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HANFORD LABORATORIES MONTHLY ACTIVITIES REPORT

DECEMBER 1963

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of 189 pages.

HANFORD LABORATORIES
MONTHLY ACTIVITIES REPORT
DECEMBER, 1963

HANFORD
87273

Compiled by
Section Managers

January 15, 1964

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By Authority

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HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

PRELIMINARY REPORT

This report was prepared only for use within General Electric Company in the course of work under Atomic Energy Commission Contract AT(45-1)-1350. Any views or opinions expressed in the report are those of the author only.

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Table I - Hanford Laboratories Force Report

Date: December 31, 1963

	<u>At Beginning of Month</u>		<u>At Close of Month</u>		
	<u>Exempt</u>	<u>Salaried</u>	<u>Exempt</u>	<u>Salaried</u>	<u>Total</u>
Chemical Laboratory	145	132	146	133	279
Reactor & Fuels Laboratory	205	195	204	198	402
Physics & Instruments Laboratory	100	78	102	76	178
Biology Laboratory	43	64	43	64	107
Applied Mathematics Operation	18	5	19	5	24
Radiation Protection Operation	42	93	42	99	141
Finance & Administration Operation	149	118	151	119	270
Programming Operation	18	2	17	4	21
Test Reactor & Auxiliaries Operation	63	317	64	317	381
General	<u>4</u>	<u>5</u>	<u>4</u>	<u>4</u>	<u>8</u>
TOTAL	<u>787</u>	<u>1009</u>	<u>792</u>	<u>1019</u>	<u>1811</u>

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BUDGET AND COST SUMMARY

December operating costs totaled \$2,566,000, a decrease of \$313,000 under the previous month; fiscal year to date costs are \$16,134,000 or 49.6% of the \$32,547,000 tentative control budget. Hanford Laboratories' research and development costs for December compared with last month and the tentative control budget are shown below:

(Dollars in thousands)	COST				
	Current Month	Previous Month	To Date	Budget	% Spent
HL Programs					
02	\$ 67	\$ 76	\$ 461	\$ 1 180	39
03	12	53	223	250	89
04	1 096	1 318	7 052	13 726	51
05	105	123	724	1 456	50
06	258	297	1 622	3 604	45
08	11	12	71	100	71
	<u>1 549</u>	<u>1 879</u>	<u>10 153</u>	<u>20 316</u>	<u>50</u>
Sponsored by					
NRD	168	171	974	1 798	54
IPD	29	49	323	490	66
CPD	<u>147</u>	<u>128</u>	<u>738</u>	<u>1 668</u>	<u>44</u>
Total	\$1 893	\$2 227	\$12 188	\$24 272	50%

RESEARCH AND DEVELOPMENT

1. Reactor and Fuels

Two fluted single tube N-Reactor fuel elements have been irradiated to an exposure of 1600 Mwd/ton. Although the elements incurred a 0.9% increase in volume, the elements continue to show no evidence of damage and the irradiation will continue.

Destructive examination of an N-Reactor outer fuel component irradiated to 3100 Mwd/ton has shown no deficiencies in the performance of the closures, clad, or bond.

Evaluation of target elements discharged at a calculated GVR of 8 has shown a GVR of 13 as measured by vacuum fusion.

An extrusion process developed in conjunction with the fabrication of lithium aluminum target elements has produced excellent surfaces on soft 1100 aluminum. The process combines the use of a thin electroplate of copper and a commercial lubricant.

A prototype N-Reactor fuel fouling detector, fueled with Th-1.5 wt% Orallo-1 wt% Zr, has successfully operated 18.8 effective days in an ETR loop.

Evaluation of irradiated Zircaloy-2 clad uranium rods containing internal cladding striations have shown that the depth of the striation remained unchanged during irradiation and that necking occurs primarily inward from the external cladding surface.

A hot straightening process developed in Hanford Laboratories has been used to straighten 49 NIE warp reject fuels. These components were initially warped from 0.035 in. to over 0.230 inch. Forty-seven of the 49 elements were straightened to within the 0.030 in. warp limit.

A novel swaging technique has been developed which permits tubing stock originally swaged over a mandrel to be increased in diameter by a swaging pass and thus be easily removed from the original mandrel.

Room temperature burst tests of Zircaloy-2 N-Reactor process tubing have been performed at hydride concentrations of 275 ppm and 180 ppm. Both failed at about the same stress as normal material (about 30 ppm H), but ductility was severely affected.

The stress at which a defected process tube specimen (milled slot about 1 in. long) fails was reduced about 20% by the uniform hydride and reduced more than 80% by the uniform hydride plus massive case.

A digital computer program was written and put into use to handle the data obtained in the heat transfer experiments with the full scale

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electrically-heated model of the downstream half of an N-Reactor fuel column and process tube.

Several preliminary shipping cask designs for irradiated N-Reactor fuel elements were reviewed for adequacy of heat dissipation capabilities.

A review of four boiling burnout correlations was made to determine the accuracy with which they would predict burnout heat flux for the laboratory tests performed for N-Reactor. No correlation was found which would predict burnout over the entire range of test conditions.

Heat transfer tests were continued to determine the thermal hydraulic characteristics of self-supported I&E fuel elements in zirconium tubes at the K-Reactors. The results indicate that the present procedures for fixing operating limits will have to be modified only slightly for the K-V self-supported fuel charge.

An out-of-reactor rupture test on an irradiated N-Reactor fuel piece did not demonstrate any advantage from a rupture behavior standpoint of alloying the core with small amounts of iron and silicon.

In out-of-reactor tests, aluminum corrosion was less in process water adjusted to pH 6.6 with CO_2 than in neutral process water.

A long-term test to evaluate NH_4OH for pH control in N-Reactor primary coolant showed (1) no excessive crud formation on crud detector surfaces, (2) no accelerated corrosion of fuel and coolant systems components, and (3) low oxygen concentrations in the coolant even during low-temperature operation.

Graphite burnout monitors showed rates of less than 1% per 1000 operating days for exposures in F- and KW-Reactors.

Measurement of contraction of large bars of graphite irradiated to 25,000 Mwd/adjacent ton in C-Reactor reaffirmed the higher contraction rate of large bars as compared to small samples.

Of 12 selected PRTR fuel elements examined in the PRTR basin, six were found to be acceptable for recharging, four were rejected because of broken wire wraps, and two (Al-Pu elements) were rejected as suspected leakers.

Two PRTR fuel elements repaired by splicing rod wire wraps successfully completed three PRTR cycles.

A PRTR fuel element having circumferential zircaloy bands on the end hanger that has been flow tested with imposed vibration several months in the TF-7 loop was discharged. The new design of end fixtures successfully prevented fretting corrosion.

Capsules containing prototypic PRTR fuel contaminated with known quantities of water and oil were discharged from the MTR on December 25, after one cycle of irradiation to determine the effect of excessive oil and/or water on Zircaloy cladding integrity.

Zircaloy capsules containing clean and oily UO_2 - PuO_2 powder were irradiated to 10^9 R by a Co^{60} source, and heated to 400 C for 100 hours. The capsule with clean material showed no change while the capsule with oily powder appeared to exhibit excessive hydriding.

Ultrasonic techniques not previously available revealed defects in ~35% of a group of Zircaloy-4 cladding tubes previously accepted for fabrication of swaged ceramic fuel rods. Newly found were metal chips impressed 0.001 to 0.008 inch.

Irradiation test capsules containing prototypic EBWR fuel (pneumatically impacted UO_2 -1.5 wt% PuO_2) are being prepared for irradiation in the MTR/ETR. Flow tests and heat transfer calculations for irradiation of 3-rod clusters of prototypic EBWR rods in a Hanford reactor were completed. Components for a 42-rod, PRTR-size dummy element for flow tests were fabricated.

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A fuel element designed to determine the effect of surface roughness on burnout heat flux is being fabricated.

Postirradiation examination of a ceramic (UO_2) fuel element that was originally enriched by means of a coaxial Pu-15 wt% Zr wire showed that the wire disappeared, as desired, leaving no evidence of a second phase. The wire presumably was oxidized and dispersed in the molten UO_2 .

Plutonium cermet (SS-20 vol% PuO_2) pellets were successfully impacted to densities greater than 96% TD. Out-of-reactor heating (25 hours at 1300 C) decreased the cermet density appreciably.

Four swaged PRTR fuel elements containing outgassed Nupac UO_2 -1 wt% PuO_2 were fabricated.

Welding parameters were established for the closure of PRTR Vipac fuel elements; the crevice between the end plug and the cladding has been eliminated.

In-reactor inspections of PRTR pressure tubes since June 1962, indicate that the severity of fretting in the PRTR process tubes has diminished substantially.

In general, it was found that considerable deviation exists between the experimental data and the predictions of pressure drop in steam-water mixtures.

Boiling burnout data obtained during the past 2 years with 19-rod bundle test sections were correlated, making special allowance for coolant mixing within the bundle.

Information developed on the transient heating of UO_2 in mixed PuO_2 - UO_2 oxides was presented to the General Electric Technological Hazards Council. The calculations indicated no appreciable delay in in Doppler coefficient feedback.

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Three plutonium cermetes were prepared for irradiation testing: PuN-50 vol% W by pneumatic impaction; PuN-15 vol% Pu, and PuN-24 vol% Pu by arc melting.

A chapter titled "Plutonium Refractory Compounds" is being revised and updated for the Plutonium Handbook to be presented by the AEC at the 1964 Geneva Conference.

A long term, low temperature irradiation study was begun on eight carefully characterized UO_2 specimens, including both irradiated and non-irradiated samples.

UN-W and UN-Mo cermetes were dimensionally and chemically stable during 21 days of irradiation at cladding surface temperatures greater than 2000 C.

Vibrationally compacted ThO_2 elements are being irradiated in MTR for later evaluation of fuel loss through cladding defects and conversion to U^{233} .

Enriched (2.42 wt% U^{235}) UO_2 was pneumatically impacted for exchange with AERE, Harwell, England.

Pre- and postheat controls were added to the magnetic force resistance welder to increase its versatility.

Three tungsten-clad cermet pellets were fabricated using newly developed powder cladding techniques.

Load bearing studies on annular insulation for the coaxial piping of the model gas loop indicate it has adequate strength to hold the inner piping in position.

A computer programmed analysis of the pressure drop through the model gas loop indicates the blower at design capacity will deliver the desired 500 lb of helium per hr at any loop pressure over 270 psig when the test section temperature is 2000 F.

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Fifteen thermal and bending cycles of Grayloc connections for the ATR gas loop have been performed manually with no detectable leakage of helium.

Microstructural examination of irradiated AISI 348 SS reveals that microcracks initiate at nonmetallic inclusions.

Room temperature tensile tests were completed on Inconel 625, Inconel 718, Hastelloy X-280, Hastelloy N, Hastelloy R-235, and TD nickel. These alloys were irradiated in 280 C (536 F) water to exposures as high as 5.4×10^{20} nvt.

Tensile tests at room temperature on Cb-752 and Cb-1 Zr refractory metal alloys irradiated at 50 C (122 F) to exposures of 8.8×10^{21} to 1.5×10^{20} nvt were completed. These tests showed a 50% increase in yield strength and a marked decrease in total percent elongation of the Cb-752 alloy. A 20% increase in yield strength was observed in the Cb-1 Zr alloy irradiated to the same exposure.

In addition to the steady state creep correlation with the Arrhenius plot, it has been possible to correlate creep data before reactor shutdowns with Dorn's theta parameter. With this parameter, it is possible to predict creep strains at constant stress at temperatures much lower than those actually used in testing.

Bright etched and preautoclaved Zircaloy-2 corrosion specimens exposed out of flux to 535 F (279 C) ETR G-7 loop coolant 1 sec downstream of the core differed markedly in appearance after 18 days of exposure. The response of the preautoclaved samples was typical of normal out-of-reactor corrosion behavior. Weight gains for etched material were two or three times expected values and rough, grey-white oxide films were established.

The relationship between hydrogen pressure and the composition of the zirconium hydride phase with which the gas is in equilibrium has been determined at 750 C (1382 F) and compared with the limited available literature. The agreement is fair.

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Long-term irradiations of the EGCR and N-Reactor graphite in the GETR continued satisfactorily.

Graphites prepared with furfuryl alcohol binder to maximum exposures of 7×10^{21} nvt, $E > 0.18$ Mev, contracted more than pitch bonded counterparts.

Continued study of the effects of irradiation on the reaction of carbon monoxide-water vapor mixtures has shown the G values to be relatively unaffected by variations in the water and CO concentrations. The G value was relatively unaffected by changes in total pressure and surface areas of the reaction vessels.

A new high temperature dilatometer was received and has been calibrated at 1150 C. The standard deviation is about ± 0.00002 in. /in.

Samples of boronated graphite are being irradiated in KW-Reactor in the newly installed 2C facility. The two temperature zones of the capsule are operating respectively at 650 F and 850 F within limits of the design specification.

An additional case of core size reduction for the Military Compact Reactor is being studied, together with some changes in control arrangement, refinement of estimates of thermal hydraulic parameters, and comparison with a smaller size United Nuclear design for the MCR.

An extended run of over 500 hr duration has been completed in the EDEL-I Loop study of fretting corrosion in the PRTR.

An "excessive vibration" detector to indicate possible incipient fretting conditions has been designed and tested in the laboratory and installed on a PRTR inlet jumper.

Scope design of the prototype liquid sodium loop is complete, including schematic flow and instrumentation diagrams, a component and pipe layout, heat balances, and pressure drop calculations.

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The redetermined steady state creep rates of the beta and gamma phases of plutonium under a compressive stress of 112 kg/cm^2 verified the previous data.

It has been established that a thin plastic coating on metallographic specimens of plutonium not only retards oxidation but also prevents spread of contamination.

There is preliminary and indirect evidence that beta rolling does not introduce a deformation texture in plutonium, at least not to an extent comparable to that found after alpha rolling.

Plutonium metal with a diffraction pattern that had been significantly altered by 3-month postcasting storage was vacuum melted and recast. The diffraction peak resolution expected in freshly cast material was restored.

Metallographic examination of unirradiated high purity uranium control specimens which were annealed at 625°C (1157°F) for 30 days in NaK and in high vacuum, respectively, revealed that exaggerated grain growth and a small amount of second phase particle coalescence had occurred. This is in sharp contrast to the complete lack of grain growth observed with specimens irradiated at 625°C for times as long as 200 days. Fission products are apparently extremely effective in controlling grain growth.

The examination of replicas prepared from uranium specimens subjected to postirradiation, pulse annealing has continued.

Fourier analysis of x-ray peak profile changes in irradiated molybdenum foils has shown that the maximum rms displacement of lattice points is only $\pm 0.08\text{\AA}$ at an exposure of 10^{19} nvt ($E > 1 \text{ Mev}$).

Transmission electron microscopy of sections prepared from irradiated molybdenum single crystals has been accomplished. Defect structures identical to those present in irradiated molybdenum foils have been observed.

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Electron microscope examination of molybdenum foils containing <10 ppm carbon, irradiated to 7×10^{18} and 1.1×10^{19} nvt, discloses spot defects comparable in number to those observed in foils containing 100 to 200 ppm carbon.

The first of three capsule tests designed to evaluate the swelling performance of metallic uranium containing a submicron dispersion of uranium carbides has been charged into the ETR.

The second EBWR vibrational compaction line was made operational.

Eight hundred kg of UO_2 -1.5 wt% PuO_2 were pneumatically impacted to greater than 98% TD for EBWR Physics fuel elements. More than 250 rods for EBWR Physics tests have been vibrationally compacted to 86-89% TD using this material.

2. Physics and Instruments

Special physics and instrumentation preparations were completed for the N-Reactor startup and physics tests.

All fuel failure detection instrument channels were placed into operation during successful startup tests of the PRTR fuel rupture test loop.

Analog simulation tests of the N-Reactor steam generator and secondary loop were completed. Design of the control system simulator is underway.

Nuclear safety criticality experiments continued with compacts of polystyrene and PuO_2 (2.2% Pu^{240}) having a H/Pu atomic ratio of ~15. Useful data were obtained this month on the effects of core density changes and various neutron reflector situations.

Progress was made in the development of field methods for determining the subcriticality of systems containing fissile materials. A k_{eff} of about 0.8 was found for an underground waste crib (Z-9) known to contain

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significant amounts of Pu in the soil. This is based on the measured neutron multiplication decay rate following neutron pulsing, and the neutron lifetime calculated from analyses of the moisture and Pu contents of the soil.

Studies were made of the feasibility of measuring subcritical reactivity from analyses of reactor noise without an independent measure or assumption of the value for the ratio of the delayed neutron fraction to the prompt neutron lifetime. This appears feasible through use of very low frequency information in the noise spectrum. Work is continuing towards developing a reactivity monitor which would have many useful applications, but its practical realization will require extending the art of noise measurement and analysis.

Criticality calculations for rods of enriched (1-3%) uranium in water can now be made with increased confidence. Good correlations were obtained between experimental data and calculations made with our GAMTEC computer code. These methods will be useful in nuclear safety applications as well as criticality calculations for reactor lattices.

Substantial progress was made on the reduction of data on the inelastic scattering of neutrons from 95 C water to the scattering law representation.

A significant improvement in the performance characteristics of He³ filled proportional counters was achieved by chemical repurification of the counting gas.

A master magnetic tape library was produced for storage of the completed measurements on the 3 to 15 Mev total cross sections of the elements.

A report, "Phoenix Fuel Reactor Program Proposal," was prepared and forwarded to DRD, AEC-Washington, in answer to their request. A rough draft of a report summarizing Phoenix fuel studies to date was issued. In continuing studies the effect of Pu²⁴¹ decay on low load factor reactor applications was analyzed. For a load factor of 0.1 and 10,000 full power

hours, the shim control requirements increase to 11% compared to 6.6% for a unity load factor. This has the effect of shortening the reactor life for a fixed composition or requiring a larger excess reactivity initially for equal lives. Work continued on Be-Pu systems.

The evaluation of the burnup data from the destructive analysis of three Pu-Al PRTR elements have been completed and the results recorded in an informal document, HW-80067 RD. It is planned to submit these results for journal publication in the near future.

Preparatory work for the approach-to-critical lattice experiments using EBWR fuel rods were completed during the month. Experiments will begin when sufficient fuel is available; 300 of the initially required 600 rods were delivered in December. Meanwhile, the approach-to-critical facility was used to perform an exponential experiment and evaluate the effect of aluminum templates using the 2.0 wt% (16% Pu²⁴⁰) Pu-Al fuel rods.

Reports are in preparation which will present the results of the startup and initial experiments performed in the D₂O-moderated PRCF. These will include the initial loading and calibration experiments, the Pu-Al substitution experiments, and a comparison of theory with experiment on the interaction of safety rods in the PRCF.

In addition to the ones using the EBWR fuel, other light water-moderated, mixed oxide-fueled experiments are being planned. Calculations were made on several plutonium compositions and were used as a basis for predicting the quantity of fuel required for the experiments. The fuel was ordered during the month.

The mechanical components for the Split Table Assembly have been received from KAPL and stored. Planning of the facilities for the assembly continues.

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A code, BARNS-II, for processing the RBU Basic Library has been written and is undergoing final debugging. The nuclide cross section data in the Library are being examined and updated. When this work is completed, the Library and associated processor codes will be available as a standard source of data for HAPO and offsite users. Documents describing the total RBU code system are in preparation. Evaluation of the code is under way.

In addition to the methods used in MELEAGER and DUAL NORMAL MODES, a third method is being developed for solving the differential equations that describe the isotope concentrations in a reactor as a function of burnup. This method should reduce the limitations of the other two methods. Adequacy-evaluation calculations have begun, with the objective of making it available for applied analysis use in January.

The one-dimensional burnup chain ZODIAC employing several Hanford physics codes has been altered so that successive iterations can be run automatically with the varying compositions as burnup proceeds. This should greatly speed up burnup studies such as the Phoenix fuel studies.

Offsite fabrication is proceeding on two experimental regenerating neutron flux monitors. Each will use a coating of U^{234} and U^{235} . Tentative results have been obtained in the spectrometer analysis of irradiated Pu detectors which suggests that the cross section for conversion of Pu^{240} to Pu^{241} is larger than originally assumed. Modified beta current monitors irradiated in the KW facility did not perform as anticipated. Signal currents persisted even after the probes were withdrawn from the reactor, evidencing a need for additional detector improvements.

Adoption of the multiparameter eddy current tester to the inspection of tubing is moving rapidly ahead. Eddy current tests have shown that direction of current flow in liquid Wood's metal is a function of frequency. Measurement of electrical resistivity of Wood's metal from 25 to 90 C has given values appreciably different from published values at temperatures

above melting. Improved eddy current hydride detection instrumentation successfully detected 250 ppm hydride concentrations in sample specimens. Destructive tests confirmed that this level of hydrogen adversely affected sample ductility.

Continued evaluation of the prototype ultrasonic sheath tubing tester with Hanford and AECL tubing has further confirmed the equipment's satisfactory performance. Minor circuit changes have been made to improve analog recording of test results. Construction of the electronic portion of the final instrument is 50% complete; mechanical design is also complete. A major improvement in metal fabrication techniques for calibration standards has been developed with the use of a Rockwell hardness tester. Preliminary indication suggests notches may be simply made with this equipment with 0.1 mil accuracy.

Implanted transducers have successfully measured temperature, respiration and pulse rate of sheep. Continuing efforts are being made to obtain improved results by implanting the transducers at deeper levels. Other instrument development work was performed in support of biology programs.

The problem of counting P^{32} in vivo appears to have been solved by development of a beta coincidence counter. Although the efficiency is low, the sensitivity is sufficient to measure, despite interference from gamma emitters, the body burden of P^{32} in subjects who have recently eaten whitefish from the Columbia River at Hanford. The apparatus also is suitable for use in the mobile whole body counter.

In other radiological physics work, the Hanford Mobile Whole Body Counter was used for successful measurements on people who had been working in the mill of a uranium mine. This brief study showed that important basic information about the inhalation of fine particles can be obtained by using whole body counting in addition to conventional techniques.

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Recent atmospheric physics work has important implications for the problem of reactor site evaluation. Wind variability factors were determined for 2 to 24 hr atmospheric release periods at Hanford through studies of the effect of wind variability on plume growth. Addition of wind variability reduces the calculated exclusion distance as compared to the results of currently used short-period release calculations. The amount of reduction depends on the particular site, control limits, and postulated release modes, but is expected to be significant in almost all cases.

Two activities highlighted the Laboratories' increasing computer capabilities: A new 156-amplifier Beckman analog computer was delivered and is now being installed and checked out in the 3707-C Building Analog Computer Laboratory. This acquisition will significantly improve performance on the current heavy work load of systems studies for N-Reactor. Also this month, 12 HAPO engineers and scientists completed an on-site course in programming the GE-412 process control digital computer which is being obtained for developmental studies on chemical process, reactor, and other applications.

Nondestructive testing applications work continued at a high level. Eddy current tests successfully pinpointed a leaky PRTR heat exchanger tube. Some 10,000 N-Reactor steam generator tubes were cleaned and inspected to ensure that they are free of primary coolant system filters which failed. Tests are under development for the waste calcination demonstration and isotope heat source development programs.

3. Chemistry

Emissivities of aluminum-clad uranium fuel elements at elevated temperatures were experimentally found to be three- to four-fold higher than those used (0.1) in estimating the temperature rise of an irradiated element in ambient air. Calculations based on the new data predict that an element under these conditions will not melt.

Dissolution of thorium metal elements irradiated in F-Reactor is underway in the B-Cell one-slug dissolver. The U^{233} and Pa^{233} are to be isolated and purified for detailed isotopic determination.

New calculations show that Th^{228} in recycle thorium (cooled for 270 days) does not increase on successive cycles of irradiation unless the U^{232} content of the U^{233} is above about 3 ppm. Other calculations indicate that a cooling time of 270 days is required to reduce Th^{234} content of recycled thorium to a concentration equivalent to that in aged natural uranium.

Efforts were not successful in making use of the reported volatility of mercury polonides at low temperature as a recovery scheme for polonium.

Sodium sulfoxalate formaldehyde is an effective reducing agent for Pu(IV) in nitric acid solution and is being considered as a partitioning agent for the Purex process vice ferrous iron. Its stability under plant conditions is being studied.

A field test was started to determine whether water in a piezometer tube in a perforated well is exchanged with ground water surrounding the well. Results of this test are needed to evaluate the ground-water "turn-over time" in project wells equipped with piezometers and to evaluate sampling techniques.

Studies on the effect of radiation on BAMBP in CSREX solvent have been continued. It now appears that the unexpectedly high G value for the decomposition of BAMBP in CSREX solvent is due to the presence of Soltrol. Other diluents are being scouted as a substitute for Soltrol.

Work has continued on the separation and purification of Tc^{99} from Purex wastes. The results of preliminary tracer-level experiments on the extraction of Tc^{99} from Purex wastes into 0.3M TLA-Soltrol have now been confirmed by hot cell experiments with as-received Purex wastes. Preparations are being made for further processing of the crude technetium concentrate (containing ~ 1 kg technetium in 100 liters of solution).

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Gadolinium-containing AISI 304-L SS (0.3 and 0.7 wt% Gd), of interest because of its neutron absorbing worth, has less corrosion resistance in boiling nitric acid and Zirflex decladding solution than 304-L without gadolinium. When welded with 308-L rod (standard procedure for 304-L) the base metal-weld metal interface is subjected to preferential attack in HNO_3 and HNO_3 -HF- $\text{Al}(\text{NO}_3)_3$ solutions.

An analytical method using gamma spectrometry has been developed for determining nanogram quantities of Th^{234} in uranium billets.

The first attempt on an engineering-scale to codeposit PuO_2 and UO_2 electrolytically from a fused salt bath resulted in the uranium being depleted in plutonium by factors of three to six. The second attempt was more successful, with the Pu:U ratio in the product being about 75% of that in the initial salt bath.

A method adapting an electroanalyzer has been successfully developed for determining water in PRTR oxide fuel materials.

Recirculation rates in the 18 in. spray calciner were found to be about 1.5-fold greater with a simple draft tube than with a finned tube. The benefit of greater heat transfer surface area in the finned tube is largely nullified by the reduced recirculation rate.

A hot cell run using acidic Purex waste confirmed that phosphites are beneficial in reducing ruthenium volatilization during calcination. Final results on calcination of sugar treated, low-acid waste, show that the ruthenium volatilization is about the same as when calcining normal, high-acid Purex wastes.

Overall decontamination factors of 23, >250 and >500, respectively, for Ru^{106} , Cs^{137} and Sr^{90} were demonstrated during ion exchange treatment of Purex tank farm condensate while 7200 gal were treated in the pilot plant. The run was terminated due to excessive pressure drop across the beds caused by solids in the feed. Plausible causes for these solids are

hardness, introduced by the addition of raw water to the system, and bacteria. Both are being investigated and corrective measures are being sought.

A promising method using two large sodium iodide detectors is being studied to detect radionuclides which emit three or more cascade gamma rays per disintegration. The method is ultrasensitive for certain isotopes.

Experiments performed on the hemolysis of red blood cells by radiation produced a surprising result: the cells did not decrease in size as occurs when cells are hemolyzed by other means. Generally, the cells swell before the loss of hemoglobin is very evident.

Work on an acid-side high capacity, HEDTA process for promethium purification has continued, with the installation and use of two new identical sets of jacketed columns. A run with 0.06M HEDTA gave good results, with no precipitation problems, with rapid band elution, and with completion of the run in only about 30 hours.

Five compactions were completed this month, the purpose of which was to determine capability to produce thin-walled compacts by the high energy compaction process. Two approaches were tested, both successfully and with promising results: (1) the use of a thick-walled can followed by measurement of can wall thickness and mechanical removal of excess metal; and (2) placing the loaded, thin-walled can inside a mild steel sleeve, compacting the unit and then removing the mild steel.

4. Biology

The name of the Pharmacology Operation was changed to Inhalation Toxicology.

The Vertan 675 that N-Reactor Department is considering for pipe cleaning appears to be about five times more toxic to rainbow trout than Vertan 690.

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Water 4 F above normal river temperature caused an increased mortality and growth depression in trout and tended to increase columnaris incidence.

By measuring, as a function of time, the release of columnaris organisms from an infected fish, and finally observing healing of the infection, it appears fairly definite that an immunity buildup accounts for recovery.

Toxic levels of copper, X-irradiation, and a combination of the two administered to rats fail to cause effects showing the two assaults are related.

Serum levels of inorganic phosphorus in miniature swine were observed to decrease with age, again similar to humans.

The difference we noted in the sensitivity among male and female rats to administered Np^{237} is being checked in sheep. In the first series of animals tested, we have noted no sex related difference in Np toxicity.

Following intravenous injection of Pu into rats, excretion into the GI tract was measured. About one-half of the Pu comes from the bile, and DTPA markedly increases the excretion.

Thirteen surviving dogs that were exposed $3\frac{1}{2}$ to 4 yr ago to $\text{Pu}^{239}\text{O}_2$ now have 2 μc Pu and less. They are undergoing extensive physiological tests. Most show some degree of respiratory insufficiency; two show tumors.

The dose dependent leakage of intravenously injected I^{131} -labelled polyvinyl-pyrrolidone into the GI tract of irradiated animals was eliminated by the prior administration of cysteine or AET.

When day-old flour beetles were exposed to 830 rads of fast neutrons, their reproductive capability was reduced to two-thirds that of the control. This reduction was completely additive when two irradiated flies were mated.

The uptake of iodide ions into plants from the environment of their roots was found to be, at least in part, independent of water uptake. This provides strong evidence that a metabolic reaction is involved, or that there are specific sites on the root surface that must absorb the ions before they can enter the plants.

By measuring radionuclides in floating and fixed (attached to stones) plankton in the Columbia River, we have obtained evidence that suggests floating plankton simply sorb reactor-produced radionuclides via a physical process, while a biological process is involved for the fixed plankton.

A total of 1315 salmon nests were counted in the vicinity of HAPO. This is the second highest annual count on record, and is slightly higher than the number observed last year. Seventy percent of the nests were between 100-B and Hanford, as compared with 60% for 1962.

Wintering waterfowl inhabiting the Columbia River within the Hanford Reservation increased from 120,000 last year to 220,000 ducks and geese this year.

5. Programming

Typical seed-and-blanket fuel cycle cost studies indicate decreased fuel cycle costs if two or more seed loadings are used before the blanket is replaced. However, the fuel costs for all cases studied have been higher than the 1.14 mill/kwh value for the same reactor operated on a conventional "graded" fueling scheme.

From trends predicted in the AEC Report To The President - 1962, a fifty-billion-dollar nuclear fuel industry 100 years hence should not be a larger fraction of the future total economy than coal (for the same purpose) is of today's economy.

A fuel cycle analysis demonstration and guide, based on MELEAGER plus 42 other computer codes, has been prepared to fill offsite requests for a working sequence of these codes.

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The AEC has approved operation of the Plutonium Recycle Critical Facility with light water moderator, for testing $\text{PuO}_2\text{-UO}_2$ EBWR fuel.

TECHNICAL AND OTHER SERVICES

About 20 curies of I^{132} (2.3 hr half-life) were emitted from the Purex stack during the week beginning December 14, 1963. The I^{132} emission rate decreased throughout the period in question in a manner consistent with the theory that the Te^{132} parent (78 hr half-life) of I^{132} had been released from the dissolver and then had plated out somewhere in the ventilation system. CPD personnel suspected that hand-sorted elements dissolved during the night of December 13-14, 1963, probably had contained one or two undercooled fuel elements. Iodine-132 was not anticipated or detected in any environmental samples.

There were three new plutonium deposition cases confirmed by special bioassay analysis during the month. The body burdens, which were estimated to be less than 1% of the MPBB in each case, resulted from inhalation incidents which occurred in the Plutonium Metallurgy Building (231), the Redox Final Products Concentration Building (233-S), and an injury which occurred in the Weapons Manufacturing Building (234-5). The total number of individuals who have received internal plutonium deposition at Hanford is 327. With the termination of two of these employees, the number of deposition cases currently employed at Hanford is 235.

Concentrations of fallout materials in the air of the Pacific Northwest averaged $0.9 \text{ pc } \beta/\text{m}^3$ air in December, not significantly different from the low value of $1 \text{ pc } \beta/\text{m}^3$ recorded last month as the lowest since the Fall of 1961.

Work in support of planning and scheduling for the Containment System Experiment has been started.

As part of a program for improving the apportionment of N-Reactor's total production, a statistical procedure was designed to facilitate an objective classification of the relative power factors for each producing channel.

Extensive data analysis is continuing for the evaluation of the dimensional distortions and other characteristics of the behavior of hot-die-sized fuel elements.

A comparison was made between plutonium nitrate samples taken at 234-5 Building and the Purex Plant to check the adequacy of the sampling methods.

Using a boundary value approach, a program has been written to solve the nonlinear differential equations expressing mass transfer in a pulse column.

Continuing assistance was provided for formulating of mathematical models to describe the radioactivity in a reactor effluent stream.

The EDM Program which prepares direct magnetic tape input to the prototype automatic Sheffield rotary contour gage has been completed.

A computer program was written to record data and perform specified statistical calculations for Zn^{65} fission studies.

SUPPORTING FUNCTIONS

PRTR output for December was 1404 Mwd, for an experimental time efficiency of 77.7% and a plant efficiency of 64.7%. There were 14 operating periods during the month. Seven of these were terminated manually as follows: three due to excessive helium leakage, one to investigate "leaker element" indications, one due to a malfunction of the S-60 valve, one due to excessive leakage out of the rupture loop, and one due to a ventilation unbalance. Seven operating periods were terminated by scrams as follows: one by a spurious flow monitor trip, four while switching from automatic to

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manual control, one by a ΔP trip on the rupture loop, and one due to the failure of a flow monitor. A summary of the fuel irradiation program as of December 31, 1963, follows:

	Al-Pu		UO ₂		PuO ₂ -UO ₂		Other		Program Totals	
	No.	Mwd	No.	Mwd	No.	Mwd	No.	Mwd	No.	Mwd
In-Core	6	516.7	1	233.7	78	8675.3			85	9425.7
Maximum		99.5		233.7		198.4				
Average		86.1		233.7		111.2				
In-Basin	37	3157.5	31	3603.8	17	426.4			85	7187.7
Buried							1	7.3	1	7.3
Chemical Processing	32	2309.3	35	1965.8					67	4275.1
Program Totals	75	5983.5	67	5803.3	95	9101.7	1	7.3	238	20 895.8

Note: (Mwd/Element) $\times$ 20 $\approx$ Mwd/ton_U for UO₂ and PuO₂-UO₂.

A total of 80 reactor outage hours was charged to repair work. Main items were:

HX-5	31 hr
Valves	14 hr
Rupture Loop equipment	13 hr

Examination of the multitube rupture detection heat exchanger (HX-5) which developed a leak last month has revealed fretting corrosion between the tube and end support baffle. An 18 in. section of the tube containing the failed area was removed. Two 4 in. access ports were provided to allow visual examination of the area where the tube failure occurred.

The December heavy water inventory indicates a loss of 705 lb for the month.

Plutonium Recycle Critical Facility project work (CGH-999, conversion of facility to H₂O moderator) was completed with minor exceptions.

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All qualified personnel participated in a 4-day training seminar for H₂O experiments. Subjects included electrical and mechanical descriptions of the modified PRCF, Process Specifications, Test Descriptions, selected Operating Procedures, and data taking practices.

FERTF Test 2-B, operation with a new Moxtyl element was completed. FERTF Test 4, irradiation of a Pu-Al leaker, was begun and is in progress at month-end.

Technical Shops Operation total productive time for the period was 21,176 hr. Distribution of time was as follows:

	<u>Man hr</u>	<u>% of Total</u>
N-Reactor Department	2 078	9.8
Irradiation Processing Department	5 778	27.3
Chemical Processing Department	398	1.9
Hanford Laboratories	12 922	61.0
Hanford Utilities and Purchasing Operation	-	-

Laboratory Maintenance Operation's total productive time was 17,400 hr of 19,000 potentially available. Of the total productive time, 91.1% was expended in support of Hanford Laboratories components, with the remaining 8.9% directed toward providing service for other HAPO organizations. Manpower utilization for December was as follows:

A. Shop Work		2000 hr
B. Maintenance		6600 hr
1. Preventive Maintenance	1600 hr	
2. Emergency or Unscheduled Maintenance	1500 hr	
3. Normal Scheduled Maintenance	3500 hr	
C. R&D Assistance		8800 hr

The heavy water inventory at the end of December 1963 showed a loss of 719 lb (\$9915) for the PRTR. Heavy water scrap generated during the month amounted to 1214 lb, resulting in a \$1554 charge to operating cost. Heavy water on hand at month end for return to SROO totaled 8879 lb with a value of \$111,082.

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Cumulative data on Hanford visits follows:

	<u>Number of Visitors</u>	
	<u>In December</u>	<u>Since June 13, 1962</u>
Visitors Center	1101	60 285
Plant Tours	64	n. a.

HAPO professional recruiting activity this month is summarized below:

	<u>Plant Visits</u>	<u>Offers Extended</u>	<u>Acceptances Received</u>	<u>Rejections Received</u>	<u>Open Offers at Month End</u>
Ph. D.	5	1	1	0	2
BS/MS (Direct Placement)		6	4	4	1
BS/MS (Program)		58	8	1	51

Two technical graduates were placed on permanent assignment. Four new members were added to the roll and one member terminated, bringing the program total to 70 at month end.

A booklet with colored pictures of Hanford facilities, which was prepared to assist diversification efforts, was used for the first time during a December visit to Air Force installations by a Hanford group.

In response to an AEC-RLOO request, a Review Committee has been appointed and a detailed review of existing classification and security practices has been initiated.

Authorized funds for nine active projects total \$6,505,500. The total estimated cost of these projects is \$10,754,000. Expenditures on them through November 30, 1963 were \$1,761,067.

HM Parker:JEB:dph

for W. H. Bear
Manager, Hanford Laboratories

REACTOR AND FUELS LABORATORY MONTHLY REPORTDECEMBER 1963TECHNICAL ACTIVITIESA. FISSIONABLE MATERIALS - O2 PROGRAM1. Metallic Fuel Development

Fluted Fuel Element Irradiation. The two fluted N-single tube size fuel elements being irradiated in the ETR are currently undergoing their ninth cycle of irradiation in the M-3 pressurized loop. These elements, which are Zircaloy-2 clad, 0.947 enriched uranium operate with a maximum fuel temperature of 520 C. At the end of the eighth reactor cycle an exposure of about 1600 MWD/T had been achieved and the elements had shown a 0.9% increase in fuel volume.

N-Reactor Fuel Evaluation. Radiometallurgical examination of an N-outer fuel component irradiated to 3100 MWD/T in KER-4 has continued. The examination has shown no deficiencies in the performance of closures or the heat-affected zones in the fuel, clad, and bond. Metallographic examination shows a highly distorted microstructure throughout the full cross-section of the fuel. The structure is typical of uranium irradiated at low temperatures. Even though the element being examined experienced nearly 2½% swelling, electron microscopy has indicated no large amount of voids or porosity in the microstructure.

Three small samples of the above N-outer fuel component were pulse annealed to 980 C (1800 F) and cooled. Samples were held at temperature for each of 0, 5, and 30 minutes prior to cooling. In all cases severe cracking developed, apparently during the cooling cycle. The specimens increased in size because of the large amount of void space created by the cracks and presumably also by the development of gas porosity during the anneal. Density measurements indicate fuel volume increases of 19, 26, and 38% for the samples. The pulse annealed samples are being metallographically examined to determine the extent of gas void development in each case.

Target Element Development. Irradiation of eight experimental lithium-aluminum target elements in KER Loop 2 has continued at a coolant pressure of 1600 psi and a calculated target temperature of 300 C.

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Evaluation of target elements discharged at a calculated GVR* of 8 has continued. Vacuum melting with the subsequent recovery and mass spectrographic analyses of the gas released from samples of the irradiated target element alloy (nominal 2 wt% Li in aluminum) have been completed. These results indicate an average GVR of 13. Li^6 burnup analyses of the same irradiated cores indicate a GVR of as high as 24. At the present time these differences have not been resolved, but it is believed that the vacuum fusion results are the most reliable.

A 13-element test of co-produced fuel elements has been scheduled for the KER loops. These elements are to be fabricated by co-extruding an aluminum-lithium core within an aluminum jacket. This coextrusion will be cut to fuel lengths, recessed and plug welded, then sealed inside a helium-filled Zircaloy can. To date the cores have been cast and are being machined. The billets can be extruded at a 20:1 reduction ratio without danger of bonding. One test at 40:1 at a very high extrusion exit speed did not result in bonding. All material has been procured and we expect to meet the deadline.

Aluminum Extrusion Studies. Several extrusions of 1100 aluminum have been made to arrive at a satisfactory extrusion process which will produce a good surface on coextrusions of aluminum clad Li-Al target elements. Best results have been obtained by chemically plating copper on the surface of the billets. The copper coat has a very pronounced effect in producing a smooth extrusion surface when used with Fiske 604 (a commercial lubricant consisting of a suspension of aluminum fines). The Fiske 604 used alone without the copper coat will not prevent gross galling to the extrusion die. Gross galling also resulted with other lubricants which were tested.

A properly conditioned die cone surface appears to be very helpful in preventing light die pick-up. A good oxide coating on the die seems to prevent the die from picking up; however, the oxide coats seem to be good for only about two extrusions. A coating of Electro Film 1000 (a bonded solid film lubricant) also seems to prevent light galling. Further tests will be needed to verify the results of the Electro Film 1000 and determine the endurance of the coating. Further extrusions are planned to determine the effect, if any, of billet and die temperature on the extrusion surface as well as extrusion speed.

*
$$\text{GVR} = \frac{\text{cm}^3 \text{ of He} + \text{T}_2}{\text{cm}^3 \text{ of target alloy}}$$

Several samples were autoclaved in water at 170 C and 150 psig for 40 hours to determine the effect of the copper coat on the corrosion properties of the extrusions. The samples were autoclaved under the following conditions: (1) degreased as extruded; (2) 0.001" of material removed from the surface by machining; (3) dry blasted and given an aluminum bright etch; and (4) caustic etched and given an aluminum bright etch. All samples showed no corrosion with the exception of the degreased as-extruded pieces which indicated some light corrosion.

Extrusion of Al - 8% Li. Two billets were extruded with Al - 8% Li cores canned in thin 1100 aluminum cans. The billets were preheated to 450 and 500 C and extruded at a reduction of 15:1 to 0.252 ID x 0.629 OD. The as-cast cores were very porous, resulting in considerable folding of the aluminum can during upset. Examination of the cores indicated that the porosity in the core did not completely heal. The extrusion constants were approximately 16-17 TSI compared to 8-9 TSI for Al - 3 $\frac{1}{2}$ % Li extruded at 450 C.

Fuel Fouling Detector. A Zircaloy-2 clad thorium - 1.5 wt% enriched uranium - 1 wt% zirconium alloy fuel rod containing a double sheathed Zircaloy-2 clad thermocouple successfully operated 18.8 effective days in the ETR-P7 loop under prototypic N-Reactor conditions. This prototype N-Reactor fuel fouling detector operated at 450 C maximum core temperature and saw 15 power cycles during the irradiation test.

Two fuel fouling detectors are ready to be assembled with their thermocouple trains for charging in KER Loops 2 and 3 in January 1964.

Cladding Deformation Studies. Thirty-six NaK capsules containing a total of 94 Zircaloy-2 clad uranium rods have been irradiated to provide data on the strain capabilities of Zircaloy-2 cladding as a function of cladding thickness, uniformity, temperature, and exposure. All the samples have been examined visually and diameter measurements completed. The correlation of cladding strain limit and striation depth was reported previously.

Metallography is being performed on transverse cross sections of samples in which plastic instability of the cladding was observed. Measurements made on photographs of the cross sections from two samples show that the depth of the intentional striation remains unchanged and that necking occurs primarily inward from the external cladding surface. A comparison of the increase in width of the striation and the increase in cladding circumference shows that

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12 to 15% of the total strain occurred in the approximately 0.050-inch wide striation existing initially in the cladding of these two rods.

Corrosion of Uranium-Contaminated Braze. Several as-brazed and as-welded sections of uranium fuel closures are being autoclaved to determine the corrosion resistance of the braze at various distances from the uranium core. Difficulties encountered in showing the effect of autoclaving on the sections through conventional photography have been overcome by using color photography. Comparison of the brazed sections with standard braze and uranium coupons autoclaved under the same conditions should indicate the levels of uranium contamination in the braze closures.

Uranium Alloy Studies. A series of binary and ternary alloys of uranium containing up to 5% total niobium and/or zirconium have been prepared by arc button melting. Hardness measurements have been taken on the as-cast buttons, and they will be rolled to differing degrees of cold work. Corrosion specimens will be prepared and autoclaved under varying conditions of pressure and pH to determine the corrosion characteristics of each alloy.

Uranium Sulfur Alloys. Sections of rolled buttons of uranium-sulfur alloys (0-1 wt% S) were sealed in evacuated quartz capsules and heated for 24 hours (450-1100 C). Although samples heated at 1000 and 1100 C were wrapped in tantalum foil to prevent reaction between Si and U, a metallic coating was present on the inside of the quartz capsule after heating. Spectrographic analysis indicated the coating contained uranium and silicon. Heated samples are now being prepared for metallographic examination.

Freezing point determinations indicate a possible eutectic in the U-S system near 2000 ppm sulfur.

Heat Treatment of Uranium-Carbon Alloys. Metallography of ingot uranium specimens heated to temperatures in the gamma range (800-1100 C) did not show the carbon losses that analysis indicated. There were no apparent concentration gradients within any single sample.

Hot-Headed Closure Studies. Sixty-five sections of hot-headed N-inner fuel elements, four inches long, were prepared for welding. These sections were carefully measured. Measurements of these sections revealed that the ID hole consistently had a six to eight degree taper for the first two inches from the hot-headed end. Modification in hot-heading technique or tooling may have to be

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made to compensate for this tendency toward taper in future hot heading operations, or a sizing operation after hot-heading may eliminate it. Since the hot-headed end of these sections have been carefully machined, it would not be feasible to size them. Tapered ID restraining plugs will be made before end cap welding is attempted.

Fuel Straightening. Forty-nine NIE warp reject fuels have been hot straightened in the three-roll straightener. Prior to straightening the elements were processed through beta heat treatment wherein the elements warped from 0.035 to in excess of 0.230 inch double throw warp. Thirty of the 49 elements were warped in excess of 0.100 inch. Forty-seven of the 49 elements were straightened to within the 0.030 inch warp limit, with 41 of these 47 elements warped 0.020 inch or less. All elements received one straightening cycle only. Work is continuing to determine the stability of these elements following this straightening treatment.

MTR Irradiation of I&E Fuel Elements. Four Hanford I&E fuel elements were irradiated in the GEH-4 loop facility at the MTR to investigate the possible occurrence of large volume increases or grain boundary tearing at intermediate irradiation temperatures. Dimensional measurements showed a maximum diameter increase of less than 1% on any of the four elements. Chemical burnup analysis of two elements showed 0.23 and 0.20 at% burnup. From this information recalculation of temperatures gives maximum uranium temperatures of 440 C and 380 C, respectively. Although these temperatures are considerably below those previously reported for this test, they are in a range where grain boundary tearing has been observed in other tests. Metallographic examinations have been completed on two of the elements. The uranium microstructure in both elements is undefined and the uranium has the severely distorted appearance typical of low temperature irradiation. There is no positive evidence of grain boundary tearing in these samples although a few small cracks, up to 0.01 mm long, are found throughout the transverse cross sections. The cracks are not associated preferentially with any inclusion and the grain boundaries are so poorly defined that it cannot be determined if the cracks are associated with them. Some larger radial cracks were also seen in the fuel cross sections.

Rolling Metal Foils. Techniques obtained from KAPL on the production of foils have been successfully applied by the Metals Fabrication Development Operation. Foils of Zircaloy-2, copper, beryllium, copper, and tantalum have been rolled to one mil or less. Attempts to produce still thinner foils and foils of more of the exotic metals are under way.

Tube Expanding. A major obstacle occurring in the fabrication of small diameter tubing is the removal of the mandrel over which the tube was formed. A swaging technique has been developed which works exceptionally well in this respect. Swaging dies, that ordinarily are used to sink tubing down onto a mandrel, have been redesigned to expand the tube away from the mandrel. In a recent test a Zr-2 tube with a 200-mil OD was expanded to 204 mils OD, thereby releasing it, over a length of 45 feet, from a 0.157-inch music wire mandrel.

Rupture Testing in IRP (242-B). One N-Reactor inner fuel piece, irradiated to 2100 MWD/T at 240 C water temperature, was pre-defected with a 0.025-inch hole in the side and rupture tested in the IRP using the old N-Reactor cooldown schedule. The purpose of the test was to determine whether addition of iron and silicon to the core changed the rupture behavior of the element. The pattern and extent of the rupture were similar to previous ruptures of fuel elements not containing iron and silicon.

Nickel Plating of Uranium. The pretreatment of uranium prior to nickel plating is frequently accomplished in a phosphoric-hydrochloric acid bath by anodic etching. The properties of the etched surface produced are very important to the eventual performance of the nickel-uranium bond. The concentration of uranium in the plus 6 oxidation state has a marked effect on the character of the etch. The etch produced by a bath containing plus 6 uranium, U^{+6} , was finer grained and less sensitive to variations in current density than a bath containing mostly U^{+4} .

An etch bath composed of 6M H_3PO_4 , 0.4 M HCl and 7.5 to 12 g/l U, was oxidized to successively higher U^{+6} concentrations by additions of H_2O_2 followed by heating to the boiling point to remove excess peroxide. The etch produced in this bath after six minutes at 5.9 amps/dm² became finest grained at about 80% U^{+6} . Plating and metallographic sectioning of uranium etched in this bath is now in progress.

2. Corrosion and Water Quality Studies

Carbon Dioxide for pH Adjustment. The process water in present production reactors is slightly acidified with sulfuric acid (to pH 6.6) to minimize corrosion of aluminum. It has been proposed that acidification with CO_2 (potentially available from Hanford stack gases) might be a satisfactory alternate to sulfuric acid, and one which could result in operating economies. To evaluate the proposal, coupon samples were exposed for periods up to 92 days in treated

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Columbia River water at 110 C in the 242-B Water Studies Apparatus with pH adjusted to the range 6.6 to 6.7 with carbon dioxide gas from a standard pressure cylinder. Other coupons had been previously exposed for 44 days in the same facility without CO₂ addition with temperatures in the approximate range 100 to 120 C.

Equilibrium corrosion rate for both X-8001 and 1100 aluminum samples was approximately 0.3 mil per month in the carbonated water. A penetration of 1.6 mils was calculated for these samples after the first 44 days of exposure, compared with 1.9 and 2.1 mils for X-8001 and 1100 aluminum, respectively, in the water without CO₂ addition or pH adjustment. Carbon steel corrosion rate in the carbonated water in these tests was approximately 0.35 mil per month.

The carbon steel coupons in these tests were corroded by the initial formation of many small pits, which increased in diameter to produce a rough surface. Average penetrations calculated from weight loss measurements, and measured maximum pit depths were, in general, lower by a factor of about two than for the samples exposed in the same water without CO₂ addition. A comparison between CO₂ and sulphuric acid pH control is currently in progress.

Conclusions from tests to date are: (1) CO₂ can be used for pH control, and (2) corrosion of X-8001 and 1100 aluminum and carbon steel in CO₂ adjusted water is less than in neutral water.

Evaluation of Cleaning Solutions for N-Reactor Primary System. Two cleaning solutions (3% ammonium citrate and 10% Vertan 675), proposed for cleaning the N-Reactor primary system of loose rust, were evaluated in laboratory tests. No attack was noted following a 24-hour test on either the intergranularly attacked areas in the N-Reactor steam generator tubing or on Zr-2 coupons. As a further test, TF-8 loop containing three N-Reactor fuel elements will be cleaned with Vertan 675 at conditions more severe than planned for the N-Reactor cleaning.

Evaluation of Descaling Solutions for N-Reactor Secondary System. Stress-crevice corrosion samples of A-212 carbon steel, 70-30 Cupro nickel, and Admiralty metal were exposed 24 hours to a 10% Vertan 690 descaling solution passivated in $\frac{1}{4}$ oz/gal Turco 4517 to simulate N-Reactor secondary system cleaning procedures, and then exposed for 2 $\frac{1}{2}$ months to 530 F, pH 10 lithiated water. No localized corrosion was noticed on the test samples in the crevice areas.

Use of NH₄OH to Regulate pH in N-Reactor Primary System. The first long-term test in K-1 to evaluate NH₄OH as a replacement for LiOH

in the N-Reactor primary system was terminated because the crud detectors had reached an exposure where reaction between the UO₂ and stainless steel might occur.

In the test the pH was adjusted to 10.1 ± 0.2 with NH₄OH for a total of 63 days in three phases: 47 days of operation at normal temperature and pressures (285 C and 1450 psi), 4 days of operation at minimum temperature (72 C and 700 psi), and the remainder at 210 C and 1450 psi. Loop leakage caused the reduction to minimum temperatures; during a subsequent outage some of the leaks were repaired so it was possible to attain the intermediate temperature for the remainder of the test.

None of the coolant samples obtained during the entire period were visibly turbid, and total solids concentrations were low (0.5-3.0 ppm). pH control was within 10.1 ± 0.2 except for a few brief occasions when the pH dropped to about 9.7 due to temporary mechanical problems with the chemical injection system.

The two instrumented crud detectors used in this test were in the reactor for about 100 days and operated for about 1500 EFPH (~ 95% of goal exposure). The crud detectors gave satisfactory performance during the entire test, with all eight thermocouples giving valid readings. There has been no indication of gross crud buildup on the elements. Brief visual examination of the crud detectors revealed a thin film on them; presumably the film does not noticeably alter the over-all heat transfer characteristics of the elements.

During the entire first phase (47 days) of operation the coolant conditions were similar to those reported earlier, namely that the ammonia loss by radiolysis was about 0.03 lb/day and that this rate agrees well with measured H₂ and N₂ concentrations in the coolant. During the second phase (4 days) ammonia radiolysis increased by a factor of about four and dissolved gas concentrations increased accordingly. Hydrazine was observed as a stable radiolysis product at this time (concentration ~ 60-70 ppb). Contrary to observations under similar operating conditions in this loop using lithiated coolant, no gross formation of O₂ or H₂O₂ was observed. Presumably, the presence of hydrazine inhibited formation of these products. During the third phase (12 days) ammonia radiolysis was only slightly greater than at normal operating conditions.

Plans are continuing to convert all four KER Loops to NH₄OH. During the month K-4 Loop was modified and is now being cooled with ammoniated coolant. It is anticipated that the change to ammoniated coolant in K-2 and K-3 will take place in about one month.

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Instrumentation for N-Reactor. The interference of sodium sulfite in the automated procedure for dissolved O_2 (Hays analyzer) in N-Reactor secondary system water was investigated. No interference is observed during normal operation with sulfite present. However, sulfite does cause interference during calibration operations when nascent oxygen is present. By using a modified procedure, the analyzer can be calibrated satisfactorily at sulfite concentrations from 0-10 ppm. Above 10 ppm sulfite, the analyzer cannot be calibrated satisfactorily; in this case a separate stream with a lower sulfite concentration is required.

3. Gas-Atmosphere Studies

Thick Film Effects on Hydriding of Zircaloy-2. It has been observed previously that Zircaloy-2 with a thick oxide film may slowly hydride in an atmosphere which contains sufficient oxidants to protect thin film samples. A new experiment was started last month where Zircaloy-2 with preformed films of 0, 50, 100, 200, and 500 mg/dm^2 was exposed to He, 1% H_2 , 1% H_2 - 1% CO with 500 ppm (vol) H_2O at temperatures of 350 and 450 C (662 and 842 F). Hydrogen contents after 28 days indicated all of the samples at both temperatures had absorbed gaseous hydrogen indicating the water supply rate was insufficient to produce inhibition, probably due to too low a gas flow rate. The results confirmed earlier data that H_2O is necessary and CO is an adequate hydriding inhibitor. A new experiment has been started with higher H_2O supply rates.

Graphite Burnout Monitoring. Small graphite monitors exposed in Channel 3580 at F-Reactor, from August 5 to November 20, 1963, showed less than 1% burnout per 1000 operating days (%/KOD). Monitors in Channel 1880 at KW-Reactor from August 3 to November 21, 1963, also measured below 1%/KOD.

A program has been started to empirically relate the burnout of graphite in a typical reactor configuration with the data obtained from burnout monitors. A 10-inch diameter tube furnace with 7-foot section having five separately controlled temperature zones will be used to simulate a channel temperature profile. An important objective of this study is the assessment of the role of diffusion of the oxidant into the graphite on the gross reaction with the large blocks.

4. Process Tube Development

Project CAH-922 Irradiated Burst Test. The construction of this facility for the evaluation of irradiated reactor pressure tubing

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has progressed favorably during the past month. The delays encountered in the vendor's shipment of the furnace-containment vessels (originally scheduled for shipment on Sept. 15, 1963, but actually received on Dec. 9, 1963) have caused some delay in the project completion date. Similarly, the instrument panels which were scheduled for shipment on Oct. 24, 1963, were awaiting shipment on Dec. 12, 1963.

N-Reactor Steam Generator Tubing. Stress rupture tests on the N-Reactor steam generator tubing have been continued throughout the month. Two tube sections failed, one after a total exposure of 1422 hours, the other after 1838 hours. Both were at test conditions of 300 C (572 F) and 3000 psi. Both failures were longitudinal cracks about one-fourth to three-eighths inch long. Ten of the original 25 tube sections with flaw defects in excess of 80% of the tube wall thickness remain after 1839 hours at test conditions. Five new tube sections with numerous flaws in the depth range of 50% of the tube wall or greater were installed on the 300 C - 3000 psi manifold. These tests have undergone only four hours at test conditions to date.

Process Tube Testing. Gas phase hydriding has been performed at 400 C (750 F) on specimens of Zircaloy-2 N-Reactor process tubing. At this temperature a uniform dispersion of about 275 ppm can be achieved, with any excess hydrogen in the system forming a massive hydride case at the surface.

Room temperature burst tests have been performed with strain gage instrumentation on specimens hydrided to concentrations of 180 ppm and 275 ppm. Ultimate strength was unaffected, both specimens failing at virtually the same stress as normal material. However, ductility was severely reduced. Although slight plastic deformation was exhibited both specimens failed by fragmentation at less than 0.1% deformation. Tests are planned at 300 C to determine the effects at that temperature of the hydrides remaining above the 100 ppm solubility limit.

Brittle fracture tests have been performed at room temperature on tubing containing 275 ppm hydrogen both with and without an additional case of massive hydride. Specimens were defected by milling slots in them about one inch long and then were pressurized to failure. The stresses at which the defected specimens failed were markedly less than for similarly defected tubing with normal hydrogen content. The failure stress for the specimen with 275 ppm uniform hydrogen was about 80% of normal and that for specimens with the additional hydride

case was only about 20% of normal. From these results it appears that the presence of a massive hydride case has a marked effect on the brittle character of Zircaloy tube fracture.

5. Thermal Hydraulic Studies

N-Reactor Studies. A digital computer program was written to handle data obtained in the heat transfer experiments with the full scale electrically heated model of the downstream half of an N-Reactor fuel column and process tube. Processing the data is in progress.

This program will calculate the values of pertinent experimental variables from instrument readings. These variables include: flow rates, coolant temperatures, steam qualities, powers, heat fluxes, ratios of heat flux to calculated burnout heat flux, heat losses, Reynolds numbers and pressure drops. These variables will be calculated for several portions of the experimental test section and apparatus in addition to the fraction of total power transferred to each of the three coolant channels in the fuel column.

Heater rod power and flow rate will each be calculated from two different sets of variables to check on the accuracies of the measurements and to serve as a guide for refining the calculations. It is planned to perform a first set of calculations based on experiments with no bulk boiling to determine liquid-phase flow versus pressure drop relationships and to check on the accuracies of the flow and power measurements. A subsequent set of calculations, incorporating any correction factors determined from the first set and including provisions for calculating two-phase to liquid-phase pressure drop ratios, will be performed.

Steam Generation During Quenching of Hot Fuel. Plans were made for an experiment to determine variations in heat transfer rate at a fuel surface which is initially uncooled at a temperature above 1500 F and then, by the introduction of flowing water, is brought down to a temperature of 100 to 200 F. In such an event, heat transferred from the surface to the cooling water would be expected to generate steam; however, the heat transfer rate and rate of steam generation should vary as some function of the flow rate and shape of the coolant passage. In the analysis of certain N-Reactor conditions, a fairly precise knowledge of the rate of steam formation from such an event is required to study the adequacy of the containment system.

Shipping Cask for N-Reactor Fuel. Several proposed designs of shipping casks for the transportation of irradiated N-Reactor fuel and product isotopes were examined to determine the adequacy of the heat

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transfer capabilities. The N-Reactor fuel cask under consideration used an air thermal-siphon to transport the heat from seven fuel elements to the interior cask walls. Calculations demonstrated that this scheme would provide only marginal results, and overheating of the load would occur if the cask were tipped on its side as could occur in an accident. Further calculations revealed that with proper sizing of cask components, a satisfactory design could be obtained utilizing the direct conductive, convective, and radiative transport. This alternate design was developed for Facilities Planning Operation of CPD.

Comparison of Boiling Burnout Correlations and Laboratory Data for N-Reactor Fuel. A review of four burnout heat flux correlations was completed and comparisons were made to determine the accuracy with which they would predict burnout heat flux for the burnout tests performed for N-Reactor. No correlation was found which could predict burnout over the complete range of test conditions. A summary of the burnout correlation calculations follows:

1. Correlation by Tong, Currin and Thorp (Nucleonics, May 1963).

This correlation for circular channels was generally high, especially at high mass velocities. Below a mass velocity of about 2×10^6 lb/hr-ft², it was about 30% high.

2. Correlation by Tippetts (GEAP-3766).

At mass velocities of about 1 to 2×10^6 lb/hr-ft², the agreement was quite good ($\pm 20\%$) for all types of flow channels but gave significantly higher and lower burnout heat fluxes at lower and higher mass velocities, respectively.

3. Correlation by Janssen and Kervinen (GEAP-3899).

This correlation for an annulus heated on the inner surface was about 30% high for all cases. In no case did it predict a burnout heat flux less than those obtained in the experiments.

4. Correlation by Levy (GEAP-3961).

Levy's correlation was fairly good ($\pm 30\%$) at higher mass velocities but only at low qualities. At higher qualities ($> 20\%$) the burnout heat flux prediction

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was very low. At low mass velocities ($< 1 \times 10^6$ lb/hr-ft²) the prediction was progressively higher.

Present Reactor Studies. Laboratory experiments were continued with an electrically heated, full scale model of a charge of K-V self supported fuel elements in a smooth bore Zircaloy tube. A total of 85 steady state runs for determining pressure-drop flow relations has been completed at constant tube powers of 700 kw, 1000 kw, 1400 kw, and 1800 kw. The generalized steady state boiling curves obtained from these data indicate that the procedure for determining operating limits will need to be modified only slightly for the K-V self-supported fuel charges.

Some difficulty was experienced with the test section that conceivably could change the results obtained to date. After the tests were under way, it was found that some of the ceramic self-supports failed on the experimental test section and resulted in some plugging of the annulus channel near the outlet end. Operating limits derived from the present data with annulus plugging would tend to be overly conservative but the degree of conservatism cannot be known until additional data are obtained.

The experiments were carried to sufficiently low flow rates to result in film boiling conditions on the test section surface at a tube power of 1400 kw. The film boiling flow rate checked quite closely with the film boiling flow rate determined previously for non-self-supported K-Reactor fuel in a ribbed tube (reference HW-71074). Film boiling was first obtained with a rear header pressure of 60 psig, and then the rear header pressure was lowered to 30 psig without affecting any upstream pressures. Hence, any rear header pressure less than 60 psig would not affect the film boiling flow rate.

It should be noted that the film boiling conditions were obtained for two different degrees of annulus plugging as caused by the unintentional flow blockage of broken ceramic self-supports. While the degree of annulus plugging in both cases cannot be accurately known, the film boiling conditions agreed within 2% of each other.

Hydraulic Tests. Thermocouple tests were performed in the hydraulics laboratory to relate response time and accuracy to: (a) the distance of the thermocouple junction from the end of the well, and (b) the distance the well extends into the water stream. The data indicates that a small variation in the distance of thermocouple junction from the well bottom (1/16 to 1/4 inch) does not by itself affect the response time.

Four thermocouple assemblies containing the same epoxy material and with various well bottom depths exhibited about the same response time to reach 63% of the difference between the initial and final stream temperature. Increasing the penetration of the thermocouple well into the moving fluid stream from $-1/8$ inch to $+3/8$ inch improved the response time by approximately 80%.

6. Shielding Studies

N-Reactor Shielding Evaluation Experiment. Preparations for the N-Reactor shield evaluation study are complete and equipment is being installed at N-Reactor location. A thimble into the reflector has been fabricated and installed to provide a gas seal below the shield plug. The thimble is fabricated of aluminum and will allow placement of detectors into the reflector without disturbance of the reactor gas seal. This thimble is designed so that installation is relatively simple and very quick. The thimble can be removed or changed in a period of time such that the reactor gas seal is broken only for approximately five minutes. Current plans are to leave the aluminum thimble in the reactor for the cold physics tests, remove the thimble for the hot zero power physics test and replace and perhaps install a stainless steel thimble for the power demonstration and power ascension tests.

The thermocouple system is complete and calibrated and ready for placement in the test location. The ion chamber system was also completed during the month, was calibrated, and is ready for placement in the test location. Four types of ion chamber detectors are available. They vary in size from approximately one cubic centimeter through 100 centimeters. The smallest chambers will be placed closest to the source, the larger chambers of high sensitivity will be placed farthest from the source. Three of the chambers were taken from the DR shield gamma monitoring system, and three were fabricated from a design suggested by IPD Radiological Engineering.

Preparations are complete for foil activations. The analytical results of the PCTR experiment performed last month indicate that gold, cadmium-covered gold, cadmium-covered sulphur, and cobalt foils may be used in the shield plug for the zero power tests and for the power ascension tests. During the higher powered tests it appears that iron, titanium, and nickel foils can also be used to advantage.

The neutron spectrometer is now complete and ready for transfer to N-Reactor site. The lithium⁶ and helium³ detectors were calibrated

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with respect to counter efficiency as a function of angular distribution. The calibrations were carried out at the positive ion accelerator using monoenergetic neutron sources in the energy range of 0.5 to 4.6 mev. The calibration indicated that the sensitivity of the helium³ detector was about a factor of 100 greater than the lithium⁶ detector. This will allow some flexibility in use of these two detectors in widely varying neutron populations.

Current efforts are directed at installation of this test equipment at the N-Reactor location within the next two weeks. A supplement to HW-77917, Part I, "N-Reactor Startup Physics Program - Cold Physics Tests" has been written which explains the experimental procedures to be used in the parts of the shield evaluation test which will be accomplished during the N-Reactor cold physics tests.

The concrete blocks in the DR shield test well were removed. The foil holders were taken to the 190-D Laboratory where they were disassembled. The gold foils were of an activity level too great for counting and no facilities were available for a sulphur analysis at that time. Three of the ion chambers were recovered and decontaminated for use in the N-Reactor shield plug experiment.

7. Graphite Studies

Irradiation of Large Graphite Bars. Seven bars of CSGBF graphite were discharged from the A-test hole at C-Reactor. The 4x4x23.5 inch bars were located in a filler layer between tube rows 20 and 21. The charge consisted of a column of 18 bars extending from the inner surface of the cast-iron shielding. The seven bars discharged were located between columns 78 and 79 and the inner surface of the thermal shield.

Before insertion, dimensions of the bars were measured at each end and at the center in the direction transverse to the extrusion axis and from end to end parallel to extrusion. No weight determinations were recorded. Post-irradiation length determinations have been made on all but one of the seven bars discharged. Surfaces appeared in good condition on the four bars extending from column 79 to 89. Fine lines scribed to guide the positioning of micrometers for length determinations were still visible. Evidence of progressively more severe oxidation was noted from positions corresponding to column 92 into the reflector. The bar which extended into the reflector was severely oxidized and length measurements were not made. Pieces of metal in the form of globules were noted at the bottom of craters oxidized into the upper surface at one end of the bar. This bar

was wrapped to prevent spread of the loose graphite dust on oxidized regions and will be shipped to the 300 Area for photographs and density-profile determinations.

Average percent contraction determined for the bars is tabulated below with the column nearest the center of each bar used for position reference. The exposure indicated is an average determined from the power output of the tube above and the tube below that position.

Column	Exposure, MWD/AT _C	Length Change, %	
		Transverse	Parallel
80	25,700	-0.763 ¹⁶	-0.913 ¹
83	25,100	-0.787 ¹⁶	-0.949 ¹
86	26,400	-0.770 ¹⁶	-0.968 ¹
88	25,400	-0.729 ¹⁰	-1.103 ¹
91	24,100	-0.892 ¹³	-1.098 ¹
94	17,700	-0.614 ¹⁰	-0.884 ¹

Note: Exponent indicates number of measurements averaged.

A linear extrapolation of data obtained previously on large bars of CSGBF taken from the G-hole at C-Reactor with exposures up to 18,600 MWD/AT_C shows good agreement with the above data. These latest results thus reaffirm the existence of a difference between large and small samples as reported in HW-SA-2996.

Analysis of these data will be continued. There is apparently a correlation between the contraction at a given position along the length of a bar and the position of tube and filler blocks above and below the test hole. Exposure estimates for each adjacent pair of tubes will be obtained and combined with measured and calculated variations in fast flux across the lattice to test this apparent correlation.

N-Reactor Graphite Irradiations. The two, third-generation capsules, H-5-3 and H-6-3, in the series of long-term irradiations of N-Reactor graphite continue to operate satisfactorily. The first of the fourth-generation capsules, H-4-4, is being assembled the week of December 9.

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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

Examination of PRTR Fuel Elements. Twelve selected PRTR fuel elements examined in the PRTR storage basin during the month included seven swaged UO_2 elements (1500 to 4400 $\text{MWD}/T_{\text{fuel}}$), one $\text{UO}_2\text{-PuO}_2$ (2000 $\text{MWD}/T_{\text{fuel}}$) and four Al-Pu elements, three of which have successfully reached the extended goal exposure (> 100 MWD). Three UO_2 elements are acceptable for continued irradiation and four have one broken rod wire wrap, each. Breaks are located at the wire bend at the point of attachment to the bottom end caps. Metallographic examination is under way to determine if breakage was caused by mechanical damage or by corrosion and embrittlement. Previous out-of-reactor tests showed no potential for accelerated corrosion under the conditions to which the wires are routinely subjected.

The $\text{UO}_2\text{-PuO}_2$ fuel element was discharged earlier as a weak leaker suspect. Three large scrape marks on one rod are all that is visible. The element will be re-irradiated in FERTF and stagnated to find the leaky rod.

Three Al-Pu elements are suitable for re-irradiation, although one element has a worn spot on one bottom wear pad. The fourth element (54 MWD), discharged earlier as a leaker suspect, will be reirradiated in the rupture loop to evaluate irradiation behavior after failure. The only visible defect is a small, white corrosion blister on the tip end of one rod cap.

Fuel Element Refurbishing. Two fuel elements repaired by splicing rod wire wraps successfully completed three PRTR cycles. Inspection shows the rod wire wraps are tight, the splice is in good condition, and both the splice unit and the wire retaining nut have developed a uniform black oxide coating.

PRTR Fuel Fabrication. Four swaged PRTR elements were fabricated

for PRTR. The elements were made from impacted UO_2 - 1 wt% PuO_2 which was outgassed at 250 C, 1×10^{-3} torr, for one hour. Processing of 600 kg of impacted material for an additional eight PRTR elements was begun. Two of the elements will be fabricated by vibratory compaction and the remaining elements will be swage-compacted.

Metallographic examinations of wrinkled sections of several impaction cans revealed that the wrinkles are very weak. The 25-mil inner can appears to withstand stresses during impaction and cooling, but the thicker outer can (1/16 inch) nearly failed in many of these wrinkles. Some shearing was evident at the upper corners, where part of the can had been extruded between the punch and the die wall. This weakness has been remedied by using a thicker and larger diameter punch protector. Cans with 0.035-inch walls were ordered for trial use in combination with the 0.025-inch wall inner can.

Welding parameters were established for the swageable type end cap for vibrationally compacted PRTR fuel rods. An order was placed for 450 end caps to fabricate eight fuel clusters.

Weld closures were made on six plutonium-bearing, 0.022 aluminum-clad N-Reactor experimental elements for Physics tests.

Buffer rods (40) for the PCTR PuO_2 - UO_2 -bearing fuel elements were completed.

Irradiation Testing Program for EBWR Prototypic Fuel Rods. Two capsules containing vibrationally compacted UO_2 -2.5 wt% PuO_2 have accumulated over half the goal exposure of 1.43×10^{20} fissions/cm³ (5000 MWD/ton of fuel). One capsule (GEH-14-421) contains pneumatically impacted UO_2 - PuO_2 while the other (GEH-14-424) contains a physical mixture of UO_2 - PuO_2 .

Prototypic EBWR fuel (UO_2 -1.5 wt% PuO_2), prepared by pneumatically impacting a physical mixture of ceramic grade UO_2 and purified PuO_2 , was outgassed in vacuum at 625 C prior to incorporation in other irradiation test capsules.

Pu Wire Enriched Ceramic Fuel Element. Post-irradiation examination of a fuel rod that originally contained sintered UO_2 pellets enriched with a coaxial Pu-15 wt% Zr wire revealed the disappearance of the wire and no evidence of a second phase. The wire was presumably oxidized, then dispersed in the molten UO_2 . The extent of

plutonium relocation will be determined by microsampling a transverse cross section from the rod center and longitudinal cross sections from the rod ends.

Fretting Corrosion. A PRTR fuel element having circumferential bands on the end hanger supports that has been flow tested with imposed vibration several months in the TF-7, out-of-reactor loop, was terminally discharged. Slight local hydriding was observed in end hanger areas which experienced minor wear and in a wire wrap which had worn 10 mils. Another fuel element, having conventional top and bottom end hangers intentionally misaligned 60 degrees, is being prepared for testing.

Evaluation of Fuel Impurity Effects. Eighteen capsules containing UO_2 -1 wt% PuO_2 (prototypic PRTR fuel) contaminated with known quantities of water and oil were discharged from the MTR on December 25, after completing one cycle of irradiation. Destructive examination will reveal the effect of excessive oil and/or moisture on Zircaloy cladding integrity.

Less than 100 ppm zirconium hydride was observed in the Zr-2 cladding of autoclaved, non-irradiated capsules having the same fabrication history and containing fuel with the same impurity concentrations as the irradiated capsules.

PRTR Fuel Element Cladding Evaluation. Previously accepted Zircaloy-4 cladding tubes were found to contain defects when examined by ultrasonic techniques not available at the time of original inspection. Of the 172 tubes retested, approximately 35% contain metal chips impressed 0.001 to 0.008 inch. No cracks or other serious defects were found.

Cladding Alloy Procurement. Ultrasonic inspection indicated that burrs and scratches on internal surfaces of EBWR fuel element cladding tubes were satisfactorily removed using a specially designed centrifugal hone. Approximately 400 EBWR fuel element cladding tubes will be reclaimed in this manner.

Glove Box Atmospheres. Water sorbed into ceramic fuel materials has frequently caused processing difficulties and, presumably, one cladding failure. These problems will be eliminated or reduced by equipment, on order, for drying glove box atmospheres and for vacuum outgassing.

Zircaloy Compatibility with Oil-Contaminated UO_2 - PuO_2 . Four small capsules were prepared using Zircaloy PRTR tubing and mixed UO_2 - PuO_2

powder. Two capsules contained "clean" powder and two were filled with powder scraped from oily deposits inside the jaw crusher.

All four capsules were first irradiated to 10^9 R by a Co-60 source, and two capsules, one clean and one contaminated, were heated to 400 C for 100 hours. The capsule containing clean material showed no change while the capsule with contaminated powder exhibited considerable swelling and dulling of the surface, indicating the possibility of excessive hydriding. Metallographic examination is being performed.

(Th, Pu)O₂ Irradiations. Five (Th, Pu)O₂ pellet capsules were successfully irradiated in the MTR. After an appropriate cooling period, the samples will be returned to Hanford for post-irradiation examination.

Preparation and Characterization of PuO₂-SS Cermets. Plutonium cermets were successfully fabricated by pneumatic impaction. A split die was used to simultaneously impact six PuO₂-stainless steel pellets to densities greater than 96% TD. Densities of the pellets ranged from 96.2% to 97.1% TD and averaged 96.7% TD. Two pellets were heated to 1300 C in a helium atmosphere for 25 hours. Both pellets lost weight and increased slightly in length. The density decrease was 2.2% for one pellet and 6.1% for the other. The decrease in density was probably caused by expansion of the PuO₂ crystal lattice and loss of oxygen from the PuO₂.

For comparison purposes, UO₂-stainless steel cermets (20 vol% UO₂) were heated in hydrogen to 1200 C for 127 hours and to 1350 C for four hours. No weight, dimension, or density change occurred.

Fuel Element Development. All coils for the PRTR fuel element containing eddy current probes for vibration studies were assembled with lead wires. Since coils with matched inductances and numbers of turns cannot be readily obtained, a compensatory circuit in the readout equipment may be required.

Corrosion and Water Quality Studies

Zirconium Fretting Tests. A test program is in progress to compare fretting under similar conditions in- and out-of-reactor. Samples are placed in Magnedash autoclaves in the EDEL-I Loop in 314 Building and in the PRTR primary system. The first test in the PRTR system was postponed due to operating difficulties. The first pre-autoclaved Zircaloy-2 sample removed from the autoclave installed in

the EDEL-I Loop after 4,073,000 impacts (in 565 hours) showed saucer shaped fretted area, 3/8 inch diameter by 0.013 inch deep.

Corrosion and Deuterium Absorption of Zircaloy in D₂O. Samples of Zircaloy-2, Zircaloy-4, and crystal bar zirconium are being exposed to 275 C (527 F) pH 10, LiOH heavy water. Weight gains after 168 days are normal and D₂ absorption is about 10% of that produced by corrosion for Zircaloy-4 and crystal bar and about 15% for Zircaloy-2. A 275 C pH 10 LiOH control experiment has been started and after 42 days there are no significant differences in either corrosion or hydrogen absorption between the H₂O and D₂O data.

Stress Corrosion of Steel and Nickel Base Alloys in 550 C Steam. The susceptibility to stress corrosion cracking of various stainless steel and nickel base alloys in high temperature contaminated steam is presently being investigated. "U" bend specimens have been exposed to flowing 550 (1022 F) steam contaminated with FeCl₃ solution for 14 days followed by a 15-day exposure to flowing 550 C steam contaminated with NaCl. The 10 ppm FeCl₃ and NaCl solutions were introduced in pulses into the flowing superheated steam through a spray nozzle at a rate of 0.15 l/hr. The flow rate of the superheated steam was 700 l/hr. To date, no alloy has shown signs of stress corrosion cracking. The 17-4 pH s/s and 316 L s/s were stress relieved at the 550 C test temperature. No stress relief has been noted in the remaining alloys.

Effect of Sodium Phosphate Solution on Stainless Steel Coupons. Stressed 304 stainless steel coupons have been exposed to a $\frac{1}{2}$ lb/gal, pH 4.5 mono sodium phosphate solution at 275 C (526 F). The solution contained a chloride content equivalent to 700 ppm Cl⁻ in the dry phosphate. The purpose of this test was to determine the effect of such a solution on the stainless steel phosphate addition line to the PRTR steam generator.

Samples corroded rapidly during the first 12 hours; the rate slowed upon further exposure. A sample removed after 426 hours of exposure had a corrosion rate of about 0.4 mil/year after the initial rapid corrosion. A second sample, after 1384 hours of exposure, shows a corrosion rate of approximately 0.2 mil/year. Dye penetrant testing did not reveal any cracks or defects in the samples. This solution can be safely handled by the phosphate injection tubing and the test has been terminated.

Reactor Components Development

Pressure Tube Monitoring. A preliminary analysis of the results of in-reactor inspections since June 1962 indicates that the severity

of fretting in the PRTR process tubes has diminished substantially. Since June 1962, only three new fretted areas with depths greater than 0.25 mm (0.010 inch) have been found. Two of these are associated with the end bracket spacer pads (dimensions 1.5 mm x 12 mm or 1/16 inch x $\frac{1}{2}$ inch) of AlPu fuel elements and the third associated with the spiral wire wrap of a fuel rod in a fuel element of unknown type. As yet there are no fretted areas associated with the enlarged area end bracket spacers (6 mm x 12 mm or $\frac{1}{4}$ inch x $\frac{1}{2}$ inch) with depths greater than 0.025 mm (0.001 inch).

Shim Rod Development. Assembly of the driving heads for the second generation shim rods is progressing without the heat sinks. Previous heat sink castings have been unacceptable, and successful procurement of these items before year's end appears doubtful in view of the vendor's poor continuing performance. Two driving heads have been completely wired and tested. Assembly of one lower unit is approximately 60% complete. One shield plug assembly has been completed. The motor-generator set of the shim rod environmental test facility has been used during the month to test the second generation rod drives.

Fretting Corrosion Investigation. After more than 500 hours of operation of EDEL-I with the same fuel element to pressure tube orientation, borescope examination has revealed the following information:

1. The relative size of the fretting marks made by the gusset pads was significantly increased compared with results reported after 120 hours of operation.
2. Angular marks from at least one pad confirm angular rotation previously noted on PRTR fretting.
3. Fretting opposite the top pads is less than at the bottom.
4. In addition to the pad induced fretting, five rod wrap and seven bundle wrap marks have been detected.

The borescope is being modified to enable depth estimation of fret marks.

An "excessive vibration" detector has been designed and assembled to indicate possible incipient fretting conditions. This unit receives a transducer output signal which is amplified and fed

into a bridge circuit. A pulse exceeding a preset voltage level, which is proportional to energy, registers on a counter and activates a warning light. The detector has been checked out on EDEL-I for initial voltage pot setting, relay chatter, amplifier and transistor saturation, and stability. The test results were satisfactory. The transducer has been installed on PRTR inlet jumper 1348 and connected to the detector unit in "C" cell at the -32 ft level. The installation has not yet been checked during reactor operation.

A test is now in progress in EDEL-I in which the fuel element pads are wedged, by small plates, to the pressure tube wall to eliminate the relative motion between the fuel element and wall. Each wedge is slotted and installed over a bearing pad and is held longitudinally by a stainless steel wire and spring connection. The possibility of rotational or axial fuel element movement is considered remote with this arrangement. More than 160 hours of operation have been accumulated with the fuel element wedged in place. An interesting side effect has been a reduction in pressure drop across the test section from 14psi to 11 psi at prototypical flow conditions. This effect is attributed to decreased fuel element vibration with a resultant decrease of energy dissipation of the coolant.

Following are results of zirconium water sample analyses.

<u>Sample No.</u>	<u>Temp., °F</u>	<u>Date</u>	<u>Zr, ppb</u>
1	80	7/26	0.2
2	530	10/30	0.1
3	80	10/30	0.36
4	80	12/5	5.60
5	80	12/9	0.25
6	530	12/10	1.90

The high zirconium content of Sample No. 4 is accounted for by noting that it was taken from the autoclave which houses a zirconium coupon being subjected to a cyclical impact load. The remaining samples were taken from loop water.

The lead wires for the instrumented fuel element for use in the fretting study were procured with a 100 Meg-ohm insulation rating. Apparently the magnesia insulation has absorbed moisture with a resultant loss in insulating strength. Instrumented fuel element completion is consequently delayed while the lead wires are being baked. Three fuel rods with satisfactory eddy current coils

have been completed but the entire assembly is not expected until year's end.

Pressure Tube Seal Tests. Fabrication of the PRTR pressure tube seal testing station is complete. A report is in preparation which will outline the direction of effort in this program.

Fuel Re-use Study. Scope design of the prototype liquid sodium loop for use in making engineering evaluations of the fuel re-use concept is complete. Schematic flow and instrumentation diagrams have been prepared, a general component and pipe layout finished, and initial heat and pressure drop balances calculated. The operating thermal stresses of the piping layout were shown to be acceptable as determined by an IBM 7090 piping stress analysis program. The loop will provide a test section for exposing PRTR size fuel elements in 1100-1200 F liquid sodium flowing at about 2 fps or 25 gpm.

Design Analysis

Nuclear Safety of Mixed PuO₂-UO₂ Fuels for PRCF-EBWR. Results obtained for the transient heating of UO₂ in mixed PuO₂-UO₂ fuel were presented to the thirteenth meeting of the General Electric Technological Hazards Council. On the basis of the data presented, it is thought that the council will approve use of this fuel in planned PRCF, H₂O moderated experiments. Because of the much greater excess reactivity available, further information was requested for use of this fuel in the EBWR. Although the calculations indicate no appreciable delay in Doppler Coefficient Feedback, the council felt the need for additional evidence of uniformity assumed for the physical model. In addition, they requested that the calculated time delay be incorporated in a calculation of an assumed excursion in which the power rises exponentially.

A second problem which was considered was the effect of PuO₂ particle melting and diffusion giving rise to a decrease in self-shielding and, hence, contributing to the excess reactivity during an excursion. This problem would be more severe if the PuO₂ tended to agglomerate during fuel manufacture. Hence, further evidence of uniformity of particle size would tend to alleviate concern about this possibility also. Migration of plutonium during irradiation, leading to gross segregation, was also discussed. Some experimental evidence that this may occur has been obtained, but the extent to which it may affect reactor safety has not been evaluated.

Reactor Controls Studies. Preliminary investigations are being carried out by Chemical Metallurgy, RAFL, in a program to determine the kinetics of the zirconium-hydrogen system. These data are required for studies of "spectral shift" hydrogen-augmented control systems utilizing variable hydrogen density. Such systems may offer considerable potential as a control means for compact fast reactors.

2. Plutonium Ceramic Fuels Research

Plutonium Cermets. The irradiation behavior of plutonium compounds and mixtures is being studied after long-term, high power exposures at the MTR. Three additional plutonium cermets were prepared for irradiation under this program; PuN-50 vol% W by pneumatic impaction; PuN-15 vol% Pu, and PuN-24 vol% Pu by arc melting.

Plutonium Handbook. A chapter titled "Plutonium Refractory Compounds" is being revised and updated for the Plutonium Handbook to be presented by the AEC at the 1964 Geneva Conference.

3. Ceramic (Uranium) Fuels Research

Low Temperature Irradiation Study of UO₂. Irradiation in a Hanford reactor was begun on a fuel capsule containing eight precharacterized specimens of polycrystalline and single crystal UO₂ for a proposed four-year exposure. The UO₂ specimens, including four sintered samples with previous exposures from 1.4×10^{18} to 1.3×10^{19} fissions/cc, will be used to study the microstructural changes resulting from irradiation at low temperatures for long exposure times.

In order to obtain a detailed characterization of the specimens prior to the irradiation study, complete electron microscopy examinations have been conducted on both polished and fracture surfaces. Fracture surfaces have been studied using the newly developed polyvinyl chloride replica technique for transmission electron microscopy. Non-irradiated specimens showed typical structures dependent on density and fabrication history. Irradiated pieces showed increasing tendency for intergranular fracture and marked porosity on the grain surfaces. This is assumed to be due to accumulated fission gases and is in agreement with results of previous work.

Examination of these specimen replicas and comparison with other samples of known history is continuing.

High Temperature Electrical Resistance of UO_2 . The high temperature resistivity-thermal conductivity apparatus has been operated successfully several times to about 1500 C in vacuum before the viewing window plated over with molybdenum and optical temperature measurement became impossible. This problem may be alleviated by the W vs W-26 Re thermocouple which has been installed.

Resistivity measurements were completed with both polycrystalline and single crystal UO_2 . Samples are now being prepared for the thermal conductivity portion of the experiment.

Fabrication of Cermets. Three tungsten clad cermet pellets were fabricated using newly developed powder cladding techniques.

Magnetic Force Welding. Modifications to the magnetic force resistance welder will provide additional versatility. Two vacuum chambers, one for beryllium only, are quickly and easily interchanged. New pre-heat and post-heat controls now provide a wide range of current and time control.

Irradiation of Cermet Fuels. UN-W and UN-Mo cermets were chemically and dimensionally stable during 21 days of irradiation at cladding surface temperatures greater than 2000 C. No degradation of the irradiated UN was observed during polishing with a water base slurry.

ThO_2 Irradiation Studies. Three aluminum-clad, compacted powder thorium elements are being irradiated to determine the efficiency of conversion of Th-232 to U-233 at various exposures in MTR. One element will be returned to Hanford for post-irradiation examination after one MTR cycle. One element will be deliberately defected after one irradiation cycle by drilling a 1/16" diameter hole through the wall. The defected element will be irradiated for approximately 140 minutes at the beginning of an MTR cycle to evaluate the extent of fuel loss during operation.

Pneumatic Impaction of UO_2 . A can of 2.42% enriched UO_2 was pneumatically impacted for preparation of specimens for AERE, Harwell, England.

4. Basic Swelling Studies

Irradiation Program

Two controlled temperature, general swelling capsules were brought to temperature after the reactor reached full power. These capsules

are tandemized to permit insertion into a single reactor test hole. One of the capsules is operating isothermally at 625 C (1139 F) regardless of the power level of the reactor, while the second is being operated at about 425 C (797 F) while the reactor is up but allowed to cycle to ambient when the reactor goes down. This type of operation is intended to more nearly simulate the conditions of an operating fuel element. Only enough heat will be supplied to this capsule to maintain its temperature in the 400-450 C (752-842 F) temperature range when the reactor is up.

Each of the capsules contains split, tubular specimens of high-purity ingot uranium, ingot uranium containing about 140 ppm Fe and 100 ppm Si, and ingot uranium containing about 400 ppm Fe and 600 ppm Al. Each of the three materials is present in several heat treated conditions.

Post-irradiation Annealing

A systematic study of the swelling of high burnup, clad and unclad uranium as a function of post-irradiation, pulse annealing has continued. Replicas of clad and unclad wafers which had been annealed at 650 C (1202 F) for five hours have been processed for quantitative metallography. Qualitative observations reveal that cladding has no effect on the extent of porosity present in the bulk of the specimens after the anneal. Both specimens show small recrystallized grains which are outlined by pores as well as non-recrystallized areas. Pore size varies greatly, from 0.1 μ to 1.0 μ in diameter. There is a 30-40 μ wide band in the uranium adjacent to the cladding which contains pores at recrystallized boundaries in the interior of the sample. This cladding effect was observed before in another study. A depletion of large pores near carbide inclusions was also noted in these specimens.

The influence of time at any one temperature seems to be one of increasing the amount of recrystallization and the size of the pores at the recrystallized boundaries. It is interesting to note that the sizes of the recrystallized grains are about the same for the times and alpha temperatures thus far examined.

A similar wafer was pulse heated to 700 C (1292 F) in ten minutes, then cooled to room temperature. Metallographic examination of this sample showed the typical large, beta grain structure. Porosity is homogeneously distributed throughout the grains. Pore size is very uniform, 0.2 μ in diameter. In some cases porosity is located along the prior beta grain boundaries; this porosity

may contribute to the severe intergranular cracking which has occurred. Rows of pores within the large beta grains are present and suggest an outline of small recrystallized grains which may have formed as the specimen was being heated through the high alpha.

Supporting Studies. Metallographic examination has been completed on tubular, high-purity uranium control specimens that were annealed at 625 C (1139 F) for 30 days in vacuum and NaK, respectively. The specimens were prepared from the same extrusion that was used to supply samples for irradiation testing in controlled temperature capsules. There were no obvious differences between the sample annealed in NaK and that annealed in vacuum. Both exhibited marked grain growth and a small amount of coalescence of second-phase particles. In many places the grains extended completely across the 0.076 cm (0.030 inch) wall of the specimen. This is in sharp contrast to the observations made with irradiated specimens. After an order of magnitude longer exposure at 625 C in the reactor, the original alpha grain size had not changed. It is apparent that neutron irradiation is an extremely powerful grain boundary stabilizer for the uranium examined here. This is due to the fission products that are generated, "locking" the boundaries in place. It is not clear as to whether the solid or gaseous fission products are the most effective, but it is most likely that the inert fission gases xenon and krypton are largely responsible for this behavior. This is consistent with observations made in other gas-metal systems. For example, injecting He into cold-worked aluminum by cyclotron irradiation on a concentration of $> 10^{-4}$ at% severely inhibits recrystallization during post-irradiation annealing and He-filled pores inhibit grain boundary movement in recrystallized aluminum.* Uranium develops a concentration of 10^{-4} at% inert fission gas in a fairly short period of time so that this pinning or locking of boundaries takes place very quickly.

* C. E. Ells, "The Effect of Helium on Recrystallization and Grain Boundary Movement in Aluminum," *Acta Met.*, 11, 87 (1963).

5. Irradiation Damage to Reactor Metals

Alloy Selection

Tensile tests at room temperature on Cb - 1 Zr and Cb-752 refractory metal alloys irradiated at 50 C (122 F) to exposures of 8.8×10^{19} to 1.5×10^{20} nvt have been completed. The Cb-752 alloy showed a 50% increase in yield strength and a marked decrease in total elongation. After irradiation, the uniform elongation was decreased to about 1% whereas the control specimens showed a 14.5% uniform elongation. In the case of the Cb - 1 Zr, an increase in yield strength of about 20% was observed after an irradiation exposure of 1×10^{20} nvt. The uniform elongation was reduced from 3.2% to 0.6%. Further tests and analysis will be made during the next reporting period.

Several nickel-base alloys are being irradiated to determine the effect of irradiation upon their mechanical properties. Room temperature tensile tests have been completed on Inconel 625, Hastelloy X-280, Hastelloy N, Hastelloy R-235, Inconel 718, and TD nickel after irradiation in 280 C (536 F) water. With the exception of TD nickel, the effects of the irradiation upon the room temperature properties of the alloys were small. After irradiation to 1.8×10^{20} nvt, the TD nickel specimens showed a 50% increase in yield strength and almost a total loss in elongation.

A new precipitation-hardening alloy is being considered for cursory evaluation of its applicability for use in a nuclear environment. The alloy, Rene' 62, has just recently been announced by General Electric Company, FPLD, as an alloy suitable for use at temperatures to 1300 F (704 C) with excellent corrosion resistance and high stress-to-rupture strengths.

In-Reactor Measurement of Mechanical Properties

The final in-reactor creep test on 20% cold worked Zircaloy-2 is now in progress. This test is being conducted at 20,000 psi stress and 377 C (711 F). The apparent steady state creep rate is 2.0×10^{-6} /hr. When the new data point is added to the Arrhenius plot previously established, the data can be expressed in closed mathematical form as follows:

$$\dot{\epsilon}_s = 2.51 \times 10^{20} \sigma \exp 5.31 \times 10^4 \exp - \frac{9 \times 10^4}{RT}$$

where

$\dot{\epsilon}_s$ = steady state creep rate - 1/hour.

σ = stress - psi.

R = universal gas constant.

T = temperature ($^{\circ}$ K)

It is expected that above 400 C (752 F) the activation energy decreases to that of self-diffusion; hence, the above equation should be invalid above 400 C (752 F).

In addition to the steady state creep correlation with the Arrhenius plot, it has been possible to correlate first stage creep strain with the Dorn's theta parameter. This plot demonstrates that the early creep strain is only a function of the parameter theta and stress. This fact allows one to predict creep strains at constant stress at temperatures much lower than those actually used in testing. The theta correlation also shows that steady state rates will occur at the same strain value. If one uses the theta correlation up to the strain at which steady state creep occurs and then uses the Arrhenius plot, a complete time-strain history can be predicted at various temperatures.

Irradiation Effects in Structural Materials

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

Optimization of nickel alloys for reactor service by means of pre-irradiation thermal or mechanical conditioning is being investigated. High temperature deformation followed by a rapid quench and aging is reported to enhance second phase precipitation and grain substructure. Such a high temperature deformation treatment at 1200 C (2192 F) was applied to Inconel X-750. This treatment increased the hardness from 240 to 460 DPH in the as-received condition and from 345 to 460 DPH in the standard heat-treated condition. The standard heat treatment consists of a solution anneal at 1150 C (2100 F) followed by a double-aging at lower temperatures.

Lowered ductility, impending notch sensitivity, and brittleness have been found to occur in cold worked AISI 348 stainless steel with increased irradiation exposure. Microstructural examination of irradiated fractured specimens has revealed the presence of highly brittle particles of, as yet, unknown identity. In the material examined these particles have cross sectional areas approximately five times greater than the metal grains. Near the fracture region of the specimen, these particles were invariably found to have fractured. Due to the high stress concentration at the crack tips in these particles, the cracks extended into the metal itself. As a result, several microcracks were seen near the fracture trace. The size of these cracks was large in the annealed and 10% cold worked specimens, indicating the ability of the material in this condition to contain a relatively large microcrack without catastrophic failure. In contrast, the microcracks formed in the more severely cold worked condition were only slightly larger than the size of the particles where they originated. It is quite probable that the particles contribute to the notch sensitivity of cold worked AISI 348 stainless steel after nominal neutron exposure. It remains to be seen whether or not these particles can be removed by heat treatment.

Damage Mechanisms

The objective of this program is to determine the mechanism by which defects produced by neutron bombardment interact with dislocations to modify the plastic deformation characteristics of the metal. The investigation is currently concerned with the role of the interstitial impurities in α - iron.

Two samples of zone-refined iron have been tested, one at 290 K and the other at 200 K, using the strain rate cycling technique described in previous reports. There was little difference in the $\Delta\sigma$ values obtained at 200 K on this sample of zone-refined iron and the sample of Ferrovac "E" previously tested at 200 K, indicating that the values of effective stress, γ^* , were the same for these two samples in spite of the large differences in the long range internal stresses, γ_i . Differences in $\Delta\sigma$ values were noted, however, in the room temperature tests, where the higher purity zone refined iron was found to have $\Delta\sigma$ values approximately twice the values for Ferrovac "E".

Several advances were made in the interpretation of test results especially significant in explaining the strain rate sensitivity observed in room temperature tests. Furthermore, a method was developed to calculate γ^* from experimental data only.

Environmental Effects

Examination of Zircaloy-2 corrosion specimens exposed to 535 F (279 C) ETR G-7 loop coolant in a downstream out-of-flux position during 18 full-power operating days of ETR cycle 58 showed marked differences in appearances and weight and hydrogen gains between material charged in the preautoclaved and bright-etched conditions. Weight gains and hydrogen pickup fractions for preautoclaved material were low and comparable with expected results for out-of-reactor exposure. The surfaces of these specimens were uniformly smooth and glossy and interference colors were detectable over small regions. On the other hand, large areas of the bright-etched material were covered with a rough grey-white film of ZrO_2 , as determined by x-ray diffraction, although some regions were coated with a thin, dark and adherent oxide. Weight gains for the etched coupons were two to three times those expected for exposure to similar environmental conditions out of reactor. Fractional pickup of theoretical corrosion hydrogen for these specimens was approximately 50% as compared with 13% for the preautoclaved coupons.

Coolant transport time from the active zone of the reactor to the downstream samples was approximately one second as compared with the approximately one minute delay prior to contacting the upstream out-of-flux samples as reported last month. Major differences between exposure results for the two locations based upon examination of a total of only eight coupons appear to be (1) slightly reduced oxidation rate for preautoclaved material, (2) greatly reduced oxidation rate for bright-etched material, and (3) higher fractions of theoretical corrosion hydrogen picked up by material in both pretreatment conditions at the upstream position. Water oxygen and pH levels during exposure of the upstream coupons of ETR cycle 57 were generally higher than obtained during the exposure of downstream coupons during cycle 58.

ATR Gas Loop Studies

Insulation Studies. Outgassing and load bearing studies have continued on the cast Fiberfrax insulation. An insulation specimen loaded on a flat surface by a one square inch indenter to the same bearing pressure as anticipated for the insulation of the model gas loop (0.15 psi) has a 0.001 inch penetration after 24 hours at 2100 F (1149 C). A specimen with ten times this load had a penetration of 0.170 inch at the same conditions. Preliminary results from the outgassing studies indicate that heating to 600 F (315 C)

gives about a four-fold decrease in the time required to evacuate small samples to five microns pressure compared with no heating. Heating plus simultaneous purging with helium gives a further 15% decrease in time. Tests are continuing on larger volume samples to permit prediction of approximate times required for outgassing the insulation used in the double-contained piping of the model gas loop.

Model Gas Loop Test Section. The model gas loop Mark I test section* consists of the following: pressure containment tube of type 347 stainless steel, metallic foil insulation at the lower and middle sections of the tube to maintain this tube at relatively low temperature, and a Haynes alloy 25 flow guide at the top of the test section for attemperation. Access to the top of the test section is provided by a Grayloc-type blind flange.

Test section construction has continued. An alternate design of the metallic foil insulation for the upper part of the test section has been received from Hawker-Siddeley. The bellows for sealing between the top of the pressure tube and attemperator flow guide tube was received but was not according to purchase specifications and is being returned to the vendor for correction. All other materials have been received and welding is ready to begin.

Shroud Piping for the Model Gas Loop. During November 1963, the shroud piping for the model gas loop was received. The shipment consisted of 316-H stainless steel, NPS 10-inch and 12-inch, schedule 20 fittings and straight sections which had been fabricated from plate. Prior to shipment, these pieces passed standard hydrostatic tests prescribed by the ASME code, but the weldments were not radiographed in the fabricator's shop because the purchase order did not require radiographic examination.

Upon receipt, the piping sections were given complete radiographic examination. Of the 19 sections received, six sections met the ASME Boiler and Pressure Vessel Code for weldments. The balance of the piping had one or more unacceptable areas which consisted of cracks, excess porosity, and slag in the weldments.

* D. R. Doman and R. L. Knecht, "The Model High Temperature Gas Loop Test Section - An Interim Report," HW-79159, Oct. 3, 1963.

The shroud pipe and fittings will be pressure bearing members designed to operate at 300 psig and 1150 F (621 C) temperature. At these operating conditions in the model loop the weldments must have high integrity and strength. Consequently, all unacceptable welding defects are being ground out and repaired. Subsequently, all repaired areas will be re-radiographed to assure that all defects have been removed.

Model Gas Loop Pressure Drop Studies. Purchase specifications for the model gas loop bearing compressor called for the capability to circulate 500 pounds of helium per hour at an inlet temperature of 650 F (343 C), an inlet pressure of 340 psig, and an outlet pressure of 350 psig. Based on these specifications, the model loop was designed for a pressure drop equal to the head developed by the compressor at the operating conditions stated above.

Subsequent to the purchase of model loop components, the ATR gas loop inlet pressure for the test section was reduced to about 227 psig. As a result of this change a theoretical study was made to determine the capabilities of the model loop for operation at reduced pressures. Using a computer program, model loop pressure drops were calculated as functions of various gas flows and pressures. Results of the study showed that, for a full flow condition of 500 pounds per hour, pressure drop in the loop exceeded the available compressor head for any pressure below 270 psig.

Design Test 1172. Thermal and bending tests of Grayloc connections for the ATR gas loop have been started. Fifteen cycles have been performed manually with no detectable leakage of helium. The test setup was programmed for automatic cycling by December 15, 1963.

6. Gas-Cooled Reactor Studies

Irradiation of Experimental Graphites. Irradiation experiments have been conducted during the last three years on several series of graphites formulated to test the influence of furfuryl-alcohol binder on the dimensional stability of the graphite. The samples were irradiated in the MTR and ETR in uninstrumented "hot capsules." Samples of CSF graphite, whose irradiation behavior is well known, were included in each capsule as a reference material.

Because capsules were moved three times to different reactor positions during the first irradiation, some variation in temperatures undoubtedly occurred. Dimensional changes of the CSF reference samples indicate that the temperature variation may have been as great as 350 to 550 C. Comparison of dimensional changes, therefore, is possible only within each capsule. Irradiated were (1) two series of graphites from the Armour Research Foundation molded from No. 90 flour, Texas coke, using, respectively, 20 parts furfuryl alcohol and 37 parts pitch and graphitized at 2900 C, (2) Dragon Project graphite, pitch bonded and furfuryl-alcohol bonded, and graphitized at 2700 C, and (3) a proprietary fine-grain graphite developed for use as a fuel matrix.

Specimens of these graphites have been irradiated in a series of four consecutive tests to a maximum exposure of 7.23×10^{21} nvt, $E > 0.18$ mev. Samples were measured and re-encapsulated in the same assemblies after each irradiation.

Exposures in all capsules were sufficient to cause large dimensional changes in the graphites, the greatest being a contraction of 5.2%.

Furfuryl-alcohol-bonded graphites contracted consistently more than their pitch-bonded counterparts. The needle-coke graphite, AGOT-LS, contracted much less than any of the other materials, only 1/4 that of the corresponding CSF reference sample.

Effect of Irradiation on the Tensile-Strain Limit of Graphite. A simple in-reactor test assembly is being utilized to produce a tensile strain on an EGCR graphite specimen at 650 C. The tensile strain is produced by a carbon body which has a high radiation-induced contraction rate relative to the test specimen. It is expected that a strain-rupture limit can be established. The strain limit for graphite in ex-reactor tests is on the order of 0.2%. Of the four assemblies now being irradiated maximum tensile strain presently attained is 0.17%. Since the strain limit in an irradiation field is expected to be higher, the tests will be allowed to accumulate strain until either a strain limit is found or enough deformation in excess of 0.2% is produced to definitely establish the existence of strain relief under these conditions.

Radiolysis of Carbon Monoxide-Water Mixture. In the study of the radiation-induced reaction of carbon monoxide-water vapor mixtures, an attempt has been made to determine the effect of concentration,

total pressure, and surface area on the 100-ev yields of hydrogen and carbon dioxide.

Varying the concentration of carbon monoxide from 2.8×10^{-3} to 13.5 moles per liter and water vapor from 3.3×10^{-3} to 15.3×10^{-3} moles per liter did not perceptively affect the $\underline{G}$ values.

Increasing the total pressure appeared to cause a small decrease in the $\underline{G}$ values. However, there was enough uncertainty in the mass spectrometer gas analysis to make this conclusion questionable.

The effects of an increase in surface area on the 100-ev yields, as determined by packing the capsules with Pyrex wool before irradiation, were somewhat questionable but indicate a possible decrease in $\underline{G}_{H_2}$ over that found in the unpacked capsules and an even larger decrease in the $\underline{G}_{CO_2}$.

Further experiments are planned in an attempt to confirm these results.

7. Graphite Radiation Damage Studies

High Temperature Dilatometer. A Brinkman high temperature (25-1500 C) inert-atmosphere automatic dilatometer has been received and assembled. The dilatometer was calibrated to 1150 C by measuring the length change of a quartz sample. The instrument length change per sample length was found as a function of temperature by subtracting the quartz expansion as a function of temperature from the recorded length changes. The standard deviation of the instrument calibration for two runs was about ± 0.00002 in./in. of sample.

Initial runs in the dilatometer with unirradiated TSGBF graphite samples showed no perceptible chemical reaction with the alumina holder and rod assembly up to 1300 C with a helium atmosphere, but some specimen oxidation did occur. Steps are being taken to minimize this oxidation.

8. Boronated Graphite Studies

Long-term Irradiation Test. The long-term irradiation capsule containing boronated graphite samples was installed in the 2C test facility at KW-Reactor during this period and successfully achieved temperatures within limits specified before irradiation.

The nominal 650 F section of the three-section capsule is operating at goal temperature. The two duplicate high temperature sections

that were designed to operate at a nominal 1000 F are both operating at about 850 F. Although lower than expected, the temperature is within the acceptable tolerance of ± 150 F. Temperatures of these two sections differ by only 20 F, indicating a high stability of the capsule design and reproducibility in manufacture of the sections. The temperatures in both sections have increased slowly with time, probably as a result of radiation-induced reductions in thermal conductivity of the graphite tubes containing the samples.

The capsule design emphasized high longitudinal conductance and close coupling of the samples to minimize longitudinal temperature variation that otherwise would result at high heat removal rates. By locating samples according to individual differences in heating rates the over-all axial variations of the monitored sample temperatures were reduced to less than 10 F.

Before operation the free volume of the capsule was measured with a reproducibility of one part in 500 and an accuracy limited by the gauge of one part in 100. The capsule was loaded with helium to 17.39 psia. Average pressures now are about 19.2 psia. The pressure increase is predominately due to temperature changes of the gas. Helium production as a function of irradiation exposure will be monitored.

9. Aluminum Corrosion and Alloy Development

Status of C-1 Loop. The C-1 Loop is operating with dummy fuel elements to demonstrate reliability prior to charging fuel elements. Four dump tests were run in the loop to demonstrate flow reliability during the changeover from recirculating water cooling to single pass process water cooling. The first test was made with cold loop water. These last three tests were made at loop operating conditions, 572 F and 2250 psi, and simulated off-standard conditions which would cause the loop to dump: (1) a high temperature trip at 590 F, (2) a low pressure trip at 2200 psi, and (3) a dump without the backup accumulator in operation. In all tests the loop operated as intended.

10. Metallic Fuel Element Development

Irradiation of Thorium-Uranium Fuel Elements. Three tubular Zircaloy-2 clad thorium - 2.35 wt% U-235 - 1.0 wt% Zr fuel elements are undergoing their fifth cycle of irradiation in the ETR P7 loop. Weight measurements made at the end of the fourth

irradiation period showed a maximum fuel volume increase of 0.5%. The maximum exposure achieved by the center fuel element is 1.3×10^{20} fissions/cm³ (3600 MWD/T) at a temperature of 585 C.

Thorium-Uranium Alloys. The fabrication, irradiation and defect corrosion behavior of the Th - 2.5 wt% U - 1.0 wt% Zr alloy has been described. The effects of higher zirconium and uranium compositions on the structure, fabrication and defect corrosion behavior of thorium base alloy fuels have not been thoroughly studied. A program has been initiated to study these effects.

Nine additional alloys have been primary melted, machined, canned in copper and extruded from 750 C into 1.4-inch diameter x 40-inch long electrodes for remelting. The electrodes have been copper stripped, straightened, threaded on one end, cleaned and are currently being remelted into final ingots. Six of these have been remelted by consumable arc using 26-27 volts, 3100-2300 amperes yielding ingots about 7-8 inches long and weighing approximately 25 pounds.

Increasing the uranium content from 2.5 to 5.0 wt% has very little effect on either the room temperature hardness or the 750 C extrusion constant. The room temperature hardness curve shows a minimum for both uranium levels between 2-3 wt% Zr. This minimum is also apparent in the 750 C extrusion constant curve but is nearer to 1.0 wt% Zr. Increasing the zirconium content from 5 to 10 wt% does not increase the 750 C extrusion constant.

Irradiation of Fine Carbide Uranium Fuel. The first of three capsule tests designed to evaluate the swelling performance of metallic uranium containing a submicron size dispersion of uranium carbide was charged into the ETR. Uranium core temperature measurements obtained during reactor startup indicate that the capsule is operating successfully.

Compatibility of Structural Materials with the HTLTR Environment. A 1000-hour test of the compatibility of cladding and structural material with the HTLTR environment was discontinued because of failure of the test chamber. The test involved exposure to a nitrogen gas-graphite environment at 1200 C. After 780 hours the Hastelloy-X test chamber developed leaks due to selective oxidation at the corners and edges of the welded box. The nature of the accelerated air oxidation is being investigated to determine the necessary preventive measures for a rerun of the test.

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

Two-Phase Pressure Drop Through Pipe Fittings

Analysis was continued of the two-phase pressure drop experiments performed to determine the pressure loss behavior of various piping components at typical reactor operating conditions. The basic pipe size examined was two-inch schedule 80 pipe and the components included a straight run of pipe, bends of 2-, 3- and 10-inch radii, a branch tee, and valves of both globe and gate design. In addition, 2 x 3- and 1½ x 2-inch pipe expansions were studied as well as contractions of 3 x 2-, 2 x 1½- and 2 x 1-inch pipe. All of the experiments were confined to a horizontal pipe orientation. Mass velocity through the 2-inch pipe ranged from 500,000 to 4,000,000 lb/hr-sq ft and steam quality up to 24% were covered at a pressure of 1200 psia.

In the analysis of the data the two-phase pressure loss of the various components at each of the flows and qualities considered was compared with the all-liquid loss for the same component at the corresponding flow. The resulting ratio of the two-phase pressure loss to the liquid pressure loss at a given pressure is primarily a function of quality and permits comparing the experimental data to various two-phase models and correlations in the literature as well as to studies made at other sites.

The experimental ratio was compared to the Martinelli-Nelson correlation and the Bankroff variable density model. Another model, Levy's momentum exchange model, agrees closely with the Bankroff model in the quality range covered by the experiments and was, therefore, not considered separately. A smooth curve through the plot of the experimental straight pipe ratio versus quality shows the ratio varies from 1.0 at zero quality to 5.1 at 24% quality. The experimental curve is considerably below the Martinelli-Nelson correlation, being 25% lower at 2% quality and 33% lower at 24% quality. On the other hand, when compared with the Bankroff model, the experimental curve is 10% higher at 3% quality, 10% lower at 15% quality, and 24% lower at 24% quality. There was no apparent flow effect within the range of flows examined.

The tee and the various elbows produced ratios which were higher than the straight pipe ratios at the same quality. Correlation of the fitting ratio to the straight pipe ratio results in an equation in which

$$\left(\frac{\Delta P_{2\phi}}{\Delta P_1} \right)^f = K \left[\left(\frac{\Delta P_{2\phi}}{\Delta P_1} \right)^{s.p.} - 1 \right] = \left(\frac{\Delta P_{2\phi}}{\Delta P_1} \right)^{s.p.}$$

where

$\left(\frac{\Delta P_{2\phi}}{\Delta P_1} \right)^f$ = the ratio of the two-phase pressure drop to the all liquid pressure drop for a fitting.

$\left(\frac{\Delta P_{2\phi}}{\Delta P_1} \right)^{s.p.}$ = the ratio of the two-phase pressure drop to the all liquid pressure drop for straight pipe.

K = correlating constant.

The value of the correlating constant is 0.3 for the tee, $3/4$ for the 10-inch radius bend, and $1\frac{1}{2}$ for the 2- and 3-inch radius bends. These constants correlate the curve through the data within $\pm 10\%$ for the conditions examined. The fitting loss for the bends and the tee was determined in the same manner for both the liquid case and the two-phase case. The method consisted of measuring the static pressure drop from a point upstream of the fitting to a point sufficiently downstream such that fully developed straight pipe flow is re-established. This over-all loss is made up of the loss due to the fitting as well as the straight pipe loss which would exist even in the absence of the fitting. The loss chargeable to the fitting was determined by subtracting the normal straight pipe loss for the length of straight pipe between the pressure taps from the over-all loss.

The analysis of the expansions and contractions is in progress at the present time. To date, the $2 \times 1\frac{1}{2}$ expansion and contraction have been examined. In both cases the two-phase to liquid ratio coincides with the ratio for straight pipe throughout the quality range. The determination of the diameter change loss follows the approach used for the bends with the additional consideration of the velocity change effects on the over-all pressure drop. Velocities in the two-phase case were calculated assuming the mixture to be homogeneous. Calculated velocities based on the nonhomogeneous Bankroff model did not give a velocity change adequate to account for the pressure loss.

Correlation of Wire-Wrapped Rod Bundle Burnout Data

The DNB correlation of Tong, Currin and Thorp reported in the May 1963 issue of Nucleonics was used to correlate the boiling burnout data obtained at Hanford over the past two years with 19-rod bundles using wire wraps to maintain rod spacing. The correlation was proposed to be applicable for rod bundles if the enthalpy rise used in the correlation were calculated for a hot channel formed by neighboring fuel rods with no mixing between channels.

It was found that the correlation tended to predict heat fluxes lower than those found experimentally, particularly for longer test sections. A test section having a spacing of 0.050-inch between rods and a heated length of 76 inches had boiling burnout heat fluxes from 1.4 to 2.2 times those predicted. This points out that the assumption of no mixing between subchannels of the bundle is unduly conservative.

A tentative alternate approach to the handling of the problem of mixing between the subchannels was used in an attempt to reduce the spread between the calculated and experimental burnout heat fluxes. This approach assumed that the coolant is perfectly mixed one wire wrap pitch upstream of the downstream end of the test section. No further mixing is assumed between subchannels occurring through the length of the last wire wrap pitch. Justification for this approach is the belief that mixing caused by the wire wraps occurs primarily in steps where a wire passes between two rods.

When this assumption is made, it is found that the experimental boiling burnout heat fluxes are about 70% of those calculated. A total of 88 burnout data points from five test sections was examined including test sections with 0.015-, 0.050- and 0.074-inch rod spacing, each 19½ inches long and a test section with 0.050-inch rod spacing and 76 inches long. It was found that 82 of the points were within ± 30% of 0.7 times the boiling burnout heat fluxes predicted by Tong, Currin and Thorp.

The data points tending to deviate most from the 0.7 value were those at the lowest flow rate, 500,000 lb/hr-sq ft, and those with the 0.015-inch rod spacing.

The fact that the experimental burnout heat fluxes were about 70% of the correlation is a measure of the validity of the assumption that the coolant is perfectly mixed one wire wrap pitch back from the downstream end of the test section. Obviously, the mixing is not

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quite that good if it is assumed that the correlation applies. However, it is interesting to note that by making such a mixing assumption, the equation correlates the data from several test sections of different lengths and spacing between rods. In particular, it brought data from the 76-inch long test section in line with data from the 19 $\frac{1}{2}$ -inch long test section and data from a 0.015-inch spaced test section in line with a 0.074-inch spaced test section.

12. Advanced Reactor Concept Studies

Fast Supercritical Pressure Power Reactor. The rough draft report of the Fast Supercritical Pressure Power Reactor was issued for comment at the first of December.

Large Sodium Cooled Fast Reactor Study. The cross section set reported last month was found to contain errors. These errors have been corrected and a cross section set is now available to analyze large sodium cooled fast reactors.

Military Compact Reactor Fueling Studies. Additional studies are being carried out on the effects of using plutonium in the Military Compact Reactor. Core pressure drop and fuel temperatures are being recalculated using FUGUE and STHTP computer programs, taking into account the temperature drop in the fluid film adjacent to the fuel element, and using the maximum-to-average power ratios indicated by physics studies of the cores. Results obtained to date, for 8.5, 9.5 and 15-inch diameter cermet-fueled cores, show very nearly the same temperatures and pressure drops as those calculated previously by less precise methods. Temperatures of the ceramic-fueled cores are expected to be somewhat higher than previously calculated, however.

Investigations were made of a core equipped with a tungsten reflector, to determine the potential savings in shield weight. A core, 10 inches in diameter by 10 inches in length, cermet-fueled, appears adequate from aspects of reactivity, control strength, and thermal hydraulics. The control strength for this core was augmented by backing the boron strips on the control drums with layers of hydride material about 2 cm thickness.

MCR shield weight reduction calculations for the 10" x 10" plutonium-fueled core with a 5" tungsten reflector are being performed. The control drums containing a 1" thick boron carbide and lithium hydride poison segment, were considered equivalent to an outside lithium hydride ring, $\frac{1}{2}$ " thick for the purpose of shielding

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calculations. Hence, the reflector is considered to be $4\frac{1}{2}$ " tungsten and $\frac{1}{2}$ " lithium hydride.

Results of the studies are being compiled and will be issued as a supplement to HW-79449.

Further physics calculations were performed on the MCR to refine the calculations and data presented in HW-79449. Although the absolute accuracy of these calculations is not regarded as very precise, the results obtained are all compared to a base case for the reference MCR design calculated in the same manner; therefore, the calculations should be sufficiently accurate for comparative purposes.

The reactivity loss from fuel burnup was apparently underestimated in the report by up to $0.015 \Delta k/k$. More recent calculations also show that cores IB, IC, IVA, and IVB, (9.0-inch, PuO₂ ceramic, 8.5-inch PuO cermet, 7.0-inch PuO ceramic, and 7.5-inch PuO cermet) will not quite be able to reach the desired burnup. These cores need to be slightly increased in volume or in fuel density. Changes ≥ 0.2 inch in diameter and length would be adequate. The maximum reactivity loss from fuel burnup was $0.107 \Delta k/k$ for case IVA. In cases IVA and IVB the burnup reactivity loss is approaching the control strength so adequate control may be a problem.

Hydride Moderator. The first phase of this investigation has been to determine the equilibrium isotherm of the zirconium-hydrogen system at 750 C (1382 F), using -6 +10 mesh crystal bar zirconium pellets. These data have been obtained over the composition range from ZrH_{0.25} to ZrH_{1.38} at intervals of approximately 10 at% hydrogen (H_{0.1}). The results obtained in this investigation checked those of Gilbert* (ZrH_{0.25} to ZrH_{0.95} are limits of the beta phase; ZrH_{0.95} to ZrH_{1.46} of the beta plus delta region, and ZrH_{1.46} to ZrH_{1.53} of the delta phase region) reasonably well. Since Gilbert's values must be taken from a graph which gives them an accuracy of $\pm 10\%$, a very accurate check cannot be obtained. His are the only known published values. The most significant observation is a shift in the composition demarking the two phase $\beta + \delta$ region and the δ phase to about ZrH_{1.37}.

*Gilbert, "Compendium on the Systems Zirconium-Hydrogen and Hafnium-Hydrogen," NAA-SR-158, Oct. 15, 1956.

13. Other Studies

Chemonuclear Studies. The H-1 Loop has been modified in preparation for the test to determine yield of hydrazine from ammonium salt solutions. It is planned to use boric acid additions to produce alpha radiation. A test authorization has been written in rough draft form.

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.

Analysis of the broadened diffraction peaks of irradiated molybdenum foils is being continued. The technique has been slightly modified in that the copper K β wave length is being used to record the {400} reflection instead of the usual K α wave length. The advantages of the revised technique are (1) shift of the {400} peak to a lower angle ($124^\circ 2\theta$ instead of 156°) so that no Lorentz-polarization correction is needed; (2) simpler background corrections; and (3) fewer points required to define the peak profile. Preliminary observations show that line broadening after irradiation to 10^{19} nvt ($E > 1$ mev) is not symmetrical for the high purity (< 10 ppm carbon) foils, the broadened peaks showing a slight "tail" extending toward higher angles. Foils with 150 ppm carbon showed symmetrical broadening. Specimens studied to date have shown only slight changes in line profile. Analysis of the profile changes by Fourier methods shows a root-mean-square displacement of lattice points from their equilibrium positions of about 0.08A at all distances greater than about 100A from any arbitrary origin. If the displacements are considered to follow a Gaussian distribution, the probability of a displacement large enough to allow the insertion of an extra atom is extremely small. Thus, interstitial solvent atoms probably do not exist as isolated point defects in these samples, and the increase in lattice parameter in irradiated molybdenum must be ascribed to other causes. Future work will be undertaken on samples irradiated to higher exposures as well as samples containing different impurity levels.

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Transmission electron microscope examination of molybdenum foils containing < 10 ppm carbon and 150 ppm carbon irradiated to 1, 4, 7×10^{18} and 1.1×10^{19} nvt ($E > 1$ mev) has continued. The density of the defects is much higher in the high carbon samples which were irradiated to 1 and 4×10^{18} nvt. As the exposure is increased to 7×10^{18} and 1.1×10^{19} nvt, the number of defects increases, but the difference in the number of defects observed in the low and high carbon samples becomes negligible at the higher exposures. After an exposure of 1.1×10^{19} nvt, the specimens containing < 10 ppm carbon reveal a defect concentration of $2.7 \times 10^{16}/\text{cc}$, while the 150 ppm carbon specimens contain $2.9 \times 10^{16}/\text{cc}$. As postulated previously, the diameter of the defects increases with exposure after 4×10^{18} nvt. Nucleation of clusters appears to be essentially complete at 7×10^{18} nvt; the number of defects increases only slightly upon further irradiation, while the size of the clusters increases rapidly.

The nature of the defects and dislocation loops observed in irradiated molybdenum has been the subject of considerable conjecture. At the temperature of irradiation - 60 C (140 F) - the mobility of interstitial atoms in molybdenum is about 10^8 x that of vacancies, and one would expect the clusters to consist of interstitials. The occurrence of prismatic dislocation loops in high-carbon molybdenum after irradiation implies that impurities are associated with clusters of radiation-induced point defects. The trapping of vacancies by interstitial carbon atoms is extremely favorable, since the lattice dilation associated with the carbon atom is relaxed in the vicinity of a vacancy. If a large cluster of vacancies assumes a disc-like configuration, it may then collapse to form a stacking fault, which for the body-centered cubic metals, is found primarily in the $\{112\}$ planes. The stacking order of $\{112\}$ planes in the body-centered-cubic structure is a sequence of the form ABCDEFABCDEF....; a stacking fault formed by the collapse of a vacancy disc results in a change in the stacking sequence to ABCDABCDEF.... This fault is bounded by an imperfect sessile dislocation with a Burgers vector of the type $1/2 a \langle 112 \rangle$. This dislocation may be converted to a prismatic loop by nucleation of a glissile imperfect dislocation, $1/6 a \langle 111 \rangle$, which sweeps over the stacking fault according to the reaction

Growth of this dislocation loop must involve mass transfer, e.g., absorption of vacancies.

The grip end of a ruptured single crystal molybdenum tensile sample, containing 400-500 ppm carbon and irradiated to 1×10^{19} nvt, has been sectioned and prepared for electron microscopy. Defect structures in the form of spots and loops were observed. The number and size of these defects compare with those observed in foils irradiated to similar exposures. Channels, similar to those observed in deformed irradiated foils, were also observed. Intersecting channels were not observed, so the planes involved could not be determined. The fact that defect structures observed in specimens prepared from the bulk single crystals are similar to those observed in irradiated foils demonstrates that the nature of radiation damage is similar.

2. Plutonium Physical Metallurgy

The objective of this program is to determine some of the basic physical metallurgical properties of high-purity plutonium and to establish the effect of certain specific alloying additions on these properties.

Steady state creep data for the beta and gamma phases of plutonium were extended. The steady state creep rate of the beta phase under a compressive stress of 112 Kg/cm^2 varied from 0.01% per hour at 147°C (297°F) to 0.3% per hour at 197°C (387°F). The activation energy for creep was computed to be 31 Kcal per mole. For the gamma phase the steady state creep rate ranged from 0.024% per hour at 202°C (396°F) to 1.4% per hour at 297°C (587°F) under a similar compressive load. The activation energy for creep of the gamma phase was calculated to be 24 Kcal per mole. These data tend to substantiate the previously reported results.

The steady state creep rate of the delta phase varied from 0.035% per hour at 285°C (545°F) to 3.0% per hour at 394°C (741°F) under a compressive stress of 38 Kg/cm^2 . The activation energy for creep was calculated to be 31 Kcal per mole, the same as that determined for creep of the beta phase.

Additional data have been obtained to support the previously obtained evidence that self damage in alpha plutonium results in significant lattice distortion. It had been noted that after three months of room temperature storage after casting, certain strong line pairs in the x-ray diffraction pattern could no longer be resolved. The resolution had been quite good in freshly cast material. In order to establish that this apparent lattice strain

was not an inherent and permanent condition in the material in question, it was melted and recast in vacuum. It was found that the (113)-(201) and the (020)-(211) line pairs could again be individually distinguished in the diffraction pattern. This result lends support to the suggestion, previously made, that the helium produced in the decay process is primarily responsible for production of this apparent lattice distortion. The condition was not relieved by vacuum annealing whereas the melting, during which the helium was removed, did restore the strain-free condition. It would appear that x-ray diffraction presents a sensitive technique for the investigation of self-damage in plutonium.

It has been reported earlier that the texture induced in plutonium by alpha rolling is altered but not destroyed by going through the alpha-beta-alpha cycle. As-cast material has been reduced 90% by rolling in the high beta range and the diffraction pattern investigated after transformation back to alpha. The structure appears to be completely random. This suggests that a deformation structure is not produced by beta rolling. A definite conclusion in this regard must, however, await further work. An elevated temperature camera will permit the crystallographic investigation of material so worked, prior to any phase transformation.

Plutonium is an extremely toxic metal; a 0.6 microgram quantity exceeds the maximum permissible body burden. Thus the normal requirement is that plutonium and its alloys be totally contained so that they cannot contaminate the atmosphere and endanger personnel. Formvar coatings are known to be tough and should therefore be effective in containing radioactive debris on metallographic samples of plutonium. This was demonstrated to be the case by the following test: an uncoated polished sample of plutonium was vigorously swabbed with a cotton ball. The smearable contamination picked up on the cotton was 5000 d/m. An identical sample was coated with the Formvar and swabbed vigorously with cotton. The smearable contamination from the coated sample was nondetectable. Since such abuse of the coating far exceeds the abuse expected in normal metallographic operations, it was concluded that satisfactory containment is guaranteed over reasonable periods of time.

A Formvar coating on metallographic specimens of plutonium retards the initiation and progression of oxidation. The progressive development of oxide was observed on a coated and an uncoated sample of alpha phase plutonium containing 1140 ppm iron. The samples were set side by side in an air atmosphere and micrographs were

taken periodically to record oxide development on each sample. The oxide on the uncoated sample was observable within eight hours and completely obliterated the microstructure after 53 hours. The coated sample, on the other hand, showed no sign of oxidizing within the 53-hour period.

The following two documents have been prepared:

- (1) Miller, G.E., and T. K. Bierlein, "Metallographic Application of Formvar Coatings on Radioactive and/or Chemically Active Materials - Plutonium," HW-79845, Dec. 6, 1963.
- (2) Miller, G.E., T. K. Bierlein, and B. Mastel, "Microfractography of Alpha Plutonium - Replica Techniques and Results," HW-79846, Dec. 6, 1963.

E. CUSTOMER WORK

1. Radiometallurgy Laboratory

Examinations and Measurements. Routine examinations and measurements are or will be reported as part of the sponsoring research and development programs.

The following listing includes major items of work done during the month:

Metallography

Samples processed	126
Photomosaics	25
Autoradiographs	28

Chemistry

Burnup dissolutions	16
Decladding dissolutions	6
Rare gas collections	2
Vacuum induction furnace sampling	16
Defilming for film analysis	2

Physical and Mechanical Properties Testing

Tensile tests (rm temp.)	66
Rockwell hardness tests	4
Density Measurements	14
Gamma scan analyses	2
X-ray analyses	1

General

Negatives processed

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Physical and Mechanical Property Testing Cell, Project CGH-857. Information received from the vendor indicated that repair of the annealing furnace will be completed in time for shipment before the end of the year. Shipment of the dilatometer repair parts is also scheduled for this month.

Remotized 15,000-lb Tensile Testing Grip. Installation and testing of the remotely operable 15,000-pound tensile testing grip was completed. The grip is now in operation on the "G" Cell Instron straining frame.

Microhardness Testing Blister. Preliminary design was started on shielding for the remote microhardness testing blister.

High Temperature Vacuum Tensile Testing Machine. Acceptance tests of the high temperature vacuum furnace and tensile testing machine was conducted during the month. The tests were satisfactory and the equipment has been shipped.

"E" Cell Metallography Facilities. Cell castings and lead glass viewing windows were received. Acquisition and fabrication of equipment components continued.

High Temperature Tensile Testing Furnace and Extensometer. The high temperature furnace was received and was mounted on the Instron tensile tester for temperature profile measurements with grips and specimen in place. Modification of the high temperature extensometer has been completed and testing of the system is in progress.

Stereo Zoom Macroscope. An order was placed for a stereo zoom macroscope for evaluation as a replacement for the stepped magnification viewers currently used for viewing through the lead glass windows.

Microsampling Equipment. A report titled, "Microsampling of Irradiated Materials," was issued as HW-79122.

2. Metallography Laboratories

During the report month 311 samples were processed, a total of 678 macrographs and micrographs taken, 1622 negatives made and 6204 prints processed.

Routine Metallography Laboratories activities will be reported as part of the sponsoring research and development component's work; however, items of unusual interest or representing departures from routine operations will be reported here.

An information exchange on uranium with low alloy additions was carried out with several other AEC sites during a two-day meeting at National Lead Company of Ohio. A trip report has been issued covering new metallographic techniques and other subjects discussed.

A metallographic examination of as-polished samples of uranium bonded to uranium by coextrusion of tube in tube type N-Reactor elements showed that after beta heat treatment the bonding surface could not be identified by grain configuration or inclusions at the bonding surface. A light electro-etch in phosphoric acid reacted with sub-microscopic defects at the bond line to outline the original uranium surfaces.

The recently constructed all-metal vacuum cathodic etching apparatus is in operation and specimens of Zircaloy-2 and stainless steel have been etched with remarkable success. The etches produced on these two were superior to any obtained with the previously operated cathodic etching apparatus. A vacuum of 5×10^{-5} mm of Hg can be achieved in two hours starting with cold diffusion pump oil initially at atmospheric pressure. The air cooled, two-inch oil diffusion pump has a pumping speed of 90 liters per second at 5×10^{-5} mm of Hg. A vacuum of 5×10^{-6} of Hg has been obtained with the apparatus. The blank-off leak rate has been measured at 12 microns per hour.

3. High Temperature Lattice Test Reactor

HTLTR Safety and Control Rods. As a requirement resulting from discussions with the customer and the HTLTR project engineer, current design philosophy assigns final position readout authority of the control rods to the stepping motor. The LVDT will act as a backup indicator and a scram readout. Procurement and testing of the LVDT will not be possible until input and output (to the data logger) characteristics are established by the customer.

Fifty drops have been made successfully with the vertical safety rod brake and drum assembly mockup. Preparations have been made to establish acceleration and deceleration curves.

HTLTR Prototype. Detailed shop drawings of the core insulation and structural design of the shell for the HTLTR prototype mockup are

97% complete. Drawings for the recirculating gas system are 65% complete. Fabrication of the steel containment shell and graphite core are 20 and 85% complete, respectively. Orders for the Hastelloy-B components and graphite for the bus bars and recuperator have been placed. Graphite timbers to support the core section have been received and the vacuum pump also has been received.

Heater Rod Mockup. All the thermal insulation and the graphite test section have been installed in the containment shell which is now complete. External gas piping and electrical work remain to be completed. Scheduled completion is January 1964.

HTLTR Vault Shielding Calculations. MAC code was set up to calculate the HTLTR vault wall thickness. Evaluation of the final computer runs, with application of a geometric correction factor (rectangular geometry, two spherical geometries), have indicated that a shield thickness of $3\frac{1}{2}$ feet should be adequate to meet the HTLTR specifications. This will effect considerable savings in the cost of the project, since it was previously estimated that 6-foot walls would be required.

4. EBWR Fuel Elements

EBWR Plutonium Fuel Element Fabrication. Approximately 250 EBWR fuel rods, containing pneumatically impacted UO_2 - PuO_2 , were vibrationally compacted to fuel densities of 86-89% TD. Differences between lots of UO_2 - PuO_2 powder were noted. Ninety percent of the fuel rods compacted for an average time of 23 minutes, using the better lots of powder, met density specifications. The effects of oxygen-to-metal ratio, particle density and/or fracture characteristics are being investigated to determine differences in powder compaction behavior.

Eight hundred kg of UO_2 -1.5 PuO_2 have been pneumatically impacted to greater than 98% TD for the EBWR Physics fuel elements.

EBWR Fuels. A second EBWR vibrational compaction line was made operational. It employs a 1500-pound force thrust Calydine unit with a $3/8$ " by 4" mild steel beam extending through three powder loading hoods.

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5. Other Offsite Customer Work

NASA Honeycomb Fuel. Molybdenum tubing, bar, and plate have been ordered in quantities sufficient for six honeycomb extrusion composite billets. This is to be used as can and sacrificial material. One order of hexagonal molybdenum rod coated with tungsten by extrusion has been ordered from NMI. This material will be used to assemble the honeycomb portion of one 4-inch coextrusion billet. Tooling is being fabricated locally to be used to draw-form hexagonal rod from 5/16-inch diameter molybdenum rod which is on hand. This rod will be coated with tungsten by vapor deposition and used to assemble the honeycomb portion of a 3-inch diameter coextrusion billet. Delivery of all of this material is expected by the 15th to 20th of January 1964.

NASA Cermet Studies. No significant quantity of UO_2 was lost from a UO_2 -tungsten cermet fuel plate during four hours of irradiation at 3000 C. A second NASA cermet plate, irradiated at ~ 2700 C for 31 minutes, is being returned to HL for destructive examination.

A square honeycomb cermet grid shape was fabricated by pneumatic impaction and delivered to NASA. The square bar mandrels were welded to broached plates and vibratory compaction was used for loading the cermet powder. Good grid dimensions were maintained.

Steel mandrels and end caps, used in the Nupac fabrication of NASA grids, were tungsten plated offsite using a vapor deposition process.

Further work was done to develop welding of the cermet "cross" configuration. The unbalanced heating of the two joints, which appeared in the first several weld attempts, was overcome by modifying the welding fixture. Sound welds were produced with a 100% bond, excluding the tungsten cladding, across each interface. A peak current of 28,000 amperes for 5 milliseconds was used. Routine welding of this configuration is now possible.

The first attempt to weld a tree configuration, which is several "cross" welds on one central member, met with limited success. Each cross weld, upon visual examination, appeared to be of the same high integrity as the individual cross welds reported in the previous paragraph.

No significant quantities of UO_2 were vaporized from a NASA supplied, UO_2 -tungsten cermet fuel plate during four hours of irradiation at

3000 C. X-ray diffraction analyses revealed a thin film deposited on the inner surfaces of the initially evacuated outer capsule to be tungsten. No UO_2 was detected by the analysis. The tungsten was lost from the outer cladding surfaces of the fuel plate, which appeared etched after irradiation.

The second of two NASA UO_2 -tungsten cermet plates was irradiated (at > 2700 C) for 31 minutes in the ETR core. The test capsule will be returned to Hanford for destructive examination.

Thoria Development. The first lot of the "Sol-Gel" thoria (650 pounds) received from Mallinkrodt Chemical Works was canned, and is now being leak tested and autoclaved. A uniform bulk density (65.5-67.3% TD) was maintained for the 205 fuel elements canned.

Of the nine thoria fuel elements canned with the ORNL "Sol-Gel" thoria, the four having the highest density (83.7-85.9% TD) were charged into a production reactor December 6, 1963.

J. J. Caldwell/dh

For Manager
Reactor and Fuels Laboratory

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PHYSICS AND INSTRUMENTS LABORATORYMONTHLY REPORTDECEMBER 1963FISSIONABLE MATERIALS - O2 PROGRAMREACTORN-Reactor Lattice Parameter and Spectral Measurement Tests at Startup

Procurement and fabrication of materials were completed for cold pile physics startup tests. Lattice parameters to be measured include ϵ , p , f , the neutron temperature, and the r -value of the epithermal flux. The spatial and energy dependence of the flux will be measured using Pu-Al, U-235-Al, fuel enrichment uranium, depleted uranium, Lu, Eu, Au, and Cu pins, both bare and cadmium covered.

The fuel elements required for cold tests were welded and successfully passed a helium leak check. The graphite foil sleds have been delivered from shops and are ready to load with pins. Arrangements have been made for a cask to ship the irradiated elements and for removal of the pins and foils in the 300 Area. Four scintillation counting systems have been assembled, and spare equipment is being checked.

The fuel elements for the hot test are nearly ready. All pins have been loaded except for those containing plutonium. The remainder of the arrangements is nearly identical to the cold test.

NPR Utilization Studies

A preliminary, classified report, summarizing the status of the NPR utilization studies was issued. A supplement to this report, describing in more detail the methods of calculation and the approximations used is presently being prepared.

Instrumentation

Design, assembly, test and installation of the special instrumentation and mechanical devices required for N Reactor physics tests are now completed. All equipment needed for the physics tests is checked out and in place. Considerable difficulty was encountered with fabrication of the water-cooled thimbles to be used for containing the various detectors; however,

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satisfactory welding and sealing was finally obtained.

Additional instrumentation completed for use during the N Reactor testing program included a scintillation counter to be used for counting filters exposed to the reactor coolant and a special counter-timer to be used with the rod travel timing system. The filter counter will detect alpha particles from possible minute quantities of uranium in the coolant, following drying of the filters.

Fission counters for N Reactor low-level flux monitors were received from the manufacturer and performance tests were satisfactory on the one counter tested to date. The fission counters and associated preamplifiers will be required in approximately six weeks.

General startup tests were conducted with the new reactor fuels testing loop installed at PRTR. Tests were carried out with a fuel element charged in the loop and monitoring was achieved with all channels functioning. Efforts are now being made to correct slight non-linearities noted in the spectrometer channels. Most of the originally-planned instrumentation has now been installed; however, several additional instruments have been planned and will be procured. A circuit was developed and installed to make the X-Y recorder compatible with the multichannel analyzer.

Inspection was made and modifications proposed on a step-type plug shield to be used with an instrumentation system designed by Instrument and Electrical Development, IPD. The modified shield was installed and satisfactory shielding achieved.

The possible use of gamma spectrometry to measure post-discharge time of irradiated reactor fuel has been considered with Reactor Design, IPD. Preliminary studies suggest that intensity measurements of 3.1 MeV photons emitted by Ia-140 would distinguish between 120 days of decay and 90 days, since this period corresponds to about three half-lives and a factor of ten change in intensity.

System Studies

The initial N Reactor steam generator and secondary loop simulation testing planned for the small EASE computer was completed. Some problems were encountered as a result of separating the two major portions of the system which eliminated significant interactions between them. Data were obtained which will be useful to the over-all N plant simulation planned for the new analog computer.

Work was started on a nomenclature list for the N Reactor simulation and a similar list for simulation constants is being prepared. The lists are

being made up initially on FORTRAN sheets in such a way that the IBM computer can be used to print up-to-date nomenclature and lists of constants as changes are made in the analog simulation.

MIDAS programs for the N Reactor primary loop flow and steam generator systems were written and are being debugged. Difficulty was experienced with the algebraic loops with which the system's equation is structured.

Design of the N Reactor control system simulator is in progress. Bids were received on the operational amplifier manifolds and power supplies. The use of separate inexpensive components for the control system simulator frees approximately 40 amplifiers on the main computer for use in other parts of the simulation. The control system simulator will have flexibility which will allow it to be used at high speeds for repetitive optimization computations.

A Keithley electrometer amplifier was tested with external bias and high voltage supplies to obtain N Reactor neutron noise signals during N Reactor physics startup tests. The amplifier and bias circuits were tested at PCTR during the month to check measurement procedures and equipment operation. Performance of this system is better than the one used on earlier noise tests and may improve results on future PRTR noise tests.

Measurements on the two-dimensional reactor simulation were analyzed and found to be in good agreement with known parameters. The experiments measured simulation coupling coefficients by making tests similar to those which must be made on an actual reactor. The results agreed with the actual value of the coupling coefficients used.

SEPARATIONS

Critical Experiments with PuO₂-Plastic Mixtures

Critical mass experiments were continued with PuO₂-polystyrene compacts and the Remote Split-Table Machine. The plutonium concentration in the compacts is 1.14 g/cc (2.2% Pu²⁴⁰), with an H/Pu atomic ratio of ~15. Critical core configurations were comprised of bare and reflected rectangular prisms. In connection with the proposed design of a dissolver for slightly enriched uranium, data were obtained on the reflector savings of an 8-in. thick reflector composed of a 3% enriched uranyl nitrate solution. Other critical experiments provided information on the effects of core density changes on criticality of Lucite reflected prisms; data were also obtained for the effect on criticality of the rubber coating which is used on the PuO₂-plastic blocks for contamination control.

The critical length of a rectangular prism (12-in. on a side) was reduced by 5.9 cm. when the unit was reflected on one end by a 3% enriched uranyl nitrate solution (~ 374 g U/l) of 8-in. thickness. Interposing a 0.19-in. stainless steel plate containing ~ 0.3 w/o gadolinium reduced this reflector savings by 1.4 cm. The reflector savings of the uranium solution--gadolinium steel plate combination is approximately equal to that of an "infinite" water reflector.

In the case of the Lucite reflected prism, the effect of the rubber coating on the plastic cubes (which reduces the average Pu density in the stack and adds moderation) is to reduce the critical mass by about $2\frac{1}{2}\%$. This decrease is only about half that observed for a bare rectangular prism of near cubic geometry.

Some interesting data were obtained for the effect of core density change on the criticality of Lucite reflected prisms. Reductions in core density were achieved by inserting styrofoam spacers between the plastic cubes making up the assembly. The void space between each 2-in. cube was about 0.07-in. for one case and about 0.15-in. in another, which gave average density reductions of about 11% and 16%. The critical height and mass were consequently increased by about 16% and 34%, respectively; in either case each layer of the stack was comprised of the same number of cubes. For a reflector at full density, the critical mass may be expressed as, $M = \text{Const.}(\text{core density})^{-n}$. Calculated core exponents (n) have ranged between ~ 1.3 -1.5 for a uniform change in core density of a comparable system. Although the results are subject to further analyses, the variation observed here in critical mass with core density change may be predicted to within $\pm 3\%$ by using an exponent of 1.5. Thus, although the core density change is in this case certainly not homogeneous, the increase in mass is within about 3% of that predicted from theory on the bases of a uniform change in density over the entire core. The small air gap thus appears to be quite effective even though not uniformly distributed.

Feasibility of Using Reactor Noise to Measure Subcritical Reactivity Independent of Knowledge β/ℓ

The feasibility of measuring subcritical reactivity without having the measurement depend on an a-priori assumption of a value for the parameter β/ℓ was studied. It was found that it is feasible to do this using a measured reactor noise spectrum which depends on the very low frequency information attributable to delayed neutron effects as well as the higher frequency information which depends primarily on the prompt neutron lifetime.

It appears that an instrument to measure reactivity directly would be very desirable in many safety applications since information on the parameters of the system is not required in order to obtain a value for the reactivity. The applications of such a device to the monitoring of chemical processes where fissionable material is handled and the monitoring of shutdown reactivity during fuel handling operations in reactors as well as the use of such an instrument in criticality experiments are very appealing.

The device envisioned would have a rather slow speed of response (a time constant of a minute or so) which occurs because of the necessity to observe delayed neutron effects. It appears that the device would be most accurate and reliable in systems having a prompt neutron lifetime less than 200 μ sec or so and in systems in which the kinetics may be adequately approximated by a lumped parameter, space independent kinetics model.

Pulsed Neutron Source Experiments

Pulsed neutron source experiments were previously performed on the Z-9 underground waste crib, which is known to contain significant quantities of Pu in the soil. A moisture analysis of the soil in the vicinity of where the crib was pulsed, and sample data on Pu concentration, have provided information for estimating the neutron lifetime in the system. Based on the calculated neutron lifetime and measured decay constant, the effective multiplication factor for the crib is about 0.8. To further substantiate these results, the neutron lifetime will be measured in the earth (clean soil, no Pu) from a pulsed neutron source experiment.

Buckling of Partially Filled Spheres

Further checking of the fluxes calculated by the double quadratic fitting code indicated that some of the more subtle boundary conditions are not being met precisely. Namely, the projections of the radial and angular derivatives along the top surface are not equal and opposite as they should be. The radial derivatives do not appear to converge to a particular value as more and more fitting points are taken. These deviations are not large, but extreme accuracy in every detail is necessary.

INTERSET - Interaction Code

The formal document discussing this work is ready for publication.

Consulting Services on Nuclear Safety - Criticality Hazards1. Nuclear Safety in HL

Two new nuclear safety specifications were issued:

B-9 - Storage and Handling of EBWR Fuel Rods in 305-B and 3731 Buildings.

B-10- Storage and Handling of 4.9 w/o Pu-Al Capsule Pieces in 305 and 3731 Buildings.

2. Nuclear Safety in NRD

A nuclear safety review was continued of the 333 Building for the Engineering Section. Six review sessions were held. A report of recommendations is under preparation.

3. Nuclear Safety in IPD

A new design of a charging magazine for K-IV-E type fuel elements was reviewed for the Equipment Development Operation. The design utilizes styrofoam as the construction material for supporting the fuel elements. The fuel elements, as contained in the magazine, would be at near optimum moderation under conditions of water flooding; however, the styrofoam (which has low hydrogen content itself) would prevent water from entering the interstices between the fuel elements and the system is safely undermoderated. Limits on styrofoam density and on what might happen to a storage array of elements under accident conditions will be used in assessing safety should the new design be adopted.

NEUTRON CROSS SECTION PROGRAMScattering-Law Measurements for H₂O at 95°C

Measurements were continued on 95°C H₂O samples of different thicknesses to study effects of multiple scattering. Analysis continued on deriving the scattering law from data previously obtained on 95°C H₂O. The scattering law representation has been obtained for about half of the data obtained with standard energy resolution. The determination of the sensitivity function for the high-resolution measurements is not yet complete.

Time-of-Flight Spectroscopy for Slow Neutrons

The study of neutron monochromating-crystals for this spectrometer was inactive due to a faulty beam shutter at the 105-DR spectrometer. The shutter was repaired near the end of the month. Testing of phased-rotor systems continued with the test of two stabilized hysteresis synchronous motors which ran at 10,300 rpm for two weeks. The phase stability was ± 0.25 degrees over the period with a short-time phase jitter of ± 0.006 degrees. Development work on He^3 proportional counters was continued with an apparent significant improvement in performance which resulted from further chemical purification of the counter gas. Measurements were made on the pulse-height spectra and time jitter of two Hanford-produced counters filled with a mixture of He^3 , He^4 , and CO_2 . The time resolution was a factor of 2.5 better than that measured for similar commercial counters.

Fast-Neutron Cross Sections

The data obtained on measurements completed in November have been processed via the data reduction program. The measurements on samples of Ru and Rh appear to be of no value due to erroneous data. The total cross section results obtained for 50 elements on this program have been transferred to a master magnetic tape for storage and easier transfer to customer tapes. Results of measurements on five elements were shipped to two different laboratories in France at their request. A computer program, CONTOUR, which emphasizes certain features of the fast-neutron cross section variations for ease in analysis and presentation has been written but not debugged.

REACTOR DEVELOPMENT - O4 PROGRAMPLUTONIUM RECYCLE PROGRAMPRTR Burnup Experiments

The evaluations of the available burnup data from the destructive testing of three low exposure, aluminum-plutonium elements (Nos. 5051, 5095, and 5092) have been completed and the results are being included in an informal report, HW-80067 RD. The integrated fluxes from cobalt wires and pins will be analyzed when available. An ALTHAEA one-dimensional burnup calculation has been initiated for the purpose of correlating the calculated Pu isotopic variations radially in an aluminum-plutonium fuel element with the values received from the mass spectrometry analysis of the three elements above.

The Effect of Uncertainties in Physics Parameters on the Accuracy of Fuel Cycle Calculations

Calculations have been carried out for heavy water moderated reactors to obtain perturbation coefficients for the effects of uncertainties in the physics parameters such as the cross sections and alpha on the initial reactivity and on fuel exposure and on fuel cycle costs. The results were similar to those reported in the October 1963 monthly report for light water moderation. The results and conclusions from these and the previous calculations are being reported in an informal document.

Low Exposure PuO₂-UO₂ Lattice Studies

The Ceramics Research and Development Operation is working on the fuel for these experiments. The pellets which have been ground to size are being sorted according to their grams per unit length. This will allow the selection of pellets having the same grams per unit length as given by the method finally used for the fabrication of the remainder of the rods. The selected pellets will be used for the central portion of the center cell, although there are enough pellets to fill the tubes for the center cell. High energy impaction, followed by grinding and vibrational compaction, is being considered as a method for making the remainder of the fuel rods.

Approach-to-Critical Experiments

Experiments using a lattice spacing of 0.80 inch and 2.0 w/o Pu-Al fuel rods with 16% Pu-240 were completed with a template, which was aluminum 1/4 inch thick, placed at the top of the fuel and then again with the template 1-1/2 inches above the top of the fuel. The extrapolated number of rods to produce critical were 769.3 and 768.0, respectively.

Vertical and horizontal flux traverses were measured in an exponential experiment on this lattice loading with and without .040 inch of cadmium around the curved surfaces of the cylindrical loading.

A generalized least squares program has been prepared for fitting a $\sinh x$ function to data obtained in the H₂O exponential measurements. Data obtained from vertical traverses in loadings which are 36 inches high have appreciable contributions from end effects so that the usual exponential approximation is no longer valid.

Five complete sets of templates and a template assembly have been fabricated for the subcritical experiments which use EBWR fuel in H₂O moderator. Specifications have been set and a work order issued for fabrication of a

set of templates for a more compact loading. This set is scheduled to be completed by January 8.

The Critical Facility of the PRP - Experiments in D₂O Moderator

The final draft of a formal report, entitled, "Approach-to-Critical and Calibration Experiments in the PRCF," is nearly complete. This report presents the results of the initial approach-to-critical experiments, control rod and power level calibration experiments, the time response of the safety system, the moderator sensitivity measurements, the temperature and pressure coefficients, and the β/λ ratio measured by the poison injection method. A first rough draft has been written of a report on the Pu-Al substitution experiment conducted in the PRCF.

Safety Rod Interaction in the PRCF

The interaction of the three safety rods in the PRCF have been calculated using one-group diffusion theory. The agreement between an experimental value and the calculated value is good. The calculations were made for the safety rods at other radii than that at which their worths were measured. The results show that where the safety rods are now located (radius = 16.00") the safety rods have a maximum anti-shadowing effect. In this position the worth of three safety rods together is 32% greater than three times the worth of one rod alone. A formal report describing the calculations is being prepared.

H₂O Moderated Mixed Oxide Experiments

Light water critical loadings are being carried out as a part of the EBWR burnup experiment planning program. Additional H₂O moderated, mixed oxide experiments are being planned under the Plutonium Recycle Program. Calculations were performed to predict the critical loadings of mixed oxide fuels containing various isotopic mixtures of plutonium in the PRCF. The plutonium contained in the UO₂ (natural enrichment) will have Pu-240 compositions of 8, 16, 26, and 30% of the plutonium and will be added to give a 2.0 w/o total Pu concentration. The fuel was ordered during the month.

All of the calculations are for light water moderation at room temperature and were carried out with the following computer codes: GAM-1, THERMOS, TEMPEST, and HFN. The calculation methods used were described in detail in the June 1963 monthly report in the section on the EBWR analysis.

Phoenix Fuel Program

A rough draft of document HW-79977, "Nuclear Statics of Some Compact, Water-Moderated, Plutonium Burners," has been prepared.

A document, entitled "Phoenix Fuel Reactor Program Posposal," has been prepared and forwarded to DRD, AEC-Washington, in answer to their request.

Pu-241 has a half life of ~ 13 years. In all Phoenix burnup calculations, the loss of Pu-241 via radioactive decay has been taken into account. It has been assumed, however, that the reactors operated continuously at a load factor of unity. If the reactors are used as power sources for propulsion devices, load factors could be very low, and, consequently, the decay of Pu-241 would become increasingly important. The effect of the Pu-241 decay was evaluated for a typical Phoenix core. A load factor of unity was compared with the very low load factor of 0.1. The effects of the Pu-241 decay are quite marked toward the end of the reactor life. For instance, at 10,000 FPH, the shim control requirements increase from $\sim .066 \Delta \rho$ to $\sim .110 \Delta \rho$. Provision for an increase in shim control requirements must be made in any practical design.

The work on Be-Pu systems started last month has now been extended to include a wider variety of Pu compositions.

Code DevelopmentAnalysis of the Double Mass Gas Model of RBU

Analysis of the double mass gas model of RBU continued. Currently the double mass parameters are evaluated by requiring that the average energy transfer and average scattering cosine be prepared. We tested the revised SPECTRE R, which contains the double mass feature and generates kernels and spectra, against the original SPECTRE S and IDEAL GAS for the ordinary ideal gas case (all masses equal one), and the agreement appears to be complete. In addition, the double mass kernels simulating water were found to give average energy transfers that agree to within a few percent with the energy transfers for water derived from the Nelkin model, which we have taken as the standard.

Although it appears that the current method of obtaining the double mass parameters has been consistently and correctly evaluated, we have found that the spectrum calculated with these parameters is too cold compared to the spectrum calculated directly with the Nelkin water kernels. The reason for this may be in determining the double mass table for RBU by conserving the energy transfer and the cosine of the scattering angle.

Several alternate methods for determining the double mass parameters are being considered.

RBU System Development

The final draft of the RBU operating manual, HW-80003, is complete and ready for final reviewing. It is to be issued as a third of three volumes describing all phases of the RBU system.

RBU was issued informally to M. Temme, one of its originators, now at Lockheed Missile and Space Company.

The distribution package for the RBU Basic Cross Section Library nears completion with the edition of a new FORTRAN program to extract, list, and average nuclear data in the library plus a FORTRAN routine capable of updating the binary library tape. The RBU library editor (an RBU service routine) now has page numbering and other desirable identification information in its output.

Spectra produced by SPECTRE S using the two-mass thermalization model were unsatisfactory.

RBU Basic Library

In connection with the release of the RBU Basic Library and associated processor codes, expected within the next few months, the nuclide data in the library are being re-examined. To correct errors in the inelastic spectrum tables reported last month, a simple optical model code has been written to calculate the excitation probabilities of the discrete energy levels of a target nuclide. This code is presently being debugged. A graphical check to detect remaining typographical errors in the isotope cross sections is about 50% completed.

HFN II

Modifications to HFN II (a revised HFN) were continued. The homogenization of a reactor using the critical flux has been debugged. Recalculations using these homogenized parameters yields a value for k substantially different from one. Further work is necessary to discover the cause of the deviation.

Nuclear Fuel Cycle Analysis Development

In advanced design work on fast reactors, in which spectral shift effects vary quite slowly with time, there has evolved a useful range of applica-

bility for a linearized representation of isotopic transmutation effects, of the sort

$$dN(A,t)/dt = \sum_{A'} N(A',t) H(A' \rightarrow A). \quad (1)$$

Such a representation also has potential usefulness for thermal and resonance reactors, subject to the limitation that the analysis must be broken up into several time segments to assure adequate piece-wise quasi-constancy of the long-term spectral shift effects contained implicitly in the isotopic transmutation probability rates $H(A' \rightarrow A)$.

This coupled set of linear first-order differential equations can be solved analytically for the isotope concentrations $N(A,t)$ as a function of isotope A and time t, in the matrix exponential form

$$N(A,t) = \sum_{A'} N(A',t=0) e^{tH(A' \rightarrow A)}. \quad (2)$$

Two general methods of solving equation (1) have been developed at Hanford. The first method (GE-HL program MELEAGER, and its ascendant family REACTOR BURNUP, CALX, and ALTHAEA) integrates equation (1) numerically, using a local fourth-order-polynomial digital representation. The second method (GE-HL program DUAL NORMAL MODES) numerically evaluates the analytic solution (2), by matrix diagonalization methods involving construction of the complete set of dual eigenvectors for the asymmetric matrix H.

Numerical limitations of both these available methods, encountered in recent breeder design studies, have led to the formulation and machine programming of a third method (GE-HL program ALCHEMY), which numerically evaluates the matrix power series representation of the analytic solution (2), making exhaustive use of scaling and rounding logic to minimize the accrual of truncation error. Adequacy-evaluation runs with the new deck have begun, with the objective of making it available for applied analysis use next month.

ZODIAC Chain

The revised version of CLERK B was incorporated into the non-iterative ZODIAC Chain, which is frozen at this point. REFIRE, the link which prepares input data for successive iterations of the Chain, was written this month, and is conditionally operative. A test case has been successfully run through two iterations.

BARNS-II

BARNS-II, an extended version of BARNS for use in the processor package for the RBU Basic Library, to be released in a few months, has been written by EDPO personnel and is undergoing final debugging. BARNS-II will print all or part of the RBU Basic Library, and will compute point or group cross sections. The latter can be averaged over any of four spectra, constant, $1/E$, fission, or Maxwellian, with specification by group of the spectrum desired. The cross sections can optionally be written out by isotope, along with applicable resonance and inelastic scattering tables, to binary tape for further processing, e.g., calculation of elastic and inelastic transfer cross sections or preparation of data tapes for nucleonics codes. Codes for this further processing are not yet available for BARNS-II, nor are they considered as part of the basic processor package.

Isotopic Analysis of PRTR Samples

Isotopic analyses were provided on 40 plutonium samples of PRTR-irradiated fuel elements in support of the Plutonium Recycle Program. Of these, 22 were from UO_2 element No. 1006, 1 was from UO_2 element No. 1041, 1 was from UO_2 element No. 1101, 13 were from UO_2 element No. 1501, and 3 were rechecks from Al-Ni-Pu element No. 5108.

Instrumentation and System Studies

Plans have been made to increase the collimator aperture size of the PRTR under water gamma scanner and to employ additional water shielding to improve both the counting rate and the signal to background ratio. Future modifications will also add collimator sections which could be easily assembled to accommodate widely varying fuel element activities.

Circuitry development was accomplished on an aural-signaling monitor for use with the PRTR automatic controller. One circuit was tested with good results, and efforts are being accelerated to provide a final model.

An effort to analyze the power density spectrum of the PRTR vibration data taken in November by use of a sweeping oscillator failed to yield satisfactory results. Preparations were started for devising filter networks on the analog computer to analyze many channels of data simultaneously so that the power densities in the various frequency channels can be obtained simultaneously. The method may also be applicable to N Reactor vibration tests.

HIGH TEMPERATURE REACTOR PHYSICS PROGRAM

The third of a series of high temperature tests of materials in nitrogen was stopped after about 780 hours of operation because of a leak which had developed in the containment vessel. Another test at 1200 C has, therefore, been planned in which samples of Ni, thoria dispersed Ni, Hastelloy B, UO₂ in a nickel capsule, carbon felt and thermal insulating materials will again be placed in the furnace. In addition, samples of ceramic and aluminum coated Hastelloy X, and boron containing ceramics will be included. To reduce the chance of leaks developing, the containment vessel will be surrounded by an inert atmosphere in the furnace.

The Title I design of HTLTR has been reviewed and comments submitted to the AEC and Vitro Corporation.

A preliminary mock-up assembly containing a short section of a graphite heater has been constructed. It is planned to test first the low voltage operation of the heater (20 to 40 volts). Later a system at higher voltage may be tested. The results of the preliminary tests will determine which type of heater is to be run in the large scale mock-up. The large scale system will contain heating rods of approximately the same lengths as are to be used in the HTLTR.

A design and performance specification for the time-of-flight neutron spectrometer for the HTLTR has been written. This specification is intended to provide information necessary for the preparation of a detailed design. Calculations that form the basis for specific requirements are included in the specification.

With the reactor power at 2 kw the spectrometer is expected to scan the spectrum of neutron energies from 0.0025 ev to 5 ev in a period of less than eight hours. Four rotor speeds, which will be changed remotely, will be required to cover the spectrum in four overlapping regions. Resolution of the spectrum $\Delta E/E$ is expected to be about two percent through the thermal, and first part of the resonance energy region, but decreasing to about five percent at 5 ev.

NEUTRON FLUX MONITORS

Purchase specifications were completed for the offsite fabrication of two reactor in-core ionization chambers which will employ regenerating material. The two chambers are to be a matched pair to provide comparison test data and each will utilize a coating of U-234 and U-235 to provide the regenerating effect for long life in the reactor.

Evaluation and analysis continued on four irradiated plutonium regenerating detector sample elements. The analyses were carried out using a mass spectrometer. Initial interpretation of the data provided the following tentative results:

	<u>Original</u>	<u>Isotopic Abundance - Percent</u>			
		<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>	<u>Sample 4</u>
Pu-239	28.405	22.08	18.86	14.12	11.38
Pu-240	71.425	68.94	67.01	63.90	61.46
Pu-241	0.156	8.50	12.85	18.51	21.43
Pu-242	0.014	0.48	1.28	3.46	5.73

Subsequent corrections might change these results slightly. The four uranium samples irradiated with these plutonium samples have not been processed; therefore, it is not possible to compare the results directly to the calculations. Examination of the plutonium data indicated that the cross section for conversion of Pu-240 to Pu-241 is larger than assumed in the original calculations. This cross section is quite sensitive to the spectral parameter, r . A complete analysis of the data cannot be made until all of the mass spectrometer work is finished.

An experimental assembly was completed for reactor testing of the beta current method of in-core neutron flux monitoring. The fabricated assembly incorporated four separate detectors using B-11, Al-27, Rh-103, and Tc-99 elements. The conducting wire from each detector was 3 mil stainless steel and each was supported in holes in ceramic insulators positioned in a 15 feet long metal tube with the composite chamber at one end and suitable connectors at the other end. The assembly was charged into the test facility at KW Reactor and generated current from each detector element was measured using special low input impedance electronic equipment.

Initial results were not considered to be satisfactory as excessive and varying currents were observed at times. Once the assembly was withdrawn from the reactor, the current signal from each detector initially decreased as predicted. Later however, the currents again increased and stabilized at levels comparable to those measured with the assembly in the reactor. It is apparent that a phenomenon is taking place which obscures the expected beta current signal. Consideration is being given to contact potentials, galvanic cell action, and thermoelectric junctions; however, none of these logically explains the data. Another experimental model will be undertaken as soon as possible following more detailed consideration of the effects observed.

NONDESTRUCTIVE TESTING RESEARCHElectromagnetic Testing

The multiparameter eddy current nondestructive testing device is being converted for use as a multiparameter tubing tester. Initial tests revealed several problem areas not observed in the original tester. These require a redesign of the test coil drive circuits, bridge circuits, and input amplifier circuits. In order to avoid making developmental changes in the tester which would make it inoperative for its original function as a multilayer thickness gauge, new drivers, bridge circuits, and input amplifiers will be developed specifically for the tubing test. Requirements for these circuits are now being determined.

Measurements of the direction of flow of eddy currents around discontinuities in a conductor as a function of frequency were made using a liquid Wood's metal bath and a small voltage probe. The results of this test show that the direction of current flow near the discontinuity changes with frequency. The currents in the vicinity of a subsurface crack were found to flow more nearly parallel with the surface of the metal bath as the frequency was increased. This result is in agreement with an interpretation of the vector potential theory dealing with the flow of currents in a conductor.

The electrical conductivity of Wood's metal was measured over a range of 25°C to 90°C using an absolute eddy current method at a frequency of 1000 cycles. Measurements were reproducible below the melting point, but considerable variation in results were noted in the region around the melting point. This is now believed to be due to the complex nature of this alloy. It is noted that the International Critical Tables show different values of conductivity for it in this region depending on whether measurements are made during cooling or heating.

Heat Transfer Testing

The heat transfer testing equipment in 314 Building has been reassembled and used in tests on fuel elements in an attempt to evaluate the new emissivity independent test concept.

A 60 cycle interfering signal resulting from a difference between the original and reassembled version of the instrument has not yet been eliminated. However, it was reduced enough by filtering to permit preliminary tests on the entire system.

Variations in scanning speed during heat transfer tests must be less than one percent during any one second period to insure synchronization with the time delay unit being used in the emissivity compensation system. Belt slippage in the scanning lathe was minimized by applying a friction agent to the main drive belt. Short-time speed variations now appear to be low enough that the lathe can be used in experiments to evaluate the new emissivity compensation system. Attempts to produce a noise-free splice of the continuous tape loop in the time delay unit were marginally successful. Connection between the heat transfer test equipment in 314 Building and the time delay unit in 3707-C Building is accomplished by means of telephone lines. Initial tests showed that the lines were performing satisfactorily.

Tests were made on fuel elements having high emissivity spots produced with black tempura paint. These tests showed that the thermal conductivity of the tempura paint is low enough that its surface temperature is much higher than that of the adjacent metal when it passes under the radiometer. This interferes with tests of the emissivity compensation system. Areas are now being sandblasted on the surfaces of several fuel elements in an attempt to produce high emissivity spots without changing the thermal conductivity of the surfaces. Work to minimize the 60 cycle interfering signal is continuing.

Zircaloy-2 Hydride Detection

The new stabilized eddy current hydride detection circuits were used last month to detect a purposely hydrided N Reactor process tube containing 250 ppm hydrogen (determined metallographically). Burst and brittle fracture tests by Materials Engineering, HL, have indicated that the 250 ppm hydride content adversely affected ductility of the sample.

Maps were made on five samples of N Reactor process tubing which had been hydrided to levels of 90 to 500 ppm in selected areas by Chemical Metallurgy, HL. Most of these samples had deep longitudinal gouges up to .020 inch deep and 1/2 inch wide in their inner surfaces. These caused spurious signals which were similar to those resulting from the hydrided areas. An attempt to eliminate the interfering signals was made by increasing the coil-to-sample spacing and readjusting the bridge for lift-off compensation. However, this resulted in loss of sensitivity to hydride. Further investigation of methods for minimizing signals from surface imperfections will be made.

Results from the transistorized version of the 44 kc eddy current hydride detector are promising. Higher gain in this circuit has made it possible to eliminate the d-c amplifier and its associated drift contribution. A second model of the transistorized circuit has been fabricated to allow greater flexibility in development.

Fundamental Ultrasonic Studies

Critical angle tests to determine the effects of boundary waves generated at solid-solid interfaces continued. These experiments have demonstrated that boundary waves can be generated at the interfaces but, in order to explore possible applications, test samples must be obtained which have particular bond layer problems. Efforts to extend the work beyond the point of demonstrating that the effects exist are not planned until such problems become evident and test samples are available.

The first draft of a report which includes the critical angle experiments on Zircaloy-2 surface hydride, surface stresses, and the aforementioned bond layers is complete.

Analytical studies to better describe the wave propagation with attenuation continued. This work is being conducted by Applied Mathematics Operation, HL. In order to compare the analytical solutions with experimental observations it will be necessary to obtain the attenuation coefficients as a function of frequency for typical test samples. Coefficients for both longitudinal and shear waves are needed. The techniques which are normally used for measuring attenuation are involved and usually require special equipment. Methods for using the existing ultrasonic equipment to obtain these coefficients are being developed. Some preliminary measurements of the longitudinal attenuation coefficient in aluminum were made to check values quoted in the literature. The measured values were not in agreement with the quoted values and the reason for this is not clear at this time.

Additional colored schlieren photographs were taken for use in an article concerning the schlieren method for imaging. The draft of this article is complete and is being submitted for possible journal publication.

A usable calculation procedure for Lamb waves in a hollow cylinder has been set down, and the equations to be used derived and checked. A memorandum is being prepared giving the results, with comments, and suggestions for possible next steps, to be followed by a full scale report (or paper) giving details of the theory and the equation derivations.

USAEC-AECL COOPERATIVE PROGRAMNondestructive Testing of Sheath Tubing

Utilization of the prototype sheath tubing tester continued. Testing of two hundred 750 mil diameter 35 mil wall tubes for PRTR and thirty reject 17 mil wall tubes received from AECL was completed. Down time was limited to two instances, one due to failure of the gating vacuum tube and the other due to failure of a transducer. As the system provides for the automatic rechecking of a standard with each tube inspected, these failures were immediately recognized and the equipment was put back in service with a minimum of down time. It was not necessary to retest material already inspected.

Minor circuit changes were made to enhance the analog records and simplify tester calibration. These changes do not significantly affect the basic system design, and construction of the electronic portions of the final model is 50% completed and proceeding on schedule. Detail drawings of the mechanical system were also completed. Design of electrical control circuitry which will integrate the various testing functions of electronics and mechanical systems is nearing completion; thus completing the design of a complete tubing test station which could easily be installed in a tubing manufacturer's plant.

Five samples, characteristic of the defects located in the 750 mil diameter 35 mil wall tubing, were sectioned. These defects were located on the internal surface precisely as predicted by the tester. Cross sections revealed an area of impressed metal with deeper cracks along the edges. The depth of these cracks correlated well with the depth predicted by the tester. Cross sections revealed an area of impressed metal with deeper cracks along the edges. The depth of these cracks correlated well with the depth predicted by the tester. The 30 reject 17 mil tubes received from AECL consisted of 10 each from Harvey, Reactor Metals, Inc., and Wolverine. The ten Harvey tubes produced only one defect indication, confirmed to be a 3/16 inch long shallow scratch located on the outside surface and less than 5% of the wall-in depth. Each Wolverine tube produced many defect indications, many with amplitudes corresponding to defect depths greater than 30% of the tube wall. Most of the defects were easily visible. No sectioning was performed on the Wolverine tubes because the defects were deep and covered appreciable lengths of the tubing. The ten Reactor Metals, Inc. tubes were also all rejects; however, most of the defects located in these tubes were between 5% and 30% of the wall depth. Analog records of defect location and size were obtained for each tube and select tubes were examined destructively. Eight I.D. and O.D. defects, as determined by

the tester, were located visually on the surfaces. Polished cross sections of each defect are being prepared for photographing and more accurate correlation of the analog record.

The punch method of manufacturing standard notches has shown definite advantage in that it economically produces notches which are very uniform; however, it has proven difficult to apply to wall thicknesses greater than 0.17 mils. This difficulty has been circumvented with use of a Rockwell hardness tester. By fitting the hardness tester with a punch tool and nonconducting fingers so that an ohmmeter can be used to determine when the punch makes contact with the tube surface, notches of accurate depth were produced and measured with the differential dial indicators. The dial indicator is calibrated to .08 mils and preliminary tests indicate notches can be manufactured to within 0.1 mil of the desired depth.

Transducer evaluation continued. Twelve spherically focused units, ranging in diameter from 3/4 inch to 3/32 inch, were accurately measured for performance characteristics. These transducers will be used to take notch depth versus amplitude data in different wall thickness of zirconium, aluminum, and stainless tubing for the final report.

WASHINGTON DESIGNATED PROGRAM

Isotopic Analysis Program

Isotopic analyses were provided on program samples during the month in accordance with current schedules.

Studies of the operational characteristics of the mass spectrometer equipped with the newly installed scintillation-type ion detector continued. The abnormally high pressure in the spectrometer tube, mentioned previously, was corrected. However, the abundance sensitivity did not improve proportionally to the tube pressure and is still several times worse than past performance. The reason for the poor abundance sensitivity has not been determined. Failure of the 50 kV ion-detector power supply has temporarily curtailed this study. Several minor modifications are being made to the ion test bench preparatory to evaluating the new vacuum lock sample changer for the mass spectrometer. The basic parts of the vacuum lock have not yet been received from the vendor because of problems encountered in their fabrication.

BIOLOGY AND MEDICINE - 06 PROGRAMAtmospheric Physics

Based on the mathematical expression for the lateral growth of a diffusing plume of airborne material reported last month, estimates of environmental exposures from emissions of up to 24-hours duration from a 70-meter stack were made using Hanford meteorological measurements. Except for calculation of seasonal and annual exposure levels, Hanford calculations for the release of radioactive material to the air have been based on short period releases (a few minutes). By accounting for the wind variability characteristics, it was shown that extension of the duration of the release period for a given quantity of material would reduce the level of peak exposure significantly. In addition, and, perhaps, more important in reactor site evaluations, the distance from the reactor to a given exposure level is reduced. Thus, calculations of the environmental consequences of "contained accidents" in which a fraction of the containment volume is released per day, or where technical evaluation of the accident indicates a prolonged release is appropriate, should include estimates of dispersion characteristic of the longer release period.

Field testing of replacement instrumentation for the portable mast continued at a location near the meteorology tower. Temperature and wind speed systems appeared to work satisfactorily over the range of these variables observed during December. A major problem with the digital voltmeter has developed which our instrument technicians have been unable to resolve. Contact with the vendor has been initiated.

Plotting and analyzing of the large amount of Hanford dispersion data for determination of the area within given dosage isopleths progressed during the month. Computation of least squares regression lines of unstable meteorological conditions was initiated for the ground source data. Iso-plething the areal distribution of ground level exposure values for the first series of elevated source experiments was completed and determination of cross-wind distributions started.

Radiological Physics

The beta-ray coincidence counter proved to have excellent characteristics for determining P^{32} in vivo. All people counted so far have given very nearly the same background (background differences between people limited the usefulness of the bremsstrahlung counter). When necessary, counting a subject with a beta-ray absorber over the counter gives a satisfactory individual background. The counting rate per unit activity in the body was within a $\pm 15\%$ range for five subjects containing known body burdens

(supplied by Oregon State Medical School and by Swedish Hospital). Retention studies on two of these subjects gave effective half-lives of ten days, in agreement with medical experience. The counter employs a relatively small lead shield so it is suitable for use in the mobile whole body counter.

We used the beta-ray coincidence counter to measure the P^{32} in two subjects who had eaten meals of Columbia River white fish. Body burdens of 114 and 91 nanocuries were found. Parts of the fish are being analyzed to relate body burden to intake.

We used the Radiation Protection Operation mobile whole body counter to make a successful set of measurements of people who had been working in the mill of a uranium mine. In the previous attempt too long a time elapsed between exposure and counting; the inhaled activity decayed away before measurement. This time body burdens of about one nanocurie were measured even though air concentrations were about one-fifth what they were previously. Tests with a plastic phantom indicated minimum detectable amounts of about 0.2 nanocurie. The nose, mouth, and throat contained about as much activity as the lung. This brief study showed that important basic information about inhalation of fine particles can be obtained by using whole body counting in addition to conventional techniques.

Hair samples collected from Alaskan Eskimos last summer showed the presence of Sr^{90} .

Receipt of a new multichannel analyzer permitted excessing the old one, which had given so much trouble, and resumption of the study of the sensitivity and background of the plutonium counter. Am^{241} in the plutonium makes detection in vivo easier, but the results are harder to interpret.

Failure of components caused shutdown of the Van de Graaff several times during the month. The faults showed no pattern; presumably the components failed simply because of age. The space and power saved last summer by substituting transistorized equipment for that using vacuum tubes is permitting us to rearrange the control room to secure more space for experimental work.

Neutron detectors employing pulse shape discrimination do not possess enough sensitivity at low energies for use in dosimetry. Polyethylene moderated LiI scintillators have too much sensitivity at the 250 Kev resonance of lithium to make a useful complement to the pulse shape discrimination detectors. Measurements were made with boron loaded polyethylene moderators to see if they were any better.

A hydrogen-xenon filling of the neutron spectrometer proportional counter gave difficulty and is still not working properly. Plans are being made to use a He^3 filled proportional counter also for neutron spectrometry.

A method that was hoped might simplify shielding studies proved unsatisfactory. The method tried to substitute small cone-shaped sections of the shielding material for the complete shield in transmission measurements.

Room temperature fluctuations and unavailability of a spare for a part that failed prevented any calorimetric measurements being made on Pm^{147} this month.

Changes in the control circuitry of the new calorimeter produced a radical improvement in the control of the shield temperature. Control to within 80 microdegrees resulted for periods of a few hours; for twenty-four hour periods the range was about 200 microdegrees. This was much better than we had hoped to achieve at this stage of the development.

Instrumentation and System Studies

Promising results were obtained in field tests of the temperature measuring portion of the experimental animal biological function telemetry system to be used for measurement of temperature, respiration, and pulse rate. Following laboratory tests, the temperature measurement portion, consisting of a thermistor-controlled oscillator transducer and a tunnel diode 100 Mc/sec transmitter, was field tested at the Biology Animal Farm. With cooperating biologists, the transducer was implanted under the skin of a sheep and the transmitter was attached externally. General operation was satisfactory; however, external temperature changes influenced the results since the transducer was mounted just under the skin. Because of this problem, work is being accelerated to modify the system with longer leads between the transducer and transmitter; the transducer will then be implanted considerably deeper within the sheep, possibly in the intestine. This will exclude environmental temperature effects. Circuit and transducer development work was accelerated for the respiration and pulse rate portions of the system.

Circuit development was initiated on a peak pulse reader instrument for use in radiation dosimetry work. The instrument is to provide a readout from the previously-developed pulse ion chamber reader that will not go off scale. In essence, the instrument under development will be a peak reading voltmeter; for single pulses a digital readout is planned.

Detector experiments continued on a special alpha air monitor for use in the Biology Inhalation Laboratory. Alpha energy analysis techniques will be employed to provide acceptable sensitivity and minimal effects from variation of radon-thoron air concentrations.

Progress was achieved on necessary circuitry development and general instrument layout modifications for the wind component meter system for use in atmospheric physics studies. Large common mode signals precluded accurate measurement of the desired signals, and the oscillator frequency was determined to be too near the chopper frequency of the included amplifier. The oscillator was revised to eliminate this problem. Band width and low-pass filters were designed and incorporated in one channel, and the azimuth readout system was considerably modified to incorporate a new supply, different calibration circuits, and improved readout circuits. These were designed to be compatible with the tape recorder data collection system.

Satisfactory progress was made on the fabrication of an experimental scintillation detector and all solid state circuitry six decade logarithmic response radiation monitor. Basic circuit development has now been completed and testing of the experimental unit, when fabricated, will be necessary to determine if modifications need be incorporated.

General fabrication work was accelerated on the second experimental data station for use with the HAPO Radiotelemetry System. The three-channel radiation level monitor was completed and tested satisfactorily. Work commenced on the wind direction integrator portion of the data station.

General calibration and field testing continued on the portable mast data logging and recording system, which was developed for use in atmospheric physics studies.

Debugging continued on the 400 channel analyzer during the month. The analyzer is to be used for time-of-flight and pulse height studies at the Positive Ion Accelerator Facilities. Automatic turn-on circuits for the typewriter and paper punch were added.

Tape recordings of wind speed were received from the Atmospheric Physics Operation for which an analysis was to be made involving a coordinate transformation from spherical to cartesian coordinates. The work required two tape recorders, one in the playback mode and one in record mode. As only one tape recorder unit is presently available, the work is being delayed until a second unit can be obtained.

TEST REACTOR OPERATIONS

The PCTR operated routinely during the month. There were no unscheduled shutdowns.

The experiment to measure fluxes to be expected in N Reactor in special columns for isotope production was completed during the month. The PCTR was used as a neutron spectrometer and the noise measurement equipment to be used in the NPR startup. A set of mica detectors were irradiated to detect the presence of uranium in NPR fuel element welds.

The TTR was operated on a two nights a week basis for the University of Washington Graduate Center. There were two unscheduled shutdowns due to electronic failure. Two sets of foils were irradiated for normalization and standardization.

The mechanical components for the Split Table Assembly have been received and stored.

CUSTOMER WORKWeather Forecasting and Meteorological Services

Meteorological and climatological consultation services included 1) a continued study of wind variability in relation to dispersion of N-reactor effluents, 2) advice on release of toxic fumes during "pigtail" decontamination operations for IPD, and 3) preparation of solar radiation data summaries for determination of hydrogen tank storage requirements for IPD.

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

Weather Summary

<u>Type of Forecast</u>	<u>Number Made</u>	<u>% Reliability</u>
8-Hour Production	93	85.3
24-Hour General	62	93.6
Special	158	93.7

December was somewhat colder, wetter, and less windy than usual. All of the lowest temperatures occurred during the first half of the month.

Mass Spectrometry

Isotopic analyses were provided on 5 samples of uranium in support of HAPO U²³³-production studies and 7 analyses were provided in support of research in Nucleonic Instrumentation.

Instrumentation and System Studies

The soil moisture measuring probe developed for Advance Technical Planning, CPD, and Chemical Effluents Technology, HL, has been completed. Its twenty pound weight can be easily supported by the available cable-drum system of CET. Following PuBe source installation and final laboratory testing, the probe will be installed on the cable and field tested.

Construction and tests on a ground water analog system for the Chemical Effluent Technology Operation continued during the month. The system is intended for use in simulating the ground water potential conditions in the Hanford area. A 662 node test model assembly was completed and tests, which were made to confirm the accuracy of the wiring, indicated that an inter-grid boundary condition was causing a large error between experimental values and the predicted theoretical values. In an effort to more fully isolate the error, a smaller, uniform density analog network was proposed and is presently under construction. A formal report describing the reliability and feasibility of this type of analog system and recommendations for a larger model is presently being prepared.

An electronic timer was developed for Waste Calcination Demonstrations, HL. The timer provides adjustable timing for both on and off times from 0.5 to 19.5 seconds as required. Engineering modifications were presented to Waste Calcination Demonstrations, HL, regarding control circuits for use in the 324 Building. The required circuits are being modified to suit the environmental conditions and space limitations.

Engineering assistance was rendered to Biology Laboratory instrument maintenance personnel in determining the reason for faulty operation of a xenon lamp probe and power supply used in biology experiments. The difficulty was determined and corrective procedures were suggested.

Detailed data were obtained and provided to Calibrations Operation, HL, on the various voltages and waveforms expected for the modified gating circuit to be used in the next group of Model II Scintrans. These will be fabricated offsite.

Design work continued on the face mask monitor for mixed fission products. The instrument will be used by Protective Equipment Decontamination, HUP0.

Part of the necessary commercial items for the U-235 fuel enrichment measurement instrument were received. General assembly will commence when the remainder of the counting system is received. Initial drawings were started on the portions to be fabricated onsite. The instrument was designed for Metal Fabrication Development, HL.

A small scintillation probe, using a 10 mil thick terphenyl in polyvinyl-toluene scintillator directly attached to a small multiplier phototube, was provided to Radiation Monitoring, HL. The probe was tested and could easily detect 1×10^4 d/m of Pm-147 as required for the application.

Ten runs on the complex model for the C-column simulation were made. There are seven additional runs to be made from the original batch of 52. These runs cannot be made until additional data are obtained from the customer.

Further debugging of the creep capsule data logger was accomplished. The system is now running on automatic interrogation of a dummy micropositioner. Installation will proceed about the first of the year.

An invention report was written for a device for remote displacement measurement. The device is being developed for use by Reactor Metals Research in high temperature metals research.

Optics

Lens mounts, shutters, and other component parts of a camera which will be used to restore true relative dimensions to electron microscope pictures were designed or specified. Distortion in the electron microscope image is unavoidable when reflection microscopy is used to study metal surfaces. A dimension rectifying camera was assembled on an optical bench using available components. Several pictures were taken which demonstrate the image rectifying action. Equations were derived from which the camera adjustments can be calculated for any degree of image distortion in the original picture.

Modifications were made in the camera coupler for the 1-3/4 inch diameter borescope to adapt it for use with a new 16 mm motion picture camera.

Fabrication of the N Area seismoscope was completed. The unit was installed, a memorandum was written describing how adjustments should be made to the seismoscope when required, and drawings detailing modifications incorporated in the new seismoscope were prepared.

During the four week period (November 17 to December 15) included in this report, 432 manhours shop work was performed including 32 manhours of overtime work. This work included:

1. Repair of three camera shutters.
2. Fabrication of 10 glass bearings.
3. Fabrication of components for an electrical readout traverse mechanism.
4. Fabrication of a second gap measuring probe for Physical Testing.
5. Fabrication of 25 quartz coil forms for Physical Testing.
6. Modification of a galvanometer for use of multiple reflection amplifier techniques.
7. Boring out of two large pyrex chemical process pipes.
8. Modification of a borescope head for Physical Testing.

Physical Testing

At the request of PRTR Operations, an eddy current test was developed for inspection of installed PRTR heat exchanger HX-5 tubing. Despite limited access and substantial background radiation levels, a test employing the Model 1004 Eddy Current Tester with a specially designed coil was successfully applied to a tube containing a known leak. Out-of-exchanger examination of suspect areas identified by the tester revealed the leak to exist at a point where the tube ran adjacent to a baffle plate. Apparently, the leak was caused by wear between the two. PRTR Operations have requested continuing assistance with the development of methods of measuring this wear quantitatively.

An emergency call was answered to determine the cause of leaking on some helium valves which prevented startup of the PRTR. The ultrasonic translator was used to determine which valves were leaking externally as well as those bypassing helium internally. The information provided by the translator contributed to a successful startup the same day.

A complete inspection of the tubes within five steam generators was completed in record time in preparation for fuel loading of the N Reactor. Each tube was cleaned by blowing a plug through it, examining the contents and recording the results. Only seven shifts were required to inspect 10,000 tubes. Borescoping service, with photographic record and interpretation of the results, was applied at N Reactor on some process tubes used for fuel loading tests and for evaluation of two isotope horizontal rods. The final report on the N Reactor steam generators, presenting a graphical record of the eddy current indications in Generator 4-A, was completed and sent to printing. A probe, using strain gages for sensors, was developed to measure

the height of fuel element supports after charging in the reactor. The probe was not used during the initial charging of N Reactor.

Nondestructive testing technology is being applied to a Chemical Laboratory problem involving the periodic examination of the proposed storage tanks for the Waste Calcination Demonstration Program (WCDP). A scope document is being prepared outlining an integrated examination facility capable of measuring various parameters describing the contents and integrity of the storage tanks. Techniques appearing applicable include neutron radiography, ultrasound, infrared, autoradiography, multicolor pyrometry and strain gaging. Intense radioactivity is a factor in the environmental considerations.

Instrument development support is being provided Plutonium Metal Development on property measurement and inspection programs. Progress this month included a satisfactory photo-voltaic cell for measurement of rapid temperature changes; response times of less than five microseconds were achieved.

Ultrasonic tests were developed to accurately measure the varying wall thickness of remote energy source fuel cells. The cell contains isotopes in compressed ceramic form and is encased in Inconel. Measurements were made both prior to and following machining to size, accuracies were within thousandths of an inch and confirmed by sectioning. Ultrasonic thickness measurements were made on Inconel melting pots to determine if nickel residue in the simulated waste product was caused from ablation of the pot. Test results indicated as much as fifty percent of the 0.400 inch wall was missing in some areas. Radiographic examination substantiated the ultrasonic test results.

Development work in neutron radiography is continuing. A Pu-Be source was borrowed from Radiological Physics, and although not intense enough for radiography the source provides the desired strength for research work in electron microscopy by Ceramic Research.

Conventional radiography was employed on slitter blades for removing process tubes from reactors, on welds, on tanks, concentrators, pipes, tube bundles and miscellaneous repair jobs to assess the quality of the welded joints.

COMPUTER FACILITIES

Analog computer utilization was as follows:

152	Hours Up
48	Hours Scheduled Downtime
8	Hours Unscheduled Downtime
<u>0</u>	Hours Idle
208	Hours Total

The times given above include all off-shift operation (swing shift and weekends).

Problems considered during the month were:

1. N Reactor Primary System.
2. N Reactor Steam Generator.
3. N Reactor Secondary Loop.
4. C-Column.
5. PRTR Vibrational Analysis.
6. PRTR Prompt Excursion.
7. Coordinate Transformation (Meteorology).

The new analog computer arrived on Friday, December 6, and is now under installation and check out with the assistance of a vendor field engineer. After a careful inventory of the computing equipment associated with the new computer, it was discovered that the vendor had included only 144 uncommitted operational amplifiers instead of the 156 called for in the specifications. Steps are being taken to correct this deficiency. At present, it appears that the earliest possible date for operational use will be about February 1, 1964.

Preliminary ground work for acquisition and utilization of the digital process control computer is moving rapidly ahead. A meeting was held in Phoenix on December 2, at which the physical layout of the computer, input-output cabinets, and console was determined. Several questions on programming were also resolved.

A course consisting of seven six-hour sessions devoted to programming of the G. E. 412 computer was held at Hanford December 10 through 17. The course was instructed by a vendor representative. Twelve Hanford participants were awarded certificates upon its completion.

Initial steps have been taken for acquisition of a semi-trailer to house the computer. Detail design of interior furnishings has begun by Laboratory Engineering.

INSTRUMENT EVALUATION

Six of the seven offsite fabricated combined alpha-beta-gamma scintillation hand and shoe counters have passed all acceptance tests and are ready for plant service. Training of technicians in the general operation and maintenance of the instruments was completed for 300 Area and 200 Area technicians. In addition, circuit changes to be incorporated in future models were determined and established on the blueprints. Three additional combination counters, fabricated offsite by a different manufacturer, were received and testing was started.

Comparison tests were conducted with the scintillation hand and shoe counters and the older G-M tube detector instruments. The detection efficiencies were 3 to 4 times better for the scintillation instruments; thus, considerably less contamination can be detected.

Evaluation tests were completed on a commercial Victoreen Model 440 portable beta-gamma dose rate meter. The evaluation report was completed in initial draft form.

General field testing continued on the experimental gamma background compensated beta-gamma hand and shoe counter in the 321 Building. Testing to date has appeared to be quite satisfactory.

Engineering modifications were incorporated on the blueprints for Model II Scintrons and all prints were updated to permit offsite fabrication of more units. In addition, specifications and prints were updated for the CP-TP dose rate meters.

Manager
PHYSICS AND INSTRUMENTS LABORATORY

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CHEMICAL LABORATORY
RESEARCH AND ENGINEERING

FISSIONABLE MATERIALS - O2 PROGRAM

IRRADIATION PROCESSES

Emissivity of Aluminum-Clad Fuel Elements

Measurements of the emissivity of aluminum-clad uranium fuel elements were concluded and a report was drafted (HW-79859). Emissivities determined were approximately three to four times higher than that previously used (0.1) in estimating the temperature rise of an irradiated element in ambient air. A comparison, based on an assumed reactor power, was made between the temperature rises estimated from calculations using previous emissivities and temperature rises estimated from calculations using emissivities determined in this experiment. It was found that estimations based on previous emissivities predicted that the melting point of uranium (~ 2066 F) would be reached 280 seconds after the element left the reactor, while estimations based on emissivities determined in this experiment predicted that the maximum temperature reached would be approximately 1870 F.

Fission Product Release from Production Fuels

A study was undertaken of the feasibility of performing heating and quenching experiments on fully irradiated N Reactor fuel elements. A tentative conclusion was reached that these experiments are feasible on a short schedule, but a decision cannot be made until a hazards review reveals the experiment to be safe. The tests will involve heating the outer and inner elements with induction heating to a predetermined uniform temperature, then quenching with a flow of water.

Preliminary experiments using the currently available 15 KW induction heater gave promising results on a 12-inch long unirradiated element. Uniformity in heating was obtained.

Electrodeposition of Nickel on Uranium

Electron micrographs have been made (by the Metallography Laboratory) of the surface of a nickel-plated uranium specimen. The pictures show unplated areas 5 to 10 microns in diameter, appearing to be caused simply by (1) a failure of the nickel to nucleate at this spot, and (2) stopping the plating operation before the coating could grow in from adjacent areas. This particular sample had been given a 7 micron coat, using the standard H_3PO_4 -HCl anodic etch

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surface preparation procedure and a Watts bromide plating bath. The visual evidence from the electron micrographs correlates well with results obtained in the porosity test described in the November report.

SEPARATIONS PROCESSES

U-233 Production Studies

Three thorium metal elements, which had been irradiated in F Reactor for 21 days, were received during the month and fluoride-catalyzed dissolution begun in the B-Cell one-slug dissolver. Dissolution of one element had been completed at the end of the report period and isolation of U-233 and Pa-233 was underway. Following these operations and disposal of the waste solutions generated, the other two slugs will be processed and the combined uranium fraction removed from the cell for final purification.

Aluminum cladding was removed by adding 1 liter of 4.5 M NaNO_3 , heating to boiling, and then adding 500 ml of 25 percent NaOH slowly until reaction ceased. Four hours were required. The coating solution was sampled, found to contain only quite minor amounts of activity, and discarded. The thorium was then dissolved in approximately 48 hours in two cuts totaling 3800 ml. In both cases, 6 M HNO_3 containing 0.2 M NaF was placed in the pot, heated to boiling, and concentrated HNO_3 added as required to maintain the desired dissolution rate (as evidenced by off-gas production). After the second cut, no residual thorium was found in the dissolver. A gamma spectrometer scan showed only Pa-233 activity in the solution.

The solution has been processed for Pa-233 removal by a manganese dioxide scavenging process, devised from previous tracer-level laboratory studies and small-scale hot-cell experiments. In the scheme adopted, the feed was diluted two-fold with water and additions made of $\text{Mn}(\text{NO}_3)_2$, KMnO_4 , and sulfamic acid equivalent to 0.024, 0.016, and 0.04 M, respectively. Heating for one to two hours produced filterable precipitate carrying 93 to 94 percent of the protactinium. Standing overnight reduced the recovery to about 92 percent. Use of more concentrated feed, deletion of the sulfamic acid, or use of smaller amounts of precipitant resulted in much less efficient recovery of protactinium.

Laboratory experiments (using U-235 as tracer) and gamma spectrometry for both uranium and thorium analysis indicated that batch extraction of U-233 with 10 percent TBP-Soltrol is the best of several schemes explored and should be satisfactory for hot-cell use. Use of trioctylamine or acetic acid-TBP solvent extraction systems, or ion-exchange (Dowex-1) of the uranyl acetate anion complex all gave inferior results. Use of TBP concentrations greater than 10 percent resulted in the formation of two organic phases and largely offset any benefits of higher extraction coefficients. Best conditions appear to involve partial neutralization of excess acid, dilution to a fairly low thorium

concentration, and multiple batch extractions with half volumes of 10 percent TBP-Soltrol. The extracted uranium is stripped with a tenth volume of 5 M $(\text{NH}_4)_2\text{CO}_3$. Only very minor amounts of thorium were extracted into the organic phase. Thorium daughters also remained in the aqueous. No data are yet available on protactinium or fission product behavior.

Thorium Recycle

Calculations have continued to define radiation problems in the recycle thorium. The U-232 concentration at which Th-228 increases each cycle in the recycle thorium depends on the initial Th-228 concentration in the unirradiated thorium, the irradiation history, and the time cycle outside the reactor. In view of the large number of reactor cases and the variety of ex-reactor conditions that are being considered, only a few general conclusions have as yet been drawn. Assuming a cooling time of 270 days before chemical processing, the conclusions are as follows:

1. The Th-228 concentration will decline for several cycles at a concentration of 2 ppm U-232 in U-233.
2. Near 3 ppm U-232 in U-233, the Th-228 concentration in recycle thorium will increase slightly for several cycles for several of the cases being considered.
3. At 5 ppm U-232 in U-233, the steady-state Th-228 concentration will be about 1.2 to 2 times the amount present at equilibrium in aged natural thorium.
4. At 10 ppm U-232 in U-233, the steady-state Th-228 concentration will be about 3 to 5 times the amount present at equilibrium in aged natural thorium.

If shorter cooling times are assumed, higher U-232 concentrations are required before Th-228 begins to increase each cycle and the steady-state Th-228 concentrations will be lower for a given U-232 concentration in the product.

Further calculations have also been made on the cooling time requirements for Th-234 decay. Assuming a thermal flux of 3×10^{13} and a U-232 concentration of 1 ppm in the product, the Th-234 content at discharge is about 0.03 grams per ton of thorium. It is expected that, if the thorium calcination operations are similar to uranium calcination operations, the allowable Th-234 content will be about equal to or less than the Th-234 content in aged natural uranium. A cooling time of 270 days since reactor discharge is required to reduce the above Th-234 content (0.03 g/ton Th) to that of aged natural uranium. A cooling time of 350 days since reactor discharge is required to reduce the above Th-234 content to 0.1 that of aged natural uranium.

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Neptunium-Plutonium Separation by Batch Amine Extraction

The batch extraction flowsheet test (HW-79626 C) was repeated using centrifugation on all phase separations. The decontamination factor for plutonium from neptunium was increased from 350 to 7000 by this change. Only a small separation from neptunium was obtained by stripping the plutonium from the 15 volume percent trilauryl amine and 10 volume percent n -octyl alcohol in dodecane with fresh 0.2 M ferrous sulfamate in 1 M HNO_3 . However, it has been demonstrated several times that plutonium(IV) can be extracted from neptunium(V) solutions with tertiary amines by stabilizing these valences with excess nitrous acid in 1 M HNO_3 .

Trilauryl Amine Extraction of Neptunium and Plutonium from Purex 1WW

During recent months, various aspects of stripping neptunium and plutonium, scrubbing cerium and washing other contaminants from TLA-Soltrol solutions have been studied using simulated solutions traced with appropriate isotopes. Batch contacts were completed this month testing these procedures on solvent which had been contacted with Purex plant 1WW solution. In almost all instances, results obtained were in excellent agreement with those obtained using simulated solutions. Even the high ruthenium decontamination factors (100 - 500) obtained during washing of simulated solvent with NaOH-KMnO_4 solutions were observed.

Poor extraction of neptunium from Purex 1WW during a recent plant test of the trilauryl amine neptunium and plutonium recovery procedure is attributed to inadequate mixing of the waste with the trilauryl amine-Soltrol extractant. Tests performed during the last month with a specially designed agitator have demonstrated that adequate blending of the two phases can be attained in a 5000-gallon tank if the batch size is no greater than 3000 gallons.

Polonium-210 Studies

Mercury polonides are reportedly volatile at low temperatures, e.g., 200-300 C. Accordingly, it was presumed possible that Po-210 could be volatilized in vacuum more efficiently from dilute Hg-Bi alloys than from Bi alone. To test this assumption, a 1:1 Bi-Hg alloy was prepared by heating these elements together at 150 C, spiked with irradiated Bi and placed in a Vycor bulb with a long tip. The bulb was evacuated to 8×10^{-5} mm and sealed off.

The bulb and its contents were heated to 400 C in the rocking furnace, melting the contents and mixing them thoroughly over a 3-hour period. The tip of the bulb was then pulled out of the furnace and cooled with moist asbestos to provide a condensing surface upon which to condense Po-210, Hg and Bi.

After 24 hours a few droplets of metal, presumably Hg, had distilled. Preliminary tests indicate that no Po was carried by the mercury.

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Flowsheets for Scrap Recovery Process

Greater than anticipated extraction of Pu(III) by dibutylbutyl phosphonate (DBBP)-CCl₄ solvent has forced abandonment of the current study flowsheet for reprocessing uranium-plutonium-thorium scrap. In this procedure, uranium would have been removed by extraction into TBP-CCl₄ and thorium by extraction into DBBP-CCl₄ from an aqueous in which plutonium was maintained as Pu(III). Currently, a flowsheet in which uranium and thorium are co-extracted into TBP-CCl₄, leaving plutonium in the raffinate, is under study. Adequate thorium extraction appears possible at high salting strength and organic/aqueous flow ratio.

Metathesis of Uranium(IV) Fluoride

The rate of metathesis of UF₄ in sodium hydroxide solution was studied. The data are needed in development of procedures for Zirflex decladding of N Reactor fuels in the Purex plant. Uranium(IV) fluoride (UF₄·0.58H₂O) used was air dried (110 C), ground and sieved through a 100-mesh screen. In 2 M NaOH at 25 C, percent metathesized ranged from about 50 at 5 - 15 minutes to 75 at one hour and 95 at five hours. Increased temperature and caustic concentration as well as air sparging the caustic increased the rate of metathesis.

Partitioning Reagent for the Purex Process

Sodium sulfoxalate formaldehyde, a strong reductant used in the dyeing industry, is being considered as a possible plutonium reducing agent to replace iron(II) in the Purex process. Batch contact studies show it is a very effective reducing agent for Pu(IV) in nitric acid solutions. A major concern is the stability of the reagent in pertinent process environments. Tests are underway to determine this. Neither sulfamic acid nor hydrazine significantly reduces the rate of oxidation of the reagent in nitric acid systems.

Ion Exchange Contactor Development

A mockup of a proposed countercurrent plutonium anion exchange column for remote installation has been operating for the last month. The contactor consists of a 4-in. diameter, 20-ft. high loop with intermittent resin movement achieved by an air-operated bellows pump. The effect of pulsing variables, column flow rates and times, acidity, temperature and resin loading (using thorium as a stand-in for plutonium) on resin movement have been studied. Increases in flow rates, length of the solution flow period, acidity, temperature, and resin loading generally decrease the net rate of resin movement. Even under the worst conditions encountered so far, the net rate of resin movement during a reasonable pulsing time (2 to 3 minutes) resulted in processing times of at least 88 percent, over a total time cycle of 20 to 30 minutes.

Disposal to Ground

A field test was designed and is now underway to determine whether water within a piezometer tube is exchanged with ground water in the sediments surrounding a perforated well casing. Well 299-W22-14, located adjacent to the 216-S-7 Redox process condensate crib, was chosen for the test. Sufficient water was pumped from the tube to insure obtaining a representative sample of the contaminated ground water (4×10^{-5} $\mu\text{c } \beta/\text{cc}$). After the water level in the well returned to normal, 250 gallons of clean water were poured into the piezometer tube to displace the contaminated water into the sediments. A small sample taken from the water surface in the tube following the introduction of the uncontaminated water had a gross beta-emitter concentration of 2.4×10^{-6} $\mu\text{c/cc}$. Two days later a surface water sample showed the concentration had increased to 3.7×10^{-6} $\mu\text{c } \beta/\text{cc}$. This test will be continued, with periodic sampling, until the well reaches equilibrium or until a significant period of time has elapsed. Results will be used to evaluate the ground-water "turn-over time" in project wells equipped with piezometers; also, the need for and frequency of pumping piezometer tubes periodically to obtain non-stagnant samples will be determined.

Recommendations were made that the nearly-completed 216-S-7 replacement crib not be activated until additional positive radiostrontium results are found in samples from wells monitoring the active S-7 crib. Radiostrontium concentrations in all monthly samples from the three monitoring wells have been below the detection limit, $< 7 \times 10^{-8}$ $\mu\text{c/cc}$, since March 1963. The series of positive results noted in March may have been due to the higher-than-normal amounts of activity and dissolved salts discharged to the crib in February and March. Continued surveillance of the ground water in the vicinity of the crib is being maintained.

WASTE MANAGEMENT AND FISSION PRODUCT RECOVERY

Strontium Extraction Process

A high-efficiency lead sulfate carrier process for the removal of Sr-90 from dissolved tank farm sludges has been reported in previous monthly reports. The process is characterized by a high degree of strontium removal (≥ 95 percent) and has been rather thoroughly investigated in the laboratory, the chemistry hot cells and in the Cold Semiworks. Despite successful performance in these facilities, efforts to demonstrate the process in the Purex Head-End centrifuges and to apply it to routine strontium-90 processing have resulted in low recoveries (≤ 80 percent). One postulated explanation was that the sugar-treated LWV used in the plant runs contained some organic complexant (derived from sugar) which interfered with strontium precipitation. A B-cell experiment was accordingly performed to test this hypothesis. A quantity of fresh, raw, Purex LWV (obtained for waste fixation studies) was sugar treated

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in-cell and used as feed for a strontium precipitation simulating the plant flowsheet as closely as possible. Only major difference was use of filtration rather than centrifugation for phase separation. The recovery of 96 percent was identical to previous hot cell and Cold Semiworks experience.

CSREX Studies

Studies, reported last month, on the effect of radiation on BAMBP in CSREX solvent were continued. G value for decomposition of BAMBP, when exposed as pure BAMBP (not diluted with D2EHPA and Soltrol), was 3.5, about the same as for "normal" organics and much lower than for BAMBP in CSREX solvent. Decomposition of BAMBP in a BAMBP-D2EHPA mixture (no Soltrol) was also less than in CSREX solvent, seemingly implicating Soltrol as the major source of BAMBP decomposition. In conformity with this theory, very little BAMBP decomposition was observed when diisopropylbenzene was substituted for Soltrol (however, cesium extraction coefficients are unsatisfactorily low with diisopropylbenzene). A variety of other diluents will be scouted, as will certain free-radical scavengers.

In other CSREX related work, the measurement of freezing point depression was undertaken in an effort to shed further light on the CSREX extraction mechanism. Very preliminary results appear to indicate that D2EHPA is primarily dimeric and BAMBP monomeric (in cyclohexane) and that the two interact in the ratio 4 BAMBP/D2EHPA, as also indicated by earlier NMR measurements.

Amine Extraction of Technetium from Purex High Level Wastes

The results of tracer-level experiments on the extraction of technetium-99 from synthetic Purex LWW and STW wastes into 0.3 M trilauryl amine-Soltrol were reported last month (HW-79726 C). Confirmatory hot cell experiments have now been performed with full level LWW and STW. In equal-volume contactings, 84 percent of the technetium was extracted from as-received LWW, and 93 percent from STW. Twenty-five and 56 percent of feed ruthenium was also extracted (as qualitatively expected).

Technetium Purification

Chemical analysis of the technetium concentrate was completed. Composition of the crude, which contains ca. 1 kg of technetium in 100 liters of solution was as follows:

Fe	0.87 M	NO ₃	5.4 M
Cr	0.25 M	Ce-144	0.27 c/l
Ni	0.13 M	Ru-106	0.013 c/l
H	2.1 M	ZrNb-95	0.40 c/l

Further processing in an unshielded, or lightly shielded, facility would be greatly hampered by the exposure problem associated with the ZrNb-95. Laboratory experiments and a hot-cell test demonstrated that 94 percent of the ZrNb activity can be removed by passing the solution through a bed of silica gel, thereby reducing the exposure problem to a tolerable level. A stainless steel cartridge for the purpose has been designed to fit into a standard lead-lined waste disposal drum. Cerium-144, the next most significant radioactive impurity, does not present as severe a gamma dose problem as does the ZrNb (because of much lower gamma yields); however, the beta energies are high and some shielding of the purification column will be required. For this purpose, a lucite shield is being fabricated which will surround the column.

It was initially intended to achieve final purification of the technetium by loading onto an anion exchanger from neutral or alkaline solution. Because of presence of iron, chromium and nickel (which would precipitate and clog a column), absorption at lower pH was investigated. It was found that technetium can be satisfactorily loaded at pH's as low as 0.5. A pH of 1.0 appears to give optimum capacity, but the exact pH is not particularly critical. A column containing 15 liters of resin can be expected to absorb the technetium from the crude feed without appreciable loss. In other experiments, diluting the feed showed no improvement in loading characteristics. However, some dilution may be desirable to prevent the resin from floating.

Waste Tank Circulator Studies

Circulation of waste solutions in the new Purex waste tanks will be achieved using 22 air-lift circulators. In cooperation with the Chemical Processing Department, a single circulator (30-in. diameter, 16-ft. tall, 241-AX design) has been mocked up in the 200-W shop for testing and evaluation. An important factor in operation of the system is the amount of air required to provide adequate circulation since the quantity of air used is limited by the tank vent system capacity. Initial tests indicate that each circulator will deliver 5000 gpm of water when supplied with 7 scfm of air (the maximum amount specified). No vibration problems were encountered. Further tests are underway to characterize flow patterns around the circulator and provide information concerning the ability of the present design to maintain solids in suspension.

Strontium-Cerium Equilibrium on Linde 4AXW and 13X

Study of zeolite ion exchange systems containing trivalent cations was continued. A third system, Sr-Ce, was determined, along with the previously reported Na-Ce and Na-Sr systems, to check the accuracy of the three resulting rational thermodynamic equilibrium constants. The equilibrium constants at 25 C were 251 with 4AXW and 1.28 with 13X for the exchange reaction,

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The derived Gibbs free-energies were -3300 cal/mole and -200 cal/mole for 4AXW and 13X, respectively. The free-energy relationships between the exchange systems Na-Ce, Sr-Ce and Na-Sr indicated that the results were accurate to ± 100 cal/mole. The zeolite-trivalent cation studies will include yttrium because of the pertinence to the Waste Management Program of the behavior of yttrium during ion exchange reactions.

Thermodynamic Relationships in Multication Systems

A simple equation employing mass action quotients for trace cesium in NH_4^+ , Na^+ , or H^+ systems was developed for computing K_d values for cesium with ion exchange resins in mixed $\text{NH}_4^+ - \text{H}^+$ or $\text{Na}^+ - \text{H}^+$ solutions. The equation for computing the cesium K_d in a $\text{NH}_4^+ - \text{H}^+$ system is, for example:

$$\frac{1}{K_{\text{d Cs} - \text{NH}_4 - \text{H}}} = \frac{(\text{NH}_{4\text{N}})}{K_{\text{NH}_4} \text{Cs}^*} + \frac{(\text{H}_{\text{N}})}{K_{\text{H}} \text{Cs}^*}$$

Where:

Cs^* and Cs^*
 K_{NH_4} and K_{H} = Mass action quotients for trace cesium in NH_4^+ and H^+ systems.

$(\text{NH}_{4\text{N}})$ and (H_{N}) = Concentration of NH_4^+ and H^+ in equivalents per liter.

Cesium distribution coefficients for two ion exchangers and five combinations of ions were determined experimentally and found to agree with the coefficients calculated by the above equation. This equation will be particularly useful for predicting the effect of pH changes on trace cesium breakthrough for cation exchange resin columns and low intermediate-level wastes containing NH_4^+ , Na^+ and possibly other cations. Cesium breakthrough often governs the amount of waste that can be put through a resin column before regeneration or disposal of the resin is necessary.

EQUIPMENT AND MATERIALS

Welder Qualification Corrosion Tests

Corrosion tests are nearly completed on a series of 304-L stainless steel weldments in which deliberate attempts to produce bad welds were made. In general, significant increase in corrosion rate as shown by the Huey test

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has not been observed for samples which were welded under oil, welded with insufficient gas shielding, welded with virtually no slag removal between passes, or in which the initial weld was ground out and new weld metal laid down. The one sample which did show significant increase in corrosion rate (Huey test) was welded with 304 rod under submerged arc conditions. A similar weldment made under tungsten inert gas welding conditions did not show a corrosion rate increase.

Corrosion of Mild Steel Weldments

The 19 mild steel weldments fabricated by Consolidated Western Steel Co. using a wide variety of welding techniques (pertinent to fabricating underground waste storage tanks) were inspected after six weeks' exposure to 40 percent NaNO_3 - 10 percent NaNO_2 solution at 80 C. Attack on all weldments was negligible and the test was terminated.

Corrosion Tests on Gadolinium-Containing Stainless Steel

Corrosion rate determinations were made on two alloys, basically 304-L but containing (a) 0.3, and (b) 0.7 w/o gadolinium. Huey test corrosion rates on as-received (a) and (b) alloys were about two- and four-fold higher, respectively, than for 304-L. A weldment fabricated from the (b) alloy and 308-L welding rod was severely attacked at the base metal-weld metal interface in the Huey test and in a HNO_3 - HF - $\text{Al}(\text{NO}_3)_3$ solution. Annealed and sensitized specimens of both alloys and a weldment fabricated from the (b) alloy corroded at about 25 - 30 mils/mo in Zirflex decladding solution (about twice the rate expected for 304-L). No preferential attack occurred, however. Heat treatment which would normally sensitize 304-L appears to decrease corrosion of the gadolinium-containing alloys. This effect will be explored further.

Non-Metallic Materials

In static immersion tests a four percent borated polyethylene exposed to 25 v/o DBBP- CCl_4 solution at 50 C increased four percent in length and 30-40 percent in weight very soon after immersion; there was little if any further change during the remainder of the exposure. When the coupons were removed from solution, they lost weight rapidly, decreased in length, and stiffened. Tests are continuing to determine the degree of recovery and the amount of permanent plastization. Polypropylene Pallrings exposed in the same solution showed a similar gain in dimensions and weight. There was little if any plastization.

A polyethylene compound CAB-XL (G.L. Cabot Co.) was exposed (static immersion) at room temperature to 60 percent HNO_3 , 50 percent NaOH and several typical plant solvents for 32 days. There was no noticeable change in the material

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other than a slight swelling (no more than two percent) in any of these solutions. The material is a highly filled (up to 50 percent carbon black), heat curable, chemically cross-linked polyethylene compound.

PROCESS CONTROL AND DEVELOPMENT

Air Pulser Control Instrumentation

The recently developed solid state frequency controller operated a solenoid valve at 200 cycles per minute for a period of 144 hours; no malfunctions occurred during the test. A circuit is now being designed to linearize the setting of the frequency control potentiometer and to reduce the temperature sensitivity of the present circuit.

Two alternate systems for measurement and control of pulse amplitude have been developed and tested. One system uses a strain gage flowmeter; the other an electronic differential pressure cell. Present plans call for installation of both systems in the Plutonium Reclamation Facility; this instrumentation will operate in conjunction with the Gradient Control System for overall control of the plutonium solvent extraction columns.

In-Line Plutonium Detectors

Laboratory evaluation of scintillating glass alpha detectors continued using the 400-channel analyzer to determine gamma discrimination capabilities. Three mils of the cerium-activated layer (initially 15 mils thick) were removed to aid in determining optimum thickness of the layer. With a 20 mr per hour Cs-137 source, an increase of 200 counts per minute was observed. Alpha counting efficiency remained at about 30 percent. Comparison of the glass scintillator with a 17 kev X-ray crystal indicated comparable resolution. With a dry source, the integral count from the scintillator was found to be a factor of 25 greater than that from an X-ray detector, as would be expected from the relative occurrence of the alpha and X-ray events. However, when used with solutions, the alpha attenuation is much greater and the actual sensitivities of the two devices are expected to be more nearly equal.

Advanced Process Control Development

Analysis of experimental data from the completed C-column runs continued. Recognizing the dependence of uranium mass transfer on nitric acid concentration, a model for acid extraction was investigated. It was determined that a Colburn extraction equation adequately fits the experimental acid data with a standard error of 0.3 gram per liter. This is well within the experimental accuracy. The Colburn equation relates the concentration at a given point in the column to column operating parameters and equilibrium distribution between the phases.

Development of a continuous uranium photometer for use in organic continuous systems requires a method of correcting for any yellow color of the organic solution itself. Research is currently centered on determining the absorption spectra of the material, presumably a degradation product, which causes the yellow color. Experiments have been designed to study the effects of acidity conditions, light exposure history and radiation on the absorption spectra.

ANALYTICAL AND INSTRUMENTAL CHEMISTRY

Determining Th-234 in Uranium

Nanogram amounts of Th-234 were determined directly in pound-size uranium billets by counting them gamma spectrometrically with a 3-in. by 3-in. NaI(Tl) detector. The relatively un abundant 1.0 mev photopeak from thorium's Pa-234^m (half-life = 1 min.) was used to measure thorium content. Billets were suspended about 6-in. above the detector to reduce the effect of low-energy gammas and to reduce the effect of slight variations in billet sizes.

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REACTOR DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Salt Cycle Process Engineering Development

In continuation of the UO_2 - PuO_2 run reported last month, a 57-gram spike of PuO_2 was added to the salt bath. Analysis showed that, after sparging with HCl at three liters per minute for 24 hours, essentially all the PuO_2 added had dissolved to give a resulting salt bath composition of 27 w/o U and 0.18 w/o Pu. A 14-pound UO_2 deposit was obtained by electrolyzing the salt bath for 20.5 hours at 1.7 volts with an initial current density of 0.19 amps/sq.cm. The salt bath, at a temperature of 550 C, was sparged with one liter per minute each of Cl_2 and O_2 during the electrolysis. The current efficiency of the electrolysis was 66 percent. Samples of the bottom, middle and top sections of the deposit showed 0.11, 0.13 and 0.21 weight percent plutonium in the uranium or depletion factors (of plutonium in the uranium) of 6, 5 and 3, respectively.

After leaving the salt bath with an argon blanket for 10 days, it was found that the plutonium concentration had dropped to 60 percent of its initial value. However, sparging with HCl at two liters per minute for 48 hours brought it back up to near its initial value.

A second deposit (16.9 pounds of UO_2) was obtained by electrolyzing, at 1.65 volts with an initial current density of 0.18 amps/sq.cm, the initial salt bath which was 18 w/o U and 0.170 w/o Pu. During electrolysis at a temperature of 555 C, the salt bath was sparged with 0.2 liter per minute Cl_2 and 1.8 liters per minute O_2 . The electrolysis had a current efficiency of 78 percent. At the end of the electrolysis the salt bath was nearly depleted of uranium with a final composition of 0.74 w/o U and 0.018 w/o Pu. Preliminary analysis on one sample of the deposit showed 0.70 weight percent plutonium in the uranium, giving a Pu/U ratio about 75 percent of that in the initial bath.

Molten Salt Spectrophotometry

The equilibrium constant for the reaction

has been determined to be 0.013 at 700 C in LiCl-KCl eutectic. This compares with values of 0.0016 at 500 C and 0.0050 at 600 C.

Determination of Water in UO_2 - PuO_2 Reactor Fuel

A commercial electro-analyzer was used to control water contents of prospective PRTR oxide fuels consisting of UO_2 , PuO_2 and blends. Samples were heated to

volatilize the water which was trapped on phosphorous pentoxide and electrolyzed. Water was measured by the quantity of electricity needed for complete electrolysis. The analyzer's induction heating permitted a 180 C temperature, adequate for removing 80 percent of the water in UO_2 and 60 percent in PuO_2 . The remaining water was removed with a tube furnace. Generally, 400 C was adequate for removing all water from UO_2 , while 600 C was necessary with PuO_2 present.

X-Ray Fluorescence Determination of Plutonium and Tantalum in Carbides

An X-ray fluorescence method was developed for simultaneously determining plutonium and tantalum in mixtures of their carbides. Indicated precision was one percent. Fusing 0.1 g of material with 10 g of potassium pyrosulfate boric anhydride flux (60:40) avoided an aqueous acid dissolution system and fixed the plutonium in buttons, thus avoiding any subsequent contamination of the X-ray spectrograph. Included also in the flux were known amounts of potassium niobate hexadecahydrate and hafnium oxide, providing niobium as an internal standard for plutonium and hafnium as an internal standard for tantalum. The buttons, strong and with almost perfect optical surfaces, represented complete dissolution of all materials in the flux. A molybdenum target tube and a lithium fluoride crystal in connection with the L_α lines of plutonium and tantalum were the bases for the determination.

RADIOACTIVE RESIDUE PROCESSING DEVELOPMENT

Calcination Studies

Analytical results were completed during the month on the low-acid Purex spray calcination run (which was reported briefly last month), and an additional Purex spray calcination run was made, the latter to test the effect of phosphate addition on ruthenium behavior.

Final results on calcination of low-acid (sugar treated) Purex waste indicate a greater evolution of ruthenium than reported last month. The fraction evolved was 10 to 11 percent of the feed ruthenium, almost the same as the 12 to 20 percent which is normal for high-acid Purex waste and much higher than the 2 percent observed with Redox waste. Since acidity of the Redox and low-acid Purex wastes were virtually identical, the reason for the large difference in ruthenium behavior is not apparent. One hypothesis is that it is related to the large difference in sulfate concentration - ca. 1 M for the Purex waste vs. 0.02 M for Redox. Alternately, ruthenium species in the waste from the two plants may differ, or dissolved hexone in the Redox waste may serve as a reducing agent.

The second hot-cell runs used acidic Purex waste and a sufficient phosphorous acid addition to form orthophosphates of all the metal ions. Ruthenium loss

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to the condensate was only 2.5 percent, about the same as obtained when calcining acidic waste in the presence of sugar.

In neither run (low-acid Purex or acidic waste plus phosphorous acid) was a true melt obtained, probably because these runs were not preceded by "cold" runs and conditions may have been on the "ragged edge" for good melting to occur. This should, however, not affect fission product behavior.

Cold Semiworks Spray Calciner

In continuing studies to define the design and operational parameters of the 18-in. diameter spray calciner, recirculation rates were measured with a simple 16-in. diameter, 4.75-ft. long draft tube. The rates were 1.5-fold greater with the simple tube than with a similar tube containing longitudinal fins under the same heat load conditions. The benefit of the added heat transfer surface was apparently nullified by the increased flow resistance of the fins.

Four simulated waste compositions were run during the month with the simple 16-in. draft tube. Simulated Redox waste with silica and borax was run at a reactor wall temperature of 650 C. During the course of the run, the recirculation annulus became plugged, at the top and bottom, with sintered powder.

The other three compositions were used to provide powder samples for a corrosion study to be performed by the Pulp and Paper Research Institute of Canada. A partially killed LWV composition was run at 700 C; neutralized LWV with sugar, and LWV with lithium and phosphate additions were run at 600 C. No sintered deposits on the wall were observed. The phosphate feed tended to plug the outer orifice of the internal-mix nozzle. An external-mix nozzle was installed; it performed well with the remaining phosphate feed and with neutralized LWV with sugar.

Continuous Glass Making

Laboratory glass making studies have continued. These are currently aimed at (1) supporting current hot-cell and Cold Semiworks development and prototype design, (2) insuring a suitable recipe for the forthcoming hot-cell continuous glass experiment, (3) investigating the effect of fission products, particularly at future power reactor goal exposures, on glass or calcine compositions, and (4) making preparation for the hot cell production of small samples of highly radioactive glasses (to assess effects, if any, of radiation and isotopic decay on stability, solubility, etc.). Experiments in behalf of the latter objective have shown that 13 percent cerium can be successfully incorporated in either a Brookhaven-type phosphate glass or an ORNL-type lithium glass. Use of fission product cerium will result in a dosage of approximately 10^{12} rads per year, a dosage equivalent to that of high-burnup power reactor fuels.

Addition of mixed fission products to the feed for Brookhaven glass production resulted in a cloudiness soon after mixing which turned to a dense precipitate on prolonged standing. Since it will not be possible to prevent delays after mixing (in a hot operation), provision must be made for operation with considerable dense precipitate in the feed.

A trip was made to Brookhaven during the month to observe the continuous glass experiment equipment which will be shipped to Hanford in January for installation in A-cell following conclusion of the present calcination studies. Some familiarization experiments also continued in our laboratory with somewhat similar equipment (not remotized for in-cell installation) to gain an appreciation for operating problems and procedures and to test an inclined tube melter approach for continuous glass making. The falling film evaporator (which is common to both the BNL and Hanford equipment) operated well with pre-concentrated feed, but was less efficient with low-viscosity slightly-concentrated feed, which ran through too fast. Efforts to use high-density ceramic tubes (such as zircon) inside a quartz housing for the melter proved unsatisfactory, either because of poor heat transfer or porosity, or both. As a result, a platinum liner is being fabricated.

Calcine Melter

Two melt runs were made with a calcined simulated Redox waste. Borax and silica were added to the feed to allow production of a "glass" on melting. Feed rates up to six pounds of powder per hour were successfully demonstrated at melt temperatures of 840-900 C.

Later inspection of the melter showed a deposit of lithium phosphate-type solids (from prior experiments) which could not be remelted at 950 C and which had frozen the bellows valve closed. Analysis of this high melting material is in progress.

Corrosion of Inconel Waste Melt Pots

Several Inconel crucibles have been exposed to spray-calcined waste at temperatures of 750 and 900 C for 68 hours. Calcined waste was added to the crucibles over a four-hour period at the start of the exposure. Corrosion rates were very sensitive to temperature; at least an order of magnitude higher at 900 C than at 700 C. Feed composition also affects the corrosion rate. Further tests to evaluate feed composition effects will be made.

Pilot Plant Runs with Alkaline Condensate

Purex tank farm condensate is being used to demonstrate a process for decontamination of an important intermediate-level type of waste from a reprocessing plant. The pilot plant process consists of a steam-stripper, a thin bed, 60-100 mesh clinoptilolite filter (1 sq.ft area x 1/2-inch thick), an anion exchange column (5.2 gallons Dowex-1 resin), an acid adjustment step to pH 4, and a cation exchange column (5.2 gallons Dowex-50 resin).

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Run 5, which was initially terminated after 2100 gallons of feed were processed because of bed plugging, was extended by replacement of the thin bed and agitation of the anion exchange column until 7200 gallons of feed were processed and plugging was again evident. Overall decontamination factors of 23, > 250, and > 500 were obtained for Ru-106, Cs-137 and Sr-90, respectively. Decontamination factors across the thin bed were < 2.

Run 6 was performed using 100 to 200 mesh clinoptilolite on the thin bed exchanger. This run was terminated after 1400 gallons of feed had been processed due to excessive pressure drop across the thin bed exchanger.

Intermediate-Level Waste Studies

Plausible causes for solids in the Purex tank farm condensate are: (1) hardness due to the temporary addition of raw water to the condensate receiver tank, and (2) bacteria. Bacteria were found in minor concentrations in the raw feed water and the condensate collection tank and in major amounts in the tank trailer and tank storage system at the 271-CR Waste Treatment Pilot Plant. Three or more types of bacteria were observed in the steam-stripped feed being stored for process studies. Conditions are quite favorable for bacterial growth in this particular waste stream since the solution is warm and has small amounts of nitrogeneous and organic matter present. Further studies of these problems are underway and corrective measures are being sought.

The electrodialysis unit is now in operation. Diluted Purex acid condensate is being used as feed for ruthenium removal studies. The unit is functioning well, but the overall system has not reached equilibrium as ruthenium continues to plate out on the stainless steel piping and storage tank and interaction with the ion exchange membranes is still occurring.

Columbia River Sediment Studies

In a meeting held December 9 at Portland, Oregon, with representatives of the U.S. Geological Survey, Water Quality Branch, decisions were made to reduce the sample load for radionuclide analyses which had been in effect for about one year so that special samples could be analyzed. These special samples will come first from the Columbia River estuary to provide some bases for planning the overall estuary study.

A particle size separation was made on another sample of sediment from the McNary Dam reservoir in order to determine the most desirable procedural steps. The data indicate that approximately 10 percent of the radioactivity is associated with the organic fraction which was removed before particle sizing was accomplished. Co-60 has the strongest preference for the organic fraction and Cr-51 the least. As a result of this run procedural changes were made which will be used in a study of the radionuclides associated with sediment from different depths of the deposit at McNary reservoir.

BIOLOGY AND MEDICINE - 06 PROGRAMTERRESTRIAL ECOLOGY - EARTH SCIENCESHydrology and Geology

The test model, 662-node analog (related to electrical analog simulation of the ground-water regime) was operated, and comparisons of analog outputs to analytical-model solutions were made. An average potential (voltage) reading error of 4 percent occurred due to straight coupling of three different size grid spacings. Maximum errors of about 10 percent were noted at the grid boundaries. More complicated coupling techniques would decrease the errors, but they are not considered practical for the project analog. Therefore, the final analog network will probably consist of a single grid size.

An 81-node, three-dimensional network was constructed and is in operation to evaluate errors associated with resistance tolerances and continuum simulation with a discrete network. A moderate-sized, two-dimensional network will be assembled to study errors due to warping the mesh in one dimension.

Comparison of numerically determined streamlines with the mathematical closed-form solution indicated that a more precise numerical method is needed. The streamline configuration in the present test case has a complete, rather sharp reversal of flow which is in the only region of current difficulty. A different scheme is now being programmed which should overcome the inaccuracy due to looping streamline configurations.

The possibility for reducing the several boundary permeability measurements to a single independent field determination as reported last month continues to look encouraging (field data acquisition for ground-water analog). The complexities of analysis for transient systems will be involved and considerable research effort would be required, since the mathematical description of the flow system for heterogeneous soils is one step beyond the Lagrangian description derived a year ago.

RADIOLOGICAL & HEALTH CHEMISTRYBioassay Techniques

The unknown gamma emitter reported present in a pooled urine sample from the 329 Building was identified as Na-22. This radionuclide could not be measured in a 2 liter sample of reactor effluent water and thus is not present in water supplies as a result of reactor operations. The possibility of the source being fallout is being investigated.

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Multidimensional Spectrometry

A special experimental arrangement was set up to study the measurement of radionuclides which emit three or more cascade gamma rays per disintegration. The apparatus consists of two large (6-in. x 4-in.) sodium iodide detectors in a sodium iodide annulus, a lead absorber to shield the three crystals from gamma rays scattered from each other, and a multidimensional analyzer. The two detectors feed the X and Y axes of the multidimensional analyzer but data are recorded therein only when another gamma simultaneously strikes the annulus. Those events recorded on the energy-energy plane of the multidimensional analyzer spectrum represent triple coincident gamma events. Gamma-gamma coincident events are also recorded but only on the X and Y axes. Preliminary measurements on two-day-old reactor effluent water showed measurable peaks for Ga-72 and La-140. Older reactor effluent water showed the La-140 peak and several other as-yet unidentified peaks. This technique is an ultra-selective method for the above radionuclides and Na-22 and Sc-48, to mention a few.

Radiation Chemistry

Several experiments were performed in which washed human red cells were irradiated in 0.15 M NaCl solution buffered to a pH of 7.4 with phosphate. Evidence for hemolysis was sought with a Coulter Counter Model B in which red blood cells are counted electronically and cells smaller than an arbitrary size may be eliminated from the count. The surprising feature found was that the cells hemolyzed by radiation did not decrease in size as occurs when cells are hemolyzed by other means. Generally, the cells swell before the loss of hemoglobin is very evident, and this swelling may be correlated with the multi-reaction mechanism of radicals with the cells. The Coulter Counter size distributions obtained using a multichannel analyzer promises to give a more intimate view of the changes in structure of the cell population, and correlation with the hemoglobin data will show at what physical size the loss of hemoglobin occurs at the fastest rate. A survey of chemicals which can cause the cells to change to this size in the absence of irradiation may indicate what the nature of the chemical change is at the surface during irradiation.

ATMOSPHERIC RADIOACTIVITY AND FALLOUT

Particle Sampling Studies

The magnitude and sources of experimental uncertainties in subisokinetic sampling errors were investigated. Non-reproducibility of microscopically determined particle size distributions was found to be greater than desirable, due in large part to differences between individuals doing the microscopic sizing.

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Confidence limits are being calculated for each size distribution in order to calculate the confidence limits for the sampling errors. To date the errors have been calculated from "smoothed" curves of the size distributions. Attempts to fit the sampling error data to models are as yet unsuccessful.

A run was completed for 9.0 mph, using a nozzle to obtain the isokinetic flow. Many large particles were found to have deposited around the edge of the filter and underneath the edge of the retaining ring. The filter holder had the standard backing. Thus, a greater portion of the filter must be counted to obtain the sampling errors. The sampling errors at 9.0 mph were approximately the same as for 6.9 mph.

Data have not been obtained for windspeeds of 2.7, 3.7, 5.0, 6.9 and 9.0 mph with a subisokinetic flow rate of 0.29 cfm. In the last run at 9.0 mph, the subisokinetic flow rate was increased from 0.29 to 2.82 cfm, which is near the flow limit of approximately 3.4 cfm which can be drawn through the Millipore filters. The sampling flow corresponds to an isokinetic to subisokinetic flow ratio of 4.0. Samples from these runs are being counted.

Fallout Studies

The use of multidimensional analysis techniques on fallout samples has made possible the measurement of Na-22, Sc-46, Co-60, Y-88 and Pr-144. Except for Pr-144, which is a short-lived daughter of Ce-144, the other radionuclides are not fission products. The concentrations of these materials are about 0.1 percent of the ZrNb-95 present. Y-88 was measured in a fallout study in Italy in August 1962, and found to be about 5 - 10 percent as abundant as ZrNb-95. Measurements of filter samples taken the past two years will be made to determine the variability of the concentration ratios of these radionuclides.

Tracers for Meteorological Studies

Because of some interfering fluorescence from the membrane filters which are used for sampling in the meteorological studies the sensitivity limit for fluorescein is 5×10^{-11} g and for calcium acetylsalicylate ("calcium aspirin") is 3×10^{-9} g. The filter fluorescence is not excited until sodium hydroxide solution is added prior to measurement of the aspirin. As soon as weather conditions are favorable a dual tracer study will be made using these tracers.

Iodine Studies

Laboratory studies of the scrubbing efficiency of various liquids for molecular iodine were begun. It is intended that the same solutions will also be tested for retention of organic iodide compounds. It is possible

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that scrubbing solutions other than NaOH may prove to be more efficient for the retention of iodine and iodine compounds. Such solutions have potential use in plant equipment and in analytical scrubbers.

To date only the retention of molecular iodine has been measured. The reported efficiencies were measured with a laboratory scrubber at 0.1 cfm with a liquid depth of 6 cm. No packing was used. A BPL charcoal back-up measured the iodine which passed the scrubber. Long term retention of iodine in the solutions was not measured during these tests, but will be in future tests.

<u>Solution</u>	<u>% I-131 Retained</u>
1 <u>N</u> NaOH	97.6
1 <u>N</u> NaOH + 0.1 <u>N</u> KI	98.1
1 <u>N</u> NaOH + 0.1 <u>N</u> Na ₂ S ₂ O ₃	98.4
1 <u>N</u> AgNO ₃ in 50% Alcohol	99.3

Only small differences in efficiency were noted for the solutions studied. Retention of iodine compounds will constitute a more critical test.

A sample of coconut charcoal has been loaded with increasing amounts of inert iodine and the retention measured periodically with I-131. To date no significant decrease in efficiency has been noted at loadings of 32 mg I-127/gram of charcoal.

ISOTOPES DEVELOPMENT - 08 PROGRAM

Ion-Exchange Purification of Promethium

Work on an acid-side high capacity, HEDTA process for promethium purification continued. Two new identical sets of jacketed columns were installed in the laboratory to facilitate this work. Each set consists of: (1) a short 1-in. diameter bed of ammonium cycle resin (operated at 90 C) to serve as a degassing unit to remove dissolved gas from the eluate solution, (2) a 3/4-in. diameter feed absorption column containing 100 ml of resin, and (3) a 1/2-in. diameter elution column containing 230 ml of resin. The columns are larger and longer than those previously used such that more rare earth can be used per run and the band can be eluted a greater distance (2.3 band lengths vs. 1.5).

Two runs were completed in the new equipment. A control run with 0.03 M HEDTA and a run at 0.06 M HEDTA compared to 0.015 M maximum concentration with either EDTA or DTPA. Both runs were at pH 5.6 and 60 C, with H⁺ as the barrier ion. The higher HEDTA concentration in the second run caused no precipitation problems at all, the band eluted twice as rapidly as in the control, and the run was completed in only about 30 hours.

High Energy Compaction of SrTiO_3

Five compactions were completed this month, the purpose of these runs was to determine capability to produce thin walled compacts by the high energy compaction process. One approach was the use of a thick-walled can followed by measurement of can wall thickness and mechanical removal of excess metal. A heavy wall (0.130 in.) Inconel can was filled with 493 grams of SrTiO_3 and compacted at 334,000 psi. The can was descaled with a wire brush and then the wall thickness determined by ultrasonic ("sonar") methods by Non-Destructive Testing Operation. The thickness of the can top ranged from 0.127-in. to 0.138-in. and averaged 0.133-in. The bottom thickness ranged from 0.131-in. to 0.135-in. and averaged 0.133-in. The can side ranged from 0.179-in. to 0.200-in. and averaged 0.189-in. The can was then machined down in a lathe (0.050-in. from the ends and 0.080-in. from the wall). A re-determination was made of the wall thickness. The top ranged from 0.074-in. to 0.083-in. and averaged 0.077-in. The bottom ranged from 0.083-in. to 0.089-in. and averaged 0.086-in. The wall ranged from 0.099-in. to 0.120-in. and averaged 0.109-in. The can was cut open and inspected. The weld structure looked very good and there were no cracks or voids. The product density was 4.73 g/cc. The can thickness, top and bottom, appeared to be as the measurements indicated. However, the can wall thickness was 30 percent more than indicated. This was probably due to the fact that the can used had an internal Inconel sleeve which welded fairly well to the outer wall but may have left a demarcation zone beyond which the ultrasonic beam did not go. This can undoubtedly be corrected by better calibration.

The other compactions were designed to produce a compacted thin-wall can without wall irregularities. This was accomplished by placing the loaded can inside a mild steel sleeve (the sleeve was heated to 1000 C prior to insertion), and then compacting the unit. This concept looks quite promising. The walls of the first can compacted by this method were not folded (as with thin-wall compacts not using a sleeve) but were slightly bellowed out at top and bottom. The other cans compacted with sleeves were machined to remove the sleeve, descaled with a wire brush and then recompact inside a second stainless steel can. The object behind the second compaction is to produce the final capsule by minimum distortion of the final can. In the second compaction the hot metal is forced into all the irregularities of the first can and gives a very good uniform can.

Source Material Studies

Laboratory work is underway aimed at (1) scouting a variety of fission product compound forms suitable for isotopic heat source use, (2) preparing materials for high energy compaction studies, and (3) developing and evaluating preparative techniques for later remote in-cell use. Highlights of the month's work included scouting of the borates as cesium or rare earth heat

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source materials, demonstration of a promising method for preparing Ce_2O_3 , and testing one route to PmF_3 (intermediate for promethium metal production).

Study of the borates was suggested by favorable experience of the Martin-Marietta Company with strontium borate. On the basis of our experiments, cesium borate appears especially attractive for heat source preparation. Melting point (estimated) is about 800 C, and the glassy material is easily molded or cast into desired shape. While not insoluble, the material is non-deliquescent and the rate of dissolution is quite low compared to most cesium compounds. Assays of prepared melts were in the range 50 to 60 weight percent cesium, much higher than cesium borosilicate glass, and it may be possible to increase this appreciably. Measurements of pertinent physical properties will be undertaken, as will preparation of material with a higher cesium content. The neodymium and cerium borates were quite slow to react with water and might be attractive if this characteristic is required.

Reduction of CeO_2 to Ce_2O_3 by carbon at about 1000 C proceeded smoothly and appeared to form Ce_2O_3 in good yield. This reaction will be used to produce a larger batch of Ce_2O_3 for high energy compaction tests. In other preparative work, the aqueous route to neodymium fluoride (stand in for PmF_3) did not appear attractive.

for
Manager
Chemical Laboratory

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BIOLOGY LABORATORY

A. ORGANIZATION AND PERSONNEL

The name of the Pharmacology Operation was changed to Inhalation Toxicology Operation.

B. TECHNICAL ACTIVITIES

FISSIONABLE MATERIALS - O2 PROGRAM

Vertan 675

Vertan 675 is similar to the previously tested Vertan 690 in that both are proprietary materials containing EDTA and used for cleaning and conditioning pipe systems; however, marked differences exist in toxicity to fish. Vertan 675 is about five times more toxic to rainbow trout than Vertan 690. For 72 hours exposure the "threshold index" (the maximum concentration in which no mortality occurred) is 300 ppm for Vertan 675 compared to 1500 ppm for Vertan 690. Total mortality occurs at 400 ppm Vertan 675 within 24 hours.

Columnaris

The columnaris study on groups of rainbow trout held in waters of different temperatures since June 1963 was terminated. Summary of the results follows:

<u>Water Temperature</u>	<u>Total Mortality (%)</u>	<u>Columnaris Incidence (%)*</u>	<u>Avg. Wt. (g)</u>
Normal river	19.1	54.4	53.3
4F above normal	66.5	45.0	40.6
4F below normal	13.7	45.4	76.9
UV-treated river	27.7	71.8	54.1

* Applies to dead fish only.

The adverse effect of warmer waters is expressed by higher mortalities and growth depression. With the exception of the UV group, the overall incidence of columnaris appears to be about 50% of the total mortality in all groups.

Because of the seasonal cooler water temperatures, columnaris is essentially over for this season. All treatment groups with the exception of the +4F group waters showed little or no incidence of columnaris for the past month. Out of a total of 13 mortalities in the +4F group during December, seven fish showed columnaris organisms.

For the first time we have been able to follow the course of infection by columnaris in an individual fish. Of four fish isolated from a known infected group to determine rates of bacterial release, three were not infected and released no organisms but the fourth was and did. By the

25th day this fish released 12 million organisms per hour and showed a typical skin lesion. Two weeks following this peak the lesion was cured and no organisms were released. Such a disease sequence is the strongest evidence obtained so far that an immune response is initiated within the fish.

BIOLOGY AND MEDICINE - O6 PROGRAM

METABOLISM, TOXICITY AND TRANSFER OF RADIOACTIVE MATERIALS

Zinc

After feeding a single oral dose of 230 μ c to trout and killing them serially from 8 to 182 days post-administration, the decrease in their body burden of Zn^{65} from day 8 to day 182 can be described by $Y = 1.4.4 - 0.00214X$, where Y is the log μ c Zn^{65} and X is the time in days post-administration. The gastrointestinal tract had 50% of the total body burden.

Copper

Toxic levels of copper, X-irradiation, and a combination of the two did not affect the tissue distribution of Cu^{64} injected into rats in a way to suggest that effects caused by the two agents are related. Injection of high levels of copper resulted in increased liver Cu^{64} and decreased amounts in other organs. Urinary Cu^{64} excretion was elevated in animals receiving 20 mg/kg of copper, while blood Cu^{64} levels were increased in animals receiving 850 r.

Strontium

The removal of the site of release (expiration of eye-stalks) of the molt inhibiting hormone induces the molt sequence in crayfish. The growth of the gastrolith and the molt sequence can then be followed by radiography. Since the crayfish concentrates Ca before molting, primarily in the gastrolith, and then uses this Ca for the new exoskeleton, study of this animal will help elucidate fundamental relationship between Ca and Sr.

Analysis of data (collected over the last five years) on serum levels of inorganic phosphorus in miniature swine on the chronic Sr^{90} experiment reveals a marked decrease with advancing age. At six weeks of age the serum concentration of inorganic phosphorus is ~ 12 mg/100 ml, this decreases progressively to ~ 10 mg/100 ml at six months, ~ 8.5 mg/100 ml at one year, ~ 6.5 mg/100 ml at two years, and just over 5 mg/100 ml at three years of age. No differences are apparent between the values for control animals and those found for animals ingesting up to 25 μ c Sr^{90} /day. A similar change, but of lesser magnitude, has been noted in humans. The physiological basis and importance of this change is not readily apparent. This change is particularly intriguing in view of its possible relationship to changes in bone metabolism that are known to occur. The serum level of calcium in these animals is maintained within very close limits.

Two young adult miniature swine were given Sr^{85} titanate* orally to provide additional data on the gastrointestinal absorption and distribution of this form of strontium. (Analytical data are incomplete at this time. Previously, we observed in a single animal that the gastrointestinal absorption and retention of Sr^{85} on the tenth day after ingesting Sr^{85} titanate was approximately 0.3%. Oak Ridge workers observed a much higher value for absorption and retention of $\text{Sr}^{90} \text{TiO}_3$ in one pig than we have observed for the $\text{Sr}^{85} \text{TiO}_3$. Perhaps their higher value is the result of greater absorption of a more soluble chemical form of Sr present as a contaminate.)

Neptunium

The Np^{237} toxicity study in sheep was initiated and the first series of three sheep completed. After an intravenous dose of 2.75 mg $\text{Np}^{237}/\text{kg}$, liver function tests using I^{131} -labeled rose bengal dye were performed on each sheep on days 2, 4, 6, 8 and 10. (The dose level utilized is slightly less than what is considered lethal; 5 mg/kg is the estimated $\text{LD}_{50/10}$.) Each series of three sheep includes a ewe, wether, and buck. This study will attempt to determine whether there is a sex-related difference in Np^{237} toxicity in sheep (as we have noticed in rats). No apparent difference was seen in the animals of the first series. (Five more series are scheduled.)

Several dietary and hormonal treatments were investigated for their effect on Np^{237} -induced fatty livers in rats. The feeding of supplemental adenine sulfate, or choline and methionine, before Np^{237} injection, was without effect. Females were injected with testosterone and males with estradiol for two weeks prior to Np^{237} injection. The estradiol injected males showed a tendency toward higher liver fat than untreated males. Urine from these animals is being analyzed for urea, protein, creatinine and alpha amino nitrogen to assess kidney damage.

Plutonium

The duodenum, jejunum, ileum and large intestine + cecum were perfused, and the bile duct cannulated, in order to measure secretion into the intestinal tract of plutonium injected intravenously into rats. Results varied widely among different animals. Typically, about half of the plutonium excreted from the intestine originates from the bile. This proportion is increased to about three fourths in DTPA-treated animals.

* Strontium-85 titanate was produced locally by neutron activation of Sr TiO_3 and was used in preference to Sr^{90} titanate because the latter could only be obtained in relatively large quantities that we were unable to use in our present facilities.

Inhalation Studies

The following is a progress report on 13 surviving dogs on a long-term Pu²³⁹ inhalation study. They were exposed 3-1/2 to 4 years ago and have body burdens of 2 μ c and less.

1. Eleven show some degree of respiratory insufficiency.
2. Five have markedly elevated respiratory rates.
3. Five have high CO₂ and low O₂ levels in arterial blood.
4. Two dogs show probable pulmonary tumors on X-ray examination. (Four dogs that died within the past nine months had malignant lung tumors.)
5. Total white blood cell counts are:

Controls - 5.9×10^3 neutrophils, 3.0×10^3 lymphocytes.

Exposed - 5.6×10^3 neutrophils, 1.4×10^3 lymphocytes

Six dogs were exposed to Fe⁵⁹O₃ aerosols to characterize their ability to clear insoluble particles from their lungs. These dogs will eventually be used in preliminary tests to determine the effect of inhaled toxic materials on the lung clearance processes.

Gastrointestinal Radiation Injury

The dose dependent leakage of intravenously injected I¹³¹-labeled polyvinylpyrrolidone (PVP) into the intestinal tract of irradiated rats was shown to be eliminated by the administration, before irradiation, of cysteine or AET.

Microbiology

In preparation for studies of feedback mechanisms in tryptophane biosynthesis, tryptophane 2C¹⁴ and ring labeled indole were prepared by enzymatic synthesis.

Radiation Effects on Insects

When day-old flour beetles were exposed to 830 rads of fast neutrons, the reproductive capability of each sex was reduced to two-thirds that of the controls, and this reduction was completely additive when two irradiated flies were mated.

Plant Nutrition

Four varieties of barley were compared for their ability to take up I¹³¹ and water from a nutrient solution. One showed a 60% higher concentration in roots and a slight increase in shoots. No difference in water uptake was observed among the four varieties. This is indirect evidence that uptake of iodide is not merely a passive process associated with water flow.

A similar conclusion was drawn from a comparison of I^{131} uptake during periods of darkness when little water is taken up and during light periods when water is taken up relatively rapidly. The rate of iodide uptake during these two periods was essentially the same. Furthermore, the ratio of I^{131} uptake to water uptake, relative to the concentrations in the substrate, was greater than one during the entire experiment.

A new technique for studying ion uptake by isolated roots is being developed to overcome problems of diffusion and changes in ion concentration.

The frequency of dividing cells of pea root was reduced when Cs was present for three days in the nutrient solution used to grow the seedlings. The effect on cell division appears to be slow in appearing since no reduced frequency was noted following one day of treatment with concentrations as high as 3 mM Cs. The ability of K to release Cs from roots increased as K concentration increased to 1 mM but no further release was observed with higher concentrations.

In an effort to increase autoradiographic detail in studies of I^{125} location on leaf structures, a 14,000 gauss magnet was used. No significant improvement in resolution was observed.

Columbia River Ecology

Average concentrations of Zn^{65} , Cr^{51} , and P^{32} /g dry organic matter from net plankton were 270, 1600, and 75 nc, respectively. These values are little different from those of the previous month. Samples of net plankton taken as a transect across the river near Ringold show a plume of higher activity slightly east of mid-channel. It was previously presumed that this plume followed the west shore.

In contrast to the lack of change in concentrations of radionuclides in net plankton, the periphyton (material attaching to a fixed substrate) showed a 50% reduction in concentration of Zn^{65} , Cr^{51} , and P^{32} /g organic matter as compared with the previous month. This suggests that a biological process is involved in the sorption of these ions in periphyton but only a physical process for the plankton.

The sixth and last of the current year's aerial surveys of chinook salmon spawning in the vicinity of HAP0 was conducted on November 21. Peak of spawning occurred on November 12, about a week later than in past years. A total of 1315 salmon nests were observed. This is the second highest count on record, but is only slightly higher than a total of 1261 observed last year. Spawning within the reservation proper increased over last year. Approximately 70% of the nests observed this year were between 100-B Area and Hanford as compared with about 60% for 1962.

The wintering waterfowl population utilizing the Columbia River within the Hanford Reservation increased to an estimated 220,000 ducks and geese during early December, and then decreased by 10% immediately following a snowstorm on December 8. The estimated population one year ago was 120,000 birds.

Initial returns of bands placed on young ring-billed gulls last July were received and show a general northwestward movement toward Vancouver, British Columbia within a month after banding.

Terrestrial Ecology

Relations of mineral content of soil, vegetation, and beetles were studied in a sagebrush community at Rattlesnake Springs. Although data are not yet completely quantitative, it is apparent that the relative concentrations in soil are $\text{Ca} > \text{Mg} > \text{Na} > \text{K}$; in vegetation, they are $\text{K} > \text{Ca} > \text{Mg} > \text{Na}$; and in beetles, $\text{K} > \text{Mg} > \text{Ca} > \text{Na}$. Clearly, biologically specific processes are present in each organism which regulate its uptake and retention of ions.

Vegetation collection sites are being established in the Blue Mountains and Cascade Range to study the magnitude and randomness of fallout deposition. These sites are to evaluate fallout from diverse climatic areas and to relate to deer and elk samples from these same areas.

Manager
BIOLOGY LABORATORY

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TECHNICAL INTERCHANGE DATA
BIOLOGY LABORATORY

I. Speeches Presented

a. Papers Presented at Society Meetings and Symposia

Dean, John M. Hypothermia and blood parameters in the Fiddler crab (*Uca pugilator*). AAAS Annual Meeting, Cleveland, Ohio, December 26, 1963.

Dean, John M. Effects of temperature acclimation on some aspects of carbohydrate metabolism in decapod crustacea. AAAS Annual Meeting, Cleveland, Ohio, December 30, 1963.

b. Seminars (Off-Site and Local)

Hungate, F. P. Genetics. Portland State College, Portland, Ore. 12/2/63.

c. Seminars (Biology)

Uhler, R. L. Science. December 11, 1963.

Fujihara, M. P. Effect of water temperature on incidence of Chondrococcus columnaris. December 18, 1963.

Eberhardt, L. L. Testing significance in multiple experiments. December 18, 1963.

d. Miscellaneous

J. L. Palotay, R. E. Nakatani and M. E. Kerr were counselors for a vocational guidance program for Kiona-Benton City High School students, December 13, 1963.

II. Articles Published

a. HW Documents

None

b. Open Literature

Uyeki, E. M. 1963. Graft-host response in murine radiation chimeras. Proc. Soc. for Exptl. Biol. and Med. 114: 554-559.

b. Open Literature (continued)

Proceedings of the Hanford Symposium on the Biology of Radioiodine, Richland, Washington, 17-19 June 1963. Health Physics 9.

Kornberg, H. A. Introduction. 1081.

Hungate, F. P., J. F. Cline, R. L. Uhler, and A. A. Selders. Foliar sorption of I^{131} by plants. 1159-1166.

Wood, D. H., E. E. Elefson, V. G. Horstman, and L. K. Bustad. Thyroid uptake of radioiodine following various routes of administration. 1217-1220.

Casey, H. W., A. C. Case, R. O. McClellan, and L. K. Bustad. Metabolism of Te^{132} - I^{132} in lactating sheep. 1223-1226.

Bustad, L. K., D. H. Wood, E. E. Elefson, H. A. Ragan and R. O. McClellan. I^{131} in milk and thyroid of dairy cattle following a single contamination event and prolonged daily administration. 1231-1234.

Hanson, W. C., A. H. Dahl, F. W. Whicker, W. M. Longhurst, V. Flyger, S. P. Davey, and K. R. Greer. Thyroidal radioiodine concentrations in North American deer following 1961-1963 nuclear weapons tests. 1235-1239.

Ragan, H. A., W. J. Clarke, R. O. McClellan, V. G. Horstman and L. K. Bustad. Effect of I^{131} on reproductive performance in ewes. 1343-1347.

McClellan, R. O., W. J. Clarke, H. A. Ragan, D. H. Wood, and L. K. Bustad. Comparative effects of I^{131} and X-irradiation on sheep thyroids. 1363-1368.

Bair, W. J., M. D. Snyder, R. A. Walters and R. F. Keough. Effect of I^{127} on thyroid uptake of inhaled I^{131} . 1399-1410

Watson, E. C., I. C. Nelson, D. H. Wood, R. O. McClellan, and L. K. Bustad. Effect of varying stable iodine in diets of cows fed I^{131} on uptake of I^{131} in man drinking the milk: an abstract. 1419.

Bustad, L. K. Conclusion and acknowledgments. 1421.

III. Visits and Visitors

a. Visits to Hanford

- 12/4/63 - Washington Assn. of Sanitarrians toured Biology facilities and were oriented by Palmer, Stuart, Olson, and McClellan.
- 12/5/63 - Dr. B. P. McNamara of the Toxicology Division, Edgewood Arsenal, Md. discussed Biology research and toxicology problems with Drs. Kornberg and Thompson.
- 12/10/63 - W. D. Eastman of the Blaisdell Publishing Company, New York, toured Biology and discussed research with Kornberg, Bustad, and Dalen.

- 12-12-63 - Dr. M. F. Clarke of GE's Valley Forge Space Technology Center discussed space research with Drs. Kornberg, Hungate and Sullivan.
- 12/13/63 - Dr. R. W. Price of GE's Valley Forge Space Technology Center discussed space research with Drs. Kornberg, Hungate and Sullivan.
- 12/19/63 - R. I. Beggs, Manager, Business Training Course, New York, toured Biology.
- 12/18/63 - Lt. Col. C. M. Barnes, AFIP, Washington, D.C. discussed special phases of research with Kornberg, Hungate, Hanson, and Bustad.
- 12/20/63 - Governor's Advisory Council toured Biology. Orientation given by Dr. Kornberg; tours conducted by Bustad and Nakatani.
- 12/17/63 - Dr. F. P. Conte and 22 members of a radiation course from the State of Oregon toured Biology facilities, conducted by W. J. Clarke and R. F. Palmer.
- 12/24/63 - Homer J. Henney, retired Dean of Agriculture Department, Colorado State College, toured facilities with JF Cline.
- 12/26/63 - Dr. H. A. Carper of the Dept. of Clinical Pathology, Davis, California, discussed research with Bustad and Ragan.
- 12/30-1/3 - Dr. Albert W. Dade from Washington State University, sponsored by the NIH, studied autoradiographic techniques under the direction of W. J. Clarke and J. L. Palotay.
- 12/30-1/3 - Dr. David C. England, Oregon State University, Corvallis, consulted with L. K. Bustad, H. A. Ragan and V. G. Horstman.
- b. Visits Off-Site
- 11/28-12/6 - W. J. Clarke and J. L. Palotay attended Am. College of Veterinary Pathologists Meetings in Chicago and discussed pathology research at Argonne National Laboratory.
- 12/13 - M. E. Kerr, R. E. Nakatani, and J. L. Palotay visited Kiona-Benton City High School for purpose of discussing vocational interests with high school students.
- 12/5-9 J. M. Dean presented a paper at the University of Oregon, Eugene.
- 12/2 F. P. Hungate lectured at Portland State College, Portland, Ore.
- 12/11-12 - C. E. Cushing and L. L. Eberhardt collected samples for fallout study at Packwood, Washington.
- 12/20 - F. P. Hungate, L. L. Eberhardt, W. C. Hanson, and D.G. Watson conferred on sampling program with Dept. of Game, Yakima.
- 12/26 - V. G. Horstman inspected feed at Hermiston, Ore.
- 12/25-1/1 - J. M. Dean presided over a session and presented a paper at AAAS meetings in Cleveland, Ohio; discussed research at DePaul University and Iowa State University.

IV. Achievements

None

V. Honors and Recognitions - None

VI. Professional Group or Organization Assignments - None

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APPLIED MATHEMATICS OPERATION

MONTHLY REPORT - DECEMBER, 1963

ORGANIZATION AND PERSONNEL

Mr. C. A. Oster transferred from Electronic Data Processing, C&AO, as a mathematician, effective December 1, 1963.

Mr. E. C. Nebel III, an MTP trainee joined the staff for a six months rotational assignment on December 30, 1963.

OPERATIONS RESEARCH ACTIVITIES

Information Systems development continued. For H-Reactor, work is concentrated on reactor outage information, on reactor maintenance for B and C Reactors.

Approval has been received and work begun in support of the Containment System Experiment. This work involves providing planning and scheduling aids for completing the new CSE installation.

STATISTICAL AND MATHEMATICAL ACTIVITIES FOR OTHER HAPO COMPONENTS

N-Reactor Department

A statistical procedure was designed to facilitate an objective classification of the relative power "factors" which will be calculated from operating data obtained for each producing channel in the reactor. This procedure was developed as part of a program aimed at improving the method of apportioning the total production of the reactor.

A data analysis was completed relative to the feasibility of predicting variation in thickness of fuel cladding employing an extensive series of pre-extrusion measurements on the uranium billet and the zirconium shell.

A test procedure to assess quantitatively the reliability of the emergency ball system was developed.

An experimental layout was designed to pinpoint both the precision and bias characteristic of the present eddy current measurements of fuel cladding thickness.

A linear model was formulated along with the associated data reduction procedure appropriate to a set of experimental data which had previously been collected and analyzed, using an improper model, by the experimenter.

A series of empirical curves was fitted relating Pu to exposure.

Irradiation Processing Department

Work is continuing on the analysis of an experiment to assess the effects of various heat treatment variables in the preparation of uranium ingots and dingots on the preirradiation warp of fuel elements.

Extensive data from five bonding integrity measurements on fuel elements canned by the hot-die-sizing process are being analyzed to determine the optimum preheat times and furnace temperatures.

PT-572A is being analyzed in order to determine the dimensional distortion behavior of self-supported fuel elements in smooth process tubes.

An analysis is being made to determine whether the solution life of Diverssey-514 can be extended by controlling the pH factor. This is being accomplished by determining whether there are adverse drifts in such bond integrity measurements as internal and external bond counts, total counts, and total bad discs.

A program is being completed which will fit a harmonic type function to outlet temperature data in order to determine the maximum R value. A part of the program will also determine confidence limits on this maximum R value.

Some data from PT-546 were analyzed and indicate that the incremental changes at the fuel element center are larger for fuel elements canned by the hot-die-sizing process than for those canned by the AlSi process. An extensive analysis of other dimensional distortion characteristics on this test is continuing.

Work is being done in designing a thermal cycling test which will simulate (or exaggerate) the thermal heating and cooling conditions fuel elements are exposed to in the startup and shutdown of reactors. The objective is to compare the ability of AlSi and HDS fuel elements to withstand severe and continued thermal cycling.

Another test was discussed concerning the possibility of obtaining the same type of swelling in HDS fuel elements that were observed in the reactor in PT-546A by heating fuel elements in an induction furnace. This would obviate the need for long time delays due to production tests in determining why the HDS fuel elements experienced these unexpected Δ OD-2 increases.

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Chemical Processing Department

A review was made of the measurement of yield strength on "A" line components in an attempt to resolve differences between HAP0 and RFP.

A comparison of expected rejects with observed number of rejects on individual molds and crucibles failed to show significant differences between individual molds and crucibles.

A comparison of thief samples of plutonium nitrate taken from cans at the 234-5 Building with batch samples taken at Purex indicated agreement between the two sampling methods. In addition the measurements between the two laboratories (Purex and 234-5 Building) were in agreement.

The sampling and measurement variability were estimated for Ca, Fe, Cr, Mg, Na, and Ni trace element impurities in buttons.

An outline delineating a proposed Z-Plant Accountability Model was submitted.

STATISTICAL AND MATHEMATICAL ACTIVITIES WITHIN HL

2000 Program

Work continued on the programming and debugging of the boundary value approach to the solution of the system of simultaneous nonlinear differential equations expressing mass transfer in the column as a function of column position. Specifically, a program was written and is currently being debugged for performing eigenvalue and eigenvector calculations on a nonsymmetric fourth order pattern matrix which arises repeatedly in the boundary value calculation.

L. D. Coffin completed the GE-412 Process Control Computer Preliminary course and is currently preparing for the advanced course to be given by the Industry Applications Department in Phoenix in January.

Three statistical analyses of gamma absorptiometer data were started in connection with the rewriting of the paper, "A Data Logging Absorptiometer for Routine Uranium Analysis" for publication in Talanta.

Continuing assistance was provided on the problem of formulating mathematical models to describe the radioactivity in the reactor effluent stream.

Additional developmental work was done on the "shoe-box" mathematical model which describes ground water flow in a medium of variable diffusivity. In addition, work was begun on an EDPM Program to obtain numerical solutions to this model.

Sixteen particle frequency distributions are being fitted to the Weibull distribution.

3000 Program

Several magnetic tapes were prepared with special routines in anticipation of tests soon to be made on the experimental numerically controlled Sheffield rotary contour gauge.

Consultations continued on the power roll forming process.

4000 Program

Consulting services were supplied to the experimental reactor design personnel on various problems concerned with reactor component geometry.

Investigations are under way to determine the feasibility of developing a mathematical model to aid in interpreting data which will be obtained from planned carbon burn-out experiments.

Work continued on a formal Hanford report describing the quantitative metallographic techniques developed during the past several years for estimating the properties of second phase spherical particles embedded in a matrix. These techniques are being used to estimate fission gas pore distributions in irradiated uranium fuel. A machine language program developed for analyzing data collected on the Ziess particle size analyzer is being generalized to handle several methods of sample replication prior to electron microscopy.

5000 Program

Work continued on the study of the variability of standard spectra probabilities calculated for use in the GEM program of the IRA system.

Work continued on the calculation of the power function of Poisson index statistics used to check stability of counting instruments. Preliminary subroutines for the calculation of a cumulative distribution function of a linear combination of noncentral chi-square variables were completed and debugged. Power function calculations are now being done for the case of a single outlier count.

A coordinate translation subroutine for the IRA system ran successfully during the month. To save memory the FORTRAN coded version was recoded in FAP.

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Debugging of the FAP version has started. A subroutine to edit the spectra which are input to the IRA 335 calculation pass has been written and is being debugged. The edit routine will flag frequently made errors in the input spectra. Several other modifications have been made to IRA 335 to make its operation faster and less sensitive to input errors.

Work continued on the problems of crystal indexing and determining amine equilibrium curves.

6000 Program

Additional work and experimental EDPM runs were made on the "triangular diffusion" model.

Analysis of variance computer program (BIMD 11) was modified so that the output would include the sum, mean, standard deviation of each experimental cell and the sum of each level of every factor considered in the analysis.

A computer program was written to record data and perform specified calculations for Zn^{65} fish studies. The microcuries of Zn^{65} per sample and microcuries of Zn^{65} per gram of tissue are determined for several tissues of each fish. Also, the mean and standard deviation for each tissue and postadministration time are calculated.

Survival data of lethally X-irradiated mice receiving bone marrow from donors pretreated with host tissue compared to animals receiving bone marrow from normal animals were statistically analyzed.

A heat budget model was proposed and tested with data from the previous year.

OTHER

A new numerical integration subroutine using the Romberg integration algorithm was written and checked out on several known integrals.

An EDPM program for the numerical solution of the mathematical boundary value problem

$$\frac{\partial u}{\partial t} = K^2 \left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right] + S(x, y, t)$$

$$\frac{\partial u}{\partial n} = 2u.$$

has been debugged, tested, and found to possess a high degree of accuracy.

Manager
Applied Mathematics

REACTOR PROGRAM - O4 PROGRAMPLUTONIUM UTILIZATION PROGRAMExtension of Fuel Lifetime Using Plutonium and Reduced Density Recycle

The feasibility is being studied of extending the full power life of a nonbreeding enriched uranium reactor when contacts with uranium enriching facilities and natural uranium sources have been cut off leaving available only the in-reactor inventories of fuel. The approach is to re-use all the plutonium converted in the fuel during each burn up and re-use only an optimum fraction of the uranium, the optimum fraction being that which results in maximum burn up. As the quantity of available fissile material diminishes, the amount of fertile material charged in the reactor must be reduced from the initial value to allow the reactor to go critical. On the other hand, if the fertile fuel level is reduced too much, less fissile material is generated and the fuel exposure becomes shorter than otherwise possible.

The reactor used in the study was a simulated pressurized water reactor (SPWR) with a specific power of 20 megawatts per ton. The reactor was initially loaded with 2 percent enriched uranium. Other reactor types will be evaluated to complete the study. By virtue of the high specific power of this reactor and its relatively low neutron economy, the figures developed for this reactor are minimal.

Table I shows the results starting with a 2 percent enriched core. Successive burn ups with diminishing uranium inventories are simulated until calculations show the reactor can no longer go critical. The density of uranium used in each case was chosen to maximize the exposure.

It is planned that a study be conducted assuming that natural uranium is available. This should result in much longer full power operation. Future work will also include consideration of the out-of-reactor "pipeline" which will greatly increase the total full power life of the reactor when cut off from normal fuel sources.

Seed-Blanket Studies

Computations this month have been based on nominal interference of the resonances of U^{235} , Pu^{239} , Pu^{241} , and Am^{241} . All other interference is being neglected pending receipt of pertinent computations.

These studies have been on 30- and 40-centimeter-diameter seed-blanket modules using the "hot" rod design (part of the seed is removed from the reactor to reduce reactivity). Seed volume fractions of 15 and 20 percent in the larger module were considered using complete seed replacement when refueling is required. Replacement of one half of the seed at each refueling has been considered for the 20-volume-percent seed in the smaller module. In all smaller module cases, half of the initial seed loading was 93 percent enriched uranium at a concentration

TABLE I

BURN UP DATA FOR AN EXTENDED LIFETIME TWO PERCENT ENRICHED URANIUM REACTOR

<u>Initial Conversion Ratio</u>	<u>Total Fuel Costs mills/kwhe</u>	<u>U²³⁸ Density at Discharge (grams/cc)</u>	<u>Plutonium Composition at Discharge, (%)</u> *	<u>Density Fissile Plutonium Isotopes at Discharge (gram/cc)</u>	<u>Density Fissile Plus Fertile Plutonium Isotopes at Discharge (gram/cc)</u>	<u>Exposure Mwd/Initial Ton</u>	<u>Time, Years</u>
0.76	1.028	8.96	54-32-9-5	0.0294	0.0472	12,000	1.64
0.51	3.158	3.57	31-39-10-20	0.0137	0.0333	5,684	.78
0.42	15.963	0.71	12-38-10-40	0.0047	0.0214	1,694	.23
0.42	--	0.0	10-38-10-42	0.0041	0.0206	<u>70</u>	<u>.01</u>
					Total	19,448	2.66

* Composition of isotopes Pu-239, 240, 241, and 242.

of 0.6 gram per cubic centimeter. For the other half (which was to be replaced at the first refueling), one case used 93 percent enriched uranium at 0.3 gram per cubic centimeter, while the other used the same composition as the blanket. Thus, the seed for the latter case was 10-volume-percent until refueling was required. After the first refueling, each smaller module reactor contained 10 percent fresh or first cycle seed and 10 percent used or second cycle seed. Figure 1 illustrates the variation of fuel cost, and Figure 2 illustrates the blanket power sharing for various modes of operation. To the left of these figures, data typical of replacement of the entire reactor fuel load, seed and blanket, at each shutdown are presented. In all cases, the fuel cost decreases if two or more seeds are used before the blanket is replaced. It should be noted however that none of the cases studied so far has approached the 1.142 mill/kwh fuel cost calculated for this same reactor operating on a "graded" fueling scheme, rather than on the above seed-blanket loadings.

Uranium Resource Conservation

The predictions made in the AEC Report to the President-1962 regarding the size of the electrical utility industry and the role that nuclear power will play are summarized in Figures 3 and 4. Figure 5 compares the revenues and fuel costs of the future with the present GNP. Estimates of the present unit fuel costs and unit electrical revenues are multiplied by the number of units predicted. A fifty-billion-dollar nuclear fuel industry a hundred years from now will not be a larger fraction of the future economy than coal for the same purpose is of today's economy.

This projection of the size of the nuclear power industry is the basis for a program being written (called "YUKON" for uranium conservation) to calculate the amount of natural uranium used as a function of the type of reactor using it and the price of the ore. The YUKON program is now debugged. It will eventually be added to the MELEAGER-QUICK chain.

Code Development

Three of the subroutines in the PLOTTER code were modified to yield more useful information. The PHYSICS routine now plots the breeding ratio and has much better identification of output data. Two routines which plot isotopic concentrations in nuclei per barn centimeter have been converted to more popular units of grams per ton of fuel.

The MINIMIZER routine in QUICK has been modified to calculate minimum fuel costs for systems which breed. A limitation on the doubling time can be imposed during minimization, if desired.

A fuel cycle analysis program demonstration and guide has been prepared as document HW-79951. This document consists of the detailed card-by-card instructions for use of the CHAINED MELEAGER (Reactor Physics) - QUICK (Fuel Costs) - PUVF (Fuel Value) computer code sequence which actually involves some 43 codes. Using these instructions, a

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- A - 20 cm radius, 20% seed volume, full seed replacement
- B - 20 cm radius, 15% seed volume, full seed replacement
- C - 15 cm radius, 20% seed volume, half seed replacement,
0.30 gram/cc of 93% U^{235} in second half of seed region at start
- D - 15 cm radius, 20% seed volume, half seed replacement,
blanket material in second half of seed region at start

FIGURE 1

SEED REPLACEMENT SCENARIOS (Costs)

- A - 20 cm radius, 20% seed volume, full seed replacement
- B - 20 cm radius, 15% seed volume, full seed replacement
- C - 15 cm radius, 20% seed volume, half seed replacement, 0.30 gram/cc of 93% U^{235} in second half of seed region at start.
- D - 15 cm radius, 20% seed volume, half seed replacement, blanket material in second half of seed region at start

FIGURE 2

SEED REPLACEMENT STUDIES (Power Sharing)

FIGURE 3

FORECAST ELECTRICAL GENERATING CAPACITY - MWe

(Based on the AEC "Report to the President - 1962")

FIGURE 4

FORECAST ELECTRICAL GENERATION - kWh/yr

(Based on the AEC Report to the President - 1962")

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FIGURE 5

ILLUSTRATIVE MAGNITUDES OF FUTURE FUEL COSTS AND ELECTRICAL REVENUES
 COMPARED WITH CURRENT GNP

complete demonstration computer run was completed and documented (by the computer). This compilation of codes and demonstrations was completed to fill the many requests from both the USA and abroad for a working sequence of these codes. It is anticipated that, with minor adaptations to local operating conditions recipients will be able to compile the program and execute the data with a standard FORTRAN II version in monitor system tape. The tape can also be converted to Hollerith card forms for translation into other languages. A final check of MELEAGER reactivity formulations against reactor criticality measurements is being made preparatory to shipment of the packages.

The programs used in the demonstration are: MELEAGER, PROTEUS, QUICK, PLOTTER, CASE GENERATOR, and PREP.

Nuclear Safety Activities

A document is in press which will establish plant-wide procedures for shipment or change of custodian of fissile materials.

Approval of AEC was obtained for operation of the Plutonium Recycle Critical Facility with light water moderator for testing PuO₂-UO₂ fuels for use in EBWR. Safeguards analyses were transmitted for other core loadings, HW-69188 SUP⁴.

Manager
Programming

FW Woodfield:jcp

RADIATION PROTECTION OPERATION
REPORT FOR THE MONTH OF DECEMBER 1963

A. ORGANIZATION AND PERSONNEL

Ken R. Heid transferred from RMO to CDS&RO effective 12/1/63. Myrtle Wendland returned to EDO from an illness leave. C. M. McDaniel transferred to EDO from C&AO effective 12/23/63. R. C. Britton transferred from RMO to Chemical Research effective 12/2/63. J. L. Rising transferred from CPD to RMO on 12/23/63. W. L. Coles, L. W. Hankel, C. E. Rosenberry, and R. W. Clark transferred from IPD to RMO effective 12/30/63.

B. ACTIVITIES

Occupational Exposure Experience

There were three new plutonium deposition cases confirmed by special bioassay analysis during the month. The body burdens, which were estimated to be less than 1% of the MPBB* in each case, resulted from inhalation incidents which occurred in the Plutonium Metallurgy Building (231), the Redox Final Products Concentration Building (233-S), and an injury which occurred in the Weapons Manufacturing Building (234-5).

The total number of individuals who have received internal plutonium deposition at Hanford is 327. With the termination of two of these employees, the number of deposition cases currently employed at Hanford is 235.

During the month, there were five incidents involving eight CPD employees and two incidents involving four HL employees which required bioassay sampling for plutonium analysis. The following is a brief description of the more significant incidents.

A CPD electrician received a potentially contaminated injury at the Weapons Manufacturing Building (234-5) on December 11, 1963, while repairing an electrical line in the upper level of Hood 9-B. Approximately 1,000 d/m contamination was found on the surgical glove, but examination with the plutonium wound counter indicated less than the detection limit of 1×10^{-4} μ c Pu.

A process operator at the Weapons Manufacturing Building (234-5) received a potentially contaminated injury on December 17, 1963, while working in the casting area. When the radiation monitor spread the skin in the vicinity of the wound, contamination up to 5,000 d/m was detected. This was decontaminated to less than 500 d/m prior to release. Examination with the plutonium wound counter indicated less than the detection limit of 1×10^{-4} μ c Pu.

* MPBB plutonium (bone as reference) = 0.04 μ c.

Three CPD operators received skin contamination ranging from 1,000 to 60,000 d/m when a fire occurred in the chopper hood in the Weapons Manufacturing Incinerator Building (232-Z) on December 17, 1963. Respiratory protective equipment was used immediately when the fire was observed, and their nasal smears were negative. Contamination in quantities greater than 40,000 d/m was spread throughout the operating room where the hood was located. The firemen were closely supervised by monitoring personnel so that proper techniques were employed in wearing and removing protective apparel. No skin or nasal contamination was found on any of the firemen.

An HL employee received a potential plutonium contaminated injury at the PFPP Building (308) on December 19, 1963, while decontaminating cladding before loading plutonium in an element. His thumb was punctured by a pair of tweezers which read 500 d/m. No contamination was found in the wound site and examination with the plutonium wound counter showed less than the detection limit of 1×10^{-4} μ c Pu.

There were no new plutonium contaminated injuries during the month, and the total number for the year remains at 20 with 14 receiving excision. In 1962, there were 15 plutonium contaminated injuries with eight receiving excision.

Two HL employees and one IPD employee were involved in separate incidents involving a potential for internal deposition of radioactive materials. The more significant incident is briefly described below.

An IPD pipefitter received skin contamination ranging from 2,000 to 80,000 c/m while changing a gun barrel which had been used in the removal of a ruptured fuel element. The skin contamination was reduced to 2,500 c/m, sprayed with plastic spray bandage, and the individual sent home. Two days later when the bandage was removed the contamination was down to 800 c/m. Examination at the Mobile Whole Body Counter failed to disclose any internal contamination.

There were no incidents during the month which required special evaluation of an external dose.

Several other occurrences of significance during the month are summarized below:

On December 11, 1963, a film badge with a prescription blank, and a note attached was received from GE Security. The prescription

blank signed by a physician stated, "Please have above patient's film badge checked for possible over-exposure. The patient is now hospitalized". When Security was contacted, it was learned that the person's wife had called Security and told them that her husband was in the hospital with a high fever and was not responding to treatment and that the attending physician was considering the possibility of radiation damage. The film badge dosimeter reading was essentially zero. His past exposure history, initiated in 1961, indicates an accumulated whole body dose of less than 4 rems, and his routine bioassay sample taken March, 1963, contained no detectable plutonium. The exposure history information was relayed to Industrial Medical, who was to give the information to the employee's doctor.

As a result of several contamination spreads in the 308 Building, a number of recommendations were made to the Fabrication Development personnel of the Plutonium Fabrication Pilot Plant to better control and confine future contamination incidents.

On December 27, an employee in Plutonium Critical Mass Laboratory dropped a plutonium lucite compact which broke in two. Personnel cleared the area immediately and subsequent entry was made with assault masks to assess the contamination spread. The floor near the point of contact was contaminated to greater than 10^6 d/m and contamination up to 40,000 d/m was widespread. Nasal smears taken were only slightly positive. Decontamination is in progress. The incident was documented as Radiation Occurrence No. 63-0-34.

Personnel dose rates up to 4 R/hour were experienced during removal of small cobalt shim rod bearings which had lodged in one end of the fuel element examination tray in PRTR storage basin area. The bearings indicated greater than 50 R/hour while under 2 feet of water. Personnel exposures were controlled to less than 200 mr during removal of the bearings. The tray was decontaminated to 500 mr/hr at 2 inches.

Environmental Experience

Concentrations of fallout materials in the air of the Pacific Northwest averaged $0.9 \text{ pc } \beta/\text{m}^3$ air in December, which is a continuation of a decreasing trend, not significantly different from the low value of $1 \text{ pc } \beta/\text{m}^3$ recorded last month.

About 20 curies of I^{132} (2.3 hr. half-life) were emitted from the Purex stack during the week beginning December 14, 1963. The I^{132} emission rate decreased throughout the period in question in a manner

consistent with the theory that the Te^{132} parent (78 hr. half-life) of I^{132} had been released from the dissolver, and then had plated out somewhere in the ventilation system. CPD personnel suspected that hand-sorted elements dissolved during the night of December 13-14, 1963, probably had contained one or two undercooled fuel elements. Iodine-132 was not anticipated or detected in any environmental samples.

On December 9, notification was received that the level of contamination in one 307 basin was 8×10^{-5} $\mu\text{c}/\text{ml}$ which exceeded the warning level for release of the water. The activity was determined to be mainly Zr^{95} and Pa^{233} . These nuclides result from thorium irradiation research. The release of these nuclides had no impact on downstream exposure. Administrative measures should prevent repetition in addition to which eventual rerouting of the drain is planned.

A total of 308 biological, produce, and food samples were obtained for radiochemical analyses. They were:

Milk	37 samples	112 gallons
Beef Thyroids	35 sets	
Dried Oysters	16 samples	
Fresh Oysters	2 samples	4 pounds
Ground Round	3 samples	6 pounds
Fish	43 samples	
Goose Muscle	4 samples	
Duck Muscle	40 samples	
Duck Heads	124 samples	

The source of fresh milk samples in the Ringold area has "dried up" until the Spring.

Contracts for the collection of beef thyroid gland samples for another year have been established with five veterinarians in the communities of Pasco, Walla Walla, Moses Lake, Wenatchee, and Wapato.

Two aerial monitoring flights were made for background determinations. Standard patterns 1-E, 4-S and 5-S were flown.

Studies and Improvements

Drawings detailing building layout, ventilation systems, process flow and monitor systems for the High Temperature Lattice Test Reactor were reviewed for comment on radiological aspects of the design. Several recommendations were incorporated into the HL comment package directed to Vitro Engineering Company.

Design criteria were established for assuring isolation of sanitary water systems from process or potentially contaminated water systems for all new facilities. In addition, appropriate measures to prevent back flow in old systems were defined.

The electronic system for the neutron spectrometer was aligned and calibrated using the positive ion accelerator. The linearity and resolution of the over-all system is considered quite good. The system is linear, ± 30 Kev, up to 5 Mev; with resolution of 3% at 4.72 Mev or 140 Kev.

Examination of plutonium carbide particle size distributions data obtained from air samples taken in the Plutonium Metallurgy Building indicates an aerosol of rather uniform small diameter with a few isolated larger particles. A series of air samples were taken routinely at a location near a plutonium oxide hood in the Weapons Fabrication Building. These samples were collected on membrane filter paper, and the particle sizes determined by alpha track counting of nuclear track emulsions exposed to the filters. The data demonstrated the considerable variation in particle size that occurs from day to day in the operation of a PuO_2 hood.

The research and development work conducted during the past year by others at General Electric facilities has indicated that mica and certain plastics may be used to detect fission fragments. In the use of these materials, a fissionable isotope such as U^{235} is placed immediately over the plastic or mica. Upon exposure to a neutron flux fission fragment, some of the uranium will penetrate into the plastic or mica material. The physical damage resulting from this penetration provides a change in chemical reaction rate which may be used to detect the path of the fission fragment. Some preliminary investigation of the use of this principle for personnel neutron dosimetry has indicated that natural uranium adjacent to the plastic Makrofol or Lexon will produce 2 etched pits/ cm^2 for each mrem of thermal neutron dose delivered. For fast neutrons from a PuBe source, 1 pit/ cm^2 for 120 mrem was observed. The sensitivity of this detector system may be increased by using enriched uranium next to the detector material.

The new meter faces were designed, printed, and are currently being installed on all Emergency HCP. They are direct reading in Roentgen/minute; the full scale reading on range X1 is 1 R/min. The film jig and both calibration wells were audited during the month. Most of the exposure positions were within +3% of the established dose rate, and a few within $\pm 5\%$.

The use of "pocket" ionization chambers for terrestrial gamma dose measurements was discontinued. The more sensitive Stray Radiation chambers (Victoreen Model 239) will be retained at two locations -

700 Area and Rt. 10, Mile 1.6. The recording gamma monitors and the film badges located in the atmospheric monitoring stations (614 Buildings) in each operating area will provide sufficient gamma dose information.

Concurrence was received this month from the AEC and USPHS with the decision to realign off-project air sampling stations into a closer, more complete ring around the project.

Collection of integrated water samples was begun at the Richland Filter Plant on December 19. The sample of sanitary water is taken by means of a timer and solenoid valve.

Review of the condition of burial grounds at Hanford were begun. Both active and retired burial grounds are being checked for such things as radiation levels, fences, signs, monuments, etc.

Research Studies

Effect of Reactor Effluent on the Quality of Columbia River Water (02)

One of the questions to be answered by this study is whether a single monitoring point can be found that will give a reliable measurement of downstream temperature changes. A review of all temperature traverses to date showed that one or two points do exist at each traverse location at which the mean river temperature could be determined to within 0.2° C. In no case, however, did these points occur near the shoreline. Shoreline effects cause departures from the mean temperature of as much as 1° C.

An initial attempt was made at a statistical correlation of the differences in the daily average river temperatures between the Priest Rapids gauge and both PRTR and Pasco. In spite of known inadequacies in the data, a model was found which would predict the temperature changes with a residual standard deviation of $\pm 0.3^{\circ}$ C.

Mechanisms of Environmental Exposure (02)

Results for K^{40} concentration in the flesh of whitefish caught immediately downstream of the reactor (e.g., Hanford-Ringold Area) are significantly higher than for whitefish caught at Priest Rapids, or at Richland, and further downstream. The significance of this is being investigated.

C. RELATIONS

Safety meetings were held throughout the Section during the month. There was one security violation.

Eight suggestions were received, three evaluated, and five are pending. No suggestion awards were made during the month.

Four three-hour training sessions in "Disaster Monitoring" for IPD personnel attending the Reactor Certification Training School were well received.

The fourth session of the third round, and all four sessions of the fourth round, in the RM Refresher Course were held. Total attendance was 53, of whom seven were CPD employees and one AEC employee.

A one-hour training program was held for about 20 Chemical Laboratory personnel, covering basic radiation protection material.

One three-hour training session on Disaster Monitoring was presented for IPD Processing Personnel.

Response to the letter of invitation and outline for the Radiation Protection Training Course for exempt personnel was overwhelming. A total of 96 exempt personnel requested permission to participate. The class will be limited to about 25 persons.

D. SIGNIFICANT REPORTS

- HW-78977 - "The Effect of Temperature on Personnel Dosimeter Film", by G. E. King.
- HW-79954 - "Radioactive Liquid Waste Disposal for October", by R. H. Wilson.
- HW-76525 11 - "Radiological Status of the Hanford Environs for November, 1963", by R. F. Foster.

PERSONNEL DOSIMETRY AND RADIOLOGICAL RECORDS

<u>External Exposure Above Permissible Limits</u>	<u>December</u>	<u>1963</u>
Whole Body Penetrating	0	3
Whole Body Skin	0	0
Extremity	0	1

<u>Hanford Pocket Dosimeters</u>		
Dosimeters Processed	2,882	77,441

<u>Hanford Beta-Gamma Film Badge Dosimeters</u>		
Film Processed	9,705	126,616
Results - 100-300 mrad	144	2,208
Results - 300-500 mrad	12	211
Results - Over 500 mrad	3	47
Lost Results	19	274
Average Dose Per Film Packet - mrad (ow)	6.0	7.4
- mr (s)	30.0	30.8

<u>Hanford Neutron Film Badge Dosimeters</u>		
<u>Slow Neutron</u>		
Film Processed	1,623	22,104
Results - 50-100 mrem	0	18
Results - 100-300 mrem	0	2
Results - Over 300 mrem	0	0
Lost Results	2	111
<u>Fast Neutron</u>		
Film Read	533	6,153
Results - 50-100 mrem	0	282
Results - 100-300 mrem	76	705
Results - Over 300 mrem	0	8
Lost Results	2	90

<u>Hand Checks</u>		
Checks Taken - Alpha	34,066	439,910
- Beta-Gamma	50,149	672,581

<u>Skin Contamination</u>		
Plutonium	33	307
Fission Products	23	443
Uranium	0	5
Tritium	0	0
Thorium	0	1

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Whole Body Counter

<u>Subject</u>	<u>Number of Examinations</u>			
	<u>747-A WBC</u>	<u>1963</u>	<u>Mobile WBC</u>	<u>1963</u>
GE Employees				
Regular	43	675	18	515
Incident Cases	5	150		1
Terminations	7	136		1
New Hires	25	547		1
Special Studies	1	481	1	1
Non-Employees				
Children	11	35		
Visitors	2	47		
Environmental Studies	7	27		
	<u>101</u>	<u>2,098</u>	<u>19</u>	<u>519</u>

Bioassay

<u>Analysis</u>	<u>Current Reporting Limit</u>	<u>Results Above Reporting Limit</u>		<u>Samples Assayed</u>	
		<u>Dec.</u>	<u>1963</u>	<u>Dec.</u>	<u>1963</u>
Plutonium	2.2x10 ⁻⁸ µc/sample	71	964	283	6,671
Fission Prod.	3.1x10 ⁻⁵ µc/sample	4	111	130	5,971
Strontium	3.1x10 ⁻⁵ µc/sample	-	45	-	45
Tritium	5.0 µc/l	230	1,768	225	2,837
Uranium	0.14 µgm/l	-	-	144	1,832
Special Studies		-	-	34	438

Calibrations

	<u>Number of Units Calibrated</u>	
	<u>December</u>	<u>1963</u>
Portable Instruments		
CP Meter	953	12,713
Juno	245	3,092
GM	557	6,860
Other	211	2,342
Audits	94	1,268
	<u>2,060</u>	<u>26,275</u>
Personnel Meters		
Badge Film	972	10,124
Pencils	105	1,275
Other	348	3,698
	<u>1,425</u>	<u>15,097</u>

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	<u>Number of Units Calibrated</u>	
	<u>December</u>	<u>1963</u>
Miscellaneous Special Services	157	14,532
Total Number of Calibrations	3,642	55,904

Manager
RADIATION PROTECTION

AR Keene:ICN:ald

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FINANCE AND ADMINISTRATIONACCOUNTINGCost Accounting

At the request of RLOO-AEC, Hanford Laboratories prepared a FY 1964 Midyear Budget Review of the 04, 05, and 06 Programs, including both research and development and equipment requirements. Also provided were requested data concerning the impact of reduced planning levels on the various programs. A comparison of the amounts requested in the Midyear Budget Review with the current control budget is provided below:

(Dollars in thousands)	<u>Current Control Budget</u>	<u>Midyear Budget Review</u>
04 Program		
Research and Development	\$13 726	\$14 907
Equipment	298	843
05 Program		
Research and Development	1 456	1 565
Equipment	100	180
06 Program		
Research and Development	3 604	3 624
Equipment	125	300

A Target Budget for FY 1965 was prepared at the request of Contract Accounting to bring forth potential problem areas and to facilitate advance planning for the regular preparation of the Budget for FY 1966 and Revision of Budget for FY 1965.

During December, Hanford Laboratories was allocated additional equipment and miscellaneous capital work order funds as follows:

<u>Equipment Allocation by Program</u>	<u>December Allocation</u>	<u>FY 1964 Allocation To Date</u>
02	\$201 000	\$801 000
03	30 000	90 000
04	19 500	298 100
05	--	100 000
06	--	125 000
08	--	25 000
<u>Miscellaneous Capital Work Orders</u>	16 000	176 000

Hanford Laboratories was allocated an additional \$50,000 in Service Assessment funds by the General Manager - HAP0 to provide sufficient funding in FY 1964 for the Nuclear Health and Safety Operation that was established in June 1963.

Special accounting codes were established during December for the activities described below:

- .3X Studies in connection with the investigation of submicron dispersions for the National Aeronautics and Space Administration. Amount authorized was \$50,000.
- .8Q Consultation with APED by J. J. Fuquay on the dispersion and deposition of radioactive materials associated with hypothetical reactor accidents. Billing will be for three days of consultation.
- .8R Packaging and shipping of test coupons to Dow Chemical Company, Kalama, Washington, in connection with services provided Hanford Laboratories under contract SA-311 for Testing Services.

General Accounting

Letter AT-316, AEC Monograph on Iodine 131 - L. K. Bustad and J. K. Soldat, remains in process.

The following revised OPGs were issued during December 1963:

<u>OPG No.</u>	<u>Title</u>
3.4.5	Attendance Recognition Plan
3.4.6	Employee Service Recognition Plan
3.4.7	Solicitation Among Employees
6.7	Employees Testifying in Legal Actions and Proceedings
3.3.2	Work Schedules
3.1.8 (pp. 1 & 2)	Suggestion Plan
22.1.1	Hanford Laboratories Organization

Classification activities for the month included the review of 849 purchase requisitions, 655 work orders and 29 appropriation requests for capital or expense determination, compounding, work review and for reimbursability. The trend of HL classification activities continues to increase as indicated by comparing the activities of the first six months of FY 1964 with the same period in FY 1963 and FY 1962:

	<u>FY 1962</u>	<u>FY 1963</u>	<u>FY 1964</u>
Purchase Requisitions	4 043	4 915	5 895
Work Orders	<u>3 249</u>	<u>4 015</u>	<u>4 502</u>
	<u>7 292</u>	<u>8 930</u>	<u>10 397</u>

Hanford Laboratories' net material investment at December 1, 1963 totaled \$24.4 million as detailed below:

(In thousands)

SS Material		\$23 107
Reactor and Other Special Material		988
Spare Parts		351
Yttrium		26
Subtotal		<u>24 472</u>
Reserve: Spare Parts	\$79	
Yttrium	<u>26</u>	<u>(105)</u>
Net Inventory Investment		<u>\$24 367</u>

The cumulative value of nuclear material consumed in research by Hanford Laboratories during FY 1964 (at December 1, 1963) is \$386,451 comprised as follows:

02 Program	\$ 16 877
03 Program	151 879
04 Program	<u>217 695</u>
	<u>\$386 451</u>

A total of 459 Extended Property Passes covering the routine movement of specific categories of property within the plant areas during CY 1964, were distributed to HL personnel.

Preparations were completed for the physical inventory of all movable catalogued equipment in custody of Hanford Laboratories to begin January 2, 1964. This inventory, which will be a "certification" type inventory by HL custodial personnel, is the first time a certification type inventory of this magnitude has been attempted at HAPO. The physical count is expected to be completed in March 1964.

The heavy water inventory at the end of December 1963 showed a loss of 719 pounds (\$9,915) for the PRTR and a loss of 50 pounds (\$690) for the PRCF. Heavy water scrap generated during the month amounted to 1,214 pounds, resulting in a \$1,554 charge to operating cost. Heavy water accumulated at December 31 for return to SROO amounted to 8,879 pounds valued at \$111,082.

Notification was received from the AEC that our request for 27,500 pounds (55 drums) of heavy water will be filled and will leave SROO on January 3, 1964. The shipment is expected to arrive at HAPO January 13, 1964.

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HW-79999

Savannah River Operations' calculations on a heavy water shipment made in November indicated receipt of 19,204 pounds, which was 112.77 pounds higher than the HAPO computed weight. Consequently, a credit to cost of \$823 was made during December.

Inventory materials valued at \$2,172 and comprised of Palladium powder, Silver soldering wire, and Hafnium powder excess to HAPO needs were shipped to Los Alamos Scientific Laboratory.

Laboratory Storage Pool activity is summarized as follows:

	<u>Current Month</u>		<u>FY to Date</u>	
	<u>Quantity</u>	<u>Value</u>	<u>Quantity</u>	<u>Value</u>
Beginning Balance	1 747	\$ 950 280	1 480	\$ 811 520
Items Received	47	526 009-1)	995	914 355
Items Reclaimed by				
Custodians	(6)	(2 201)	(137)	(48 316)
Equipment Transfers	(26)	(30 783)	(185)	(83 580)
Items Disposed by PDR			(140)	(11 290)
Items Disposed by Excess			(251)	(139 384)
	<u>1 762</u>	<u>\$1 443 305</u>	<u>1 762</u>	<u>\$1 443 305-2)</u>

(1- Includes a Preliminary Pile Assembly (PPA), valued at \$455,000, received from Knolls Atomic Power Laboratory for use by Physics and Instruments Laboratory. This item will be stored at the Pool until installed in a permanent location.

(2- Includes 171 items worth \$118,810 which were on loan at December 31, 1963.

During the month, 115 items valued at \$63,152 were loaned and/or transferred in lieu of purchases. A total of 505 items, valued at \$206,792, has been redirected to useful purposes this fiscal year. Operating costs for the same period totaled \$9,033.

The following statistics reflect the trend of Laboratory Pool activities by calendar year since its inception in December 1959:

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HW-79999

	CY 1960		CY 1961		CY 1962		CY 1963	
	Items	Value	Items	Value	Items	Value	Items	Value
.Begin. Bal.	--	\$ --	560	\$ 224 804	976	\$ 481 962	1 354	\$ 785 979
.Items Rec'd.	669	309 946	717	572 729	1 342	696 056	2 083	1 311 592
.Items Re-claimed by								
Custodians	(15)	(27 800)	(64)	(209 219)	(132)	(93 196)	(317)	(237 068)
.Equip. Tran.	(81)	(43 628)	(232)	(103 612)	(176)	(71 581)	(335)	(131 681)
.PDR			(1)	(101)	(69)	(18 687)	(287)	(20 639)
.Excess	(13)	(13 714)	(4)	(2 639)	(587)	(167 310)	(736)	(264 878)
.Others (Removal of installation charges)						(41 265)		
Total	<u>560</u>	<u>\$224 804</u>	<u>976</u>	<u>\$ 481 962</u>	<u>1 354</u>	<u>\$ 785 979</u>	<u>1 762</u>	<u>\$1 443 305</u>
.Items placed in lieu of PO	86	\$ 45 071	232	\$ 102 991	256	\$ 145 294	720	\$ 311 737
.Op. Costs		<u>(12 356)</u>		<u>(10 986)</u>		<u>(14 322)</u>		<u>(15 657)</u>
Net		<u>\$ 32 715</u>		<u>\$ 92 005</u>		<u>\$ 130 972</u>		<u>\$ 296 080</u>

Laboratory Pool Investment at Calendar Year End:

.Equipment	\$224 804	\$ 481 962	\$ 785 979	\$1 443 305
.Reactor & Other				
Special Mat'ls.	87 205	181 901	161 844	290 667
.SS Material	--	--	22 626	154 800
.Other Material	<u>5 844</u>	<u>109 548</u>	<u>112 505</u>	<u>494 065</u>
Total Calendar Year End Investment	<u>\$317 853</u>	<u>\$ 773 411</u>	<u>\$1 082 954</u>	<u>\$2 382 837</u>

Action on projects during the month follows:

Physical Completion Notice Issued

CAH-958 Plutonium Fuels Testing and Evaluation Laboratory, 308 Building

Contracts processed during the month were:

CA-371 - SI	Washington State University
CA-425	Victor F. Zackay
DDR-177	Great Lakes Carbon Corporation
SA-311	Dow Chemical Company, Dow Industrial Service Division
SA-313	Public Utility District #1 of Franklin County
SA-317	L. M. Bodie
SA-324	Betz Laboratories, Inc.

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The following Assistance to Hanford agreement was authorized during the month:

ATH-HL-7-64-A Large Steam Turbine-Generator Department, Consultation Services - Dr. Sumio Yukawa

Personnel Accounting

The following shows the number of payroll changes during 1963. The work force grew from 1,637 on December 31, 1962 to 1,811 as of December 31, 1963 - a net increase of 174 employees.

	<u>Exempt</u>	<u>Salaried</u>	<u>Total</u>
Additions and Transfers in	246	259	505
Removals and Transfers out	<u>151</u>	<u>180</u>	<u>331</u>
Total Activity	<u>397</u>	<u>439</u>	<u>836</u>
Net Increase	<u>95</u>	<u>79</u>	<u>174</u>

The following patent awards were made this month:

J. T. Russell	HWIR 1575	The Field of Nondestructive Isotopic Analysis
L. E. Mills) R. F. Bolen)	HWIR 1560	A Graphite to Graphite Weld
W. L. Bunch) G. F. Garlick)	HWIR 1593	Monitoring Neutron Flux Within a Reactor
R. E. Peterson) S. L. Stewart)	HWIR 1584	Nuclear Reactor Design
R. B. Richman) A. P. Larrick)	HWIR 1204	A Chemical Composition and Process for Removing Oxide, Film and/or Scale Layers from Metals
J. H. Kleinpeter) G. Jansen, Jr.)	HWIR 1595	A Method for Securing the Separation of Electrolytically Deposited Uranium Dioxide from Graphite Electrodes by Utilizing a Non-Porous Pyrolytic Graphite Coating

During 1963, 33 Patent Awards of \$125 each were paid to Hanford Laboratories employees.

TECHNICAL ADMINISTRATIONEmployee Relations

Seventeen nonexempt employees were hired; 20 open requisitions remain.

Suggestion plan activity included 49 submissions, 17 adoptions and 46 rejections.

Information and Presentations

Visitors Center activity:

December attendance	1 101
Average attendance per day open	46
Cumulative attendance since 6-13-62	60 285
Conducted groups	8 (totaling 180 people)

Plant tour activity:

	<u>Number</u>	<u>Total People</u>
General Public Relations Tours	2	159
Special Tours	3	21
Cumulative visitors since 1-1-63 (all tours)	-	2 753

Documented information flow during the month was comprised of 1,148 titles (11,069 copies) received at Hanford and 60 titles (5,230 copies) sent off-site.

A recently prepared picture booklet, in color, describing Hanford facilities and capabilities was used by a Hanford diversification group which visited Air Force installations early in December.

In response to an AEC-RLOO request to initiate an immediate and detailed review of classification and security practices, a Classification Review Committee has been appointed and a preliminary questionnaire has been developed and tested.

Professional Placement

Advanced Degree - Five Ph.D. applicants visited HAPO for employment interviews. One offer was extended; one acceptance was received; no rejections were received. Two offers are currently open.

BS/MS (Direct Placement) - Six offers were extended. Four acceptances and four rejections were received. There is one offer currently open.

BS/MS (Program) - Fifty-eight offers were extended. Eight acceptances and one rejection was received. Fifty-one offers are currently open.

Technical Graduate Program - Two Technical Graduates were placed on permanent assignment. Four new members were added to the roll and one terminated. Current Program members total 70.

FACILITIES ENGINEERING

At month end, Facilities Engineering Operation was responsible for nine active projects having total authorized funds in the amount of \$6,505,500. The total estimated cost of these projects is \$10,754,000. Expenditures on them through November 30, 1963 were \$1,761,067.

The following summarizes project activity in December:

Authorized projects at month end -----	9
New projects authorized -----	0
Projects completed -----	0
New projects submitted to the AEC -----	0
New projects awaiting AEC approval -----	1
CAH-114, Critical Mass Laboratory Addition	
Project proposals being prepared -----	7
CAH-123, Laboratory Fire Protection System	
Waste Transport System	
Heat Transfer Apparatus for Model Studies	
Modifications to 5201 Building	
141-M Building Addition	
Geological and Hydrological Wells - FY 1964	
Atmospheric Physics Building	

The status of active projects follows:

CAH-916 - Fuels Recycle Pilot Plant - Construction is 25 percent complete compared to a scheduled 21 percent. Work is still primarily confined to construction of the concrete building, imbedded process piping and ventilation system. Approximately 3,400 cubic yards of concrete have been placed, but the present cold weather is slowing down the concrete work.

CAH-922 - Burst Test Facility for Irradiated Zirconium Tubes - Construction is 91 percent complete compared to a scheduled 97 percent. Procurement by the Company is completed. The five containment vessels were received from the vendor on December 10, 1963, and the instrument panel arrived on December 16, 1963. Late delivery of these items has been delaying construction progress. A jurisdictional dispute in the J. A. Jones Company shops is delaying rework of the containment vessels.

CAH-962 - Low Level Radiochemistry Building - The Commission and Architect-Engineer brought the A-E's completed detailed design package to the Company for a cursory review on December 10, 1963. This was the third submittal of the final design. The review revealed a need for amplification of the mechanical and instrument design. The A-E submitted the revised drawings for approval on December 17, 1963.

The project proposal revision, requesting total project funds, is being routed through RLOO-AEC in an attempt to obtain local approval this week.

CAH-977 - Facilities for Radioactive Inhalation Studies - The Company approved the Architect-Engineer's drawings and specifications as meeting the design criteria. The Commission is preparing a final set of drawings for transmittal to the Company.

The Company submitted "Special Conditions" information to the Commission for incorporation in the construction bid package.

CAH-982 - Addition to Radionuclide Facilities, 141-C Building - The Company reviewed the Architect-Engineer's drawings and specifications and discussed our comments with the Commission on December 17, 1963, preparatory to the Commission's presentation to the A-E on December 18, 1963. The A-E is revising the drawings to incorporate the comments.

CGH-999 - Plutonium Recycle Critical Facility Conversion to Light Water -

Construction is 90 percent complete compared to a scheduled 91 percent. Installation of new components is almost complete. Component and circuit testing is under way.

Fabrication of fuel followers for the control rods by Hanford Laboratories has not been successfully accomplished. If the followers are not ready by January 15, 1964, it may be necessary to list them as an exception to completion on the directive completion date of January 30, 1964.

CAH-100 - High Temperature Lattice Test Reactor - The Title I design package was issued by Vitro Engineering Corporation on December 21, 1963. No design schedule has been established.

CAH-114 - Critical Mass Laboratory Addition - The project proposal requesting design funds was approved by RLOO-AEC. The proposal is to be transmitted to Washington accompanied by a letter recommending authorization of the project.

CAH-116 - PRTR Decontamination and D₂O Cleanup Facilities - Vitro Engineering Corporation issued a design schedule to the Commission for approval on December 9, 1963. The schedule indicated Title I design will start December 16, 1963 and be completed January 30, 1964, and detailed design will start February 15, 1964 and be completed May 1, 1964.

CAH-119 - PRTR Storage Basin and Experimental Facilities Modifications - A Work Authority, dated November 27, 1963, authorized Vitro Engineering Corporation \$31,000 for performance of Title I and II design services. Design has not been started.

CAH-123 - Laboratory Fire Protection System - The project proposal is being rewritten and will be resubmitted to the Commission for approval.

Engineering Services

Engineering work was performed in support of design and construction on active projects, project proposals, preliminary planning and design criteria for new projects. Principal work items included: (1) field liaison, review of shop drawings and approval of submitted materials on CAH-916, FRPP; (2) review of A-E design on CAH-962, Low Level Radiochemistry Building; (3) review of A-E preliminary design and consultation with A-E on CAH-982, Radionuclide Facilities; (4) review of A-E preliminary design on CAH-100, HTLTR; (5) study of 327 building addition; (6) study of scope and design criteria for modifications to 5201 building; and (7) study of facilities for the split table assembly being transferred from KAPL.

Scope design and design criteria are being prepared for the Containment Systems Experiment. Discussions have been held with the J. A. Jones Company and with potential suppliers of the major equipment pieces.

Engineering and consulting work provided to research and development personnel included: (1) engineering assistance on experimental neutron spectrometer, 105-KE building; (2) study of feasibility of extending future waste disposal railroad spur to 324 building; (3) engineering assistance on high temperature gas loop, 314 building; (4) scope design for pressure bonding autoclave installation, 314 building; (5) engineering assistance on HTLTR mock-up; (6) operation and engineering of NPR charging machine modification to utilize magazine loader; (7) operation and modification of 108-F source handling equipment; (8) engineering and test work for installation of 20,000 psi pressure bonding autoclave; (9) ventilation study of 144-F

building; (10) engineering assistance on fast reactor concept study; (11) engineering on Waste Calcination Program; (12) engineering assistance on critical mass experiments; (13) assistance to HUPPO on engineering standards; (14) engineering of Biology transfer cart and hood; (15) engineering of instrumentation for control of hood atmosphere, 308 building; and (16) engineering assistance was provided to CPD for an audit of the 233 S ventilation system and consulting assistance on Project CAC-880 and CAC-121 instrument design.

Plant Engineering

Engineering service was provided on numerous maintenance and laboratory modification and improvement jobs. Major items were: (1) engineering of modifications to improve quality of compressed air supply to 308 building hoods; (2) engineering for installation of 325 building emergency electrical generator; (3) engineering of modifications to 325 building counting room air-conditioning system; and (4) engineering to adapt double filtration filter boxes for use in 325-B with activated charcoal media.

Pressure Systems

Specifications for a laboratory type high pressure (10,000 psig) gas station were reviewed.

The 3717 building gas system was reviewed and recommendations made for over pressure protection and operating safety.

Vibration studies were initiated on PRTR rupture loop piping.

The third-party inspector was conducted on inspection of the 314 building gas loop and reviewed x-rays of piping welds.

Facilities Operation

Costs for the month of November were \$200,931, which is 108.9 percent of the forecast for the month. Fiscal year costs for the first five months were 107 percent of the predicted. Again, maintenance costs are high. Apparently, landlord work is receiving a higher share of the maintenance work force than was anticipated based on past experience. Curtailment of unusual maintenance has been initiated as a control measure.

Criticality alarms were tested on December 31.

The following table summarizes waste disposal operations:

<u>Item</u>	<u>October</u>	<u>November</u>
Concrete waste barrels disposed to:		
300-N burial ground	0	0
300-Wye burial ground	4	4
200-W plutonium burial ground	0	0
Loadluggers of dry waste disposed from 325 Building to:		
300-N burial ground	0	0
300-Wye burial ground	2	3
200-W plutonium burial ground	1	0
Loadluggers of dry waste disposed from other 300 Area sites to:		
300-N burial ground	0	0
300-Wye burial ground	25	19
Crib waste volume (gallons)	380 000	400 000

In backfilling the 300-N burial ground, the AEC uranium barrels and about one-half of the last used trench have been covered. There are some miscellaneous pieces of equipment to be buried and the vertical barrels need to be backfilled and capped with concrete.

Five thousand gallons of off-standard liquid waste from the 321 building and 5,000 gallons of tanker decontaminating solution were disposed to the 216 BC trench. To date, 21,500 gallons of liquid waste have been disposed to the No. 2 trench. Total trench capacity is 270,000 gallons.

The high pressure air system at 308 building is being revised to supply 384 air to the process area for a period of several months when quantities of dry air required to complete experimental work will exceed the capacity of two Joy compressors in the 308 building. During this period, the Joy compressors will be in standby.

All roll-o-matic filters at 306 building are now operating on the pressure drop across the filters. These controllers were calibrated and appear to be working satisfactorily.

"B" unit freon compressor at 325 building has performed satisfactorily since overhaul on November 27. This unit was down on a scheduled outage December 24 for four hours to complete some modification of the gauge lines.

Drafting

The equivalent of 120 drawings were produced during the month for an average of 30 man-hours per drawing.

Major jobs in progress are: (1) high temperature gas loop; (2) HTLTR mock-up core; (3) plutonium powder processing line; (4) fast super pressure power reactor concept; (5) thoria processing line; (6) shielded inspection hood, 308; (7) rotating crystal spectrometer; (8) capacitor discharge test apparatus; (9) 309 building piping service drawings; (10) modifications to 309 chilled water system; and (11) hydrogen cooled fuel element. Work was also produced in support of engineering reported under previous sections of this report.

Activity during the month on construction work (J. A. Jones Company) being performed for Hanford Laboratories components is given below:

	<u>Unexpended Balance</u>
Orders outstanding beginning of month	\$269 448
Issued during the month (including suppl. and adj.)	126 373
J. A. Jones expenditures during month (includes C.O. cost)	138 612
Balance at month end	257 209
Orders closed during month	105 166

In addition, work on four maintenance work orders issued to plant forces and having a face value of \$14,032 was supervised.

Major nonproject jobs in progress during the month were: (1) feeder stalls and feeder troughs, 141-C; (2) building modifications and laboratory furniture, 141-H; (3) installation of vacuum pump, 108-F; (4) install hoods and modify ventilation system, 242-B; (5) install electrical bus and water filter, 306; (6) relocate small dynapak and install new dynapak, and renovate room 125, 308; (7) construct block addition for gas loop, construct office addition, install PRTR tube replacement mock-up and install HTLTR mock-up, 314; (8) construct roof enclosure, construct thoria laboratory in room 417, install emergency generator, modify room 520, install 440 V distribution panel and filters and exhaust ducts, construct high temperature labs and mezzanine offices, install floor tile in ceramics laboratory, enclose north entry to basement, enlarge men's restroom, and construct retaining wall, 325; (9) install lighting, 3717-B; (10) enclose mock-up area, 309; and (11) fabricate waste calcination equipment, 324.

Five requisitions were issued during the month totaling \$1,300. Total value of equipment being processed is \$15,300.

W Sale
Manager
Finance and Administration

W Sale:JVM:whm

REACTOR DEVELOPMENT - O4 PROGRAMPLUTONIUM RECYCLE PROGRAMPlutonium Recycle Test ReactorOperation

Reactor output for December was 1404 MWD, for an experimental time efficiency of 77.7% and a plant efficiency of 64.7%. There were fourteen operating periods during the month. Seven of these were terminated manually as follows: three due to excessive helium leakage, one to investigate "leaker element" indications, one due to a malfunction of the S-60 valve, one due to excessive leakage out of the rupture loop, and one due to a ventilation unbalance. Seven operating periods were terminated by scrams as follows: one by a spurious flow monitor trip, four while switching from automatic to manual control, one by a ΔP trip on the rupture loop, and one due to the failure of a flow monitor. A summary of the fuel irradiation program as of December 31, 1963, follows:

	<u>Al-Pu</u>		<u>UO₂</u>		<u>PuO₂-UO₂</u>		<u>Other</u>		<u>Program Totals</u>	
	<u>No.</u>	<u>MWD</u>	<u>No.</u>	<u>MWD</u>	<u>No.</u>	<u>MWD</u>	<u>No.</u>	<u>MWD</u>	<u>No.</u>	<u>MWD</u>
In-Core	6	516.7	1	233.7	78	8675.3			85	9425.7
Maximum		99.5		233.7		198.4				
Average		86.1		233.7		111.2				
In-Basin	37	3157.5	31	3603.8	17	426.4			85	7187.7
Buried							1	7.3	1	7.3
Chem. Proces.	32	2309.3	35	1965.8	—	—	—	—	67	4275.1
Program										
Totals	75	5983.5	67	5003.3	95	9101.7	1	7.3	238	20895.8

Note: (MWD/Element) X 20 $\approx$ MWD/TU for UO₂ and PuO₂-UO₂.

D₂O and indicated helium losses for December were 705 pounds and 140,709 scf, respectively.

Equipment Experience

A total of 80 reactor outage hours was charged to repair work. Main items were:

HX-5	31 hours
Valves	14 hours
Rupture Loop equipment	13 hours

Examination of the multitube rupture detection heat exchanger (HX-5) which developed a leak last month has revealed fretting corrosion between the tube and end support baffle. An 18-inch section of the tube containing the failed area was removed. Two four-inch access ports were provided to allow visual examination of the area where the tube failure occurred.

Reactor control through use of the automatic controller continued during the month. Approximately 440 hours of control including 40 hours uninterrupted service were accomplished.

An ion exchange system for providing demineralized water for the PRTR storage basin was completed and demonstrated. This will provide much improved viewing during fuel element examination and repair activities.

Preventive maintenance required 393 hours or 7% of the total maintenance effort.

Improvement Work Status (Significant Items)

Work Completed

Circuit Modification to Increase Scale of Effluent Monitors
Galvanometer Shunt Replacement

Work Partially Completed

Modification for Reuse of Damaged Nozzle Caps
In-Line Gas Sampling
Process Tubes Level Indicator
Inlet Gas Seal Replacement
125 Volt Battery Disconnect Contactor
Shim Rod Shroud to Top Cap Modification
Improved RTD Connector Sealant and Bracing
Instrument Power Transfer System
Installation of New Alarm Annunciator
Flow Monitor Tubing Snubber Installation
Indication of DC Solenoid Failure

Design Work Completed

Boiler Feedwater Pressure Transmitter Snubber
Battery Power for Galvanometer Light

Design Work Partially Completed

Additional Fuel Storage and Examination Facility
Vibration Snubbers for Earthquake Protection

Decontamination Building and D₂O Cleanup Facility
Flux Wire Scanning System
Supplemental Emergency Water Addition
Permanent Installation of Closed Circuit TV
Rupture Monitoring System Modifications
PRTR Increased Power Level
Containment Valve By-Pass for Sump Pumpout Lines

Process Engineering and Reactor Physics

An informal document, HW-79929, the Effect of Primary Coolant Degradation on Core Reactivity in PRTR, was issued.

A document, HW-80027, has been issued outlining proposed revisions of the PRTR process water system.

The failed cone was removed from the secondary system deaerator. The sulfite addition lines were also revised to provide better sulfite distribution. Additional sampling is scheduled to determine adequacy of sulfite mixing following these revisions.

PRTR Test No. 71 was completed, in which it was established that control of HX-1 below the pH-phosphate curve is feasible. Operating instructions and specifications for continuous use of monosodium phosphate addition are being prepared.

Procedures

Operating Procedures issued	1
Revised Operating Procedures issued	2
Revised Operating Standards issued	7
Temporary Deviations to Operating Standards issued	6

Drawing As-Built Status:	<u>December</u>	<u>Total</u>
Approved for As-Built	121	1 181
In Drafting	4	22
In Approval	(2)	1
Deleted or Voided		81
		<u>1 285</u>
Scheduled for Review		217
		<u>1 502</u>

	<u>ManHours</u>
Personnel Training:	
Qualification subjects	36
Specifications, Standards, Procedures	54
Emergency Procedures	8
Automatic Controller	32
Maintenance Procedures	36
	<u>166</u>
Status of Qualified Personnel at Month-End:	
Qualified Reactor Engineers	9
Qualified Lead Technicians	6
Qualified Technicians	17
Provisionally Qualified Technicians	1

Nuclear Safety Specification K-8 covering the experimental EBWR fuel element to be irradiated in the PRTR was approved and issued during the month.

Experimental Reactor Services

The status of the various test elements at the end of December 1963, is shown below. Those elements which had reached their assigned goal exposure or had been permanently discharged for other reasons prior to December 1, 1963, have been deleted from the table.

Test Channel No.	F.E. Location	F.E. Number	Description	Date Initial Charge	Dis-charged	Approximate Accumulated MWD	
14	1956	5097	Moxtyl-Swaged	4/2/62	--	122.9	Repad
14	1352	5098	Moxtyl-Vipac	5/8/62	--	198.4	Repad
14	1758	5099	Moxtyl-Vipac	5/8/62	--	141.9	Repad
48	1156	5150	Moxtyl ($\frac{1}{2}$ " x $\frac{1}{2}$ " Pads)	8/1/62	--	139.4	
47	1649	5121	Unautoclaved LX Pu-Al	6/13/63	--	90.9	
47	1552	5194	Unautoclaved LX Pu-Al	7/6/63	--	85.0	
47	1449	5193	Unautoclaved LX-Pu-Al	7/6/63	--	84.3	
54	1542	5116	Moxtyl (Clip-On Pads)	5/8/62	--	140.6	
54	1554	5118	Moxtyl (Clip-On Pads)	5/8/62	--	198.3	
61	1249	5185	Moxtyl-Physics	5/28/63	--	107.8	
61	1354	5186	Moxtyl-Physics	5/28/63	--	100.8	
61	1556	5192	Moxtyl-Physics	6/13/63	--	107.5	
67	1152	5119	Moxtyl (Repaired Wire)	10/20/63	--	41.9	
67	1457	5117	Moxtyl (Repaired Wire)	10/20/63	--	84.8	
80	Basin	5210	Moxtyl (1% PuO ₂ , Swaged)	11/8/63	12/27/63	26.5	
80	Basin	5211	Moxtyl (1% PuO ₂ , Swaged)	11/8/63	12/27/63	23.5	
80	1253	5212	Moxtyl (1% PuO ₂ , Swaged)	11/11/63	--	29.2	
80	1544	5213	Moxtyl (1% PuO ₂ , Swaged)	11/11/63	--	28.6	
80	1847	5214	Moxtyl (1% PuO ₂ , Swaged)	11/18/63	--	23.4	

Two 1.0% Moxtyl fuel elements failed during the month and were removed from the reactor.

The Fuel Element Examination Facility is temporarily out of service. Until necessary FEEF repairs are completed, fuel element inspection will be done in the basin.

A total of 22 fuel elements were examined in the basin during the month, nine of which are UO_2 fuel elements for the physics irradiation program. Three of the 22 elements were rejected - two for broken wire wraps and one for a split rod.

Plutonium Recycle Critical Facility

Project work (CGH-999, conversion of facility to H_2O moderator) was completed with minor exceptions.

All qualified personnel participated in a four-day seminar of training for H_2O experiments. Subjects included electrical and mechanical descriptions of the modified PRCF, Process Specifications, Test Descriptions, selected Operating Procedures, and data taking practices.

Fuel Element Rupture Testing Facility

FERTF Test 2-B, operation with a new Moxtyl element was completed. FERTF Test 4, irradiation of a Pu-Al leaker, was begun and is in progress at month-end.

Vibration in the low pressure portion of the loop caused failure of a sample line connection. This has been replaced with a vibration absorbing connector.

TECHNICAL SHOPS OPERATION

Total productive time for the period was 21,176 hours. This includes 12,998 hours performed in Technical Shops, 5,575 hours assigned to J. A. Jones Company, 2,586 hours assigned to offsite vendors, and 17 hours to other project shops. Total shop backlog is 16,826 hours, of which 90% is required in the current month with the remainder distributed over a three-month period. Overtime worked during the month totaled 266 hours or 1.4% of the total available hours.

Distribution of time was as follows:

	<u>Man Hours</u>	<u>% of Total</u>
N Reactor Department	2 078	9.8
Irradiation Processing Department	5 778	27.3
Chemical Processing Department	398	1.9
Hanford Laboratories	12 922	61.0

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LABORATORY MAINTENANCE OPERATION

Total productive time was 17,400 hours of 19,000 potentially available. Of the total productive time, 91.1% was expended in support of Hanford Laboratories components, with the remaining 8.9% directed toward providing service for other HAPO organizations. Manpower utilization for December was as follows:

A. Shop Work	2000 hours
B. Maintenance	6600 hours
1. Preventive Maintenance	1600 hours
2. Emergency or Unscheduled Maintenance	1500 hours
3. Normal Scheduled Maintenance	3500 hours
C. R&D Assistance	8800 hours

Manager
Test Reactor and Auxiliaries

WD Richmond

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.

<u>INVENTOR</u>	<u>TITLE OF INVENTION OR DISCOVERY</u>
A. J. Karnie and R. A. Harvey	Remote Displacement Measurement (HW-79780) December 3, 1963. HWIR-1677.
M. F. Scoggins	Air Sampling Techniques - Automatic Sample Changer (HWIR-1676)
L. L. Azure and J. T. Russell	Remote Displacement Measurements (HWIR-1677)
R. H. Moore	A Pyrometallurgical Process for Separation of Po-210 and Bismuth (HW-79816)

for Manager, Hanford Laboratories

END

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