, a moderated lithium-foil covered surface barrier diode, were completed using the positive ion Van de Graaff. Further tests will be conducted with the TTR and various neutron sources. General development of the rest of the solid state circuitry will follow, depending on the test results achieved with the neutron detector and preamplifier assembly.

In conjunction with the development of a single electron counter for use in dosimetry studies, a fast pulse generator was developed to provide amplitude-controlled, 2 nanosecond wide, paired pulses with pulse separations from 10 to 28 manoseconds. This circuit permitted resolution tests on the discriminators developed for use in the counter, and it was determined that one of the discriminators was performing erratically. Circuitry changes are now being incorporated.

Continued analog computer runs were made to perform coordinate transformation of the Atmospheric Physics wind turbulence data. The data obtained from wind turbulence transducers are converted into cartesian form about a moving reference system. The reference is based on weighted averages of horizontal components of the wind velocity vector.

The analog computer model for the distribution of radioisotopes in the bodies of animals and man was further tested for Te^{132}-I^{132} isotopes in standard man. The results of computer runs for ingestion were compared with experimental data to determine the constants which define the biological processes. Good agreement was obtained in some cases; however, more investigative work is required.

Previously, the constants for I^{131} in man were adjusted so that the simulation model results are the same as those from experimental results. Constants which define Te^{132}-I^{132} in standard man, I^{131} in man, Te^{131}-I^{131}

in cow, and Te^{132}-I^{132} in cow are now available. Inputs can be ingestion, skin absorption, inhalation, and injection and the resulting time transients of the isotopes can be obtained for lungs, stomach, small intestine, upper large intestine, lower large intestine, skin, blood, kidney, total body, thyroid, milk, bone, muscle, and other organs.

WASHINGTON DESIGNATED PROGRAM

Isotopic Analysis Program

Isotopic analyses were provided on program samples as received during the month.

The vacuum-lock sample changer of Mass Spectrometer "A" failed after several years of satisfactory service. The chrome-plated sliding shaft and cylinder have been rehoned to attempt to restore the system to satisfactory operation. The system has not yet been tested. The ion pulse-counting and control circuitry of Mass Spectrometer "B" were repaired and modified during the month. The system appears to be operating reliably again. Except for minor details, specifications for the vacuum system of the new mass spectrometer were completed.

EXPERIMENTAL REACTOR PHYSICS FACILITIES

PRCF

Experiments on the Pu-Al core were continued. Moderator level sensitivity and worth measurements were made to a moderator level of 85-1/2", 16-3/4" below the normal operating level. Vertical and horizontal flux traverses were obtained for bare and cadmium covered lutetium foils irradiated at 100 watts. One irradiation of copper wire 3.38" above the center of the core was completed for comparison with other horizontal traverse data which had been taken 16.25" above the core center.

Several substitution measurements were made. A copper rod was measured as a function of radial position. A group of four EBWR fuel elements was measured simulating the fuel followers of a control rod in three different sectors of the core. The worths of three rods containing different concentrations of HfO_2 in Al_2O_3, one rod containing Eu_2O_3 in Al_2O_3, one Al_2O_3 standard, and one solid Al rod were measured in the center of the core. Lattice plate sections for the center 19 holes fabricated from "Lucite", "Lexan", 6061 Al, "Teflon", and linear polyethylene were measured in the center of the core.

A vertical traverse measurement was made in the center lattice position with a void approximately 1/2" in diameter by 8" long. A vertical traverse with a small U-235 fission chamber was completed. Similar measurements with other fission chambers are in progress.

Construction continued on Project CAH-119 throughout the month.

PCTR

Operation of the PCTR continued routinely. There was one unscheduled shutdown due to faulty bypassing technique. The NPR coproduct experiment continued throughout the month and was nearly completed.

TTR

The TTR was operated on a once-a-week basis for the U. of Washington Graduate Center. There were no unscheduled shutdowns.

Critical Approach Facility

The critical approach facility was not operated.

COMPUTER FACILITIES

The G.E. 412 process control computer has successfully completed its 30-day performance test period. Program debugging and check-out for application of this system to control of the "C" solvent extraction column continues on schedule.

A preliminary study is being made to determine feasibility of using the computer on the Waste Solidification Program. Full experimental confirmation of this possibility requires changing signal input circuits for twenty-six points, and a request for the necessary hardware was sent to the computer manufacturer. First experimental run was scheduled for early December; the test will continue for seventy hours.

A novel application of the G.E. 412 computer has arisen out of the ability of the photoelectric paper tape reader to accept faulty tapes which are not acceptable to Hanford's digital machines. Several rolls of such tapes from a data logging system have been automatically corrected, reproduced on the 412 high speed punch, and subsequently read by the 713 Building equipment with no difficulty.

Work is progressing on the application of digital control techniques to mass spectrometry. Current efforts are being made to develop a multi-

plexer which will enable a PDP-5 computer to service several input-output devices and thereby control operating conditions of the mass spectrometer, i.e., ion power supply, sweep coil power supply, and focusing controls. The system will also store data from the spectrograph's photomultiplier system, calculate isotope ratios and display or print mass spectrum data.

Analog computer utilization was as follows:

EASE 1132	EASE 2133	
168	136	Hours Up Time
0	16	Hours Scheduled Down Time
0	16	Hours Unscheduled Down Time
168	168	Hours Total

Problems considered during the month were:

1. Pot Calciner Study.
2. Meteorology Study.
3. Biological Distribution of Radioisotopes.
4. PRTR Hazards Study.
5. N Reactor Over-all Simulation.
6. Containment Study.

Failure of the IDACAS iterative control units of the Beckman 2133 computer were responsible for the 16 hours of unscheduled down time. A representative from Beckman Instruments Company repaired the units on plant under the original equipment warranty.

A study was started on the addition of digital equipment to the analog computer facility to provide a hybrid capability. Possible applications include checking of analog programs, demonstration of digital control techniques on analog simulations of processes, computations involving high accuracy to extend the capabilities of computation, demonstrations of small digital computer applications at Hanford, and to provide an interface between the analog computer and a large, general-purpose, digital computer.

The first nine sessions of the analog computer applications course have been completed. All students were given an opportunity to solve simple problems on heat transfer, chemical reactor design, and process control on the EASE 2133 iterative analog computer. The remaining classes will be devoted to the application of MIDAS for solving a chemical reactor design problem on the 7090 computer.

An interface which allows the PDP-5 digital computer to be used as a multichannel analyzer with double precision accuracy was designed. Although double precision accuracy can be achieved with the computer program capabilities, the logic interface allows a considerable time savings, thus producing less deadtime during analysis. With the modification, the PDP-5 computer can be used as a multichannel analyzer with $(2)^{24}$ counts per channel capability, using the computer's "data break" facility.

A second interface was designed to allow a digital magnetic tape unit to operate with the PDP-5 computer. The logic provides for computer control over the magnetic tape operation and read-write functions. This modification which uses the "device selector" of the computer provides a large, slow-speed buffer memory for data interchange with the computer core memory. An optical digital magnetic tape interface, using the "data break" facility instead of the "device selector" facility, is under study.

CUSTOMER WORK

Weather Forecasting and Meteorological Services

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

Weather Summary

Type of Forecast	Number Made	% Reliability
8-Hour Production	30	82.2
24-Hour General	60	85.1
Special	79	89.9

November was a little cooler and wetter than normal. There was more fog and less wind than usual, and sky cover averaged greater than in any previous November of record.

Mass Spectrometry

Isotopic analyses were performed on four samples in support of Phoenix Fuel Studies in the PCTR.

Instrumentation and System Studies

In assistance to Health and Safety, instrumentation was provided for measurements during a series of "Hi-X" fire foam tests. Conductivity

elements were placed at various elevations in the 324 Building stack to provide readout of the foam level in the stack. In addition, ground level pressure measurements were made during the test series, which were completed.

In continuing engineering development for Waste Solidification Engineering, HL, an 11 inch long liquid level probe, which uses a time domain reflection principle, was devised and used to measure the level of a liquid glass compound at 1000°C. The probe indicated a 7-inch level change, as presented on the face of an oscilloscope. In addition, laboratory tests were completed on a 7.5-foot-long probe, which will be used in an 8-foot-long melter tank at 1000°C.

Fabrication was partly completed on the dual-detector support mechanism for the assault mask monitoring system being developed for use at the Hanford Laundry Facility. In addition, the main chassis wiring was completed and general system electronic testing was initiated.

Engineering assistance was rendered to Geochemical and Geophysical Research, HL, to solve the drift (instability) problems being encountered in their Am^{241} counting system and in their scintillation well probe. All problems were satisfactorily resolved.

Two prototype, personnel gamma-radiation dosemeters, based on an AECL design, were completed in miniature package form for use by Radiological Engineering, IPD.

Work on the river routing analog simulation was completed and documented in SRO Memo 64-44.

Transient analog computer solutions for several different versions of a mathematical model of a pot calciner were made for the Waste Solidification and Engineering Development Operation of Hanford Laboratories. The mathematical model is in development; no conclusions have been made from the simulation.

Two sections of a containment analog computer simulation were conducted for Chemical Effluents Technology. This problem is in the mathematical model development stage.

Maintenance trouble shooting was necessary on both the 6000 and 400 channel analyzers. Most of the problems were associated with the mechanical readout devices. The 6000 channel analyzer punch and printer developed problems. The punch was repaired on plant, but it was necessary to send offsite for a replacement for the printer mechanism. The paper tape punch in

the 400 channel analyzer also failed and was repaired on plant with considerable parts replacement. Also, a logic modification was made to eliminate false storage pulses in the early portions of the spectrum.

Development work continued on a method of remotely measuring the displacement of metal specimens in a high temperature oven. An improved optical arrangement resulted in better pulse waveforms. Tests indicated the resolution was a factor of 1000 less than desired. In an effort to improve resolution, the scanning speed of the light beam will be reduced by a factor of ten, and an electronic time interval counter capable of seeing a pulse width difference of 10 nanoseconds will be obtained.

Final wiring and testing of two silicon controlled rectifier stacks and associated gaters has been completed in the 105-KW Reactor test facility. Two complete systems of GEMAC automatic controllers and silicon controlled rectifiers are now ready for service. The systems will provide an automatically controlled amount of power to the heaters in the swelling test capsules.

The automatic operation of the creep data logger has been under test for one month. Its operation has been satisfactory on a dummy capsule when programmed for a logging cycle of every half hour. A new Beckman paper tape printer was installed to replace an obsolete Clary printer. This printer replacement will increase the reliability of the data readout considerably. The new printer is wired such that micropositioner data will be printed in red, while all other data will be printed in black, thus making it easy to sort the data.

Optics

A requested proposal for modification of K Area optical viewers was prepared. Principal work to be done includes installation of non-darkening lenses and two power driven eye pieces.

Difficulties were encountered in the modifications for the underwater viewer for N Area. The problem was solved by the addition of two field lenses. The modifications have been completed and the periscope is ready for installation.

A study was made of the requirements to put the PRTR profilometer back into satisfactory operation. The study resulted in two suggested proposals and two modifications for better operation.

A microscope was modified to operate inside a glove box. The modifications included an adapter for a polaroid camera.

The Optical Shop is being made ready for installation of an Elgin lapping machine and three electric furnaces.

The following work was performed:

1. Four camera shutters were cleaned and repaired.
2. An N_d laser was repaired.
3. Four N_dF_3 disks were cut and silvered.
4. Three S_mF disks were cut and silvered.
5. Seismograph support stands were fabricated.
6. A Stibene crystal, organic scintillator was ground and polished.
7. A cylindrical mirror was silvered.
8. A lithium sulfate monohydrate crystal was successfully cut into five pieces.
9. Two microscopes were cleaned and repaired.
10. Two crane periscope heads were repaired for Purex.
11. Eight high voltage glass insulators were fabricated.

Physical Testing

Development efforts have been completed on a gamma scanning system to detect voids in ceramic fuel rods. Voids can be detected and recorded as small as one-eighth inch in diameter at a testing speed of six feet per minute.

Development work on a method of detecting crack propagation in a process tube or containment vessel progressed during the month. The general method for the detection of operational growth in metals utilizes the ultrasonic energy released. Accelerometers mounted on the vessel detect the bursts of ultrasonic energy and by the use of suitable safety devices a catastrophic failure can be prevented (e.g., depressurizing the vessel). The exact location of flaw growth might be located by monitoring three transducers and using a method of triangulation. The technique was first applied to an N Reactor process tube burst-test sample. No position information resulted due to high noise levels inherent in the system such as from end-cap movement and pump strokes. A piece of 1100 aluminum alloy was flawed and bent in a vise to propagate crack growth. The recording of the accelerometer output showed definite 40 kilocycle bursts as the crack propagated. Further tests were made to determine the resolution of the instrumentation being used.

Engineering support to Plutonium Metallurgy has solved a switching problem in the capacitor discharge machine. The switch, which explodes a fine copper wire embedded in an insulator between two plates, reduces the inductance and achieves control to within plus or minus one microsecond.

Radiography of high temperature gas loop in the 314 Building determined internal alignment and positioning of critical components during operation of the loop at 2000°F. Alignment was determined to be acceptable.

The entire surface of the 105-C Reactor downcomer was inspected with fluorescent penetrant. Photographs were taken of the outstanding defects.

Radiographic inspection, to assure quality of field-erected equipment, is continuing at a steady pace during the construction of five vessels and dissolvers for CPD.

Thirty-one high carbon steel tubes were chemically cleaned and passivated in the White Bluffs Shop for use in the 234-5 Building.

Communications cable, along the right-of-way of highway construction on State Highway 24, near Vernita Ferry, was located and the position marked. A bulldozer had cut the cable.

Specimens of lignum vitae wood were exposed to gamma radiation while in both wet and dry atmospheres to evaluate the wood for bearings on fuel handling equipment in the reactor basins. An exposure of 3×10^8F altered the properties beyond usefulness.

A platinum melting pot intended for use in the waste recovery program was inspected for weld defects, wall thickness, and surface roughness. Rewelding was recommended.

INSTRUMENT EVALUATION

All evaluation and acceptance testing has now been completed on 10 offsite fabricated (two different manufacturers) scintillation, combination

$$\log\left(\frac{\text{total tracer}}{\text{tracer in solution}}\right) = \lambda \log\left(\frac{\text{total carrier}}{\text{carrier in solution}}\right)$$

A second possibility is that the simple Berthelot-Nernst distribution law is obeyed:

$$\left(\frac{\text{tracer}}{\text{carrier}}\right)_{\text{solid}} = D\left(\frac{\text{tracer}}{\text{carrier}}\right)_{\text{solution}}$$

Enrichment of the tracer material in the carrier is associated with large values of the factors λ or D.

The results of eleven experiments involving precipitation of varying amounts of bismuthyl nitrate do not clearly establish which law is followed but tend to support the logarithmic distribution. In any case, the data indicate that it may be possible to achieve substantial polonium enrichments via the coprecipitation route.

(It is interesting to note that Madame Curie used the coprecipitation of polonium in bismuthyl nitrate as a means of concentrating polonium when she discovered this element. Examination of the original literature did not reveal what enrichments were obtained for each $BiONO_3 \cdot H_2O$ precipitation.)

U-233 Support Studies

Promising results were obtained during the month on an anion exchange process for the recovery and purification of the "ultra pure" U-233 which will result from Pa-233 decay. The feed, containing 0.2 g/l U, 0.5M $MnSO_4$, and 0.05M H_2SO_4 was loaded onto Permutit-SK anion exchange resin and subsequently eluted in small volume with 1M HNO_3. Considerably more work will be required to optimize conditions and to define the effects of all pertinent process variables.

Full level B-Cell experiments on the absorption of Pa-233 on unfired Vycor glass have continued to give much poorer loadings than reported by Oak Ridge. Presence of an "unabsorbable" protactinium species is suspected and a sample of Oak Ridge Vycor has been obtained for comparative testing.

In other U-233 program support work, sufficient spray-calcined thoria was prepared for fabrication of three cold-pressed 8-in. target elements. Two of these will be irradiated and dissolution kinetics measured in the one-slug B-cell dissolver. Co-dissolution of cladding and thoria will be used in one case while the other element will be mechanically dejacketed and the thoria alone dissolved. (Dissolution kinetics of unirradiated cold-pressed spray-calcined thoria are excellent, and dissolver time cycles would be much reduced, relative to sol-gel thoria, if t[redacted] is true of the irradiated material.)

[redacted]

Thoria Dissolution

Thoria dissolution studies using a model dissolver were conducted to explore the following factors: (1) the use of an acid co-dissolution of the aluminum jacket and thoria target material, as opposed to a caustic decladding followed by an acid dissolution of the thoria; (2) the use of air jets to prevent a blocking of the passages between the solution and the material annuli; and (3) the placing of small (2-in. diameter by 4-in. high) air lift circulators beneath the grating as a means of promoting solids-liquid contact. The initial data indicate that all of these features (particularly items 1 and 3) are quite beneficial in improving the dissolution rate. Additional results are required to optimize the process and equipment, and to provide assurance that there are no hidden difficulties associated with these approaches.

The dissolution rate of large (-8 +10 mesh) particles of Mallinckrodt sol-gel thoria in boiling 12.3M HNO_3 - 0.025M HF - 0.1M $Al(NO_3)_3$ was found to be about six mils per hour. To determine the effect of crystal defects, induced by impurities, on the dissolution rate, four samples of sol-gel thoria were prepared (321 Building) containing one percent calcium oxide, magnesium oxide, strontium oxide and no impurity, respectively. The doped thorias dissolved in the above solvent only slightly more rapidly (maximum factor of two) than the control.

WASTE MANAGEMENT AND FISSION PRODUCT RECOVERY

Transient Thermal Behavior in the Fixation of Radioactive Wastes

The IBM-7090 is being used to compute the value, position and time of occurrence of the post-fixation maximum temperatures in annular containers of heat-generating radioactive materials. Studies completed this month show transient maxima as well as steady-state conditions for all possible values of inner and outer diameters in: (1) systems with insulated inner wall, and (2) systems with identical heat transfer coefficients at both walls. Inner and outer sink temperatures were assumed to be identical for these studies. Work is now underway on cases in which sink temperatures differ.

Strontium Semiworks Solvent Quality

The Ce(IV) extraction capacity of 0.4M D2EHPA - 0.2M TBP extractant diluted with NPH (normal paraffin hydrocarbon) was about the same as that for the same extractant diluted with Soltrol-170 after both were irradiated to 250 watt-hrs per liter; after 370 watt-hrs per liter the Ce(IV) extraction capacity of the NPH-diluted extractant was higher than that of the Soltrol-170-diluted extractant.

[redacted]

[redacted]

Both the NPH- and Soltrol-170-diluted solvents showed greatly reduced Ce(IV) extraction following 370 watt-hrs per liter gamma exposure and contact with sodium hydroxide. This was true also when the solvents were contacted with nitric acid immediately after contact with caustic. The extraction capacity was not regained during several days' standing at room temperature following the alkaline wash. Some extraction capacity was restored by treating the alkaline washed solvents with 0.2M $(NH_4)_2S_2O_8$ - 0.2M $AgNO_3$ - 2.0M HNO_3 - 0.0067M Ce solution for 1 hour at 25 C.

Semiworks Support

Considerable support was given during the month to continuing problems encountered in promethium processing at the Strontium Semiworks. Both laboratory experiments and hot-cell pilot runs with plant materials (the latter in the Analytical Hot Cells) were performed in an effort to pinpoint cause of the high plant losses of promethium in the "A" contact (co-extraction of cerium and promethium into D2EHPA). At month's end, the problem is still not fully resolved but several factors appear to be involved. These include substitution of DTPA for the HEDTA which was used in earlier (successful) plant runs; use of a pulse column contactor in place of batch extraction; and the presence of copious solids (and perhaps other impurities or solvent degradation products) in the feed. Reasonably satisfactory extractions were obtained in batch hot-cell extractions of the plant material.

In other process studies, 0.005 to 0.05M $NaNO_2$ was shown to be an effective and satisfactory reductant for stripping Ce(IV) from Semiworks solvent; continuing radiation damage studies further confirmed the high stability of D2EHPA extractant made up from normal paraffin hydrocarbon; and additional systematic data were obtained on the D2EHPA extraction behavior of a number of elements. The possibility of purifying americium by solvent extraction, vice ion exchange, is also under investigation and appears promising.

Technetium Ion Exchange

Examination of samples of IRA-401 resin from the two plant one-kilogram technetium recovery campaigns disclosed no evidence of degradation or loss of capacity. (Ability to reuse the resin for many cycles is crucial to economic large-scale technetium recovery.) Other technetium anion exchange experiments were directed at improving and optimizing the recovery and purification cycles of the plant process.

[redacted] [redacted]

EQUIPMENT AND MATERIALS

Slag and Crucible Dissolver

Testing of the slag and crucible dissolver for the Plutonium Reclamation Facility was completed during the month. In addition to the extended dissolution run previously reported, several runs were made to investigate the effects of additives to the nitric acid dissolvent. Tests were made with 0.25M ANN in 10M HNO_3; with 0.20M ANN in 8M HNO_3; and with plain 10M HNO_3 but with the addition of one can of sodium fluoride after every ten cans of slag and crucible material. Results of these tests were compromised by excessive plugging which was traced to the inadvertent inclusion of magnesium silicate in several cans of simulated slag and crucible material. After this problem was corrected, procedures and equipment modifications were developed in satisfactory overall performance of the equipment, as demonstrated in a final run with 60 cans added on a 30-minute cycle.

Non-Metallic Materials

Three samples of 2.3 density shielding window glass (6-in., 2-3/4-in. and 2-in. thick) were removed from a Co-60 source after receiving 1.0×10^8 r incident radiation at a rate of 7.4×10^4 r/hr. During subsequent rinsing in water, the 6-in. thick sample discharged. No known impact or scratching of the glass occurred. The polished surfaces of all three samples were crazed with very fine cracks which appeared to be as much as 1/16-in. deep. Similar but much less severe crazing occurred on two other samples of the same type of glass exposed to 2.6×10^7 r at 1.4×10^4 r/hr, and 3.7×10^7 r at 2.8×10^4 r/hr. Reduction in light transmission in the samples exposed to 1.0×10^8 r averaged about 4 percent per inch.

No radiation induced changes in hardness or dimensional stability were noted in five non-metallic bearing materials exposed to 3×10^8 r gamma radiation in water and 3×10^6 r in air. Three were molybdenum sulfide-filled epoxies, one was a molybdenum sulfide-filled urethane and one was lignum vitae wood.

Corrosion of Boron-Containing 304-L Stainless Steel

A small heat of 304-L stainless steel containing 0.2 weight percent of B-10 has been obtained for evaluation as a neutron absorbing material. Corrosion of the alloy, either annealed or in the sensitized state, in nitric acid solutions was only slightly inferior to that of boron-free 304-L. The corrosion rate in Zirflex dissolvent was about 2.5 times higher than that for boron-free 304-L.

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Vessel Corrosion During Protactinium Storage

In the proposed flowsheet for Purex plant recovery of protactinium from irradiated thoria, the product solutions containing protactinium, 0.1M H_2SO_4 and 1M $MnSO_4$, will be stored in 304-L stainless steel vessels. The corrosion of passive stainless steels in 0.1M H_2SO_4 - 1M $MnSO_4$ is essentially nil. During a 3 week test a sample of 304-L stainless steel remained passive in the solution at the boiling point. A similar sample, activated by momentary contact with mild steel, corroded at an average rate of 3 mils per month during a 24-hour exposure to the boiling solution. When the solution contained 0.01M Fe(II), HNO_3 or Cu(II), activation of 304-L stainless steel in the solution could not be induced by contact with mild steel.

PROCESS CONTROL DEVELOPMENT

Column Density Computing System

Accurate measurement of pulse column pressure is needed as an input signal for automatic control of column operation. Analysis and experimentation have shown that the time average value of the observed column pressure contains a contribution or error proportional to the product of the net flow through the column and the pulse velocity. A computing system was devised which combines the observed column density signal with the computed error value to yield a process measurement unaffected by column dynamics. The error is computed using a multiplier which accepts a current signal proportional to the net flow and a voltage signal proportional to the pulse velocity. The system was assembled, performance tested, and readied for use in conjunction with the solvent extraction columns in the Plutonium Reclamation Facility.

In-Line Plutonium Detection

The effects of varying Pu-240 concentration on indicated plutonium concentration were studied further. Experimental and calculated results were compared for three types of detection: alpha, X-ray and neutron counters.

Although more work is needed, results to date show promise of improved in-line plutonium and Pu-240 analyses using a combination of the several detectors. The presence of americium was shown to have an exaggerated effect on concentrations indicated by the X-ray detector.

REACTOR DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

PuO_2 Precipitation in the Salt Cycle Process

The precipitation of PuO_2 from molten chloride salt solutions by successive treatments with oxygen-chlorine and argon or hydrogen-argon gas mixtures has been further studied, with measurement of the effect of varying melt composition (2.5 LiCl-KCl vs LiCl-KCl), gas composition (20 - 80% O_2 in the O_2-Cl_2 sparge gas; 0 or 8% H_2 in the argon), and treatment time. Starting with melts containing ca. 20 w/o uranium and 0.2 w/o plutonium, and operating at 575 C, the following results were achieved:

1. With a 2.5 LiCl-KCl melt, and sparging with 20% O_2 - 80% Cl_2 for 3 hours and with 8% H_2 - 92% argon for 0.5 hour, 99.6% of the plutonium was precipitated. Neodymium-147 (a "representative" rare earth) and uranium DF's of 110 and 700, respectively, were obtained. The rare earth DF is reduced by increasing the oxygen/chlorine ratio in the sparge gas.

2. Essentially complete precipitation is also achieved in a LiCl-KCl melt, but the rare earth DF is only about 40.

3. Essentially complete precipitation can be achieved by use of 100% argon in the second phase of the precipitation reaction to sweep out any dissolved chlorine and oxygen and allow thermal decomposition of the plutonyl ions to occur. The reaction is slower, however, and results in markedly lower rare earth decontamination.

Oxygen/Uranium Ratio in UO_2-Containing Materials

Work is well under way on a program to develop methods for the determination of oxygen/uranium ratios in mixed oxides, UO_2-containing cermets, etc. The first technique to be investigated is the use of a reducing gas (CO or H_2) for the reduction of hyperstoichiometric UO_{2+x} to UO_2 with subsequent measurement of the gaseous reaction product (CO_2 or H_2O). The technique is being tested at present on UO_2-tungsten cermets, but also is a real possibility for use in the analysis of UO_{2+x}-PuO_2 and UO_{2+x}-ThO_2 ceramics.

The work thus far has included the following:

1. A series of thermobalance measurements of pertinent reaction rates. The results were very promising.

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2. Construction and preliminary testing of a gas handling system, in which to carry out the reduction reaction. With this equipment a series of runs has been made on micronized UO_{2+x}, reduced at 600 C with CO. The precision and reproducibility were good, a standard deviation of about ± 0.002 ratio units being calculated for an indicated oxygen/uranium ratio of 2.054. Since a coulometric determination on the same UO_2 showed an O/U ratio of 2.068, it is apparent that a significant bias exists which is under study to determine its cause.

   The effect of tungsten metal upon the reduction with CO was also examined, with particular attention paid to the possibility that the tungsten would reduce the product CO_2. The results showed no effect.

Salt Cycle Process Engineering Development

The Zircaloy cladding from a half rod of 5000 MWD/ton mixed oxide reported declad in September was sectioned and leached with 16M HNO_3 to determine the distribution of waste losses to the cladding. The uranium losses varied from 0.5% at the open end of the cladding to 0.65% near the closed end of the half rod. The average plutonium losses were 0.8%, although all of the plutonium may not have been recovered by the nitric acid leach. In some half rods about 2.5% of the total uranium was left in a large chunk near the closed end because the air hammer could not be operated sufficiently close to the end. Cladding waste losses of unirradiated mixed oxide have been less than 0.1%.

Dissolution of PRTR UO_2-PuO_2 Fuels

Laboratory work to develop procedures for dissolving PRTR UO_2-PuO_2 fuels in the Redox plant multipurpose dissolver was concluded. Two flowsheets which appear operable were demonstrated on a laboratory scale with both irradiated and non-irradiated fuels.

A service dissolver, constructed of a HNO_3-HF resistant material, has been proposed for installation in the Purex plant. A study flowsheet for dissolving Zircaloy-clad UO_2-PuO_2 fuels in the dissolver specifies decladding in 5.7M NH_4F-0.55M NH_4NO_3 to a terminal 0.6M zirconium concentration. In a preliminary test of these conditions on a section of PRTR UO_2-1% PuO_2 fuel which had been irradiated to 1000 MWD/ton, less than 3% of the uranium was converted to UF_4.

RADIOACTIVE RESIDUE PROCESSING DEVELOPMENT

Waste Solidification Engineering Prototype

Two 8-in. pot calcination runs were made using draft tubes to promote internal circulation and to accelerate capacity by delaying the initial denitration period. The feed for one run was doped with a simulated concentration of fission products representing 10,000 MWD/ton; the feed for the other was without fission products. Excessive foaming was experienced during the run with feed containing simulated fission products. Laboratory tests of the feed show it to have a sharp transition point from non-foaming to foaming conditions when concentrated. This occurs at a b.p. of 125 C and a concentration factor of about four.

Feed for the second run was a Purex high sulfate waste with $Ca(NO_3)_2$ added directly to the feed to reduce sulfate volatilization. About 528 liters of feed were calcined during 20 hours of feeding and a total of 35 hours of furnace operation. The 8-in. by 8-ft. long pot netted 84 kgs of solids, equivalent to wastes from approximately 4 tons of processed fuel.

The draft tube successfully delayed denitration until about 80% of the total feed had been added. Overall control and operation of equipment was very satisfactory.

Melt Pot Materials

A platinum crucible containing calcined Purex waste with added colemanite was held at 900 C for 24 hours, cooled and cleaned in nitric acid. This procedure was repeated with carbon, sugar, oxalic acid and tartaric acid added to 1 w/o and with carbon added at 5 w/o to the calcine. No evidence of attack on the crucible due to the added carbon or carbon compounds was observed.

Spray Calciner-Melter

A platinum melter was installed on the 14-in. calciner to permit operation with feed types and at temperatures found to be corrosive to more conventional materials. In one run the feed was a simulated 80 gal/ton U 1WW waste containing 1 M H_3PO_4 or a metal-to-phosphorous equivalent ratio of one. The spray calciner was operated at 700 C and 5 gallons per hour. During the run powder deposits were evident inside the draft tube, and filter blowback was poor. Further runs are planned to ascertain operating characteristics of phosphate feeds since other spray calciner runs without the melter did not display similar behavior.

Initial performance of the platinum melter with an external overflow weir was satisfactory, and sampling below the overflow was successful. Melt overflowed in drops from the external overflow weir on the melter.

Glass Formation

Melting points versus composition were determined for glasses or polycrystalline solids in the Purex calcined 1WW-P_2O_5, calcined 1WW-P_2O_5-PbO and calcined 1WW-B_2O_3-P_2O_5 systems. The addition of PbO to the phosphate glasses produced a small decrease in the melting point. The effect on retention of sulfate in the glass is yet to be determined. A glass forming region in the calcined 1WW-B_2O_3-P_2O_5 system was found which has melting points below 950 C and which can accommodate at least 40 w/o calcined 1WW. Mol ratio of B_2O_3 to P_2O_5 in this region is about two to one.

Continuous Phosphate Glass Experiment

Two additional continuous glass experiments were attempted in the High Level Radiochemistry Facility during the report period. Both were aimed at testing "Scheme 2" operation, wherein the condensate streams from the concentrator and melter are kept isolated from each other and separately condensed. Attempts at start-up of the first of the two runs (actually the third hot-cell glass run) were plagued with repeated plugging of the concentrator and the melter feed line, and the run was finally abandoned. Whether this failure was due to solids left in the concentrator after the second run or to some other factor is uncertain. The equipment was thoroughly cleaned before the next run and additional nitric acid was added to the feed to insure the presence of free acid. Operation was smooth and uneventful. The product appears to be a true glass containing some crystalline inclusions possibly due to insufficient temperature or time at temperature. The block will be sectioned for detailed examination. No analytical data are yet available on the condensate samples.

Leaching Rate Measurements

Leaching rate measurements have been started on samples of the glass produced in the second hot-cell Brookhaven glass run. In addition, similar measurements have now been made on geometric samples cut from certain of the calcines and "glasses" produced during the earlier in-cell spray calcination program.

Leaching behavior of the phosphate glass samples is being measured both as a function of time and of method of storage, i.e., whether stored in

dry air, saturated air, or under water. All rates measured were quite low (in the same "ball park" as Pyrex glass), but it is premature to conclude whether the rate is changing with time or whether it is significantly affected by mode of storage. The very low leaching rates (of the order of 10^{-5} gm/cm^2/day or $\sim 3 \times 10^{-6}$ cm/day) and the gross contamination of the cell result in uncertain interpretation of the data at this time.

Three types of spray-calcined material were studied: Purex waste without additives, Purex waste plus phosphate, and Redox waste plus borate and silica. As with the Brookhaven-type glass, samples of definite geometry and known superficial area were cut from the monolithic solids (by Radiometallurgy personnel) and exposed to distilled water. The first material, which consists of metal oxides in a water-soluble sodium sulfate matrix, distintegrated (as expected) to a "mud" and released much of the contained activity to the water. The Redox borosilicate glass and the Purex phosphate "glass" (actually a microcrystalline material) were much more resistant but still exhibited dissolution rates considerably higher than those of the Brookhaven glass. Selective leaching of certain fission products and chemical constituents were quite apparent. Thus, initial penetration rates calculated from cesium counting were one to two orders of magnitude higher than those based on zirconium-niobium, ruthenium or cerium and paralleled the dissolution of sodium and sulfate. The instantaneous penetration rates decreased by a factor of about ten in 200 to 300 hours of continued leaching. Primary difference between these materials and the Brookhaven glasses is a lower temperature of formation (800 C versus 1200 C) and the fact that most of the sulfate was retained in the melt whereas the Brookhaven glasses are largely sulfate-free.

Intermediate Level Waste Treatment

A scheme for the extensive treatment of intermediate level laboratory-type wastes (including removal of ruthenium) is being developed. The scheme proposed employs scavenging, ion exchange, and adsorption. For experimental purposes 300 Area cribbed laboratory wastes have been selected as being representative of a typical laboratory-type waste.

Experimentation to determine the most effective scavenger has shown that manganese dioxide possesses many properties which make it highly desirable. Manganese dioxide can be readily and inexpensively formed by air oxidation of a manganous salt in alkaline solution, and is insoluble in 10 N HNO_3 as well as in highly alkaline solutions. Decontamination factors in excess of 100 were obtained experimentally for Ce-Pr-144 and Zr-Nb-95, whereas decontamination factors for Ru-106 and Sr-90 were about 10. Maximum gross gamma removals occurred at pH 10.4.

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Various ion exchange materials are being investigated to determine which cation exchangers have the best capacity and selectivity characteristics for strontium and cesium in this waste. Decontamination factors of about 300 for strontium and cesium have been obtained using Linde AW-400, Amberlite IR-200 or clinoptilolite.

After scavenging and ion exchange the predominant radionuclides in the waste solution are Ru-106 and Sb-125. Ruthenium can be effectively removed by adsorption on activated carbon (DF = 340). A gross gamma distribution coefficient of 220 was obtained with activated carbon for the scavenging and ion exchange effluent. Activated carbon adsorbs most effectively in the neutral pH region (pH 5.0 to 7.5).

Although Sb-125 is not appreciably removed by the treatment process, the concentration is still within the maximum permissible concentration limit. Anion exchange resins were unsuccessful in removing significant amounts of this nuclide.

Approximate overall decontamination factors for the entire process were: Sr-90, 400; Zr-Nb-95, 500,000; Ce-Pr-144, >37,000; and Ru-106, 1800. This degree of treatment is sufficient to reduce all radionuclide concentrations to below MPC.

Zeolite Studies

Samples of a high-silica Type A zeolite, ZK-4, were obtained from Socony Mobil Oil Company in a continuing study of the effect of changing silica to alumina ratio on zeolite cation selectivity. The silica to alumina ratio of ZK-4 was 3.3 and 2.0 for Type A. The crystal structure of ZK-4 was the same as that of Type A. The site density was relatively less, going from Type A to ZK-4, since the anionic sites are associated with the alumina content. The resulting cation selectivities were altered, from Type A to ZK-4, in a predictable manner. The cesium equilibrium constant in a sodium-cesium system rose from 0.323 with Type A to 4.57 with ZK-4. Strontium selectivity from a sodium-strontium system fell from 83.2 with Type A to 4.22 with ZK-4.

It was concluded from this study, and similar works with Type X and Type Y zeolites, that the postulate of anionic site separation distance controlling zeolite cation selectivity was generally valid. Several unknown quantities, such as the possibility of several anionic site separation distances within the same zeolite crystal structure, render quantitative computations impractical at present.

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COLUMBIA RIVER SEDIMENT STUDIES

Experimental evidence was obtained this month which indicates that sediment scouring occurs from the McNary Reservoir during high water flow periods. Measurements of the Zn-65 to Cr-51 ratios of water obtained at the Umatilla Bridge on a weekly basis show a Spring maximum about four times as large as the average value for other periods of the year. This maximum corresponds to the period of high river flow and indicates that aged sediments are being scoured from the river bottom. Comparison of the amount of Zn-65 passing Umatilla with the amount in the river leaving the Hanford reservation indicates that approximately 65% does not immediately flow through this area. During the high flow period about 30% of this material is scoured from the bottom and moved downstream. With these values an inventory of Zn-65 in the river above the McNary Dam can be estimated as about 5500 curies. This figure agrees fairly well with the estimate of 10,000 curies made several years ago on the basis of some sediment core samples.

CONTAINMENT SYSTEMS EXPERIMENT

Major Facilities and Equipment

Erection of the containment vessel was begun by Chicago Bridge and Iron Company on November 16. Minor Construction forces continued work on the laboratory and on equipment and lighting installation. The scope of a proposed air decontamination test facility for CSE was distributed for comments.

Fission Product Simulation

Two runs were made in the Aerosol Development Facility to provide informa-

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Deposition velocities in this run ranged from 0.22 cm/sec on silver to 0.014 cm/sec on the modified phenolic coating. These values are much higher than those for the previous low concentration test and are possibly due to a higher concentration of elemental iodine.

Various decontamination treatments were evaluated on deposition panels of silver, copper, carbon steel, type 304-L stainless steel and steel painted with the modified phenolic coating. Iodine was most readily removed from carbon steel, and the painted surface was slightly easier to decontaminate than stainless steel. Exposure of deposition panels to clean air flowing at 200 ft/min resulted in significant desorption of iodine. For carbon steel, stainless steel, or the painted surfaces, roughly half the iodine was desorbed during a day's exposure.

The second run was similar to the first except that the iodine vapor was passed over a molten stainless clad UO_2 sample contained in a water-cooled quartz furnace tube. The iodine and fumes were blown into the receiver for 10 minutes. Particle concentration analyses are not yet available; however, from the weight of material from a Maypack sample at 47 minutes, the airborne particle concentration was estimated as 300 mg/m^3.

The total airborne iodine concentration in the receiver fell at a slowly decreasing rate to about 18% of initial level after 4 hours. The fraction of iodine found on the particle filters for air samples was much higher than in the previous run (17 vs 6%), and because some particles were removed by the screens which are intended to selectively remove elemental iodine, this value is probably low. It is of interest to note that the sum of particulate and elemental iodine fractions was the same in these two runs and the fractions in organic form were equal.

Deposition velocities, based on total iodine, were initially higher than for the previous run; however, the integrated deposition velocities over the 4-hour test period were about the same as the previous run for silver, copper and painted surfaces and were somewhat higher for carbon and stainless steel.

Desorption of iodine from surfaces and the removal effected by decontamination treatments were roughly the same as for the run without particles.

The problem of a crucible to contain molten UO_2 for several minutes has been overcome. A water-cooled quartz furnace tube is used and UO_2 powder is placed in the central portion of the tube as a bed for the 3-in. long stainless clad UO_2 sample. The UO_2 powder provides thermal insulation

to protect the quartz tube and forms a dam to contain the molten sample without introducing extraneous material which would volatilize. Three runs in an air atmosphere have been made: one of 7- and two of 10-minute duration. In each case, the heating period was stopped voluntarily.

Mathematical Models

The analog solution to the problem of transient heat conduction within a slab receiving heat from condensing steam was developed for adoption as an integral part of a general program for pressure-temperature transients. This "sub-program" will allow the effects of condensation and conduction in various heat sinks within the containment system to be taken into account.

OFF-GAS DISPOSAL TO GROUND

Relatively simplified test cases are being analyzed with the "Steady-State" computer program to evaluate system and solution capabilities, disposal volume and rate relationships prior to analyzing typical flow and soil systems.

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BIOLOGY AND MEDICINE - 06 PROGRAM

TERRESTRIAL ECOLOGY - EARTH SCIENCES

Hydrology and Geology

An initial calculation of predicted flow paths, travel times and soil transmissibility (permeability) distribution was made, using several recently developed computer programs and limited field data. The area analyzed was about 8 by 12 miles and extended from near 200 East Area to the river and south from Gable Mountain. The programs used represent the successful efforts to reduce theoretical mathematical expressions to usable methods for computer analysis. Even though this was a two-dimensional rather than a three-dimensional analysis and the input field data were of limited accuracy, reasonably good agreement was obtained in comparing the computed results with those deduced from ground-water contamination observations.

A study is being made to attempt to correlate porous media permeability with the velocity of seismic wave propagation in the media. Seismic data from surveys made on the plant were composited and plotted against aquifer permeability data from well pumping tests. The results show that there appears to be more than a casual relationship between velocity and permeability. Insufficient data at this time indicate that the curve should not be considered a "calibration curve" but that further investigation may be warranted to see what others have noted in this area. The possible application here is in determining permeabilities of deep aquifers by surface or near-surface seismic techniques.

Stratigraphic correlations, based on new geologic data and data collected by others, indicate that at least nine of the latest thirteen basalt flows beneath Hanford apparently advanced from the southeastward into and across the central part of the Pasco Basin. Five of the nine terminate to the northwest between Priest Rapids and the Frenchman Hills. There they abut against sediments that appear to have been deposited in lakes formed when those flows dammed the Columbia River. Northeastward of Hanford, at least two of the same flows terminate along the axis of the Saddle Mountains by thinning and pinching out. Interbasalt sediments also rapidly pinch out in that direction, indicating that the lakes did not extend long distances and that the Columbia River probably flowed to farther east than its current course.

The basalt flows are believed to have had their origin in the Joseph Creek-Imnaha River-Snake River area of northeastern Oregon, or more probably in the Monument area of north-central Oregon.

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RADIOLOGICAL AND HEALTH CHEMISTRY

Counting Studies

Concentrations of radionuclides on Alaskan lichens and on euphausids (krill) taken from the Pacific Ocean were found to be readily measurable by low level multidimensional spectrometry. Isotopes Na-22, Mn-54, Co-60, Y-88, Zr-Nb-95, Ru-106, Sb-124, Sb-125, Cs-134, Cs-137 and Ce-144 were readily measurable on the lichens; Co-60, Zn-65, Ru-106, Cs-134 and Cs-137 were readily measurable on a 25-gram euphausid sample, with indications that other radionuclides could be measured on a larger sample. These measurements give an indication of the wide applicability and extreme sensitivity of this low level counting technique.

Use of low level multidimensional analysis techniques in activation analysis of sea water salt concentrations allows the measurement, without chemical separation, of Na, Sr, Rb, Fe, Zn, U, Th, Co, Cs, Sb, Ag and Sc. Many of these elements are present in sea water at concentrations less than 1 ppb (Th, Co, Cs, Sb, Ag and Sc) and are difficult to measure by other methods. This technique should prove valuable in characterizing ocean water masses and measuring the rates of changes of their chemical compositions.

Fallout Studies

Air and rain samples collected after the Chinese bomb test on October 16, 1964, were analyzed using the multidimensional gamma ray spectrometer. Ba-La-140, Te-I-132, Mo-99 and Np-239 were readily measurable. The air concentrations showed maxima on October 23 and November 3, corresponding to 8 and 19 days following the test. The total deposition of Ba-La-140 during this period was estimated to be about 2.7 mc/mi^2. Np-239 concentrations were about 25 times as high as the Ba-La-140. Its presence indicates that U-238 was a component of the exploded device.

Meteorology Studies

A joint program with the Atmospheric Physics Operation was begun to determine the washout coefficients of airborne gaseous and particulate materials by rain. For the initial study the material released from a separations stack was used. The concentrations of material released from the stack were compared with the concentrations of these same materials carried down by rain in an arc 600 feet downwind from the stack. With simultaneous measurement of rain drop size, rain rate and windspeed, it is possible to calculate the washout coefficient for different sizes of rain drops. The first measurements of I_2 washout agreed well with theoretical calculations.

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ATMOSPHERIC RADIOACTIVITY AND FALLOUT

Aerosol Sampling Studies

Impaction efficiencies of membrane filters mounted in "standard" holders were found to be well correlated with particle stopping distance for wind speeds up to about 9 mph. For 16 and 30 mph wind speeds, higher efficiencies were obtained than predicted from the correlation at the lower wind speeds. The impaction efficiency is needed to "anchor" the curve at the zero flow point relating sampling efficiency to fraction of isokinetic flow.

The uniformity of particle distribution on a filter was shown to be a function of windspeed. Particles are preferentially deposited near the perimeter of the filter for higher windspeeds at all sampling rates. The filter retaining ring is responsible for the non-uniformity of deposit, which complicates the interpretation of sampling results.

Aerosol Generation and Characterization

Electrical charges on particles produced with the spinning disc generator were found to be not materially affected by disc speed or conductivity of the disc. The mean charge could be varied from about 300 to 1000 unit charges depending upon disc speed and concentration. With the metal disc grounded, particles with charges of both signs rather than particles with just positive charges were produced. These studies are yielding better understanding of the electrical properties of droplets separated from the edge of a high speed disc.

ISOTOPES DEVELOPMENT - 08 PROGRAM

Promethium Isotopic Composition

Chemical analysis (for Pm-146) of the four samples of high-burnup Yankee pressurized water reactor fuel was completed. Results were both unexpected and highly gratifying, from the standpoint of potential "value" or "utility" of the promethium which might be recovered from future power reactor fuels. The Pm-146/Pm-147 ratio was found to be essentially constant and independent of fuel exposure, or burnup. Values obtained were:

Burnup*, MWD/t	Pm-146/Pm-147
13,700	$4.0 \pm 1 \times 10^{-6}$
17,700	$3.6 \pm 1 \times 10^{-6}$
24,300	$4.0 \pm 2 \times 10^{-6}$
31,800	$3.0 \pm 1.5 \times 10^{-6}$

*Based on Cs production.

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For comparison, the Pm-146/Pm-147 ratio in low-exposure Hanford irradiated material is about 0.5×10^{-6}. An increase in the Pm-146/Pm-147 ratio was expected in power reactors, because of both the "harder" flux and the higher exposure. The ratio was expected to increase linearly with exposure, and Oak Ridge had predicted values over 200-fold higher than found. The hypothetical "Oak Ridge" material having a Pm-146/Pm-147 ratio of 800×10^{-6} would have required essentially the same shielding as Sr-90 or Cs-137, whereas promethium having a ratio of 4×10^{-6} should compete favorably with Pu-238 for many applications where shielding weight imposes a harsh penalty.

Theoretical analysis and reconciliation of the Yankee results, in terms of fundamental nuclear processes, is still not complete and will require radiochemical analysis of additional fuels such as the VBWR fuel samples which are awaiting Pm-148 decay. Tentatively, it appears that the low Pm-146 content is due to two factors: (1) a high Pm-146 cross section (of the order of 1000 barns), and (2) shielding of Pm-147 from resonance neutrons by U-236.

Analyses of the samples for other isotopes is continuing. A complete analysis of potentially valuable fission products and transuranics will be obtained and compared with ISOGEN predictions.

Promethium Re-entry Burnup Studies

The computer program for predicting the re-entry characteristics of cylindrical isotopic fuel capsules has been debugged and is now working satisfactorily. It is being used to determine the effects of varying pertinent parameters and to gain an appreciation for the degree of precision or accuracy required of input data (such as physical measurements of heat capacity, thermal conductivity, etc.).

Two instructive computations were made during the month, one for an unclad 6 cm diameter right circular cylinder of promethium metal (re-entering from low earth orbit at -1°) and the other for a similar cylinder clad in 1/8-in. of stainless steel. The unclad source was found to quickly reach the melting temperature (38 seconds) and to be completely gone in another 3 seconds (decrease in radius causes an increase in heat transfer which varies inversely with square root of capsule radius). A rough calculation of expected primary droplet size is 33 microns. Subsequent burnup of these droplets has not been studied in detail but is considered unlikely in the light of conclusions reached by Martin investigators (for molten droplets of Sr-90 compounds).

With the stainless steel clad source, re-entry under the above conditions did not lead to burnup. Although the promethium melted, the

clad did not reach its (higher) melting point. (This is largely because promethium metal is a good conductor of heat and thus conducted heat rapidly away from the clad.) Subsequent cooling in the lower layers of the atmosphere would cause at least part of the promethium to solidify before impact. (The fact that the coefficient of expansion of promethium is lower than that of stainless steel insures that expansion on heating and melting will not rupture the can.)

Thermal Conductivity Measurements

The thermal diffusivity of high-energy-rate impacted samarium oxide (stand-in for promethium oxide) was measured by personnel of Graphite Research and Development using an energy-pulse technique, and the thermal conductivity was calculated therefrom. A value of 0.0115 cal/sec(cm^2) was obtained, compared to an earlier value of 0.003 by a hot wire technique. Since the higher value is in good agreement with a literature value for dense Sm_2O_3, it is believed valid and the hot wire value erroneous (probably due to poor contact between wire and sample, effects of cracks, etc.). The light pulse measurements also revealed (by observation of a prompt signal) that samarium oxide is partially transparent to infrared. This effect increases the effective thermal conductivity at high temperatures. With these new data earlier calculations of the center line temperature of promethium oxide sources have been revised. It is found that the central temperature, and the temperature drop from center to surface, will not be excessive even with very large sources.

Compatibility Studies

Metallographic examination of the samples reported last month (which were exposed to samarium oxide for 1000 hours at 1100 C) showed that some nickel removal did occur in the case of nickel base alloys. Although the amount removed was not excessive, use of nickel-free alloys or metals would appear prudent.

Samples of neodymium fluoride and samarium fluoride were also impacted in stainless steel cans with coupons of candidate cladding metals and heated. After 660 hours at 800 C, one container had failed (cracked at a point of weakness) due to expansion resulting from reaction of neodymium fluoride with zirconium. All of the samples showed at least some attack.

In other compatibility experiments, coupons are being exposed to neodymium and samarium metals at temperatures below the melting points (to supplement and extend earlier measurements with molten rare earths).

[redacted]

Isotopic Heat Source Development

The 200,000 foot-pound energy release Dynapak machine has been received and at the end of the month is being set up for final acceptance tests and mocking-up with auxiliary equipment.

Installation has been completed of multipurpose process equipment suitable for the development of conversion processes and for supplying representative materials for high energy impaction of the various strontium, promethium, cerium and cesium compounds. Equipment shakedown and process development are currently underway.

The stainless steel cladding on a compacted capsule of strontium titanate was removed with sulfuric acid to provide a pellet for non-destructive testing studies. Inspection of the capsule when an estimated 50 mils of cladding remained showed about a 1/4-in. gap in the cladding running the length of the capsule. This suggests that the cladding was under tension and split during the dissolution allowing preferential dissolution along the edges of the split.

M. T. Walling, Jr.

Manager
Chemical Laboratory

MT Walling:ERI:cf

[redacted]

BIOLOGY LABORATORY

A. ORGANIZATION AND PERSONNEL

J. G. Powers, Biological Technologist, transferred from C.P.D. to Biological Analyses Operation on November 9.
C. H. Hemphill, Biological Technologist in Aquatic Biology, began Optional Retirement on November 1. He had worked approximately 15 years in Biology Laboratory.
M. H. Barron, Secretary in Aquatic Biology was deactivated (pregnancy) from the Payroll on November 30.
L. M. Strong, Biological Technologist, retired effective November 30. He had worked approximately 14 years in Biology Laboratory.
J. Eapen, I.A.E.A. Fellow completed a year assignment with Biological Analyses on November 10th and returned to Bombay, India.
T. K. Andrews, Biological Technologist in Radioecology Operation, transferred to Biological Analyses Operation on November 9.

General

On November 3, a roof fire at the Aquatic Biology Laboratory resulted in an estimated $250,000 building and equipment damage, in addition to loss of experimental fish. More than 90% of the valuable research records were saved. No radiation was involved and no personnel injuries resulted. As a result of the fire, studies on Zn^{65}, X-ray, and temperature effects in fish are temporarily suspended. Emphasis on the columnaris problem has been shifted from laboratory to field studies. Radioecology fallout samples are being processed, temporarily, in 700 Area laboratories while more permanent facilities are being constructed in the undeveloped portion of the third floor of the 108-F building.

B. TECHNICAL ACTIVITIES

FISSIONABLE MATERIALS - 02 PROGRAM

Columnaris

Agglutinating antibody titer of 1:5120 induced artificially in rainbow trout is probably near the maximum obtainable since no higher titer has been observed for two months. Antibody production continues in fish with low titer as evidenced by higher agglutinating titers observed this month. The second sampling of fish at Priest Rapids continues to show negative columnaris titer in whitefish, but positive titer in the majority of scrapfish.

Experimental fish employed in this study were lost in the fire which destroyed the 146-FR building. Laboratory phases of the study are temporarily suspended due to lack of fish and fish holding facilities.

Reactor Effluent Monitoring

To obtain eggs from the local chinook stock, large adults are being held in ponds for spawning, but successful egg taking seems unlikely at present. Four females died without reaching full maturity. Eggs will probably be obtained from Priest Rapids for the monitoring tests.

BIOLOGY AND MEDICINE - 06 PROGRAM

METABOLISM, TOXICITY AND TRANSFER OF RADIOACTIVE MATERIALS

Ruthenium

Experiments were performed to determine the efficacy of various therapeutic treatments for removal of Ru^{106} from rats. Treatments involved the administration of chelating agents (DFAB and DTPA) with and without simultaneous administration of glutathione (GSH). Accelerated excretion of Ru^{106} occurred only in the animals treated with GSH, where an approximately 50% enhancement of excretion was obtained.

Gastrointestinal Radiation Injury

Exposure of rats to fission neutrons in the Physical Constants Test Reactor (PCTR) showed that cysteine or AET afforded significant protection. Only qualitative indications were obtained due to difficulties with calibration and operation of the reactor. These difficulties indicate quite clearly that future biological studies in this reactor are not apt to justify the effort expended.

A procedure was developed for the insertion and subsequent inflation of gastric balloons in the stomach of anesthetized pigs. The procedure was tested with two miniature pigs and found to be satisfactory. Radioactive particles will be cemented on the balloons in future studies of the dose-effect relationship of ingested radioactive particles.

Preliminary work was begun toward development of procedures for studies of mechanisms for intestinal transport in large animals. The potential difference across the intestine wall was measured in the upper and lower small intestine of a male lamb. Values near 6 mv were obtained.

Inhalation Studies

Further tests to determine the requirements for optimum in vitro synthesis of fatty acids by lung tissue mitochondria confirm the importance of reduced phosphopyridine nucleotides as co-factors. Additional experiments are planned to delineate other metabolic requirements.

Plutonium analyses were completed on the tissue of a dog sacrificed 55 months after a single inhalation exposure to $Pu^{239}O_2$. The body burden at death was 0.12 μCi, 43% of which was in the lung, 50% in the bronchial lymph nodes, 3.5% in the skeleton, and 0.5% in liver.

In an experiment to learn more about the lymphopenia that occurs in dogs following inhalation of $Pu^{239}O_2$, $Pu^{239}O_2$ was injected into popliteal lymph nodes. After two months no changes in the peripheral lymphocyte counts were observed.

Dogs carrying lung and bronchial lymph node burdens of $Pu^{239}O_2$ were monitored in the Pu^{239} thorax-counter developed by Radiological Physics Operation. Use of the recently acquired dog phantom is aiding in the evaluation of external monitoring procedures for Pu^{239}. For example, site and distribution of the Pu^{239} in the chest and body weight are factors influencing the counts.

In vivo solubility of several Sr^{85} compounds was tested preparatory to inhalation studies. The oxide, carbonate, and fluoride showed greater retention in rats following intraperitoneal or subcutaneous injections than the phosphate and oxalate. Iron-59 microspheres were obtained for studies to determine whether particles 10-40 μ in diameter are deposited and retained in the lungs. These experiments are preliminary to exposure of dogs to 15 μ $Pu^{238}O_2$ particles which could be dispersed by re-entry of orbiting SNAP devices.

Pulmonary clearance of inhaled $Cr_2^{51}O_3$ particles was not altered in dogs following eleven months of smoking up to 20 cigarettes per day, 5 days per week. However, since the normal clearance of $Cr_2^{51}O_3$ is so low further tests will be run using $Fe_2^{59}O_3$ particles. This experiment is one of several preliminary tests to find methods for determining whether cigarette smoking alters the capability of the respiratory tract to remove inhaled particles.

Secondary Disease Studies

It has been reported that the antibody formed during the first two weeks following antigen injection has the sedimentation characteristics of a 19S globulin. This antibody diminishes after the first two weeks and is replaced by a 7S component. We have confirmed the fact that the hemagglutinating antibody formed during the first two weeks, in our studies, is predominantly 19S. There has been speculation that 19S antibody is formed primarily in the spleen. We have shown that splenectomized mice injected with rat antigen also produce hemagglutinating antibodies during the first two weeks, indicating that lymphoid tissue other than spleen is capable of producing antibody during this period. We have yet to establish whether this antibody is 19S or 7S.

Plant Nutrition

Growth of plants in nutrient solution containing chloramphenicol (CAP) for a period of 24 hours prior to testing, produced a significant depression in absorption of both Rb^+ and I^- ions. This is in contrast to treatment with CAP during, but not prior, to testing for ion absorption, when Rb^+ uptake, but not I^- uptake, is depressed.

Plants depleted of their energy stores by withholding light showed a marked difference in their ion absorptive rates when normal day-night conditions were re-established. At this time the uptake of Rb^+ in the dark period was relatively much greater than the uptake during the immediately preceding day period. This same difference was not apparent for I^-.

Microbiology

Indolepyruvic acid was isolated from Neurospora culture medium filtrates and positively identified. This confirmation of indolepyruvic acid is of considerable significance to the understanding of the tryptophan cycle and will provide a new basis for studies of feedback mechanisms.

Radiation Effects on Insects

Egg to adult development of three strains of tribolium was obtained on concentrations of 0.005% DDT in flour. At this concentration some retardation in rate of development, as well as some lethality, was noted in all strains tested. Several thousand pupae were sexed and are being prepared to determine the combined effects of DDT and radiation.

Columbia River Limnology

Samples of plankton, sessile green algae, diatoms, Hydropsyche larvae, chironomids, molluscs, crayfish, sponge, and shiners were collected at the F-1 station to provide information on the material balance of various radionuclides in the biota. The material is presently being counted by J. Nielsen's group.

A set of periphyton slides was placed in the F-1 riffle on October 6 and three slides removed at weekly intervals to examine the time interval for development of a stable community as indicated by chlorophyll a content. Three sets were removed before the 146-FR fire destroyed the laboratory facilities. The chlorophyll a content and animal pigments were still increasing when the experiment was interrupted.

Three aerial surveys of chinook salmon spawning were conducted in the section of the Columbia River between Richland and Priest Rapids Dam. The number of salmon nests observed on each of the surveys was as follows:

October 21	180
October 30	1021
November 16	1345

The total number of nests observed was 1443, the second highest during the 18

years that surveys have been made. The spawning area near Midway, which is between 100-B Area and Priest Rapids, was again very heavily seeded, containing more than 40% of the total number of nests observed. Manipulation of river levels by the upstream dams left some salmon nests out of the water.

Terrestrial Ecology

Barley seedlings grown in the greenhouse, in soil taken beneath hopsage, showed marked increases in sodium content following a regime of soil drought. Cheatgrass grown in the field and subjected to natural soil drought over a longer period of time showed decreased sodium content. A tentative explanation for the difference in sodium accumulation is the difference in physiological state of the plants. The barley was young and strictly vegetative, while the cheatgrass had changed to a reproductive physiology associated with maturation.

Alaskan Studies

Whole-body counts were made at Anaktuvuk Pass on 15-17 November. Eighty native residents were scanned, representing all available village inhabitants except one adult (illness) and a few children over the age of four years. Considerable equipment trouble was encountered which required operation at reduced voltage. This will delay results until calibration is accomplished at the Hanford Laboratories. Fresh caribou has been generally available to most residents throughout the period since September counts were made. Samples of caribou were obtained and are currently being analyzed.

R. C. Thompson
BIOLOGY LABORATORY

RCT:sw

TECHNICAL INTERCHANGE DATA
BIOLOGY LABORATORY

I. Speeches Presented

a. Papers Presented at Society Meetings and Symposia

B. J. McClanahan. Milk Secretion of Zinc and Cadmium in the Ruminant. IAEA-sponsored Symposium on the Use of Radioisotopes in Animal Nutrition and Physiology, Prague, Czechoslovakia. November 23-27, 1964.

b. Seminars (Off-Site and Local)

None

c. Seminars (Biology)

J. D. Berlin - Fine Structure of Centrioles and Flagella in Albugo. November 11, 1964.

J. C. Pekas - Gross and Cellular Aspects of Zn^{65} Metabolism. November 19, 1964.

d. Miscellaneous Lectures

J. D. Berlin. Peaceful Uses of the Atom. American Association of University Women, Pasco Library. November 18, 1964.

II. Articles Published

a. Open Literature

Eberhardt, L. L. Variability of the strontium-90 and caesium-137 burden of native plants and animals. Nature 204: 238-240 (1964).

Hanson, W. C. and H. E. Palmer. Accumulation of fallout cesium-137 in Alaskan natives. North American Wildlife and Natural Resources Conference, trans., 29th, 1964. p. 215-225.

Tombropoulos, E. G. Fatty acid synthesis by subcellular fractions of lung tissue. Science 146: 1180-1181 (1964).

b. HW Documents

None

III. Visits and Visitors

a. Visits to Hanford

Dr. Melvin Sikov, Wayne State University, Detroit, Michigan. A potential employee, Dr. Sikov toured the Biology facilities and discussed mutual research problems with Drs. R. C. Thompson and H. A. Kornberg. 11/17/64.

Twenty-two members of the Northwest Mosquito and Vector Conference, toured the Biology facilities, guided by R. F. Palmer and L. A. Temple. 11/18/64.

J. C. Peckham and J. E. Alexander, Washington State University, consulted with Drs. J. L. Palotay, W. J. Clarke and L. K. Bustad on mutual research problems. 11/19/64.

Dr. Miles Lodmell, Walla Walla dentist, discussed dental research problems with Dr. W. J. Clarke. 11/20/64.

Dr. W. G. Magrane, Magrane Animal Hospital, Mishawaka, Indiana, examined the experimental animals in Biology and discussed clinical ophthalmology with Biology staff members. 11/23-24/64.

b. Visits Off-site

11/2 - D. G. Watson attended a Fallout Symposium under the direction of A. W. Klement at the AEC Headquarters in Washington, D.C.

11/3 - C. E. Cushing performed biological sampling at McNary Dam, Washington.

11/3 - M. F. Sullivan discussed mutual research problems with Dr. J. Gofman at the Lawrence Radiation Laboratory, Livermore, California.

11/9-13 - W. J. Clarke discussed mutual research problems with Dr. Kirby-Smith at AEC, Washington, D.C. and P. Korychinski at NASA in Hampton, Virginia.

11/10 - R. C. Thompson visited the NASA Manned Space Center in Houston, Texas for diversification discussions with Dr. J. Billingham.

11/10-22 - W. C. Hanson traveled to Anaktuvuk Pass, Alaska for regular whole-body counting procedures.

11/14-28 - B. J. McClanahan discussed current research with Drs. I. Doniach of the London Hospital and D. M. Taylor of the Institute for Cancer Research, Royal Cancer Hospital, both in London England. Dr. McClanahan also attended the IAEA Symposium on Use of Radioisotopes in Animal Nutrition and Physiology and presented a paper - Prague, Czechoslovakia.

11/16-17 - R. O. McClellan attended the annual meeting of the American Society of Hematology in Seattle (Dr. C. Finch, President) and discussed research on thermoluminescent dosimetry with C. R. Watson at the University of Washington, Seattle.

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11/20-25 - L. K. Bustad performed library research at the University of Washington, Seattle and at the University of California, Davis. Dr. Bustad also discussed research on bone-seeking isotopes with Dr. A. C. Andersen at the University of California. Iodine-131 research was discussed with Dr. J. Gofman at the Lawrence Radiation Laboratory, Livermore, California.

11/20 - M. P. Fujihara sampled fish at McNary Dam, Washington.

11/23 - L. L. Eberhardt and W. H. Rickard sampled fallout in the Blue Mountains near Dayton, Washington.

11/25 - P. A. Olson obtained salmon eggs at the Spring Creek Hatcheries (U.S. Department of Fisheries).

11/27-12/3 - J. L. Palotay attended a meeting of American College of Veterinary Pathology in Chicago, Illinois and consulted with Drs. L. Lombard and C. Rhefeld at Argonne, Illinois.

IV. Achievements

None

V. Honors and Recognitions

None

VI. Professional Group or Organization Assignments

H. A. Kornberg was elected Chairman of the Northwest Section of the Society for Experimental Biology and Medicine for a two-year term - 1965-66.

L. K. Bustad was appointed to the Membership Committee of the Northwest Section of the Society for Experimental Biology and Medicine.

APPLIED MATHEMATICS OPERATION

MONTHLY REPORT - NOVEMBER, 1964

ORGANIZATION AND PERSONNEL

Gauin C. Moore, Technologist-Operations Research, transferred to the Finance and Administration Operation effective November 1, 1964.

ACTIVITIES FOR OTHER HAPO COMPONENTS

N Reactor Department

Closed form solutions were obtained for a mathematical model which was developed to explain and quantify the apparent exchange of materials between two supposedly closed systems.

Irradiation Processing Department

An experimental design was formulated for the purpose of determining optimal mixtures in fuel fabrication.

A study was initiated to develop a feasible sequential decision rule for the selection of the best fuel design from run-to-rupture data.

A study was initiated to develop a sampling plan and procedure for estimating the present quality of the metal in four cooling-water storage tanks.

A worst-case test result was determined such that the .90 lower confidence limit for the reliability of the Zone Temperature Monitor System would be .99 or higher.

Hanford Utilities and Purchasing Operation

A study was carried out to obtain several alternate single-stage attribute sampling plans having power curves essentially equivalent to the two-stage plan embodied in the R&D purchase specification.

ACTIVITIES WITHIN HANFORD LABORATORIES

2000 Program

Chemical Effluents Technology

The statistical study of errors in the computational sequence for permeability in heterogenous media was completed for two basic programs.

The "significance" was determined for a set of variables relative to the deposition of micron-size particles on vertical conduit walls.

C-Column Computer Control

Work continued on debugging of functional programs for the GE 412 Process Control Computer and coding of the general diagnostic program to check main frame and peripheral failures.

Radiological Development and Calibrations

A study was begun to compare the 1963 and 1964 personnel film badge exchange procedures. The respective monthly and quarterly exchange procedures are to be compared relative to excess dosages assigned per individual.

4000 Program

Both transient and steady-state solutions were obtained to mathematical models describing the application electro-magnetic wave guide theory to thermal neutron detection.

Solutions were obtained to several boundary value problems describing heat conduction in layered media, and EDPM programs were written to evalute them. These problems arose in the theory of nondestructive testing by thermal methods.

A study was initiated to compare (1) variance estimates obtained via the different "propogation of error" approximation, with (2) variance estimates obtained via a Monte Carlo technique.

An initial study of error propagation relative to the mass spectrometer considered a four-component gas. The study has been reactivated to consider the case of a twelve-component gas.

Analysis was carried out on data relative to determining an optimal shape for graphite samples used in tensile strength testing.

A design was developed for an experiment to assess the uniformity of radiation-induced changes in the length of "pieces" of TSX graphite.

A study was initiated to obtain an appropriate model for estimating the number and size of particles in a given volume of compacted fuel power as a function of time in a ball-mill.

5000 Program

Computation and Statistical Analysis

The Fortran IV program was completed and debugged for double precision calculation of the critical points of the statistical test to determine whether or not the waiting

time distribution between successive counts arises from a decaying radionuclide or from pure background. A number of tables of critical points have been computed using the program. A power function program is now being coded for this statistical test. A program is being written to determine the optimum counting schedule for the detection of a single decaying radionuclide in the presence of a constant background using the Chi-square goodness of fit statistic as the test criteria.

Improvements were made in the GEM spectrum plotter and background subtraction programs. Specifications are being written to make the MUL Multidimensional Analyzer Program applicable to the output from a new Packard 4096 Analyzer. Preparation of data for the BLU system continues.

Seven subroutines used in the calculational parts of the IRA system have been recoded in machine language to reduce program length and running time. Preliminary work has been started on a U card conversion program for the IRA system.

An analyses of data from an experiment to investigate the effect that DTPA treatment has on the removal of inhaled cerium dioxide was initiated.

Radioactive particle inhalation EDPM program which calculates body burden was modified to take into account the physical decay of the isotope.

Other

Meetings were held with Technical Information and EDPO personnel to discuss a machine program file of reactor design information to replace the current Hanford blue cover document file of this information.

Carl A. Bennett

Manager
APPLIED MATHEMATICS

CA Bennett:lg

RADIATION PROTECTION OPERATION
REPORT FOR THE MONTH OF NOVEMBER 1964

A. ORGANIZATION AND PERSONNEL

J. D. Cudmore transferred from RMO to Fission Production Chemistry effective November 16. H. N. Larson transferred from RMO to Waste Solidification effective November 16. D. E. Rickaby transferred from RMO to IPD effective November 30. H. H. Deatherage transferred from IPD to RMO effective November 30. Nancy Conrad joined EDO on November 20. Cleta McDaniel transferred from EDO to CDS&R on November 30. J. N. Paglieri became a permanent member of Nuclear Health and Safety effective November 1.

B. ACTIVITIES

There were no new plutonium deposition cases confirmed by evaluation of bioassay data during the month. The evaluation of additional urinalysis data resulted in six employees and eight former employees being reclassified as nondeposition cases. With the termination of one employee and the reclassification of the fourteen employees, the total number of individuals who have received internal depositions of plutonium at Hanford is 319, of which 226 are currently employed at Hanford.

There were five incidents involving twelve employees which required special bioassay sampling for plutonium analysis. In the one significant incident an HL employee was momentarily exposed to concentrations of air-borne plutonium up to 1.3×10^{-8} μc Pu/cc as a result of work in the Plutonium Metallurgy Facility (231-Z). High level contamination was detected, using a portable survey instrument, when the employee opened a metal can which contained plutonium waste sealed in a plastic bag. The plastic bag had apparently deteriorated and ruptured. The employee immediately replaced the plastic bag, placed the lid on the can and left the room. Nasal contamination, indicated by smears of 1000 d/m after one irrigation, was found on this employee.

There were no plutonium contaminated injuries this month. The total number for the year remains at twelve, with ten requiring excision. During the corresponding period in 1963 there were twenty plutonium contaminated injuries, with fourteen requiring excision.

Assistance was provided to IPD in the investigation of a high dose registered on an employee's badge. A home survey and subsequent filming of a small inclinometer, containing a radium painted dial, satisfactorily explained the dose to the badge. The employee kept small personal items, including the inclinometer, in a small box in his bedroom. Apparently when he left for a week's vacation he placed his badge in the box with

the inclinometer without considering the possibility of exposing the film.

Environmental Experience

During November concentrations of fallout materials in the air of the Hanford environs returned to the low values observed prior to the Chinese nuclear test explosion of October 16, 1964. Average concentrations for the six weeks ending October 16 through November 20 were 0.2, 1., 0.9, 0.4, and 0.2 pc β/m^3, respectively. Any possible environmental influence of I^{131} arriving with this fallout was masked by slightly increased I^{131} releases from the CPD stacks and by significantly increased I^{131} emission rates from the Radiometallurgy facility (327 Building) during the period October 26-November 12.

Average concentration of I^{131} in local farm milk during November was 10 pc/liter. Maximum I^{131} concentrations were 36 pc/liter at Ringold on November 10, 1964, and 32 pc/liter at Eltopia on November 4, 1964. Both farms were utilizing some fresh pasture at the time of the maximum measurement.

Surveillance of the Purex cooling swamps which had become highly contaminated in June continued. The soil sterilization program which was undertaken by CPD personnel is complete. Most of the wild grains (millet) near the swamp have been burned or covered. Wild fowl that were sampled near the end of November showed no detectable external contamination. At present, all radiation problems associated with the incident are well controlled.

Levels of radioactivity found in the Columbia River and in fish and duck flesh have been normal for this time of year. No unusual circumstances were noted during the month.

Nuclear Safety

The safeguards studies of PRTR operation at power levels up to 120 Mw were completed and a rough draft copy of the safeguards analysis document was issued for comment. It was concluded from the analyses based on a 120 Mw power level that, (1) nuclear excursions should not increase the hazard to the public over the present level, (2) consequences of coolant system failures do not vary significantly from those calculated for the 70 Mw case, and (3) the containment vessel pressure resulting from a maximum credible accident would be no higher than previously estimated for a similar accident under 70 Mw operation. Thus, environmental contamination during an accident would be essentially unchanged after increasing the power level to 120 Mw.

A simple and quick approximate method has been devised for hand calculating

fuel temperatures based on the present reactor excursion-transient model. The method is limited to calculating the following two special cases: (1) Fuel temperatures at a given constant power level. (2) Maximum possible fuel temperatures reached during an excursion.

The EASE analog computer was used for the "Intake, Distribution, and Excretion of Radionuclides in Mammals " program. This program has been dubbed IDERM. Curves for the distribution of I^{132} in tissues of a cow following the ingestion of Te^{132} have been computed. A quantitative comparison with experimental data has not yet been made, but qualitatively the model looks good. Quantitative comparisons are proceeding.

Curves for the distribution of I^{131} in man for three separate modes of intake (i.e., ingestion, inhalation, percutaneous absorption), are available. Experimental data are limited to that involving ingestion and even here only data for the thyroid burden are available. Analytical comparisons of the model with experimental data are proceeding.

Atomic Energy Commission approval of the Operating Safety Limits for the Plutonium Recycle Critical Facility and the Final Safeguards Analysis for the Physical Constants Test Reactor was given by letter on November 18.

A review of the PRTR Emergency Procedures was completed. This review found the emergency procedures to be adequate from the viewpoint of nuclear safety.

Routine audits performed during the month were as follows:

PRTR - 12
PRCF - 9

Consultations

At the request of PRTR personnel, the 256 channel analyzer was used to record the gamma spectrum of the radionuclides in the waste water at the PRTR outfall. The detector was placed in contact with the water surfaces in the outfall and the spectrum recorded. A sample of water was taken from the outfall in a small polyethylene bottle and counted several times over a period of several hours. All data and calibrations were delivered to PRTR personnel for detailed analysis.

Consultations were held with Advanced Planning Operation, CPD, on plutonium-thorium, uranium dose rates and associated shielding problems. The major difficulty is the concentration in ppm of U-232 that can be tolerated in existing facilities. Some experimental data should be available once the present batch of approximately 6 tons of thorium is processed. These experimental data will be correlated with theoretical work already completed.

Details of an air sampling system for use in the FRPP were prepared and forwarded to the Waste Calcination Operation. The system employs a crystal-charcoal filter arrangement with its associated readout equipment.

Consultation was provided to NRD on two separate occasions during November concerning methods of monitoring the release of radioactive materials from the 105-N stack during a postulated maximum credible accident.

Consultation was provided to IPD and NRD representatives on reactor effluent monitoring and sampling, emergency plans, and waste disposal procedures.

Extensive consultation was provided to RLOO and Washington-AEC Division of Operational Safety on exposure evaluation results and methods pertaining to the Columbia River.

Studies and Improvements

Twenty-four "as-built" drawings of the new densitometer were checked and approved. The drawings include all the mechanical details and assemblies, cable drawings, 026 punch modifications and electrical schematics other than card connections. Sketch drawings of the X-ray coder were prepared and forwarded to Drafting so final "as-built" drawings can be made.

The blanking die, used for cutting out the security credentials, was repaired. It was returned to the Security Operation after performance tests were satisfactory.

A Lexan film covered with dirt from the floor was irradiated at 100 KW reactor and developed. Thousands of tracks per field were present from small amounts of uranium contamination. Lexan films covering plutonium planchets were also contaminated with dirt so that no significant data were obtained. An electrodeposition machine was borrowed and decontaminated with nitric acid, detergents, and sequestrene. A new set of plutonium planchets were prepared, covered with Lexan film, and irradiated at 100 KW reactor. Blank samples showed about 10 tracks/mm^2 from contamination of the electrodeposition apparatus. Samples of 0.278 dpm of plutonium gave about 340 tracks/mm^2 when irradiated to 5×10^{16} nvt; samples of 1.39 dpm of plutonium gave so many tracks that it was difficult to count because of overlapping tracks. Planchets electroplated in a weak sequestrene solution showed that only about 50% of the plutonium was deposited. After a conference with personnel in the Optical Shop, the TV camera was remounted on the microscope and the field definition was improved significantly. The tracks are much clearer and are easy to read on the TV monitor. This method will be used to determine the track count.

The oscillating pump, installed last month to continuously meter an NaEDTA solution into the sanitary water flowing through the detector of the G.I. Dose Monitor, was unsatisfactory due to excessive vibration which eventually led to leaks in piping connections. A conventional piston metering pump was procured but found to be defective and returned to the manufacturer for repair. A motor-driven printout tape take-up reel was designed and fabricated to catch and store the water monitor output tape. The monitor is now a fully operational system and no further development efforts are planned.

The beam sweeping device for the electron Van de Graaff was installed and checked out. Initially, multiple sweeping of the beam was caused by contact bounce in the microswitches used to activate the high voltage reed switch circuits. Isolation of the microswitch noise was accomplished through installation of a mercury switch to activate the reed switch power. The microswitches operate the mercury switch which exhibits no contact bounce. Beam sweeping time is easily adjusted in a predictable manner through changing the capacitance and/or resistance in a simple time constant circuit. Sweep times as low as 0.1 msec were obtained.

The study of low level air concentrations in the Weapons Fabrication Facility was continued by collection of weekly samples at six locations. Particle size analysis was completed on an aerosol sample taken at the Plutonium Metallurgy Facility (231-Z) during a possible internal exposure incident. The mass mean diameter found was 0.32 microns with a number mean diameter of about 0.12 microns. The largest particle found was about 7 microns in size.

Two aerosol samples and a blank filter were packaged in Lexan and exposed to neutrons in a reactor test hole. After etching the Lexan, the fission fragment holes showed the typical star pattern as seen by nuclear track film. The method seems promising for relatively rapid particle size analysis of plutonium aerosols. The two filter samples showed total alpha activity levels of about 1 and 8 disintegrations per minute respectively, yet many thousands of pits were observed on the plastic. The relationship between neutron flux, number of pits, and particle size remains to be established.

A filter system for neutron detection was developed for use in a dosimeter shell similar to our current beta-gamma dosimeter. Radium-gamma and K-fluorescent X-ray exposures were made with various filter materials and sandwiches of the materials to approach gamma equivalent filters for the system. Tin, lead and solder of various amounts were used for the gamma filter. A rhodium tin and rhodium solder sandwich were used for the neutron filters. Arrangements currently are being made to develop density-dose curves for fast and slow neutron exposures from PuF_4 and an energy response curve over the available neutron emergies from the positive ion accelerator.

The positive ion accelerator was used for one series of low level neutron

exposures. Several sets of thermoluminescent dosimeters were exposed to 0.2, 0.4, 0.6 rads of 0.8 Mev fast neutrons. Since the time available on the accelerator was very limited, no further exposures could be obtained. For these exposures, every dosimeter set gave a positive result. The results from previous accelerator exposures were not this encouraging as reported earlier. The detection of 0.2 rads is more in line with the minimum sensitivity of 0.1 rads determined using the isotopic neutron sources (PuF_4 and PuBe).

Several measurements of the surface dose rate of a PuO_2 sample were taken using the thermoluminescent phosphor. The composition of the plutonium sample was 90.45% Pu^{239}, 8.47% Pu^{240}, 0.92% Pu^{241} and 0.048% Pu^{242}. The surface dose rate was between 1.55 - 1.77 rads/hr depending on energy response corrections used. These measurements agreed reasonably well with extrapolation chamber results. Several measurements taken two inches above the surface were lower than measurements taken using the Hanford film badge.

A total of 500 Stephens pencils and 14 Stephens chargers are on order. Two hundred pencils and 10 chargers were received and are undergoing preacceptance tests. The first 300 pencils and 7 chargers passing specifications will be delivered to IPD. The remaining 200 pencils and 7 chargers will be delivered to RMO. About 300 pieces of film were exposed to various doses of fluorescent and filtered X-rays from the 220 Kv X-ray for AEC, Idaho Falls. Exposures, detailed in their request letter, were made to identified film and badges supplied by Idaho Falls. During the month 70 CP Meters, 25 Juno Meters, 3 damaged GM Meters, 5 RF Junos and 6 other pieces of worn, damaged or unneeded equipment were either cannibalized or excessed.

Renovation of the iodine monitors at the Purex and Redox stacks has been essentially completed. The renovation included the installation of single-channel spectrometers, shields, and counting cells. These have been tied into the existing sample lines and scrubber columns. Initial operating experience indicates a five-fold increase in sensitivity. The monitors are now capable of detecting an emission of 0.1 curie of I^{131} in a 24-hour period. Work remaining includes tie-in to alarms and installation of a recorder in the Redox operating gallery.

The Thorium Target Element Pilot Plant (3732 Building) stack sampler has been installed and is operating satisfactorily. Sampling upstream of the absolute filter will be started at the request of IPD as a measure of filter efficiency.

The Hanford 614 Building located near the Pistol Range was discontinued. The air sampling equipment was relocated one mile east, just opposite the Hanford Transportation Maintenance Shop.

Since August of this year, routine surveillance of chemical changes in Columbia River water has been done by analysis of weekly grab samples at the Richland Water Plant. Beginning this month, the routine sample was changed to an integrated sample to give a better estimate of average river concentrations of the species of interest, hexavalent chromium and nitrate. Occasional grab samples will still be taken at times of expected maximum concentrations.

A study of the hazards of in-tank solidification (see significant reports) was completed by a task force composed of CPD personnel and a member of ES&EO. The basic program is designed to condense non-boiling process wastes, which are now stored in the tank farms, so that a salt cake is formed. Radioactive materials will, therefore, remain in the salt cake after the tanks have lost their integrity. The most serious accident that could occur appeared to be an explosion, either from organic material entering the tank and being ignited, or from a cyanide-nitrate chemical reaction. Under any circumstances it appears that significant radioactive contamination would not occur off the Hanford project.

The electronic equipment to be used for wound counting at the 700 Area First Aid Station was received. Detectors have been built and, pending final check out, the system is ready for use. The 1/4-inch crystal probe was received.

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. Advantage was taken of low river flows on weekends to run equilibrium dye concentration studies from B and K Areas. The data showed essentially complete mixing of effluents from these areas at Ringold and downstream at the low river flows prevailing (40,000-45,000 cfs).

Mechanisms of Environmental Exposure

An experiment to study the uptake and retention of P^{32} by volunteers eating Columbia River fish was completed except for measurement of the P^{32} elimination. A schedule of in-vivo measurements and excreta analyses was prepared to complete the study. Laboratory analyses and computation of the results are expected to require some time. Whole body counts to observe Zn^{65} elimination will continue for about two months. The preliminary results indicate some unexpected ambiguity, for example, the P^{32} content of blood samples appears to be lower than would be anticipated from direct counts of the subjects. There is some indication that the early creatine analyses lacked precision and this part of the experiment will be repeated.

Nuclear Facilities Monitoring Guide

A section of the Guide which reports the radionuclide composition of the effluents of the major power reactors in the U. S. was completed. It will be followed by a description of a system for evaluating the radiation protection significance of each effluent contained radionuclide. Such a description was begun during the month.

C. TRAINING

A talk on the capabilities of the Hanford beta-gamma film badge dosimeter was presented to PRTR Maintenance personnel.

A lecture on PRTR radiation protection practices was presented to new craftsmen as part of the PRTR craft training program.

Approximately 15 radiation orientations were given to personnel in 328, 329, and 325 Buildings.

Two talks and two practice exercises on the HAPO "Emergency Plan in the Event of a Criticality Accident" were presented to RPO exempt personnel.

Four more classes were held in the course, "Radiation Protection Training for Exempt Personnel." This completes the planned schedule for this course.

The final session on "Elementary Nuclear Physics" was held in the "Second Radiation Monitoring Refresher Course." In addition, the first four sessions on "Radiological Civil Defense" and "Control of Tritium Radiation Problems" were held.

F. SIGNIFICANT REPORTS

HW-84451 "Shielding Requirements for Moxtyl Fuels" by L. G. Faust, dated May 22, 1964. This was documented from a letter at the request of K. Drumheller for inclusion in a forthcoming book entitled, "Selected Reactor Topics for 1964."

HWIR-1771 "Automatic Densitometry to Read and Check Identification Numbers and Densities of Developed Films from Personnel Metering Badges and Punch That and Other Data Automatically on Data Processing Cards" by L. F. Kocher and P. C. Friend, October 28, 1964.

HWIR-1770 "A Machine for X-ray Coding the Identification Number on Personnel Film for Routine Processing" by L. F. Kocher and P. C. Friend, October 28, 1964.

HWIR-1777 "A Mechanized Film Badge Processing Machine" by L. F. Kocher and P. C. Friend, November 10, 1964.

HW-80892-10 "Radiological Status of the Hanford Environs for October 1964," R. F. Foster.

G. E. Backman, E. M. Johnston, H. C. Rathvon, L. W. Roddy and M. F. Wiitala, "Chemical Processing Department Hazards Evaluation In-Tank Waste Solidification Project CAC-965" (RL-SEP-65) November 24, 1964.

HW-84543 "Radiation Monitoring Operation Monthly Report, November 1964," A. J. Stevens.

A. R. Keene
Manager
RADIATION PROTECTION

AR Keene:np

FINANCE AND ADMINISTRATION OPERATION

ACCOUNTING

Cost Accounting

The Hanford Laboratories' control budget was adjusted during the month as follows:

1. Reallocation of the Plutonium Recycle Program to provide for the reprocessing of spent fuels:

		Increase (Decrease)
Test Reactor & Auxiliaries		
Spent Fuel Reprocessing	$171 000	
Plutonium Recycle Test Reactor	(26 000)	$145 000
Reactor & Fuels Laboratory		(72 000)
Chemical Laboratory		(69 000)
Physics & Instruments Laboratory		(4 000)
Total		$ --

2. Increase in funds for additional off-site research and development and fabrication:

NASA	$150 000
Project Whitney	40 000
Saxton Fuel Elements, Picatinny Arsenal & Others	210 000
Total	$400 000

Midyear Budget Review requirements as established by Contract Accounting were complied with and budget estimates for FY 1965 were submitted to Contract Accounting on November 20, 1964. A call letter has been received from RLOO-AEC which requests additional information on programs for FY 1966, both operating and equipment. Due date for the additional program data is December 16, 1964.

Letters were forwarded to the Product Departments detailing equipment funds needed to conduct sponsored research and development work - responses to date have been disappointing.

Available equipment funds were allocated to sections as follows:

Component	04 Prog.	05 Prog.	06 Prog.	08 Prog.
Test Reactor & Auxiliaries	$325 000-1)	$ --	$ --	$ --
Physics & Instruments Lab.	110 000	130 000	65 000	--
Chemical Laboratory	175 000	95 000	40 000	40 000
Reactor & Fuels Laboratory	180 000	75 000	--	--
Biology Laboratory	--	--	170 000	--
Total	$790 000	$300 000	$275 000	$40 000

(1- Includes $300,000 for second generation shim rods.

Activities for which special accounting codes were established are:

.5M "Plutonium Fuel Cycles - Thermal Reactors" Book - $55,000. Two Laboratories' employees will serve as principal authors on the timely preparation of this book.

.2W Laboratories has been requested to Nupak UO_2 for Westinghouse Corporation - $518.

General Accounting

Approval letter No. AT-364, AEC Monograph on Plutonium - Its Industrial Hygiene Aspects - Dr. R. C. Thompson, is in process.

OPG 2.3.9, N-Reactor Department General Manager Position Guide, page 2, and OPG 3.4.18, Technical Graduate Development Program, were revised.

Hanford Laboratories' net material investment at November 1, 1964 totaled $28.7 million as detailed below:

	(In thousands)
SS Material	$ 27 092
Reactor & Other Special Materials	1 258
Spare Parts	57
Exotic Materials	378
Subtotal	28 785
Reserve: Spare Parts	(84)
Net Inventory Investment	$ 28 701

The cumulative value of nuclear material consumed in research by Hanford Laboratories during FY 1965 (at November 1, 1964) is shown below:

02 Program	$ (10 472)
03 Program	272 942
04 Program	(255 985)
Total	$ (93 515)

The credit in the nuclear material consumed in research is due primarily to return of material to Redox at full value.

The status of Hanford Laboratories' heavy water inventory at November 30, 1964 is as follows:

	Current Month		FY to Date	
	Pounds	Value	Pounds	Value
Beginning Balance	56 884	$763 686	32 762	$447 572
Acquisitions	--	--	27 445	379 015
Scrap Returns (SR00)	--	--	--	--
Removals (Off-Site)-1)	(8)	(105)	(8)	(105)
Consumption-2)				
PRTR: Loss	(815)	(11 263)	(4 138)	(57 203)
Scrap	--	(435)	--	(17 396)
Ending Balance-3)	56 061	$751 883	56 061	$751 883

(1- Heavy water shipped to the University of Oregon at the request of the AEC.
(2- Consumption - Scrap reflects amount charged to Cost only.
(3- Includes 15,847 pounds of heavy water scrap valued at $196,064.

Laboratory Storage Pool activity is summarized as follows:

	Current Month		FY to Date	
	Quantity	Value	Quantity	Value
Beginning Balance	1 929	$1 197 990	2 027	$1 493 571
Items Received	119	53 617	598	464 653
Items Reclaimed by Custodians	(547)	(118 360)	(784)	(639 693)
Equipment Transfers	(31)	(9 532)	(184)	(85 677)
Items Disposed by PDR	(7)	(15 833)	(45)	(27 123)
Items Disposed by Excess	(55)	(89 662)	(204)	(187 511)-1)
Ending Balance	1 408	$1 018 220	1 408	$1 018 220

(1- Includes 140 items valued at $75,431 on loan at November 30, 1964.

Loans & Transfers in Lieu of Purchases	Current Month Quantity	Current Month Value	FY to Date Quantity	FY to Date Value
Loans	19	$ 8 058	81	$ 40 680
Transfers	31	9 532	184	85 677
Total	50	$ 17 590	265	$ 126 357
Operating Costs (10-31-64)		$ 1 206		$ 5 502

Laboratory Storage Pool material and equipment at November 30, 1964 totaled $1.9 million as detailed below:

Equipment	$1 018 220
Reactor & Other Special Materials	272 430
SS Material	154 800
Other Materials	446 632
Exotic Materials	57 506
Total	$1 949 588

The Laboratory Storage Pool was requested by the AEC to evacuate the outside storage yard being utilized for storage purposes prior to December 31, 1964. In connection with this evacuation and in preparation for the transfer of plant and equipment to Battelle-Northwest, a review was made of all equipment located at the Pool for disposal action. As a result of this review, PDRs and Excess documents were prepared for equipment valued at $180,000, of which $105,495 were removed from record in November. The balance will be removed in December.

Arrangements have been completed and procedures issued for the transfer of plant and equipment and materials (Reactor and Other Special Materials and Exotic Materials) from General Electric Company to the Pacific Northwest Laboratories - Battelle Memorial Institute, as of midnight, January 3, 1965. Plant and Equipment EDP runs were prepared in quadruplicate by the data processing method, listing all items of property by custodian as of November 30, 1964, and submitted to Property Control for verification. These runs, with December business (receipts and deletions) manually added to or deleted from, will become the basic official transfer document relieving the General Electric Company of responsibility and establishing custodial responsibility for these assets with Battelle-Northwest.

These tabulations with a certification signed by the subsection manager certifying as to the accuracy of the list shall be completed and returned to Property Accounting on December 31, 1964. In general, the procedure for transferring Reactor and Other Special Materials and Exotic Materials

is the same as set forth for the property, except that verification of materials will be done in conjunction with the regularly scheduled quarterly inventory at the end of December 1964. This inventory will be taken December 21, 1964 and the results returned to Property Accounting on December 28, 1964.

New money was authorized General Electric on projects as follows:

CAH-100	High Temperature Lattice Test Reactor	Additional $30,000; making a total of $80,000.
CAH-146	Atmospheric Physics Building	$750

The following contracts were processed during the month:

CA-476	Henry Eyring
SA-352-1	Dean E. Ganders, dba Ganders Aircraft Repair
SA-378	The Swedish Hospital

Personnel Accounting

Suggestion awards for November which amounted to $1,135 were paid to 23 employees.

L. M. Strong retired effective December 1, 1964.

Personnel statistics follow:

Employee Changes	Total	Exempt	Nonexempt
Employees at beginning of month	1 848	801	1 047
Additions and transfers in	38	12	26
Removals and transfers out	35	15	20
Employees at end of month	1 851	798	1 053

Overtime Payments During Month	November	October
Exempt	$ 8 132	$ 4 979
Nonexempt	29 169	29 442
Total	$ 37 301	$ 34 421

Gross Payroll Paid During Month		
Exempt	$ 819 973	$ 833 657
Nonexempt	621 971	601 525
Total	$1 441 944	$1 435 182

Participation in Employee Benefit Plans at Month End	November Number	November Percent	October Number	October Percent
Pension	1 752	98.3	1 751	99.3
Insurance Plan - Personal	381		388	
- Dependent	1 460	99.6	1 451	99.6
U. S. Savings Bonds				
Stock Bonus Plan	170	35.6	161	33.7
Savings Plan	70	3.8	71	3.8
Savings & Security Plan	1 199	86.9	1 198	86.9
Good Neighbor Fund	1 336	71.9	1 330	71.7

Insurance Claims	Number	Amount	Number	Amount
Employee Benefits				
Life Insurance	-0-	$	-0-	$
Weekly Sickness & Accident	6	437	8	639
Comprehensive Medical	37	2 146	49	2 874
Dependent Benefits				
Comprehensive Medical	89	9 351	83	7 437
Total	132	$11 934	140	$10 940

TECHNICAL ADMINISTRATION

Ten nonexempt employment requisitions were filled; 72 remain to be filled.

Suggestion Plan activity:

Suggestions received	11
Suggestions adopted	24
Suggestions rejected	26
Suggestions in process	42

Visitors Center activity:

November attendance	1 259
Average attendance per day open	52
Cumulative attendance since 6-13-62	82 366
Conducted groups	5 (totaling 112 people)

Plant tour activity:

	Number	Total People
General public relations tours	3	102
Special tours	3	28

Overall recruiting results for November are as follows:

Offers extended	6
Offers accepted	1
Offers rejected	4
Added to roll	0

Advanced Degree - Four Ph.D. applicants visited HAPO for employment interviews. Four offers were extended; one acceptance and four rejections were received. Two offers are currently open.

BS/MS (Direct Placement) - One offer was extended. There were no acceptances and no rejections received. There is one offer currently open.

BS/MS (Program) - One offer was extended. No offers were accepted and no offers were rejected. There is one offer currently open.

Technical Graduate Program - Six Technical Graduates were placed on permanent assignment. No new members were added to the roll and no one terminated from the roll. Ten members transferred to the General Electric Technical Graduate Program. Current Program numbers 19.

Hanford Laboratories hosted a meeting of the Weapon Contractors Classification Conference on November 18 and 19. Representatives of 16 weapon sites attended.

FACILITIES ENGINEERING

Projects

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 $11,899,000. Expenditures through October 31, 1964 were $5,301,000.

The following summarizes project activity in November:

Authorized projects at month end	13
New projects authorized	0
Projects completed	0
New projects submitted to the AEC in November	1

New projects awaiting AEC approval ---------- 2
- CAH-123, Laboratory Fire Protection System
- CAH-157, Services for Biology Laboratory and Future Facilities - 300 Area

Project proposals being prepared ---------- 5
- Power Supply - Million Amp Welder
- Geological and Hydrological Wells - FY 1965
- PRTR Increased Power Level
- Shielded Creep Test Facility - 3707-C Building
- Experimental Facility Addition - 309 Building

The status of active projects follows:

CAH-100 High Temperature Lattice Test Reactor

Detailed design is 96 percent complete compared to a scheduled 100 percent. A total of $337,000 has been expended for design efforts to date.

The Commission agreed with the Company's recommendation that the reactor control system be completely computerized and instructed the Company to cooperate with Vitro in the preparation of specifications for vendor fabrication of the system.

Ground was broken for Phase I construction on November 3, 1964. The contractor, George A. Grant, Inc., began excavation for the building about November 16.

CAH-116 PRTR Decontamination and D_2O Cleanup

Design is 98 percent complete compared to a scheduled 100 percent. Construction specifications for the decontamination building have not been approved, and equipment acceptance test procedures have not been issued for comments.

The J. A. Jones Company is procuring equipment and materials for fabrication of the D_2O cleanup system.

CAH-119 PRTR Storage Basin and Experimental Facilities Modifications

Design is complete except for issuance of heating and ventilating specifications and ATPs.

Construction of the basin and building addition is about 17 percent complete and on schedule.

Excavation for the basin is complete. Concrete pouring was started late this month.

An official schedule was issued on October 28. Construction is scheduled to be completed by July 1, 1965, and installation of underwater equipment is scheduled to be completed by August 1, 1965.

CAH-123 Laboratory Fire Protection System

The Commission has taken no action on the project proposal submitted to them on March 3, 1964.

CAH-126 Waste Transport System

Design is 95 percent complete compared to a scheduled 100 percent. Thirteen drawings have been issued for comment. The construction specifications have not been issued. The Company has disapproved the waste unloading system.

CAH-136 Service Addition, 327 Building

Design is approximately 98 percent complete compared to a scheduled 100 percent. Final drawings are being reviewed for approval.

CAH-137 Temporary Physical Sciences Center

Design is 95 percent complete. Construction at the 3201 building is 75 percent complete compared to a scheduled 60 percent.

Work not completed includes installation of the PABX system and telephone cables, and installation of the fire protection sprinkler system.

CAH-146 Atmospheric Physics Building

Two Architect-Engineer representatives were taken on a tour of the site to familiarize them with the environs and requirements of the Atmospheric Physics Operation.

CAH-151 Office Addition, 308 Building

Design is about 97 percent complete compared to a scheduled 100 percent. The construction specifications are being reviewed for comment. Construction drawings have not been received for final review.

CAH-153 Plutonium Recycle Critical Facility, Irradiated EBWR Fuel Handling

Design is 90 percent complete compared to a scheduled 92 percent. It is planned to install monorail supports and perform shielding block core drilling during shutdown of the facility in December.

CAH-157 Services for Biology Laboratory and Future Facilities, 300 Area (Formerly CAH-155 Services to Biology Facilities, 300 Area)

The proposal for Project CAH-155 was returned by the Commission for a major scope change to broaden its range. Project CAH-157 is the result of the rescoping. The project proposal and design criteria document were submitted to the Commission on November 12 for review and approval.

CAH-916 Fuels Recycle Pilot Plant

Construction is 80 percent complete compared to a scheduled 74 percent. Concrete pouring on the cells is continuing. Heating is now required to prevent freezing and retardation of curing. Cool, wet weather is causing some problems for the painters doing work on uncovered areas.

The main exhaust stack was temporarily used by the Commission and Hanford Laboratories for a "High Expansion Foam Test." The stack was the test vessel.

CAH-962 Low Level Radiochemistry Building

Construction is 35 percent complete and on schedule. The replacement, precast, exposed aggregate wall panels were erected on the building frame. Installation of roofing, piping, and the sheet metal and electrical systems is continuing.

CAH-977 Facilities for Radioactive Inhalation Studies

A revised design criterion is being prepared for submission to the Commission. The revision was necessitated by the change in scope of the utilities systems being provided under Project CAH-157. It is now estimated this project will cost $217,000.

CAH-982 Addition to Radionuclide Facilities

This project was also revised as a result of the changes in Project CAH-157. A revised design criterion document is being prepared reflecting the changes in scope. The estimated cost of this project is now $197,000.

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) review of Vitro's specification for - (a) automatic computerized reactor control system for High Temperature Lattice Test Reactor, Project CAH-100 - (b) PRTR Storage

Basin and Experimental Facilities Modification, Project CAH-119 - and (c) for heating and ventilating, and electrical systems of Office Addition, 308 Building, Project CAH-151; (2) review of Vitro's drawings for electrical work in 3707-C building and computer room heating and ventilation in 3201 building, as part of Temporary Physical Sciences Center, Project CAH-137; (3) issuance of four comment and seven approval drawings of 13 estimated ones for PRCF Irradiated Fuel Handling System, Project CAH-153; (4) submission of a design change to improve motor control center locations and one to provide larger access doors to lobby electrical panel in FRPP, Project CAH-916; and (5) preparation of design criteria as follows: (a) revised draft and scope drawing for PRTR replacement deaerator; and (b) for shielded creep test facility at 3707-C building.

Engineering and consulting work was provided to research and development personnel as requested. Major work items included: (1) preparation of drawings for a shielded sampler installation for 324 building waste calcination demonstration; (2) study of removal of highly radioactive filters from 327 building; (3) development of cell equipment for 292-T building; (4) determination of lighting and power layouts for 324 building sample load-out; (5) review of PRTR alarm systems; (6) preparation of a letter regarding further problems which AEC foresaw in connection with one million amp welder on 115KV system; (7) issuance of approved drawings for fabrication and installation of light water core; (8) submission of scope drawing for removal of manipulators from low bay cell to 324 building operations; and (9) investigation and preparation of preliminary drawing for proposal to add stainless steel liner in unlined radiochemical cells in 324 building.

Plant engineering work included: (1) preparation of specifications and sketches for - (a) 308 building shop ceiling - (b) improved maintenance lunch room at 326 building - and (c) replacement of steam space heaters in 314 building; (2) review of PA system bids for 314 building; (3) study of - (a) installation of 480 volt feeder and panel in 329 building - (b) improvement in air condition reliability at Priest Rapids Gage Station - (c) types of roofs and fire protection or detection systems of Hanford Laboratory buildings - (d) communication system for 325 building cells - and (e) a motor-driven light interrupting disk for use in wind tunnel for fallout studies; (4) compilation of recent electrical work in 146-FR building for roof fire investigation; (5) determination of electrical corrections required to bring new trailer at 100-F into specifications; and (6) development of a circuit to shut down 108-F chilled water pump when excess temperature occurs.

Consulting services for other departments included assistance on: (1) control of dry-air supply to the hood line at 234-5 building, wherein improper controller had been furnished and supplier will investigate; and (2) continued investigation of an alternate source of power for N-plant.

Pressure Systems

Facilities Engineering has provided assistance in directing fabrication and providing inspection for the PRTR Film and Corrosion Loop. The job is 30 percent complete. Work was done in "B" cell at PRTR during the last outage but core drilling required more time than anticipated and the piping was not extended into "A" cell as intended. Shop work will continue until the next outage, but unfortunately most of the remaining work will be in the field.

Chemical Research Operation has been assisted by Facilities Engineering in the design of a small teflon-lined Hastelloy "B" reaction vessel for high temperature acid dissolution of uranium samples at 2000 psig and 400 F.

Process Control Instrument Development has been assisted by Facilities Engineering in design and fabrication of a pressure vessel for strain gauge testing. The vessel will be carbon steel, 10" in diameter and 12" long and will operate at 2000 psig and 600 F.

Four ion exchange vessels will be built by Coolant Systems Development Operation for use in the PRTR Moderator system. The vessels will be fabricated from 14" pipe and pipe caps and designed for 125 psig and 150 F. The tanks will be part of a prototype facility.

Containment Systems Experiment

Chicago Bridge & Iron Company, subcontractor for the Containment Vessel, is on site and erection work started this month. J. A. Jones' field work is presently confined to preparatory work in the laboratory room. A few of the offices are occupied by Chemical Effluents Technology personnel.

Design is continuing by Vitro for the laboratory and associated equipment and instrumentation for the program.

The Commission approved the proposal of Struthers-Wells Corporation, and J. A. Jones is completing negotiations for the Simulator Vessel.

Expenditures to date appear in the following order of magnitude:

Design (Vitro)	$ 42 000
Scope, Administration, Estimating, etc.	28 000
Construction and Procurement	245 000*
Total	$315 000*

*Excludes Containment and Simulator Vessels which amount to about $390,000 as commitments for FY 1965 and FY 1966.

Facilities Operation

Costs for the month of October were $244,409, which is 106 percent of the forecast for the month. The costs for the first four months of FY 1965 are $703,357, which is 91 percent of the predicted year-to-date. This $703,357 also represents 65 percent of the predicted expenditures for the first six months.

Waste Disposal

The following table summarizes the Waste Disposal Operation:

Item	September	October
Concrete waste barrels disposed to 300-wye burial ground	6	0
Concrete waste barrels disposed to 200-W burial ground	12	6
Loadluggers of dry waste disposed to 300-wye burial ground from 300 Area sites other than the 325 building	45	68
Loadluggers of dry waste disposed to 300-wye burial ground from the 325 building	6	23
Loadluggers of dry waste disposed to 200-W burial ground from 300 Area sites	7	5
Containers of high level dry waste disposed to 300-wye burial ground waste tanks	83	82
Crib waste volume, gallons	280 000	280 000

No unusual incidents occurred during the month at 300-wye burial ground.

None of the retention basins exceeded the Class II activity levels during the month.

Building Operations

Minor routine maintenance work was completed at the filter plant. Additional work is scheduled as soon as 309 work load permits.

The new reheat coils were installed in #4 unit at 308 building during November. All four instrument air drying towers were recharged with alumina to increase their drying efficiency.

Numerous leaks were repaired in 306 building. Process work in this building prevents the use of filming amine in the steam supply, and the resulting steam and condensate corrosion is much greater than in those buildings where amine is used.

A new booster coil was installed in 326 building system. Supply and exhaust fan motor sheaves are worn sufficiently to affect good belt operation. Consideration is being given to replace these worn adjustable sheaves with a solid sheave. This would reduce the cost of sheave replacement by 70 percent.

All steam valves in 329 building, available for maintenance, were repaired or repacked on Saturday, November 14.

The diesel generator in 326 building is being checked on a monthly basis by Transportation mechanics, and is being operated each week by the power operators.

The office supply fan motor in 328 building was repaired and reinstalled. Belt guards are being fabricated for this unit.

Number 2 wash pump in 3760 building was overhauled.

Drafting

The equivalent of 199 drawings was produced for an average of 23.6 man-hours per sheet.

Major designs completed or in progress are: (1) powder processing line; (2) high temperature furnace for NASA program; (3) FRPP service piping, instrument and electrical work for waste solidifcation equipment; (4) underwater measuring equipment for calibrating elements in N area; (5) scope layout of new equipment for increased power level at PRTR; (6) scope arrangement of equipment and architectural work for sodium pump test facility at PRTR; (7) critical mass expansion tanks for 209-E building; (8) powder preparation laboratory; and (9) a Picatinny Arsenal Ordnance projectile design.

Drafting services are also supplied in support of other laboratory engineering programs.

Construction

	Unexpended Balance
Orders outstanding beginning of month	$646 208
Issued during the month (incl. suppl. & adj.)	252 386
J. A. Jones expenditures during month (includes CO cost)	161 942
Balance at month end	736 652
Orders closed during month	119 328

Maintenance Work Orders active - 5, Face Value - $18,860.

Major nonproject jobs in progress during the month were: (1) 100 Areas - construction of an electron microscope in 108-F building, remodeling of men's and women's rest rooms in 141-M building, construction of new concrete pads and partitions in 141-F building, remodeling of dog pens and dog runs in 144-F building, completion of fire detection systems in five buildings in 100-F Area; (2) 200 Area - containment systems experiment work in 221-T building; (3) 300 Area - procurement and installation of a new rectifier for arc melt furnace in 306 building, installation of hydraulic snubbers, construction of access manholes, fabrication and installation of corrosion film loop, and installation of Henry Pratt door openers in 309 building, construction of an enclosure for a gas loop in 314 building, performing electrical and pipe work in the 321 building and installed a metal building for an air conditioner for the 321 building, completion of five offices and women's lounge in 325 building, modified the entrance and enlarged gas bottle dock for the 329 building - also installed hoods and services in laboratory 11-B of this building, constructed a personnel change and survey building near the 340 building, constructing partitions and change doors in the 3717-B building, constructed an office and enlarged the rest rooms in the 3718 building, constructed an addition to the 3718-C warehouse; and (4) General Area - continued work on the contingency maintenance items for the 3201 building, patched miscellaneous blacktop roadways and installed guard rails in the 300 Area, and fabricated racks for the waste solidification engineering prototype.

Well Drilling Program - FY 1965

The final draft of the project proposal is being typed.

146-FR Building Fire

A fire which occurred on the night of November 3, 1964 completely destroyed the roof of this building and seriously damaged all equipment and services.

A work order has been issued to relocate the fallout and limnology laboratories on the third floor of 108-F building. Restoration of the fish laboratory, pump and ventilation rooms and services is expected to proceed shortly at the 146-FR building.

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 November was 1,477 MWD for an experimental time efficiency of 83% and a plant efficiency of 70%. There were five operating periods during the month, two of which were terminated manually, two were terminated by scrams, and one continued through month-end. A summary of the fuel irradiation program as of November 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	1953.1	77	14680.5			84	16633.6
Maximum				364.3		397.2				
Average				279.0		190.6				
In Basin	7	572.5	26	2769.0	51	6671.6			84	10013.1
Buried							1	7.3	1	7.3
Chem. Process.	68	5465.8	35	1965.8					103	7431.6
Program Totals	75	6038.3	68	6687.9	128	21352.1	1	7.3	272	34085.6

(Note: MWD/Element x 20 $\sim$ MWD/TU for UO_2 and PuO_2-UO_2.)

Heavy water loss and indicated helium loss for the month were 815 pounds and 114,290 scf., respectively.

Equipment Experience

Installation of the prototype Second Generation Shim Control Rod was completed during the month. Features of this assembly include: 1) packaged drive assembly, utilizing gearing, located above the top shield and detachable from the lower assembly, 2) Zirconium lead screws, 3) swivel calandria gas seal, 4) accurate synchro readout and rotary limit switches. Some sticking has been experienced which is attributed to the non-prototype 1/16 inch lead screw balls.

Preventive maintenance utilized 496 manhours, or 11.5% of available manhours of assigned craftsmen.

Improvement Work Status (Significant Items)

Work Completed

C Cell Instrument Tubing Penetration
Installation of Second Generation Shim Rod
Voltage Off Normal Detection and Alarm for 24 Volt Battery System
Tube #1354 Flow Test of Short Fuel Element

Work Partially Completed

Corrosion Loop Installation
Air Lock Door Operators
Modification to PRTR Warehouse 3718-C
Vibration Snubbers for Earthquake Protection
Supplemental Emergency Water Addition
PRTR Steam Utilization
Additional Fuel Storage and Examination Facility
Creep Test Facility
Flux Wire Scanning System
D_2O Cleanup Facility
Alarm Annunciator - High He Flow to RLT-1

Design Work Completed

Pneumatic Irradiation Facility
A Cell Sump Pump Control

Design Work Partially Completed

Instrument Power Supply
Decontamination Building
PRTR Experimental and Building Facility Addition
PRTR Increased Power Level
"B" Cell Instrument Tubing Penetration

Process Engineering and Reactor Physics

The primary piping radioactivity was surveyed in detail to obtain an estimate of the quantity of activity contained and to determine the distribution of the activity. It was estimated that the primary system contains activity equivalent to 35 curies of cobalt 60 exterior to the ion exchangers. This quantity of Co-60 would have a dose rate of 500 R/hr at a distance of a foot if unshielded. It was found that there was no outstanding variation of radiation along the length of piping and around valves, which would tend to indicate that loose crud is not a significant contributor.

Performance of the maximum secondary flow portion of PRTR Test No. 73 (Maximum Secondary Coolant and Raw Water Flows) was completed. Maximum boiler feedwater flow achievable under the test conditions with three boiler feedwater pumps operating was in the range of 800 to 900 gpm. Test data is being analyzed to determine the actual flow rate.

Experimental Reactor Services

The status of the various test elements at the end of November 1964 is shown below. Those elements which had reached their assigned goal exposure or had been permanently discharged for other reasons prior to November 1, 1964, have been deleted from this table.

Test No.	Channel Location	Element Number	Description	Initial Charge	Date Discharged	Approximate Accumulated MWD
14	1956	5097	Moxtyl-Swaged	4/2/62	--	240.5
14	1758	5099	Moxtyl-Vipac	5/8/62	--	249.8
48	1156	5150	Moxtyl ($\frac{1}{2}$" x $\frac{1}{2}$" pads)	8/1/62	--	252.1
54	1542	5116	Moxtyl (clip on pads)	5/8/62	--	397.2
54	1554	5118	Moxtyl (clip on pads)	5/8/62	--	270.6
61	1249	5186	Moxtyl-Physics	5/28/63	--	270.6
61	1445	5192	Moxtyl-Physics	6/13/63	--	262.9
67	1047	5117	Moxtyl (Repaired Wire)	10/20/63	--	221.5
80	1746	5214	Moxtyl (1% PuO_2, Swaged)	11/18/63	--	229.4
85	1855	5230	Moxtyl (1% PuO_2, Vipac)	1/30/64	--	163.5
37	1548	1098	UO_2-Physics	5/12/62	--	248.2
72	1253	5253	Zircaloy Coupons (1% PuO_2)	9/1/64	--	83.0
105	1354	6000	UO_2-2 w/o PuO_2, 58" long	10/26/64	--	33.0
107	1255	6001	UO_2-2 w/o PuO_2, flux wire	11/20/64	--	8.5

Five irradiated fuel elements were inspected during the month. Eight rods from element 5185 were shipped to Radiometallurgy for examination.

Fuel Element Rupture Testing Facility

The irradiation of swage compacted UO_2 fuel element 1039 with the 3 inch longitudinal slit was completed on November 15, 1964. The test element had endured 447.25 hours of operation, including three startup-shutdown cycles in which full power was achieved, and accumulated 7.87 MWD or 129 MWD/Ton exposure for a total exposure of 133 MWD. The test element was inspected and photographed in the storage basin. No evidence of defect propagation or of fuel release was apparent.

Irradiation of UO_2 element 1030 with a 6-1/2 inch slit in the cladding was started on November 25, 1964. Two scrams from powers of about 25 MW were experienced before the stable full power of 70 MW was achieved. At the end of the month, the test element had endured 134.8 hours of operation and had accumulated 2.68 MWD exposure. The coolant activity was about a factor of three higher than that observed with the 3 inch slit.

Chemical Processing of Spent PRTR Fuels

Arrangements were made with Redox Operation of CPD to conduct a chemical processing campaign in March of 1965. Approximately 14 UO_2, 4 Al-Pu and 20 UO_2 - .5 w/o PuO_2 PRTR fuel elements will be processed along with 208 I and E depleted uranium fuel slugs from Production Test 231-A to produce 7 Kg of plutonium containing 20% Pu^{240} isotope.

TECHNICAL SHOPS OPERATION

Total productive time for the period was 21,558 hours. This includes 14,432 hours performed in the Technical Shops, 4,967 hours assigned to J. A. Jones Company, and 2,159 hours assigned to off-site vendors. Total shop backlog is 17,954 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 663 hours or 3.8% of the total available hours. Distribution of time was as follows:

	Manhours	% of Total
N Reactor Department	2 495	11.6
Irradiation Processing Department	2 951	13.7
Chemical Processing Department	377	1.7
Hanford Laboratories	15 735	73.0

LABORATORY MAINTENANCE OPERATION

Total productive time was 14,600 hours of 16,000 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 November was 450 hours or 2.8% of total available hours. Manpower utilization (in hours) for November was as follows:

A.	Shop Work		1 900
B.	Maintenance		4 700
	1. Preventive Maintenance	1 300	
	2. Emergency or Unscheduled Maintenance	1 000	
	3. Normal Scheduled Maintenance	2 400	
C.	R&D Assistance		8 000

Manager
Test Reactor and Auxiliaries

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
H. L. Libby	An Eddy Current Nondestructive Test Tubing Cross Section Display Device (HWIR-1776)
V. L. Hammond	Method of using pneumatical-mechanical impaction to make high integrity spherical metal clad capsules by simultaneously densifying and encapsulating powdered materials.
R. H. Moore	A Method for Producing Diffusion Bonds Between Dissimilar Metals (HW-84516)
R. L. Moore and F. P. Roberts	The Use of Some New Sparingly Soluble Salts of Technetium in Technetium Recovery and Purification (HW-84498)
L. F. Kocher and P. C. Friend	A Machine for X-ray Coding the Identification Number on Personnel Film for Routine Processing (HWIR-1770)
L. F. Kocher and P. C. Friend	Automatic Densitometry to Read and Check Identification Numbers and Densities of Developed Film from Personnel Metering Badges and Punch That and Other Data Automatically on Data Processing Cards (HWIR-1771)
L. F. Kocher and P. C. Friend	A Mechanized Film Badge Processing Machine (HWIR-1777)

Manager, Hanford Laboratories