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HANFORD LABORATORIES

MONTHLY ACTIVITIES REPORT

JULY 1964

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AUGUST 14, 1964

HANFORD ATOMIC PRODUCTS OPERATION

RICHLAND, WASHINGTON

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HANFORD LABORATORIES
MONTHLY ACTIVITIES REPORT
JULY 1964

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By Authority of CG-PB-2
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Compiled by
Section Managers

August 14, 1964

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: July 31, 1964

	<u>At Beginning of Month</u>		<u>At Close of Month</u>		<u>Total</u>
	<u>Exempt</u>	<u>Salaried</u>	<u>Exempt</u>	<u>Salaried</u>	
Chemical Laboratory	158	125	158	126	284
Reactor & Fuels Laboratory	215	200	215	204	419
Physics & Instruments Laboratory	128	78	129	78	207
Biology Laboratory	46	67	46	65	111
Applied Mathematics Operation	21	6	19	6	25
Radiation Protection Operation	43	87	42	86	128
Finance & Administration Operation	131	119	127	116	243
Programming Operation	23	5	24	6	30
Test Reactor & Auxiliaries Operation	59	312	60	311	371
General	<u>3</u>	<u>5</u>	<u>3</u>	<u>5</u>	<u>8</u>
TOTAL	<u>827</u>	<u>1004</u>	<u>823</u>	<u>1003</u>	<u>1826</u>

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BUDGET AND COST SUMMARY

July operating costs totaled \$2,641,000, or 8% of the \$34,559,000 tentative control budget for FY 1965.

Hanford Laboratories' research and development costs for July, compared with the tentative control budget, are shown below:

<u>(Dollars in thousands)</u>	<u>July Costs</u>	<u>Budget</u>	<u>% Spent</u>
<u>HL Programs</u>			
02	\$ 52	\$ 542	10%
03	--	---	--
04	1 092	15 620	7
05	118	1 444	8
06	308	3 570	9
07	1	---	--
08	<u>39</u>	<u>290</u>	<u>13</u>
	1 610	21 466	8
<u>Sponsored by</u>			
NRD	157	1 643	10
IPD	25	450	6
CPD	<u>203</u>	<u>2 277</u>	<u>9</u>
Total	\$1 995	\$25 836	8%

RESEARCH AND DEVELOPMENT1. Reactor and Fuels

A fuel failure detected in N-Reactor on July 7 was caused by a longitudinal extrusion defect on the inside surface of one end cap on an inner fuel component. This defect was apparently covered by a thin layer of braze material during autoclaving.

Initial experiments indicate that an "Aquadag" mixture applied to the core will prevent bonding during coextruding Al and Li-Al at high reduction ratios.

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Three tubular Zircaloy clad metallic thorium-uranium fuel elements have been irradiated to over 8000 Mwd/ton in the ETR. At that exposure the measured volume increase was only 0.8%.

The effects of stress on the orientation of hydride platelets in Zircaloy-2 were confirmed on N-Reactor pressure tubing. A section of tubing containing 90 ppm hydrogen was allowed to cool slowly from over 300 C (572 F) at hoop stress levels of 0 psi, 10,000 psi, and 25,000 psi. The hydride pattern of the zero stress specimen was essentially unchanged at 10,000 psi but in the 25,000 psi specimen a significant number of hydride platelets were oriented in the undesirable radial direction.

Tests using an electrically heated mock-up of an N-Reactor fuel tube and fittings indicated the reactor would be shut down soon enough to prevent fuel melting even if the inlet butterfly valve were to close following a rupture of an inlet hydraulic connector.

The first discharge of fuel elements from N-Reactor were covered with a reddish-brown crud film indicative of no unusual corrosion or hot spot problems. Examination in Radiometallurgy showed the crud film to be very thin (about 0.1 mil), translucent, and loose enough to be easily removed by rubbing with a cotton glove.

Calculations were made of the time it would take the water to boil out of a reactor tube filled with thoria elements after a water-loss accident.

Long term irradiation testing of N-Reactor and EGCR graphites are continuing.

The calorimeter for graphite total stored energy determinations is in operation with standardization runs nearly completed.

A three-factor variance analysis of radiation-induced-graphite-contraction data as related to filler particle size and impregnation treatment was made. This analysis showed a strong two-factor interaction between particle size and exposure and one of less importance between impregnation treatment and particle size.

A newly designed N-Reactor capsule that provides for creep testing of three graphite specimens is operating satisfactorily in the ETR. The study of the kinetics of the reaction of carbon dioxide and hydrogen has indicated transition in reactor mechanism occurring at about 800 C.

Formulation of technical design criteria for the PRTR high power density core is in progress.

The final test in C-1 Loop of the corrosion of aluminum-clad fuel elements was discharged after 58 days at 250-260 C outlet water temperature and pH 4.5 with H_3PO_4 . This completes testing in C-1 Loop under the Aluminum Corrosion and Alloy Development Program.

Experiments were continued to develop a correlation of critical flow of steam-water mixtures through pipes with elbows at the discharge ends. At low pressures and qualities, the critical pressures were lower than predicted from tests with straight pipe.

In the investigation of upstream boiling burnout, changing the inlet piping in the flow apparatus to eliminate sharp elbows and remove dead legs increased the burnout heat fluxes by as much as 2.7 times. This was attributed to the greatly reduced pressure oscillations that resulted.

Studies were initiated to determine adaptability of the MTR to a full core Phoenix burnup experiment.

The descaling method developed for removal of oxide scale from iron and nickel base alloys has been successfully modified for use for molybdenum and molybdenum-base alloys.

Construction of the model gas loop was completed during the first week in July, 1964. Integrity of the loop was assured when no leaks could be found by ultrasonic leak detection methods.

A sample of Haynes 25 (a structural metal for the ATR gas loop) has been exposed three days to 0.1 Torr oxygen at 1200 C (2192 F) without catastrophic oxidation.

Strain rate tests on vacuum-melted iron and zone-refined iron irradiated to approximately 1×10^{18} nvt show that the flow mechanism below

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200 K is not affected by irradiation. The flow behavior at room temperature, however, is markedly influenced by irradiation.

An in-reactor creep test on annealed AISI 304 stainless steel at 600 C (1112 F) and 20,000 psi has been started. The in-reactor creep rate appears to decrease with time more than the control test creep rate.

Specimens of high-purity uranium, U + Fe - Al and U + Fe - Si, were recovered from two general swelling capsules. The behavior of the U + Fe - Al was superior to that of the U + Fe - Si that was in turn superior to that of the high-purity uranium.

Electron microscopy studies of Inconel 600 tensile specimens irradiated at 740 C (1364 F) to an exposure of 9×10^{20} nvt showed that much of the precipitate had formed during the irradiation. More important was the finding of pores in the matrix of the irradiated material. Further study and improved technique of replicating the alloy structure will be required to determine the nature and effect of these microstructural changes.

Uranium has been successfully thinned for transmission electron microscopy. Dislocation networks, second-phase particles, and substructure were revealed.

The first of a series of controlled pressure-temperature swelling capsules was constructed, successfully bench-tested to 525 C (977 F) at 1600 psi, and shipped to the reactor for charging.

It has been established that freshly prepared castings of LASL high-purity electro-refined plutonium can be successfully alpha-rolled from thicknesses significantly greater than those found possible with the conventional material.

The beta-to-alpha transformation in plutonium has been investigated in detail between 0 and -196 C (32 and -310 F). The data from these experiments confirm that the T-T-T curves for the beta-to-alpha transformation do have a "c" shape, in agreement with published work, and that rapid removal of heat from the specimen does not necessarily result in rapid transformation.

Foils of annealed high-purity, carbon-doped molybdenum irradiated to 10^{20} nvt (fast), and foils of high-purity molybdenum that were deformed before irradiation to 5×10^{18} nvt are being examined by X-ray techniques. Preliminary results indicate a slightly smaller lattice parameter increase for the deformed specimens than for the annealed samples.

A new fuel loading tool being used in the Vipac process reduces the cost of fuel fabrication significantly.

Finer grinding and better control of the O/U ratio has increased the particle density of impacted $\text{UO}_2\text{-PuO}_2$. Four hundred forty kilograms of mixed oxide were impacted during the month.

Improved autoradiographic techniques show comparable plutonium distribution in impacted ball milled $\text{UO}_2\text{-PuO}_2$ and in coprecipitated $(\text{U, Pu})\text{O}_2$.

Physics test quantities of 20 wt% Pu-Al disks 0.020 in. thick have been fabricated inexpensively and to close tolerances by the recently developed "spiral machining" process.

Prototypic fuel for the EBWR $\text{PuO}_2\text{-UO}_2$ loading has been irradiated to an exposure of 2.4×10^{20} fissions/cm³.

A MK-IX-B inverted cluster fuel element was successfully irradiated more than 100 full-power hours in the PRTR-FERTF. Components for an inverted cluster fuel element using dummy spike rods inserted into the coolant channels have been prepared.

Metallographic examination of an UN-20% PuN irradiation test capsule with an average calculated burrup of 2.5×10^{20} fissions/cm³ (~ 9400 Mwd/ton) revealed a central void and three structural zones.

A small wafer of PuN-5 vol% Pu was heated to 2200 C under argon with no apparent formation of free molten plutonium.

The possible existence of the defect compound $\text{Pu}_2\text{O}_3 \pm x$ is under study.

Hypostoichiometric UO_2 with L-U ratios less than 1.95 can readily be produced by heating UO_2 and uranium metal together above 2100 C.

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Visual examination of a small PuN-50 vol% W wafer irradiated to a calculated average burnup of 20×10^{20} fissions/cm³ revealed no cracks.

A thoria element containing 680 ppm NO₃⁻ added as Th(NO₃)₄ · 12 H₂O was successfully irradiated for one MTR cycle to evaluate the effect of the nitrate ion and the chemically combined water on corrosion of the X8001 aluminum cladding. An element containing Hanford processed Sol-Gel thoria was successfully irradiated for two MTR cycles.

Highly loaded (70 wt% UO₂) graphite-UO₂ pellets were fabricated for physicstests.

Marked reduction of fuel loss during thermal cycling of UO₂-W cermet has been achieved by hydrogen heat treatment of components before and after impaction fabrication. Initial tests of cermet containing W-coated UO₂ particles were encouraging.

Using molybdenum mandrels for the first time, a 20 vol% UO₂-W honeycomb grid (2.5 in. diameter, 1/8 in. hexagonal) was successfully coated with vapor deposited tungsten by an off-site vendor.

An integral hexagonal honeycomb cermet grid and surrounding thin tungsten cylinder was fabricated by pneumatic impaction. This shape conforms with advanced NASA fuel element designs.

Fabrication of the million-ampere welder is proceeding according to schedule in that mechanical design is 90% complete and electrical design is 75% complete.

Pyrolytic carbon coated UC₂ particles for electron microscopy studies were embedded in dense tantalum, niobium, and rhenium metal matrices by pneumatic impaction. Time lapse motion pictures were taken of these particles at high temperature in the microscope.

In the design of a W-UO₂ fuel element for NASA, a method of fabricating a fueled grid from rolled fuel plates has been developed. Two unfueled tungsten models are being fabricated.

In the development of extruded tungsten honeycombs, direct extrusion of unsintered tungsten powders and W-UO₂ powders has been demonstrated.

Direct extrusion, without the use of sintering, produced components at full theoretical density with smooth interfaces between the tungsten and sacrificial molybdenum components.

A program for fabrication and evaluation of tungsten-technetium alloys has been started. Eight hundred and four grams of purified technetium metal powder were prepared by the Chemical Laboratory. Two 40 g buttons of technetium metal were then prepared by inert arc melting. The resulting metal is being evaluated by chemical analysis and metallography.

2. Physics and Instruments

The physics fuel cycle analysis for Phase III operation (power only) of the N-Reactor is continuing. Basic parameters for the enriched ThO_2 cycle calculations have been selected. The enriched UO_2 calculations have also been started.

An experiment has been completed in the PCTR in support of the irradiation of thulium oxide in IPD for the Boeing Company. Tm^{170} produced by neutron capture in naturally occurring Tm^{169} is a beta emitter with a half-life of 129 days, and is being considered as an isotope heat source.

Analog simulation studies of the N-Reactor system continued with analysis of surge tanks designed for the secondary loop. Assistance was given the N-Reactor task force on control system adequacy at high power levels. Information on frequency response is being obtained, both in the reactor and in the N-Reactor simulation studies.

Analog computer studies were made in support of N-Reactor hazards review to further evaluate the effect of cold water injected into the reactor coolant channels.

Favorable results were obtained with the prototype X-ray fluorescence tester in detecting contamination on N-Reactor fuel end closures. The electronic equipment has been improved by the installation of transistor count rate meters, and a reject circuit has been developed.

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Thirty irradiated inner N-Reactor fuel elements were tested. Eleven percent had core cracking at the fuel ends. Rough handling, duplicated by dropping, did not cause cracking. No evidence of unbonding has been detected.

A three-parameter optimization of an algebraic system using random variations was adapted to the new analog computer. The problem requires unconventional memory circuits that ideally suit this instrument.

The feasibility of ultrasonically measuring laminations in B-Al splines has been demonstrated. Application of the test at the supplier's plant as well as at Hanford appears feasible. There is incentive to develop additional tests for boron concentration, carbide dispersion, work hardening, and other properties.

The resin level detectors have been installed in the 202A Building. Trouble during checkout has been experienced with the ultrasonic detectors. Glass and stainless steel transducer faces are being examined along with a stainless steel wire mesh to rid the surface of bubbles.

Criticality experiments continued with $\text{Pu}(\text{NO}_3)_4$ solutions in an unreflected sphere of 15.2 in. diameter. The effects of proximate reflectors and the stainless steel vessel wall were investigated. The critical concentration in the unreflected sphere was 40.1 g plutonium/liter, and the critical buckling was $21.820 \pm 500 \mu\text{B}$.

Analyses of recent data from homogeneous PuO_2 -polystyrene assemblies having an H/Pu atomic ratio of 15 have given a value for the critical mass of a water-reflected sphere that is ~60% larger than the previous best estimates. It thus appears that curves of critical mass and dimensions for plutonium will be considerably revised in the region of low moderation, $0 < H/X < 20$, as a result of these experiments.

SMC, a Monte Carlo code for spherical geometry, was successfully used to compute the critical radius of a bare sphere of δ phase plutonium metal. The result provides a checkpoint for the code on a fast system. The code will now be applied to the plutonium solution systems under study.

Modifications to the 105-KE tripple-axis neutron spectrometer have been completed and the spectrometer realigned for inelastic scattering measurements. The base mounts of the monochromating section of the spectrometer system for time-of-flight measurements of inelastic scattering have been installed adjacent to the triple-axis spectrometer.

Preliminary measurements have been made of the slow-neutron inelastic scattering from polystyrene.

The results of isotopic analyses of a NBS isotopic standard of plutonium were completed and reported.

A model PDP-5 digital computer was obtained for the development of a process control and data reduction system for a mass spectrometer.

Burnup data have been obtained from four UO_2 fuel elements irradiated in the PRTR to exposures varying from 39.2 to 149.8 Mwd. These data are first being evaluated for consistency and will then be used in checking burnup calculational methods.

In an attempt to gain a better understanding of plutonium-fueled light water, reactor systems, a study of several PuO_2 - UO_2 light water lattices under a variety of reactor conditions has been undertaken. Multiplication constants and temperature, Doppler, and void coefficients were determined.

Evaluation of the MTR as a test facility for a Phoenix fuel demonstration experiment progressed through the correlation of reactor analysis methods with experimental data from the 1958 MTR plutonium loading. These methods will be used in predicting the nuclear behavior of a Phoenix fuel burnup study.

A major phase of the EBWR plutonium program was completed during the month. Critical mass and buckling measurements have been made for six fuel-to-moderator ratios covering a range pertinent to both boiling and pressurized water reactors. Experiments will continue in the PRCF using approximately 500 nonpower reactor grade rods. The rods for the EBWR are now being prepared for shipment to ANL.

Estimates of potential corrosion of the HTLTR graphite stack by gaseous impurities from the insulating materials have been made. The

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diatomaceous earth is one order of magnitude more corrosive than other sources, and is sufficiently large that the Laboratories is recommending that this material not be used. The worst potential problem is transport of graphite into the heat exchanger and filter. Several methods of alleviating these potential problems have been suggested to Vitro.

Surface fatigue was detected in three metal samples by ultrasonic critical angle tests. Preliminary results seem to show promise of detecting metal structure changes before crack initiation. Fatigue areas in the prepared stainless steel samples were also detected by specially developed eddy current tests.

An infrared method for measuring the heat output of isotope containment cells is being developed. Prototype cells were inspected with ultrasound and radiography. Difficulty was experienced in applying the ultrasonic tests to cells jacketed with Inconel, this was presumably caused by large grains in the cladding material. An ultrasonic test station is being designed for use in hot cells.

An analog simulation of the High Temperature Gas Loop being fabricated in the 314 Building was completed and tested. The simulation, which includes all major components of the gas loop, uses four commercial controllers permitting operating personnel to become thoroughly familiar with the control of the system.

An additional test of the PRTR reactor noise was completed. Variations in the moderator level and flux level were recorded on tape while the reactor power level was held constant. The data are expected to yield neutron lifetime information.

A sensitivity of 10 MPC-hr for airborne Pu^{239} contamination is being achieved with the alpha energy analysis air monitor. The system is in use in the Biology Inhalation Toxicology Laboratory.

Canines are being scanned more reliably for delineation of in vivo radionuclides by using a new scanner-drive mechanism. The new mechanism provides reliable scanning at selected rates up to 10 in./min, ten times that normally used.

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Fabrication and testing is essentially completed on a scintillation detection and solid state circuitry gamma monitor for conducting ground contamination surveys from airplanes.

Preliminary data from whole body counting of Eskimos at Anaktuvuk Pass indicate Cs^{137} body burdens have doubled since March. Preliminary results with a 3 in. NaI crystal located at the groin (with the upper body bending over it) show promise as an inexpensive and portable method of determining whole body burdens of Cs^{137} .

A shielded facility for the pulsed X-ray machine was completed and tested.

Another excellent information exchange and field workshop on advanced devices for measuring atmospheric turbulence was held at Hanford on July 14-17 in cooperation with the University of Washington. Devices compared included the improved wind component meter, the University hot-wire anemometer, and sonic anemometer systems. Methods of data analysis were extensively discussed.

Leak testing of the underground export water lines has been accomplished between the 100-D and 100 F areas. The lines were accurately located with a new version of the metal finder, then searched for leaks with the aid of sound measurements. Many leaks were found in valves and fittings attached to the line, no leaks in the line itself.

Representative samples of Inconel tubes, used in retubing the defective steam generator at N-Reactor have been given a careful inspection with ultrasonics, eddy currents, fluorescent penetrant, and metallographic methods. All defect indications were verified as minor amounts of impressed metal or stringers open to the surface.

Instrument engineering assistance now includes automatic voltage control in the plutonium metallurgy sputtering process. Circuits have been developed to control the process, automatically interrupting and restarting the metal deposition upon incipient arc-overs. Results are promising.

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3. Chemistry

A first trial of a nondestructive test to distinguish between "transformed" and "untransformed" uranium metal fuel cores was successful. The surface roughness determination depends on a light anodic etch.

Plate adherence tests on hot-die-sized nickel-plated uranium specimens prepared with the new H_2SO_4 -HCl anodic etch pretreatment have shown adherences equal to those obtained with standard surface preparation procedure.

The "reactivity" of uranium metal to several nickel plating baths was measured. The results (lower reactivity to bromide baths than to those containing chloride) give further confirmation of the superiority of the bromide plating baths.

Pressurization studies on a zeolite storage cartridge loaded with fission product strontium have been resumed. Thus far, equipment problems have interfered with interpretation of the data.

Hydrogen reduction of ammonium pertechnetate to technetium metal powder (800 g) was completed and the product delivered to our metallurgy development group.

Pa^{233} scavenging studies (by carrier precipitation) have been started in Purex type, acid-deficient thorium feeds and have shown disappointingly low decontamination factors.

Test runs on the use of compact-band chromatographic ion exchange for the recovery of americium from Hanford Plutonium Reclamation Facility wastes have been very encouraging, with good separation achieved from iron, nickel, chromium, thorium, and plutonium.

Recent attempts to measure the vapor pressure of bismuth oxide have been unsuccessful because of extremely low transport of the oxide under our experimental conditions.

Laboratory and hot-cell measurements were made of the radiation tolerance of a number of Soltrol-type diluents that might be used in the Strontium Semiworks. A relatively inexpensive, commercially available solvent was found to be nearly as good as n-dodecane.

Attempts to prepare and measure the spectra of various uranium(V) compounds have continued in an effort to verify previous conclusions that species such as UOCl_3 had been produced in molten salt media. These efforts have been only partly successful.

Most of the equipment for the Hot Cell Glass Experiment has been received and shakedown testing is proceeding.

An amine extraction procedure for the separation of uranium and thorium from tissue samples has been tested and improved so as to give uranium recoveries of 86.5%.

Na^{24} from cosmic ray spallation of the A^{40} in the atmosphere was successfully measured in three rain samples collected on Rattlesnake Mountain. Through use of multidimensional analysis techniques, this work was done on much smaller samples than those used in the only previous similar study.

Travel times of the Columbia River were estimated from Na^{24} concentration changes during the peak flow period as 77.8 hr from Pasco to Vancouver (at 587,000 cfs) and 127 hr from Pasco to Astoria (at 656,000 cfs).

Surface constituents of red blood cells were selectively extracted with a series of isotonic saline solutions, the cells irradiated, and the cell hemolysis measured as a function of time. The more thoroughly washed cells hemolyzed more rapidly, indicating the removal from the cells of some constituent that affected their radiation sensitivity.

A high capacity cartridge containing a mixture of stainless steel nozzle plates and fluorothene sieve plates for the Purex 1BX (partitioning) column was developed. Pilot plant tests demonstrated a nearly 50% improvement in capacity over the cartridge now used in the plant.

Six simulated isotopic heat sources (2-1/2 in. -diameter, spherical) were produced by pneumatic impaction. Compacted densities from 82 to 90% of theoretical were obtained with strontium titanate; corresponding values for samarium oxide were 98 to 100%.

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Bench scale testing of in-tank solidification of coating wastes by immersion heating was completed: either in or out of a gamma radiation field, no significant scale deposition occurred after 2000 hr.

A vitreous carbon crucible was shown to have potential application in the Salt Cycle process. It contained molten equimolar NaCl-KCl at 900 C in air for 44 hr without noticeable leakage or oxidation.

If suspended by vigorous agitation, Mallinckrodt-prepared sol gel thoria was found to dissolve rapidly in $12M$ HNO_3 - $0.025M$ HF - $0.1M$ $Al(NO_3)_3$. One molar dissolved thorium was attained in about 1 hr.

Simultaneous feeding of spray calciner waste (plus additives to promote glass formation) to a continuous melter was tested with (1) Purex 1WW calcine and phosphate, and (2) Redox calcine and borate feeds. Melter performance was, in general, smoother than that with previously tested single feeds.

Modification of the semiworks spray calciner to more nearly simulate the prototype WSEP calciner were completed. A 50 hr run of the combined spray calciner-melter was started.

Tests of various materials to remove elemental iodine and particles from air were made in connection with CSE work. Results of studies employing fine mesh Ag-Cu screens indicated that several layers would be needed to obtain high removal efficiencies. A specially prepared silver colloid paper showed good elemental iodine removal (about 99.7%) and will be studied further.

An initial exploratory program to evaluate the feasibility of aged high-level waste storage in deep basalt (bedrock) formations beneath the plant was estimated to cost about \$400,000. The exploration would consist of three 5000 ft rotary-drilled and cored wells, in-hole measurements, and core studies.

4. Biology

Ten weeks of monitoring young chinook salmon in reactor effluent showed 5, 6.6, 11.6, and 20.6% mortality for fish reared in 0, 2, 4, and

6% uncooled effluent, respectively. Fish reared in similar effluent concentrations, but cooled to river temperatures had 3.4 to 5% mortality-- not significantly different from controls.

First appearance of columnaris in the troughs of the 146 Building occurred in the middle of June, approximately 2 wk earlier than last year.

A malignant lymphoma was identified histologically in a 3-yr-old miniature swine that had been chronically fed $125 \mu\text{c Sr}^{90}$ per day. This is the first substantiated case of neoplastic disease in over 150 animals of this age or older maintained on the chronic Sr^{90} study.

A dog that died 51 mo after inhalation of $\text{Pu}^{239}\text{O}_2$ exhibited no neoplasia. A body burden of approximately $1 \mu\text{c}$ at death was distributed 50% in the lungs, 40% in the bronchial and mediastinal lymph nodes, 4% in the bone, and 3% in the liver. Four of seven dogs that have now died 3 to 4 yr after inhalation of $\text{Pu}^{239}\text{O}_2$ have shown pulmonary neoplasia.

X-irradiation of the abdominal region of the rat with 1500 r resulted in the loss via feces, during the third day postirradiation, of bile salts equivalent to about one-half the total body content. This supports earlier observations of a radiation induced defect in bile salt reabsorption in the small intestines.

Whole-body counting of Eskimos at Anaktuvuk Pass during July 1964 showed a marked rise in Cs^{137} body burdens as compared with similar data obtained one year earlier. Seasonal values for a group of 27 adult residents indicate that summer values tend to be higher than winter values.

5. Programming

A revision in the Hanford fuel cycle codes will permit simulation of required fuel management that involves varying degrees of burnup in different fueling regions.

Better simulation of existing plants, including the Hanford isotope plant, is now possible through a modification of the QUICK economic code. Fuel fabrication and separation costs may be entered as a fixed (\$/yr) and a variable (\$/unit wt) cost.

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TECHNICAL AND OTHER SERVICES

A Hanford Laboratories technician received a plutonium contaminated injury at approximately 2:10 p. m. on July 10, 1964 while working at the Plutonium Metallurgy Building (231- Z). The employee, assisted by a second employee, was performing an operation on a coupon of plutonium metal. As approximately 230,000 psi pressure was applied to the 1/2- x 1- x 0.053-in. coupon, the outer rim apparently shattered, scattering plutonium metal radially from the press. Two fragments penetrated the employee's upper left arm. One piece, which was visible, was removed at the 231-Z Building. Four excisions were made of the tissue around the wound. After the fourth excision, an estimated 0.3 μ c plutonium remained at the wound site. The open wound was then washed with 4 liters of normal saline solution containing 0.1% DTPA. The amount remaining at the wound site after the flushing was $\sim$ 0.16 μ c. DTPA is being administered intravenously to increase the amount of plutonium excreted.

Efforts to eliminate the radiation problems associated with the cooling water swamps for the Purex Operation continued through July. New inlets have been provided for both swamps and the old, highly contaminated inlets backfilled. Backfilling was not quite completed for the B Swamp at the end of July. However, the portion of the old ditch that presented the most significant dose rates had been covered over. The contamination levels in the swamp water continued to drop and were less than $5 \times 10^{-4} \mu\text{c/cc}$ at the end of the month.

A plan was devised to sample process tube flexible connectors on four reactors to obtain time-of-deterioration data.

Formulae for the reliability of the zone temperature monitoring system have been developed as a function of the reliability of the meter relay components. A talk was given to engineers of the Plant Equipment Engineering Operation on the development and use of these formulae.

The dimensional stability performance of different kinds of fuel elements in smooth bare tubes has been analyzed (PT-572).

An analysis of the C-Reactor pressure monitor ground detector determined the modifications that would retain existing safety circuit functions under that change of supply voltage required by the installation of the Trip Identification System. These modifications were incorporated into the the ground detector and acceptance tests were conducted on July 24.

The six basic EDPM program versions of the "shoe box" flow system model for soil permeability have been completed and turned over to the customer.

Several meetings were held with Professor E. C. Lingafelter of the University of Washington. Professor Lingafelter, who is a Laboratory Consultant, spent one week here giving advice and offering guidance on crystal structure research.

The analysis was completed of data relative to the fecundity of fast-neutron treated Tribolium castaneum beetles.

SUPPORTING FUNCTIONS

Plutonium Recycle Test Reactor output for July was 1367 Mwd for an experimental time efficiency of 76% and a plant efficiency of 63%. There were ten operating periods during the month, five of which were terminated manually, four were terminated by scrams and one continued through month-end. A summary of the fuel irradiation program as of July 31, 1964, 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	0		8	1694.4	77	12296.0			85	13990.4
Maximum				317.3		322.1				
Average				211.8		159.7				
In Basin	7	572.5	25	2673.1	44	4469.9			76	7715.5
Buried							1	7.3	1	7.3
Chem.										
Process	68	5465.8	35	1965.8					103	7431.6
Program										
Totals	75	6038.3	68	6333.3	121	16765.9	1	7.3	265	29144.8

Note: (Mwd/Element) x 20 = Mwd/ton_U for UO₂ and PuO₂-UO₂.

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Heavy water loss and indicated helium loss for the month were 1,081 lb and 115,319 scf respectively.

A total of 90 reactor outage hours were charged to repair work. Main items were:

- Nozzel-to-tube regasketing
- Repair HX-1 level transmitter
- Helium compressor repair
- Rupture loop repairs

Seventeen shipments of irradiated PRTR fuel elements were shipped to Redox for storage during construction of Project CAH-119.

EBWR fueled experiments continued according to schedule. Arrangements were completed to transfer the Plutonium Recycle Critical Facility to Physics and Instruments Laboratory.

The second H_2O core will provide for testing of four 1-ft-long single rods of PRTR type in a 0.800 in. triangular lattice. Component fabrication, continued during July, is nearly complete. Installation has been rescheduled from mid-August to early September to permit the performance of additional experiments.

Early in the month, the rupture loop in the Fuel Element Rupture Test Facility was returned to service following replacement of the cleanup ion exchangers. Initial testing of these units revealed that the pressure drop increased with time at normal flow rates with only the resin bed supporting anthraflit in place. This was attributed to compaction and flaking of the anthraflit. The coal was subsequently removed and replaced with rounded and graded high density gravel. These exchangers now exhibit satisfactory pressure drop characteristics with the gravel resin bed supports.

Technical shops operation total productive time for the period was 22,240 hr. Distribution of time was as follows:

	<u>Man Hours</u>	<u>% of Total</u>
N-Reactor Department	1,930	8.7
Irradiation Processing Department	3,324	14.9
Chemical Processing Department	354	1.6
Hanford Laboratories	16,632	74.8

Laboratory Maintenance Operation total productive time was 20, 200 hr of 23, 200 potentially available. Of the total productive time, 91% was expended in support of Hanford Laboratories components, with the remaining 9% directed toward providing service for other HAPO organizations. Man-power utilization (in hours) for July was as follows:

A. Shop Work	2 200
B. Maintenance	7 400
1. Preventive Maintenance	2 200
2. Emergency or Unscheduled Maintenance	1 900
3. Normal Scheduled Maintenance	3 300
C. R&D Assistance	10 600

The heavy water inventory at the end of July, 1964, showed a loss of 243 lb valued at \$3, 360 for PRTR. Heavy water scrap generated during the month amounted to 1800 lb, resulting in a \$2, 334 charge to operating cost. Total scrap on hand at July 31, 1964, amounted to 4576 lb valued at \$55, 388.

Cumulative data of Hanford visits:

	Number of Visitors	
	<u>In July</u>	<u>Since 6-13-62</u>
Visitors Center	2 952	74 873
Plant Tours	2	---

Four exhibits were shipped to the National Scout Jamboree at Valley Forge, Pennsylvania.

Three of the four Hanford Laboratories' exhibits for the Geneva Conference have been completed and shipped. Completion of the one remaining exhibit was delayed because of translation errors in the technical Russian, French, and Spanish copy. These errors have been corrected and local art and photography work is expected to be completed early in August.

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HAPO professional recruiting activity for July:

	<u>Plant Visits</u>	<u>Offers Extended</u>	<u>Offers Accepted</u>	<u>Offers Rejected</u>	<u>Offers Open</u>
Ph. D.	6	6	3	4	4
BS/MS (Direct Placement)	-	-	-	-	-
BS/MS (Program)	-	1	2	2	1

Five Technical Graduates were placed on permanent assignment and three new members were added to the roll. Program strength at month end totaled 44.

Authorized funds for 11 active projects total \$10, 566, 500. Total estimated cost of these projects is \$11, 415, 000. Expenditures through June 30, 1964. were \$4, 165, 000.

Manager, Hanford Laboratories

HM Parker JEB da

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REACTOR AND FUELS LABORATORY MONTHLY REPORT

JULY 1964

TECHNICAL ACTIVITIES

A. FISSIONABLE MATERIALS - 02 PROGRAM

1. Metallic Fuel Development

N-Fuel Failure No. 1. On July 7, 1964, a fuel failure was detected in N-Reactor Tube No. 3361. Basin examination of the discharged fuel elements revealed a failure at the upstream end of the inner tube of the downstream fuel assembly. The exposure of the fuel component was estimated to be only 8 Mwd/ton at the time of failure. The assembly containing the failed inner component was shipped to Radiometallurgy.

Examination in Radiometallurgy showed the end cap to be almost completely separated from the fuel element and the inner cladding was collapsed to the point that it was not possible to sight through the bore to any degree. Weight data indicated that approximately 315 grams of uranium had reacted with the coolant.

Careful examination of the end cap revealed radial cracks in the ID and OD weld closures and some weld-bead porosity. After complete superficial examination and radiography, the cap was subjected to destructive metallographic examination. The superficial weld-bead porosity was shown to be associated with a longitudinal extrusion defect on the inside surface of the cap. This defect extended through the full thickness of the cap and was responsible for the failure. Since the failure was, in essence, a "delayed autoclave failure," a thin layer of braze material, probably at the base of the end cap, could have delayed water entry through the cap to the fuel.

Fuel Fouling Detector. The third thorium-alloy fueled N-Reactor fuel fouling detector to be successfully irradiated was discharged from KER Loop 4 on July 13, after receiving 1750 Mwd/ton exposure in low temperature water. The performance of this thermocoupled test probe was fully satisfactory.

Fluted Fuel Element Irradiation. Two N-single tube fuel elements with fluted outer surfaces have completed 12 cycles of irradiation in the ETR M-3 pressurized loop for an accumulated exposure of

approximately 2400 Mwd/ton. Operating at a maximum specific power of 140 kw/ft and a corresponding metal temperature of 550 C, these elements have undergone a volume increase of 2.4%.

Alternate Uranium Compositions. Studies are in progress to evaluate uranium base alloys in terms of fuel fabrication history, corrosion behavior, and irradiation performance. Billets of six vacuum arc-melted alloys were primary extruded to 2.2-inch diameter rods for making coextrusion billets and three other alloys were vacuum induction melted to ingots and machined to 3.9-inch diameter billets. Of the 17 alloys to be studied in this program, six have been processed through the stage of coextrusion, two have been machined to billets awaiting coextrusion, and nine are now being machined to coextrusion billets.

Fabrication of Target Elements for NR-8. Production Test NR-8 will consist of an enriched outer driver tube and an inner target rod. Fabrication of the target rods is the responsibility of MDO. These rods consist of an aluminum jacket coextruded over an enriched lithium-aluminum alloy, cut to length with aluminum end caps welded over the core to contain any tritium that may be released during irradiation. The aluminum clad core is, in turn, placed in a Zircaloy can and welded in helium for hot water corrosion protection. Production requirements have recently been altered to include 800 target elements of which 650 will be long elements and 150 the shorter elements. The major problem to date has been aluminum welding. However, with meticulous cleaning and 100% x-ray of the closure, the closures have been successfully completed. Attempts to automate the welding process have not been successful, and, as a result, all welding is done manually. Numerous extra steps have been added to the fabrication process, including air oxidation of the aluminum jackets to provide extra assurance that aluminum diffusion into the Zircaloy will not occur; anodizing the aluminum jacket for the same reason; extra cleaning on the Zircaloy welds. The nature of the test requires taking and recording detailed measurements on each individual piece. Delivery of all components to N-Department will be completed by August 1.

Coextrusion of Aluminum Clad Target Material. Four coextrusion billets containing 3-1/2% Li-Al cores and two billets containing 1-1/2% Li-Al cores were extruded from the 4-inch container at a reduction of 34.3 to 1 in an effort to determine conditions which will prevent the aluminum cladding from bonding to the Li-Al core at higher reductions. This test is in preparation for extruding production N-target material from the 4-inch container on the product department extrusion press.

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The 3-1/2% Li-Al cores were dry blasted. Three were coated with different water Aquadag mixtures of 2/1, 40/1 and 60/1. One was left as blasted. One of the 1-1/2% Li-Al cores was dry blasted and coated with a water Aquadag mixture of 2/1 and the other was dry blasted and oxidized at 500 C. The cores were sealed within the aluminum cans by inert arc welding. Some difficulty was experienced in welding the billets with the coated cores as the final weld zone tended to blow out.

The billets were heated to 350 C and extruded using the same extrusion techniques as employed for the recent extrusion of N-target material. The best unbonds were on the extrusions from the billets coated with the heavier Aquadag mixtures. The extrusion with the most bond was from the billet with the oxidized core. All the extrusions had small protruding dimples on the surface with the exception of one extrusion which had a ruptured clad in the lead end of the extrusion. The ruptured extrusion was from the billet with the 2/1 Aquadag coating. The dimples appear to be caused by trapped gases within the billet. The use of a vacuum sealed billet will probably solve the simple problem; however, a vacuum may result in an increased tendency for the clad to bond to the core.

Target Alloys. Facilities were assembled for continued attempts at the fabrication of a high melting lithium-brazing alloy for use in the fabrication of target elements. In earlier experiments, aluminum and lithium were melted together in vacuo in a zirconium crucible, with the expectation that zirconium from the crucible would dissolve in the molten Al-Li to form the desired alloy. The volatility of the lithium prevented realization of this goal. In another attempt, an atmosphere of welding argon (99.9+ pure) was supplied, but even at this purity, the chemically reactive lithium combined with the impurities in the argon. Creeping of the melt over the crucible rim and down the outside walls caused breakage of the surrounding ceramic sheath.

In later attempts, aluminum and zirconium were melted together first, with the intention of later holding the Al-Zr in molten Li in a purified argon atmosphere. However, no crucible has yet been found capable of withstanding the high temperature and at the same time resistant to chemical attack by the molten metals. The study is being continued.

Fabrication of Zr-2 Support Material. Increased stiffness in rolling Zr-2 strip has been observed on several occasions when several weeks have elapsed in the fabrication schedule, indicating a possible aging process. Tensile specimens were prepared from material partially

through the fabrication schedule for determination of room and elevated temperature aging. Tensile properties after 1, 5, and 20 hours at 200, 300, and 400 C have shown a maximum increase in yield strength of approximately 6000 psi. Specimens will be tested after a 72-hour, 400 C steam autoclave treatment and up to six weeks of room temperature aging.

Zr - 5% Be Wire Extrusion. A program to investigate the feasibility of fabricating 25-mil Be-Zr wire for brazing by successive extrusion of bundles of rods has been initiated. Two Be-Zr ingots canned in mild steel have been extruded at 9:1 ratio and 800 C preheat. Radiographs indicate sound extrusions. These rods will be hot swaged to 0.25-inch diameter, bundled, re-extruded, and chemically separated from the mild steel matrix as 25-mil wire.

Be-Zr Brazing Wire. Be-Zr wire has been fabricated by swaging in a stainless steel jacket. This jacket was difficult to remove chemically. Additional material is now being fabricated in mild steel with a 4-mil coat of electroplated nickel. The mild steel jacket was made with an initial wall thickness of 1/4-inch which was about twice the thickness of the original stainless steel jacket. The greater thickness served its purpose of eliminating rejacketing. The greater thickness of the softer mild steel allowed the hard core of Be-Zr to deform into a noncircular cross section. This second run will be repeated using a much thinner wall with a planned rejacketing at about an 80% reduction in cross section area.

K-5 Process Tube Damage Tests. Tests were conducted to assess fuel element support damage to K-5 process tubes in the event of a fuel element failure. Fuel element swelling was simulated by mechanically expanding a section of fuel cladding in a 16-inch length of process tubing. The cladding was expanded to give a predetermined load on the fuel supports. Loads of 400 to 500 pounds/support are necessary to produce any permanent set in the process tube. The change at this load level is about 0.002 inch in diameter. The process tube change is about 0.007 inch in diameter at support loads of 800 pounds which was the maximum load tested. The diameter change is not uniform, however, due to "squaring" of the tube in the support areas. The above changes are maximums and were measured over the supports.

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Outgassing of Lithium Aluminate. A 0.27 g sample of irradiated lithium aluminate has been outgassed at 100, 200, and 300 C (212, 392, and 572 F) to investigate tritium release characteristics. The estimated gas content of the lithium aluminate target is 22 cc T₂ + He per cc of target. Target density is 84 percent (2.14 g/cc). The release rate at 100 C was too low to permit sampling for mass spectrometer analysis. In 17 hours at 200 C, three percent of the gas calculated to be in the sample was evolved; the mass spectrometer analysis is not complete, but the gas is primarily helium, with a trace (~ 0.1 percent) of HT and no T₂.

At 300 C, in an 18-hour run, the gas release was seven percent of the calculated gas content.

Dissolution of lithium aluminate in molten salts is being investigated. The aluminate dissolved in molten sodium bisulfite and in a KCl-LiCl melt. If retort extraction of tritium from the aluminate does not prove to be practical, molten salt extraction appears to offer an alternate approach.

2. Corrosion and Water Quality Studies

Corrosion of Be, U Contaminated Zr-2. A test is being initiated to determine the corrosion characteristics of the NPR fuel end welds both in-reactor and out-of-reactor. Melts of Zircaloy-2 simulating the composition of these end welds with respect to beryllium and uranium contamination will be cast and fabricated into coupons. Effects of beryllium concentrations ranging from one percent to three percent and uranium (0.1 - 4%) concentrations will be investigated.

Duplicate series of samples of the various compositions will be tested simultaneously in both in-reactor and out-of-reactor systems in high temperature (300 - 340 C, or 572 - 644 F) pH-10 (NH₄OH) water. All samples will be exposed approximately 60 days.

Carbon Steel Corrosion in Ammoniated Coolant. Termination of a test in TF-1 after 2500 hours with carbon steel coupons exposed at 300 C in pH 10 ammoniated water showed corrosion rates of 0.15 mil/yr. The film buildup rate at the end of the exposure was 26 mg/dm²-mo and the crud release rate was - 3 mg/dm²-mo. The negative crud release rate is the result of deposition of corrosion products from the system at a rate higher than the loss from the specimens to the system.

Corrosion of Copper Alloys by Ammonia. After a three-month exposure, no stress corrosion cracks have been observed on copper tubing and brass fittings exposed to pH 9 ammoniated water at N-Reactor graphite cooling system conditions.

Stressed samples of cast manganese bronze which were exposed in the front inlet piping space and the top rear outlet space atmospheres at N-Reactor were discharged due to cracking. Several other copper alloys did not exhibit any cracking. Two valves with manganese bronze yoke bushings obtained from N-Reactor have not shown any ammonia stress corrosion cracking after two months exposure to vapors obtained by allowing pH 10 (NH_4OH), 530 F water to leak past the packing.

Testing of NH_4OH in KER Loops. Operation of the KER Loop at pH 10 with ammoniated coolant was continued. In general the coolant quality was satisfactory.

Hydrogen gas addition to the KER-1 coolant was initiated to determine the effect of hydrogen addition on the film found on fuel element surfaces in pH 10 ammoniated coolant. Some problems have been encountered in controlling the gas additions to maintain hydrogen concentrations of 20-40 cm^3/Kg (STP). Results obtained to date indicate that addition of hydrogen causes a reduction in the ammonia decomposition rate.

Crud Deposition on N-Reactor Fuel Elements. The discharged elements from N-Reactor tube 3361 (the one containing the ruptured inner fuel element) were visually examined in the viewing facility. A reddish-brown crud film similar to the film on elements discharged from KER-1 was observed. Examination at Radiometallurgy showed the crud film to be about 0.1 mil thick, translucent, and quite loose. Film samples were taken for X-ray diffraction and other analysis. After dissolving the crud in 6M HCl at room temperature, the cladding had a shiny black ZrO_2 film.

Reduction in Effluent Activity. Two tests were made on 183 KE filters to determine variations in filter effluent turbidity after backwashing. These tests showed a potential for reducing turbidity immediately after backwashing, possibly by varying separan additions.

Process Assistance. Corrosion testing of copper and brass alloys in glycol anti-freeze mixtures was completed, and samples are being processed. The different anti-freeze mixtures are proposed to replace the technical grade ethylene glycol presently used to extract waste heat from the K-Reactors.

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3. Gas Atmosphere Studies

In-Reactor Corrosion and Hydriding of Zircaloy in Contaminated Helium. A capsule containing Zircaloy-2 and Zircaloy-4 coupons was successfully irradiated two months at 400 C (752 F) in a He atmosphere contaminated with CO, H₂ and H₂O vapor. The purpose of the irradiation was to measure corrosion and hydriding rates at a shorter exposure than a previous capsule reported in February 1963 and to check gamma heating effects by attaching a thermocouple to a dummy sample for comparison with thermocouples in the gas environment.

Weight gain measurements show no irradiation effects on corrosion of etched or autoclaved (three days at 400 C - 752 F - 1500 psi steam) Zircaloy-2 or Zircaloy-4. Samples pre-autoclaved past transition show reduced weight gains attributable to the "thick film effect" previously observed in dilute water vapor. No hydriding data are yet available.

Thermocouple readings during exposure showed the gas was running 35 C(95 F) cooler than the dummy coupon. Since the first capsule was controlled by gas phase thermocouples, this implies the sample temperatures in the first capsule could have been hotter than the thermocouple measured. A 35 C temperature rise would be sufficient to account for the factor of two to three higher corrosion rate observed in the first capsule.

Graphite Burnout Monitoring. Channel 1648 at N Reactor has been assigned for use as a graphite burnout monitoring facility. The channel is located 8 lattice units from the left side of the reactor and 1.5 lattice units below the horizontal centerline. The nearest thermocouple stringer is located one graphite layer above and one graphite column to the right of Channel 1648. Since there is no gas flow through the channel, except by diffusion from the 2 by 3 in. gas passages on either side of the channel, the monitors will not be useful for measuring oxygen in-leakage. However, the monitors should prove helpful in measuring burnout caused by H₂O and CO₂.

The first graphite monitors were charged into Channel 1648 on July 9, 1964. The charge consists of 20 carriers, 20.5 in. long, each containing 4 monitors. Two of the monitors are made from TSGBF graphite (a standard material used for burnout measurements in other Hanford reactors); one is a 6 in. long transverse sample of TSX graphite, and one is a 4 in. long parallel sample of TSX graphite. In addition to initial weights, the TSX monitors were measured for length.

Graphite - Zirconium Compatibility Loop Experiment. The fourth test was completed using helium containing 1000 ppm each of water vapor, hydrogen, and carbon monoxide. The maximum graphite temperature was 820°C. The oxygen concentration (due to in-leakage) was about 4 ppm at the inlet end of the graphite sample bar.

The sample bar in this test provided for many more surface samples. Six of the sets each contained five samples ranging from 1/8 in. to 3/8 in. in 1/16 in. increments. Each sample had the same surface area exposed to the atmosphere. The results indicate that the bulk of the oxidation occurred in the first 1/8 in. of graphite.

The remaining surface samples were all 1/4 in. thick. A number of these were pre-oxidized in air before charging into the test bar. The amount of preoxidation varied from 0.13 to 5.12 percent. The rate of reaction for these samples was found to be greater than for nonoxidized samples. At approximately 5 percent burnoff, the rate had increased by about a factor of 4.

The fifth test, a repeat of the conditions of the fourth test is now in progress. At its conclusion, it is planned to obtain temperature profiles of the graphite oxidation bar to help in the interpretation of the rates at various positions.

4. Process Tube Development

Fracture Studies. Tests were conducted to determine the effects of stress on the orientation of hydride platelets in Zircaloy-2 pressure tubing. A section of N-Reactor tubing containing 90 ppm hydrogen was allowed to cool slowly from over 300 C (572 F) at hoop stress levels of 0 psi, 10,000 psi, and 25,000 psi. The hydride pattern shown in the zero stress specimen was essentially unchanged at 10,000 psi. However, a significant number of hydride platelets in the 25,000 psi specimen were oriented in the radial direction; that is, normal to the hoop tensile stress.

Irradiated Tube Testing Facility. All of the instrument problems have been resolved and the equipment is all operable. Tests in each of the new test chambers have shown that a temperature uniformity within 3 C (37.4 F) can be obtained on the test specimens. Two KER irradiated tube sections are currently undergoing stress rupture testing. The remotely operated gage is working well in measuring the diameter of the irradiated tube sections. This gage is read through approximately six feet of water with the aid of the Questar Telescope and accuracies within plus or minus 0.001 inch are obtained.

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5. Thermal Hydraulics Studies

Transient Heat-Transfer Experiments for N Reactor. Analyses were continued of laboratory experiments investigating loss-of-coolant accidents for N-Reactor fuel tubes. In these tests, the changes in flow, pressures, and temperatures were investigated following the simulation of a rupture of an inlet connector to a single tube. The experiments were performed with an electrically heated, full-scale model of the downstream half of an N-Reactor fuel column with prototypic pressure tube and fittings. The transient experiments were initiated by actuating quick-acting valves which opened the inlet connector to the atmosphere while isolating the test section from the recirculating loop. Hot pressurized water was supplied to the test section from a 1000-gallon vessel during the transient. The heat flux in the test section could be reduced at a rate corresponding to a 1500-in-hour scram of the reactor at any time desired after activation of the quick-acting valves.

The following are preliminary results and conclusions of the experiments:

- (1) The reversal of flow following the inlet connector break was established in about one to two seconds.
- (2) At equivalent reactor full-power conditions, with the inlet butterfly held open, no significant test section temperature changes occurred when the flow reversed.
- (3) At equivalent reactor full-power, with the inlet butterfly valve allowed to close with reverse flow, maximum test section temperatures of 930°F and 1200°F (initial temperature about 830°F) were measured with scram delays of 1.5 and 5 seconds, respectively.
- (4) It appears that a burnout condition would not occur in the reactor if a scram was initiated at the first indication of a connector break.
- (5) Inlet connector venturi pressure drops gave pressure fluctuations up to 300 psi at full-power conditions and should provide a good indication of a connector break.
- (6) Pressure fluctuations were not found to be excessive (generally ± 150 psia at full power) during establishment of reverse flow. Generally, the pressure surges did not exceed the initial steady-state pressure.

A report presenting the results of these experiments is being written.

Plans were made for additional experiments to determine fuel temperatures following the rupture of the line supplying an N-Reactor inlet riser. These would be different from previous transient experiments which investigated the consequences of rupturing a connector to only a single tube. In that case, coolant system blowdown was through the affected tube, providing a supply of cooling water until well after a reactor scram would have occurred.

The planned study assumes a rupture in the supply line upstream of a check valve. In such a case, the supply of coolant to the affected tubes would be limited. The check valve would prevent back flow through the affected tubes and, because of the rupture, there would be no supply of water for flow in the normal direction. It is expected that boiling would quickly expel the coolant from the process tube. As the system pressure decreases, boiling of water in the inlet connectors and riser will provide some steam flow through the tube. Because boilout times, steam flow rates, and heat-transfer coefficients cannot be calculated precisely, this accident will be simulated in the laboratory heat-transfer apparatus to obtain information about fuel temperatures during the boilout and steam-flow phases of the accident.

In additional studies, a description of the digital computer program designed to calculate N-Reactor fuel element burnout conditions was prepared for publication as a Hanford report. In setting reactor operating limits and analyzing the consequences of various abnormal situations, it is important to know the combinations of directly measurable parameters (power, pressure, inlet temperature and flow rate), which can lead to film boiling, or burnout, in a fuel column. Relationships between burnout heat flux and local coolant conditions have been developed from the results of Thermal-Hydraulics laboratory experiments.* From these local-condition relationships, the computer program calculates sets of measurable gross tube parameters which will produce burnout at some point along the fuel column.

The computer program was developed for use in the analysis of Thermal-Hydraulics experiments investigating behavior in an N-Reactor tube with net steam generation. It is being published so as to be available to persons concerned with N-Reactor safety analysis and operating limits.

*HW-77470. "Burnout Heat Fluxes for NPR Tube-in-Tube Fuel Elements," J. K. Anderson, W. L. Thorne, and J. M. Batch, June 12, 1963.

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Water Boil-Out Times for the Present Production Reactors. Calculations were made of the time it would take the water to boil out of a tube filled with thorium elements following a water-loss accident. Such information is required for calculation of reactivity changes as part of the hazards analysis of loading thorium in the present production reactors.

Laboratory data were obtained several years ago for boil-out times from present reactor tubes filled with uranium. However, the data were taken at much higher power levels than the 150 kw estimated for a thorium tube. Therefore, a simple model was devised which would allow satisfactory extrapolation of the laboratory data to very low tube powers. It was estimated from the results that it would take about 40 seconds to boil out 90 percent of the water in a thorium tube operating at an original tube power of 150 kw.

Hydraulic Tests for Present Production Reactors. Several tests were run in the laboratory to determine the hydraulic and critical flow characteristics of various orifice configurations in CG-558 front hardware. This hardware is to replace the older nozzle assembly currently in use at C Reactor.

Of primary interest were the operating characteristics of various orifice assemblies in fringe tubes which would meet the requirements of adequate tube coolant flow at given front and rear header pressures and proper Panellit response during critical flow conditions. Several orifice sets were found to be satisfactory for use with the CG-558 hardware and C-Reactor fuel loadings.

Three or four of these prototype orifice sets will be manufactured onsite and recalibrated to assure satisfactory performance with in-reactor use.

Additional hydraulic tests were conducted to investigate the pressure recovery or loss to be expected when various short lengths of perforated expendable pieces separate the fuel column and tubular pieces. During a previous study, flow tests were conducted on the positioning of tubular dummy elements next to the fuel column in a K-Reactor process tube. It was predicted at that time that the majority of the pressure recovery between the end of active section and the rear nozzle occurred within four or five inches of the end of the fuel column. More recent data supports this and indicates that about the same recovery occurs when the fuel column and tubular dummy charge are separated by a three-inch perforated section. Several reactors are contemplating modifying the dummy pattern in order to utilize excess expendable five-inch perforated pieces in the dummy charge and to permit the use of expendable tubular pieces in the dummy pattern rather than use of the costlier perforated elements.

6. Graphite Studies

N-Reactor Graphite Irradiations. The long-term irradiation testing of N-Reactor graphite continues to proceed satisfactorily in the GETR. The first of the fourth-generation capsules, H-4-4, was removed from the reactor on June 29, 1964, after successfully completing five cycles (113.4 effective days) of irradiation. All nine thermocouples in the capsule functioned properly for the entire irradiation period.

It was observed upon the removal of H-4-4 that the secondary epoxy-filled seal pot over the thermocouple connector junction had separated approximately 1/4 in. during the irradiation apparently because of vibration of the capsule in the reactor. Fortunately the primary seal, the thermocouple connector, functioned satisfactorily and the capsule did not leak.

During the reactor shutdown the F-7 filler piece which had held the H-4-4 capsule was inspected. The wear pads on the top aluminum end-box were found to be completely worn off and the beryllium filler itself had been abraded. Further investigation disclosed heavy wear on all in-core filler pieces including the three Hanford pieces, D7, E7, and F7.

The three Hanford filler piece end boxes were replaced with new end boxes identical to the old ones except anodized to give a hard coating. The filler piece modifications, although done on a tight schedule due to reactor shutdown, and under remote conditions, proceeded extremely well despite the precise nature of the work. Inspection of the filler pieces also confirmed that the stainless steel inserts, which are unique to the Hanford design, are necessary to prevent excessive wear under long term usage.

After completion of the end-box modifications, the filler pieces were reinserted in the GETR and the capsules reinstalled. H-5-4 capsule which has successfully completed three cycles of irradiation was located back in D7. The third of the fourth-generation capsules, H-6-4, was installed in the F7 position for its initial irradiation period.

Stored Energy. The oxygen bomb calorimeter is working and most of the standardization runs have been completed.

A Perkin-Elmer differential scanning calorimeter has been obtained. This calorimeter is designed to measure the rate of energy liberation or absorption, by a small sample over the temperature range from -100°C to 500°C. Sample sizes can range from 0.1 to 20 mg and heating rates from 0.625 to 80°C/min. During the check-out runs, one of the parts was found to be faulty and must be repaired prior to further operation.

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C. REACTOR DEVELOPMENT - 04 PROGRAMPlutonium Recycle Program

PRTR Fuel Fabrication. Three fuel elements were delivered to the PRTR this month; two were charged.

A new fuel loading tool is being used for Vipac fuel elements which eliminates three time-consuming process steps and the need for two throw away parts (one of which required expensive machining). In addition to the direct cost savings the new loading funnel appears less likely to scratch the weld-counterbore area in the Zircaloy tubing and is easier to remove after fuel loading. This allows a higher precision counterbore area for end cap welding, thus improving crevice uniformity in the Vipac end cap - a suspect region for corrosion "in reactor" with Vipac fuel elements. Elimination of the previously used polyethylene funnel eliminates a long suspected source of hydrogenous material contamination to the fuel.

Four hundred forty kilograms of mixed oxide were impacted by the Nupac process. This included 312 kilograms for the PRTR and 128 kilograms for the EBWR programs.

Recent chemical tests show that depleted UO_2 powder prepared commercially from scrap metallic uranium contains a gas-evolving phase which is eliminated by a treatment in wet hydrogen at 1700 C. Mass spectrometric tests of the gaseous impurities are now in process. The purified UO_2 powder is readily densified by the pneumatic impaction process.

Cladding Studies. Tests of the effect of stable fission product iodine on Zircaloy cladding were continued. A swaged UO_2 PRTR fuel rod, contaminated with 165 mg of I_2 , was exposed to 400 C, 200 psig steam for 7 days. No cladding penetration was revealed by helium leak detection equipment. The test is being continued.

Zircaloy capsules containing helium and iodine vapor were heated at 400 C. One capsule was internally pressurized to 1200 psig (STP) to produce a stress of 9500 psi. Examination after 3 days revealed no cracking. The capsule was repressurized to 1500 psig (STP) to produce a stress of 12,000 psi. After 7 additional days heating the capsules were examined. No cracking was observed but several large pits were found. Metallurgical examination revealed no hydriding. A flaky black reaction product contained zirconium but no iodine. X-ray diffraction studies are in progress to identify the material. It appears to be $\alpha\text{-Zr}$ with no ZrO_2 present.

Irradiation Testing of EBWR Prototypic Fuel Rods. Short, prototypic EBWR UO_2 -1.5 wt% PuO_2 fuel rods reached exposures of more than 2.4×10^{20} fissions/cm³.

An assembly of fuel rods randomly selected from those fabricated for the Pu Recycle Demonstration Experiment in the EBWR is being fabricated for advance irradiation in the PRTR.

Inverted Cluster (Water Tube) Fuel Element. The full-length, Mark IX-B UO_2 inverted cluster element is being irradiated in the PRTR Rupture Loop. The element is generating 600-680 kw. The maximum power generation of 130 kw/ft produces an estimated maximum fuel temperature of 2100°C. Irradiation of the element will continue until the next scheduled reactor outage.

Components for another inverted cluster fuel element using dummy spike rods inserted into the coolant channels have been prepared and are being assembled into an element for flow testing.

PRTR Basin Underwater Equipment. Authorization to proceed on the procurement of underwater machining equipment for the PRTR basin was issued by the AEC and work is proceeding.

Reactor Materials Development

In-Reactor Corrosion of Zircaloy Fuel Cladding in PRTR. A dummy rod supporting Zircaloy-2 and 4 corrosion samples with various pretreatment has been fabricated and is now waiting for attachment to a Moxtyl 19-rod fuel element cluster. Fuel element assembly was planned during the week of July 20, 1964, and reactor charging in August 1964.

Reactor Decontamination. Nine different acidic solutions were used in the laboratory in an attempt to dissolve PuO_2 samples. In each case visual observation revealed residual PuO_2 material. The solutions are being analyzed for dissolved plutonium content.

Fretting Corrosion Investigation. Vibration monitoring of the PRTR components continued in support of fretting corrosion studies. During a recent operating period significant changes in reactor component vibrations were noted. For example, previous vibration data taken on the inlet jumper of channel 1653 have indicated a usual average peak-to-peak amplitude of about 6 to 7 mils. After startup on July 13, to a power level of 70 Mw, and with the apparent reactor variables constant, the amplitude was about 2 mils for approximately 7 hours. Then in the next 1-3/4 hours the amplitude increased to about 6 mils with a beating component of about 1 mil. Similar vibratory behavior was exhibited by the other inlet jumper being monitored. There is no apparent explanation for the change in vibration level. All reactor operating variables appeared to remain constant; there were no major shim control rod moves; and the BPA electrical supply remained constant.

Vibration of the suction and outlet headers of the PRTR primary pumps is also monitored. The outlet header has a vibration amplitude of about 1 mil and the suction header has an indicated amplitude of about 4 mils with a beating component of less than a mil. On reactor startup on July 13, 1964, the pattern of change in vibration amplitude was similar to that of the inlet jumper of 1653. The significance of these data has not been determined; i.e., it is not known if the principle motions originate at the pumps or if these motions produce the vibrations in the channels and headers in the reactor.

Pressure Tube Monitoring. Eight process channels were visually examined and the gas gaps and ID's measured. Three of the process channels inspected this month were also inspected in the previous outage. These three are inspected each outage in an effort to correlate fretting corrosion with unusual vibration of the process channel. These three were also reinspected to determine whether or not the new inspection equipment could transmit improper radial forces on the process channel outlet nozzle and thereby introduce appreciable error in gas gap measurements.

Visual inspection disclosed a nine-mil deep mark in the vicinity of the fuel element upper support bracket. This mark, however, is not typical of fretting marks associated with the upper support brackets. This process channel will be re-examined in the near future in an attempt to determine the origin of the mark.

The three process channels whose vibration is also monitored disclosed no new fretting of any significance. These results were unexpected in view of the fact that the fuel element end bracket measurement indicated wear of the spacers, ranging up to about 17 mils on fuel element 5186 which was charged in P.C. 1354.

The three process channels are currently being inspected each outage in conjunction with vibration measurements. Inspection showed gas gap measurements to be identical with those obtained in the previous inspection. Hence, if top shield indexing is properly done, the gas gap measurements are valid.

ID measurements disclosed no significant change.

PRTR Pressure Tubes. The flaw in PRTR tube number 5690 has been visually examined through a borescope and through a lead glass window at Radiometallurgy. The length of this flaw was determined to be one-fourth inch, and the width was estimated to be about one-sixteenth inch.

The general appearance of the flaw was that of a small rod-like foreign object lying on the inside surface of the tube. The surface of the flaw was smooth and lustrous in contrast with the lusterless, grainy appearance of the zirconium oxide surface of these tubes. Close examination revealed that the flaw was not a foreign object but an integral portion of the tube and that the surface of the flaw had three openings. The appearance of these openings suggested the presence of a void below the smooth, lustrous surface. In other words, the general appearance of the flaw suggested that it was a blister. It most likely is a fabrication defect.

Reactor Components Development

Second Generation Mechanical Shim Rod. The second generation mechanical shim rod for the PRTR, after operating continuously last month with no evidence of mechanical faults, was removed from the environmental test facility, disassembled and visually inspected. The various components appeared to be in good condition. The shim rod was re-assembled and the following modifications were incorporated: a new lower heat sink was installed; the driving head skirt was relieved; new "O" rings and sealing washers were used throughout; solid pins were used in the lower assembly Zircaloy-stainless steel transition; the spring under the lower half of the T/C connector was eliminated; and iron-constantan lead wire was installed between the lower and upper connectors.

The shim rod assembly is now ready for installation in the PRTR.

Helium Seal-Shim Rod Assembly to Calandria. The leakage of wet helium gas to locations of dry helium gas in PRTR with attendant D_2O loss or unwanted condensation is under investigation. Initial attention is directed to the helium gasket seal between the shim rod assembly and the calandria. A small test fixture fabricated for testing the leakage at this joint indicated a leak rate of less than 2 scf/hr of helium for the present gasket design with an eighty pound load and a 3 psi differential pressure. Aluminum "O" rings have been ordered for evaluation.

Gasket and Closure Test Station. The test station for developing PRTR outlet nozzle closures with reduced or no leakage of heavy water is expected to be back in operation in August. Components have been fabricated for a novel closure combining a high strength mechanical joint and a high integrity solder freeze seal. The solder is to be melted by means of induction heating as necessary for assembly or disassembly of the closure.

HTLTR Material Studies. Diatomaceous earth brick, the insulating material in the HTLTR, is known to consist of hydrated siliceous compounds of a closed-cell structure which are difficult to outgas.

A piece of Johns-Manville Superex brick, measuring 2-1/2 x 1-1/4 x 1-1/2 inches, was exposed to temperatures of 500, 600, and 700 C (932, 1112, and 1292 F) in laboratory air (relative humidity ~ 60 percent). After each heating period the weight loss and reabsorption kinetics of the brick were determined. The brick was found to lose five percent of its weight after heating at 500 C for 26 hours, a total of six percent after heating another 23 hours at 600 C, and a total of 6.2 percent after heating another 26 hours at 700 C. After the 600 C treatment, the brick regained one percent of its original weight after about two weeks exposure to laboratory air.

Design Analysis

PRTR High Power Density Core. Formulation of a technical design criteria for the proposed PRTR operation with short fuel elements in 55 channels producing 70 Mw of thermal power is in progress. It is contemplated that total power capabilities greater than 70 Mw, if required, will be derived from operation of part or all of the remaining fringe tubes.

An investigation of control requirements has shown that shim control at least double the present strength will be required. Mechanical shim requirements are being considered in the event chemical shim does not prove feasible.

Fuel Re-Use. Recent calculations in support of the fuel re-use concept used the standard version of the QUICK code which assumes (incorrectly for this purpose) the loss of 2% of fuel in fabrication and 1% of fuel in reprocessing. An evaluation is being made of the magnitude of the error introduced and comparability to the earlier Fuel Re-use work which used a special "no-loss" version of QUICK.

2. Plutonium Ceramic Fuels Research

PuN-50 vol% W Irradiation. Visual examination of a small PuN-50 vol% W wafer irradiated to a calculated average burnup of 20×10^{20} fissions/cm³ shows that the specimen is in one piece with no cracks. Both aluminum faces adjacent to the specimen were covered with an unidentified material.

UN-20 wt% PuN Irradiation. Metallographic examination of an UN-20 wt% PuN irradiation test capsule with an average calculated burnup of 2.5×10^{20} fissions/cm³ ($\sim 9,400$ MWD/T) shows formation of a central void and three structural zones. Autoradiographs also show these three zones. There are high fission product concentrations contiguous to the central void and at the periphery of the fuel.

A longitudinal section of the capsule revealed a void formed between an end fuel pellet and a MgO guard pellet. Fission products appear to be concentrated around this void in the MgO.

Examinations of the fuel-clad interface show no reactions. The approximate temperature of the stainless steel at this interface was calculated to be 600 C at a heat flux of 615 watts/cm² (1.95×10^6 Btu/hr/ft²).

Pu-O-N System. X-ray diffraction analyses of a condensate formed during arc melting of Pu under an atmosphere of nitrogen showed the major phase had a lattice parameter of 4.944 ± 0.001 Å. Since small amounts of β -Pu₂O₃ and PuO_{2-x} were also detected, it is reasonable to assume the major phase was Pu(O,N). Specimens prepared by this technique will be used to investigate the Pu-O-N ternary system.

PuN-Pu System. A PuN-5 vol% Pu wafer with a hole drilled through the center was heated under an atmosphere of argon. No liquid Pu was detectable in this hole at 2200 C, although photomicrographs show the hole penetrated the Pu in several places. High temperature x-ray diffraction will be used to study the morphology of the Pu phase as it is heated.

Beta Plutonium Sesquioxide. Previous experiments on the preparation of β -Pu₂O₃ have indicated that the compound may exist over a compositional range. To investigate the possibility of a Pu₂O_{3±x} phase, samples of pure β -Pu₂O₃ containing additions of 10% PuH_{2.7} and 10% PuO₂ were heated for four hours at 1450 C in high vacuum and quenched. These were ground to -325 mesh and the powders annealed for 89 hours at 600 C in vacuum. Analyses indicated the compositions were PuO_{1.410} and PuO_{1.565} and the samples contained the phases PuO + " β -Pu₂O₃" and " β -Pu₂O₃" + α -Pu₂O_{3-x}, respectively. The X-ray powder patterns were read by two observers, and a computer program that solves pairs of simultaneous equations in the hexagonal crystal system is currently being written to permit accurate evaluation of lattice constants of Pu₂O_{3±x}.

BeO - PuO₂ Studies. Three more small cans of BeO-nickel coated-PuO₂ particles were impacted making a total of six cans. Fast neutron activity was detected, indicating some damage to the nickel coatings, but it was not intense enough to cause any concern about radiation exposure.

Metallographic examinations and irradiation tests of the impacted material are planned.

3. Ceramic (Uranium) Fuels Research

UO₂-PuO₂ Homogeneity Studies. Recent studies have shown that a potentially useful fast reactor fuel can be prepared by ballmilling and pneumatically impacting UO₂-PuO₂ powders. Autoradiographs of the ballmilled mixture and coprecipitated (U, Pu)O₂ were magnified 500 times to show the individual alpha tracks. Variations in local track density per unit area were the same for the two materials, thus indicating comparable plutonium distribution.

Mixtures of -325 mesh UO₂-20 wt% PuO₂ powder were also dry ballmilled for 4, 8, 16, and 32 hours to determine the effect of ballmilling time on particle size and uniformity of PuO₂ distribution. Autoradiographs show that PuO₂ dispersion improves with increased ballmilling times, although plutonium dispersion in the 32-hour ballmilled mixture is nearly as uniform as in the 64-hour ballmilled mixture.

Samples of the ballmilled impacted UO₂-PuO₂ mixtures and of coprecipitated and sintered (U, Pu)O₂ were mounted and polished in preparation for electron microprobe analysis.

Hypostoichiometric UO₂. Hypostoichiometric UO₂ with O:U ratios less than 1.95 can readily be produced by heating either single crystal or polycrystal UO₂ pellets and uranium metal together above 2100 C. The UO_{2-y} is obtained as a uniform two-phase mixture at room temperature. These samples will be used in high temperature studies of thermal and electrical conductivity.

Image Intensification Studies. An Image Orthicon TV System (Image Intensifier) is being used in developing dynamic radiography techniques for studies of fuel rods under simulated in-reactor conditions. Using ASTM penetrometers, voids with 0.070-inch diameters have been seen through 0.75-inch thick aluminum. A void of 0.020-inch diameter was visible through 0.25-inch of steel.

Cermet Fuels. Thirty-nine, 3-inch long, 30 wt% UO₂-SS cermet fuel pins were fabricated by impaction. The cermet pins were simultaneously clad and bonded with 0.006-inch and 0.010-inch wall

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thickness, 1/2-inch OD stainless steel tubing. Several UO₂ particles were uniformly dispersed throughout the metal matrix. Dimensional tolerances of the "as Nupacked" pins were better than those previously obtained, probably due to the uniformity in density of the vibrationally compacted powders prior to pneumatic impaction.

UO₂-Niobium Cermet Irradiation: A UO₂-70 vol% Nb cermet was irradiated to 0.34×10^{20} fissions/cc (1170 Mwd/ton) at 905 w/cm (990,000 Btu/hr-ft² on fuel surface) rod power to investigate the stability of UO₂-Nb cermets irradiated at high specific power.

Approximately 10% of the fission product gas formed during the irradiation was released from the fuel. The increased surface area due to radial and circumferential cracks produced in the fuel pellets during fabrication probably increased the fission gas release rates. Improved fabrication techniques now allow production of high density, crack-free material with the metal as the continuous phase. Fuel can be simultaneously densified and clad by the pneumatic impaction process.

Microstructure of the irradiated fuel indicates a maximum center-line temperature of ~ 1500 C. This low central temperature is due primarily to the self-shielding effect of the highly enriched (85% U-235 in U) fuel.

4. Basic Swelling Studies

Irradiation Program

Two uranium wafers, 0.2 mm in thickness by 3.0 mm in diameter, were successfully irradiated to 10^{17} nvt (thermal). The wafers are slightly discolored, due to oxidation. No bonding between the uranium wafer and the aluminum spacer occurred. The wafers are quite radioactive (primarily beta) and will be thinned for transmission microscopy after suitable shielding is provided. Three additional capsules containing high purity uranium and uranium alloys are being prepared for irradiation. As-extruded and beta heat-treated specimens of high purity uranium enriched to 1.44% U-235 are undergoing irradiation in a general swelling capsule controlled at 625 C (1157 F) regardless of the operating state of the reactor. These specimens will provide information with regard to the effect of fission rate on the irradiation behavior of uranium.

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The first controlled pressure-temperature swelling capsule was constructed and successfully bench-tested to 525 C (977 F) at 1600 psi. This capsule will be charged into a reactor at the first opportunity and will be operated at 450 C (842 F) and 1000 psi. Six high purity uranium specimens, two U + Fe-Al specimens and two U + Fe-Si specimens are included in this capsule. Several metallurgical states are represented for each material.

Post-irradiation Examination

Samples from two general swelling capsules irradiated at 625 C and 450 C (1157 F and 842 F), respectively, to 0.16% B.U. were successfully recovered. Each capsule contained two U + 400 ppm Fe - 600 ppm Al specimens, two U + 140 ppm Fe - 95 ppm Si specimens, and four high purity uranium (65 ppm Fe - 25 ppm Si) specimens. Several metallurgical states were represented for each composition. As was the case for the samples from the previous capsule of this series, the behavior of the U + Fe-Al specimens was far superior to any of the other specimens and that of the U + Fe-Si specimens was in general superior to that of the high purity uranium specimens. Density measurements and macrophotography have been completed. Optical and electron metallography are in progress.

It was possible to get a direct comparison between U + Fe-Al specimens and U + Fe-Si specimens which had received the same heat treatment. For specimens given a gamma-alpha treatment (1000 C - 1832 F - 24 hours W.Q. + 525 C - 24 hours), the respective volume increases were 1.1 and 3.5% for an irradiation temperature of 605 C (1121 F) and 0.5 and 2.0% for an irradiation temperature from 450-500 C (842-932 F). Alloy specimens given a beta-alpha treatment (standard beta quench plus 24 hours at 525 C (977 F)) showed volume increases of 1.1 and 11.0% after irradiation at 585 C (1085 F). A U + Fe-Al specimen given the beta-alpha treatment exhibited a 4.5% volume increase after irradiation at 400-450 C (752-842 F). The as-extruded high purity uranium specimens had volume changes of 9% at 640 C (1184 F) and 40-50% at 400-480 C (752-896 F). These data indicate that the alloy specimens exhibit a maximum in the volume change-temperature curve similar to the behavior of high purity uranium, but the maximum is smaller in magnitude. As was concluded from a previous capsule, these data also reveal the benefit of annealing alloy specimens in the gamma phase.

Supplemental Studies

Techniques for thinning wafers of uranium suitable for transmission electron microscopy are being investigated to: (1) compare particle size distributions determined by transmission electron microscopy with those determined by replica techniques, (2) study defects in irradiated and nonirradiated uranium.

Foils of pure uranium and uranium alloys containing 200 ppm Fe and 100 ppm Si have been successfully thinned and examined. No second phase particles were observed in the pure uranium. The alloy contains particles with a maximum size of 0.25 micron. Many of these large particles have been polished out, leaving holes in the foil. The smallest particles are located on dislocations and are as small as 200A in diameter. Particles of intermediate size usually have a radiating network of dislocations about them. Quantitative metallography of this alloy utilizing replica techniques showed that the majority of particles are smaller than 0.2 micron, the lower limit of resolution of the method used. Transmission microscopy is therefore in agreement with these observations and shows promise for extending the quantitative metallography to smaller particle sizes. Specimens of other alloys of uranium are being prepared for similar studies.

X-ray line broadening studies of irradiated and subsequently annealed uranium have been initiated. The line broadening has been found to be anisotropic in that the (110), (111), and (131) peaks show definite broadening whereas the (021) and (002) peaks show no measurable broadening after irradiation. The (111) peaks have been selected for detailed analysis of the line shape from which the particle size and internal strain due to irradiation can be determined. The preliminary work has also revealed a narrowing of the broadened peaks after annealing. Future work will involve more extensive studies of irradiated samples annealed at different temperatures.

5. Irradiation Damage to Reactor Metals

Several nickel base alloys are being studied to determine the effects of irradiation and environment upon their mechanical properties. These alloys are being irradiated at 280, 580, and 740 C (536, 1076, and 1364 F) and tested at both room temperature and 700 C (1292 F). Metallographic study of Inconel 600 specimens irradiated at 740 C (1364 F) and tested at room temperature was started during the past month. Both irradiated and nonirradiated specimens were polished, cathodically etched, and replicated for electron microscopy. From the replicas obtained, it was determined that significant amounts of precipitate and some gas pores were formed during irradiation. Neither precipitates nor gas pores were found in the nonirradiated materials. Further development of replication procedures and detailed study will be required to determine the nature and effect of these microstructural changes.

Tensile specimens of W, W-25 Re, Ta, Ta-10 W, Mo, and TZM are being irradiated to determine changes in the tensile ductile-brittle

transition temperature. Six capsules containing these alloys are being irradiated to a goal exposure of 1×10^{20} nvt in 50 C (122 F) water. Three of these capsules were discharged from the ETR during the month, and the remaining three were charged.

Tensile specimens of nickel base and refractory metal alloys are scheduled to be irradiated in the ATR helium gas cooled loop facility some time in FY-1966. Fabrication of loop components to operate at temperatures exceeding 1300 C (2380 F) pose a serious problem. Attempts to fabricate specimen container components from refractory metal alloys using a Dynapak machine have been initiated. During the past month, dies were designed and fabricated to compact components from tungsten powder.

In-Reactor Measurement of Mechanical Properties

In-reactor creep tests of annealed 304 stainless steel at both 500 C and 600 C (932 F and 1112 F) and at a creep stress of 20,000 psi are in progress. The 600 C test exhibited a creep rate of 9.7×10^{-6} /hr at 170 hours. The creep rate of this test appears to be decreasing faster than that of the ex-reactor control, which exhibited a rate of 1.6×10^{-5} /hr at 170 hours. The 500 C test continues to exhibit a rate less than 2.5×10^{-7} /hr. A long reactor outage is needed to confirm an indicated rate increase observed in this test during the last reactor shutdown. An in-reactor test of 304 stainless steel at 500 C and 30,000 psi was discontinued. The capsule is currently being used to determine creep activation energies.

Irradiation Effects in Structural Materials

Inconel X-750 specimens were found to have different tensile properties and microstructures when heat treated in air compared with similarly heat treating in helium-filled ampules. The significant variables involved include time and temperature of the solution treatment prior to aging, cooling rate from the solution temperature, and environment (helium versus air). To study the effects of these variables further, specimens have been given three additional heat treatments in which solution time at 2100 F (1150 C) and the cooling rate from this temperature were varied. Identical aging treatments were employed. The resulting specimens are being tensile tested at room temperature and examined metallographically.

A facility for thinning specimens of structural alloys for transmission electron microscopy is being established, and techniques for metallographically resolving martensite in austenitic stainless steels are being developed.

Damage Mechanisms

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

High-purity zone-refined iron has been found to have poor ductility at low temperatures, even though room temperature ductility is nearly twice that for less pure samples. Fracture surface replicas of zone-refined iron specimens tested at -196 C (-320 F) show the fracture to be intergranular. Assuming grain boundary segregation to be the cause, similar samples were given different heat treatments to retain the offending impurity in solution. By increasing the cooling rate from the solution temperature, 600 C to 700 C (1112 F - 1292 F), the reduction of area at -196 C was increased from 0 to 30%. Further studies are in progress to identify the specific impurity responsible and to explain why similar behavior is not exhibited by Ferrovac "E", a less pure iron.

Initial tests on both Ferrovac "E" and zone-refined iron irradiated to approximately 1×10^{18} nvt (fast) reveal a 6000 psi increase in room temperature yield and flow stress and a marked decrease in work hardenability. Strain rate change tests from room temperature to -196 C show that the low temperature flow mechanism is unaffected by irradiation, as predicted. However, flow mechanisms at room temperature are markedly altered by irradiation. Since flow at room temperature is believed to be controlled by impurity distribution, the results indicate that neutron irradiation produces a change in this distribution.

Environmental Effects

In preparation for the special ETR G-7 Loop test, using hydrogen injection to reduce the equilibrium concentration of oxygen in the water environment, 165 specimens of zirconium alloys were prepared, weighed, mounted in quadrant assemblies, and shipped with a test rack of special design for irradiation during ETR cycles 65 and 66. The experiment will compare various zirconium alloys and heats, the effect of cold work and surface treatment. A 15-inch section of prehydrided KER Zr-2 tubing will be irradiated for subsequent mechanical property evaluation. Twelve quadrants of Zr-2 and stainless steel tensile coupons will be included in the test. Over 100 control specimens were prepared at the same time for out-of-reactor exposure.

The test rack design provides for an exposure position at the fringe of the active zone where fast flux intensities will be lower by two or more orders of magnitude than obtainable with previous test assemblies.

The purpose of these special tests is to provide data which will more fully characterize the effect of fast flux and coolant quality on the chemical and mechanical behavior of these reactor structural materials.

Sparking in High Temperature Helium

The sparking potential of electrodes in high temperature helium has been studied in support of the ATR gas loop heater design. A molybdenum electrode, 3/8-inch in diameter with a hemispherical end, was allowed to approach a sheet of molybdenum. An A.C. potential from 0 to 140 volts was then impressed across the gap to determine the field required for spark initiation.

At temperatures in the range of 1150 to 1250 C (2102-2282 F), a spark could not be initiated at gaps as small as 0.030 inch. A spark could be initiated by making contact with the electrodes (at low voltage, to indicate positive contact), just breaking the contact by slight motion of the movable electrode, dropping the potential to zero, then reimposing a high potential.

The gap under these circumstances is estimated to be of the order of a mil; the sparking potential was in the range of 120 to 140 volts. At 700 C (1292 F) no spark could be initiated.

Gas Chromatograph

Two new chromatograph valves have been tested on the CMO gas chromatograph. As a result of substantial improvement in ease of operation and mechanical reliability for the new valves, it has been decided to rebuild the chromatograph, utilizing the best components of the existing instrument, specifically for the analysis of impurities in ultra pure helium.

Neutron Spectrometry

The neutron spectrometer system was recalibrated with the Van de Graaff accelerator because of discrepancies noted between spectra calculated with transport theory and spectra determined with a Li^6 spectrometer in the tests at N-Reactor with a full-pile loading; and to calibrate a new Li^6 detector which was received subsequent to the N Reactor tests. Previous calibration data were repeated and no differences in detector response were noted.

After the recalibration tests were completed, a series of tests was run in the Physical Constants Test Reactor (PCTR) with an N-Reactor lattice configuration to check the N-Reactor data and to obtain data at lattice positions which were not accessible at the reactor. The PCTR spectra agreed in detail with those obtained at N Reactor, each showing a large peak in the spectrum at about 3 Mev, which was not observed in spectra obtained with the reactor under a 350-tube loading.

In order to determine if this behavior was peculiar to graphite systems, an experiment was performed in which four Pu-Be neutron sources were immersed in water in a critical approach facility and the spectrum measured with the Li^6 detector system. No spectral peak at or around 3 Mev was observed in this experiment, indicating, perhaps, that the source of the discrepancies may be an inexact averaging of carbon cross sections used in the calculations and may not be attributable to the spectrometer.

Testing will be conducted in light- and heavy-water moderated systems in a further attempt to resolve the discrepancies.

ATR Gas Loop Studies

Progress of Model Loop Construction. Construction of the model loop was completed during the first week in July 1964. Then followed a period of pressurizing and eliminating small helium leaks. Integrity of the pressurized loop was assured when no leaks could be found by ultrasonic leak detection methods.

On July 15, loop startup began with a 40-minute operating period. Subsequent tests performed during the month included vacuum pulling capabilities for the primary and shroud piping systems, analyses of impurities in the helium of both primary and shroud systems, measurement of the pressure and temperature rise across the circulator and the helium mass flow rates at circulator speeds of 5,000 to 25,000 rpm, and measurement of the minimum power input to the electric heater.

Helium Purification System. Installation of the vacuum-helium atmosphere chamber has been completed, and check-out of components for operation in vacuum was completed. Maximum vacuum attained with heaters operating uninsulated was $<10^{-5}$ Torr. With the heaters surrounded with 1-1/2-inch thick Fiberfrax, maximum vacuum attained was 4.5×10^{-5} Torr. Installation of the helium back-fill system is 50% complete. Upon its completion, the effects of helium on heat transfer in the chamber will be determined.

Evaluation of Haynes-25 Bellows. A Haynes-25 bellows similar to the one used in the model gas loop piping between the heater and test section will be evaluated following check-out of the test chamber. Fabrication of the test stand and installation of the required instrumentation is 90% complete. Test conditions will duplicate, as nearly as possible, those anticipated in the model gas loop: maximum temperature - 2100 F; internal pressurization of bellows - 5 to 10 psi; compression loading of the bellows will be on a variable time cycle.

Gas Phase Corrosion. It was concluded on the basis of indirect evidence (HW-80783) that Haynes-25 could exist in an oxygen partial pressure of less than 0.1 Torr for long periods of time at 1200 C (2192 F) without suffering catastrophic attack. This conclusion has been recently confirmed by exposing a Haynes-25 coupon to an oxygen pressure of 0.097 Torr held at 1200 C and recording the weight change. After 4000 minutes at temperature, the sample showed a weight gain of only 3.3 mg/cm^2 , a weight gain comparable to that shown by Hastelloy X, a much more oxidation resistant material, in 25 Torr oxygen at 1200 C.

Modification of Method for Removal of Oxide Scale. The method developed for removal of oxide scale from nickel and iron base alloys has been successfully modified for use with molybdenum and TZM molybdenum alloy exposed to 1000 C (1994 F) oxygen environments. Since one of the samples showed a weight gain after descaling, it appeared that internal oxidation may have taken place. Four samples--two molybdenum and two TZM-- are awaiting metallographic examination.

Previous work includes the oxidation of molybdenum and TZM at 1000 C and at air pressures of 5×10^{-3} and 5×10^{-4} mm Hg. Use of an extra flexible joint in the glass tubing and development of a different heating technique has solved leak problems and experiments are underway at 5×10^{-5} mm Hg air pressure.

6. Nuclear Graphite

EGCR Graphite Irradiation. The long-term irradiation program of EGCR graphite is proceeding satisfactorily. The H-3-8 capsule has successfully completed three cycles of irradiation with all thermocouples functioning properly. During the last reactor cycle the E7 filler piece was removed and the end-box modified. The capsule was reinstalled in the repaired filler piece and is again operating satisfactorily.

Irradiation of Cemented Graphite

The tensile strength of a cemented graphite joint after exposure to 7.9×10^{20} nvt, $E > 0.18$ Mev, at 600°C was found to be higher than that of an unirradiated control specimen. Dogbone-shaped tensile specimens with the cemented joint at the center of 3/4 in. diameter by 2 in. long gauge sections were machined from stock prepared by Great Lakes Carbon Corporation. Heat treatment after cementing included graphitization; however, the graphite and cement types were not specified by the supplier. Examination of the joint line on the machined surface revealed a narrow straight line < 0.05 in. thick. A contraction in diameter of 0.034 percent was measured at this exposure as compared to an expansion of 0.027 percent measured at an exposure of 3.2×10^{20} nvt.

Visible alignment of coke particles in the relatively coarse-grained graphite indicates that the faces cemented together were perpendicular to the direction of preferred alignment. The diametric radiation-induced contraction was thus perpendicular to the direction of preferred alignment and the tensile force applied in testing was in the parallel direction. Tensile strengths were 1173 psi for the irradiated specimen and 697 psi for the unirradiated specimen. In both cases rupture occurred at the joint line. The joint surfaces exposed on both specimens have circular unbonded regions which appear to have been formed by air trapped in joining or gas evolved during curing. An estimated 8 percent of the irradiated joint surface and 6 percent of the unirradiated surface appeared to be unbonded. This indicates that the relative bond strength of irradiated cement could be somewhat higher than indicated by the tensile tests.

In previous irradiations of cemented joints, failures during irradiation were traced to the 1/16 in. wide cement layer in which cracks developed. No heat treatment was used in preparing the earlier joints. Reducing the joint thickness and graphitizing prior to irradiation apparently contributed to the more favorable results reported here.

Thermal Conductivity of EGCR Graphite

Thermal conductivity measurements were completed for irradiated and unirradiated samples of EGCR graphite. Data were obtained by the thermal-pulse method in the temperature range 25 to 500°C. Samples were cut from the center of a bar with a 16 x 16 in. cross section and the thermal diffusivity was measured parallel to the direction of extrusion. The thermal conductivity of unirradiated EGCR graphite was 0.50 cal/cm-sec-°C at 25°C; this decreased to 0.27 at 500°C.

Two samples were irradiated at 550 to 600°C to an exposure of about 1.9×10^{20} nvt ($E > 0.18$ Mev). Post-irradiation thermal conductivity values were 0.17 cal/cm-sec-°C at 25°C and 0.16 at 500°C. Measurements for the two samples differed by less than 6 per cent. Additional measurements are planned for samples which have been irradiated to higher exposures.

Effect of Particle Size and Impregnation on Radiation-Induced Contraction of Graphite. A series of samples from the National Carbon Company are being irradiated at approximately 600°C to determine the effect of particle size and impregnation treatment on high-temperature radiation-induced contraction. A set of 36 samples had been irradiated to 2.3×10^{20} nvt, $E > 0.18$ Mev (1715 Mwd/At_K) and another set has just been irradiated to 3.6×10^{20} nvt (3015 Mwd/At_K). All samples are of parallel orientation. Results from both sets were used in three-factor variance analysis to determine the significance of each factor - exposure, particle size, and impregnation treatment - and of interaction between factors.

All single factors are significant at greater than the 99.9 percent confidence level. As expected, there was greater contraction in the samples irradiated to high exposure.

Of the impregnation treatments, a single furfuryl-alcohol impregnation which added an average of 8.4 percent carbon was found to cause less contraction at these exposures than a single pitch impregnation which added only an average of 5.2 percent carbon.

The greatest contraction was observed in the samples doubly impregnated with furfuryl alcohol which added an average of 11.0 percent carbon. A larger contraction in the furfuryl-alcohol-impregnated samples was expected.

Of the three particle sizes, the samples with 0.030 in. maximum particle size displayed the greatest contraction followed by the 0.015 in. size. The samples with 0.060 in. size displayed the least contraction. It should be remembered that these are results on parallel samples; hence, the smaller contraction in the largest particle-size material may be due to its lower anisotropy.

Of greater interest and less obvious without the statistical analysis was the fact that all two-factor interactions were significant at greater than the 99 percent confidence level. The strongest two-factor interaction was between particle size and exposure; that is to say the contraction rates were significantly different among the three sizes. The contraction rate was greatest for the 0.030 in. size. The rate for the 0.060 in. size was less than the rate for the 0.015 in. size.

The samples doubly impregnated with furfuryl alcohol contracted at the greatest rate, followed by the pitch impregnated samples and then the samples singly impregnated with furfuryl alcohol. The difference in rate between the singly and doubly impregnated furfuryl alcohol impregnated samples must be attributed to the effect of the 2.6 percent carbon added during the second impregnation.

There also was significant interaction between impregnation treatment and particle size. This was investigated further by performing a two-factor analysis at each exposure level. It was found that the interaction was significant at the lower exposure level but not at the higher exposure level. This implies that the interaction between impregnant and particle size effects mainly the initial response to radiation and hence could be discounted in considering longer term behavior.

The Influence of Preferred Orientation on Thermal Expansion of Extruded Graphites

The objective of this study is to determine the crystallite orientations of CSGBF, CSF, and TSX graphites by X-ray methods, relate these to the thermal expansion behavior of graphites, and ultimately to radiation-induced dimensional changes.

Half-inch cubical samples of CSGBF, CSF, and TSX graphites were cut from a number of positions of a standard extruded bar. After the samples were annealed at 1700°C for one hour thermal expansion measurements were made in a three-sample dilatometer at temperatures ranging from 25 to 700°C in an argon atmosphere.

The results of the X-ray analysis show that the average concentration of c axes parallel to the extrusion direction remains essentially constant throughout the cross section of the bar. The sum of the average concentrations of c axes in the two transverse directions would then also be constant throughout the cross section of the bar, but the results show that the distribution of c axes between the two transverse directions becomes unequal toward the bar surface in such a way that the layer planes tend to concentrate parallel with the surface. It is also found that TSX graphite is more anisotropic than CSF and CSGBF graphite, and that no real difference exists between the anisotropies of CSGBF and CSF graphites.

Because the thermal expansion of the crystallites is generally much greater than the bulk thermal expansion, some accommodation must occur in the body. The accommodation factors were calculated from thermal expansion measurements using two slightly different theoretical equations. Both equations were found to give about the same accommodation factors and they were essentially constant with temperature. The accommodation factors also tended to increase as the concentration of c axes increased indicating that the porosity is greater with less perfectly aligned crystallites. This implies that the bulk material shrinks more efficiently during the graphitization process and that the structure becomes more perfect when the platelets are originally better aligned. If the difference in accommodation factors were to arise primarily from the contraction of the layer planes while cooling from the graphitization temperature, the accommodation factor would have been greater in the parallel rather than in the transverse direction because the concentration of c axes is much greater in the transverse direction.

In-Reactor Creep. The GEH-13-9 series of irradiation capsules containing single creep specimens has been completed. The last sample, GEH-13-97, was recovered from the test assembly in good condition. The data acquired from this group are presently being analyzed and will appear in HW-SA-3592, "The Effect of Tensile Loading on the Neutron-Induced Contraction of Graphite."

A second generation design, that will provide a controlled tensile load on three specimens in series, has been completed and installed in the F-6 position of the Engineering Test Reactor. The first cycle is nearing completion and the experiment is functioning properly. This test will continue for at least 100 effective days, thereby attaining exposures greater than 1.3×10^{21} neutrons/cm², $E > 0.18$ Mev.

The tests to date have established that a part of the normal contraction of graphite can be restrained at both 600 and 800 psi. The amount of restraint is dependent on load.

Kinetics of the Reaction of Carbon Dioxide and Hydrogen. In order to predict the rate of oxidation of graphite by impurities in a helium gas stream, it is necessary to have kinetic data on several reactions. Some of the reactions are the direct oxidation reactions while others are reactions that indirectly affect the concentrations of the oxidants. A reaction in the latter category is the reaction of carbon dioxide and hydrogen:

We have studied the reaction rate in the temperature range 550°C to 1100°C in a flowing system. A helium stream containing carbon dioxide and hydrogen is passed over hot copper turnings to remove any oxygen and then through magnesium perchlorate to remove water. The gases then pass through a quartz reaction vessel at a controlled temperature. The products of the reaction, carbon monoxide and water, are determined continuously using, respectively, a gas chromatograph and an electrolytic moisture monitor.

Early results showed that the reaction is catalyzed by components present in the copper furnace and that significant quantities of product gases are formed at 400°C. However, at 300°C, the products formed over the copper were present in concentrations of less than 0.001 percent a significant quantity only for those experiments performed at the lowest temperatures used.

The product concentration in the effluent was determined as a function of contact time at 900°C. The amount of product is a linear function of time but extrapolation to zero product showed that there is an induction period of 0.3 second.

The effect of reactant concentration on the reaction rate indicated that the rate was proportional to the first power of the carbon dioxide concentration and to the square root of the hydrogen concentration.

The rate expression after the first 0.3 sec can therefore be written

$$\frac{d(\text{H}_2\text{O})}{dt} = k [\text{H}_2]^{1/2} [\text{CO}_2] \quad (1)$$

The temperature coefficient for the rate of the reaction was also determined. A plot of $\log k$ vs $1/T$ shows a definite change in slope in the curve in the range 800 to 850°C. The activation energy for the reaction above 800°C is 76.5 kcal/mole but below that temperature the activation energy is only 34.3 kcal/mole.

The rate constants can be expressed as follows:

$$k = 5.9 \times 10^{12} \exp (76.5/RT) \text{ l}^{1/2} \text{ mole}^{-1/2} \text{ sec}^{-1}; T > 800^\circ\text{C} \quad (2)$$

$$k = 2.7 \times 10^4 \exp (34.3/RT) \text{ l}^{1/2} \text{ mole}^{-1/2} \text{ sec}^{-1}; T < 800^\circ\text{C} \quad (3)$$

This break in the curve is an indication that there are at least two separate reaction paths involved; one predominating at low temperatures, the other at high temperatures.

The rate expression pertains only to the reaction above 800°C. The concentration dependence has not been tested at the lower temperatures. Equation (1) agrees with that published earlier by Graven and Long⁽¹⁾, but the activation energy for the reaction was 56 kcal/mole. However, since these authors investigated the reaction over a much narrower temperature range, they did not detect the change in activation energy. In addition, they did not mention any attempt to remove trace quantities of oxygen. Since we have demonstrated that oxygen increases the rate of the reaction markedly, trace amounts of oxygen may be the cause of the larger rates and lower activation energy in the published results.

8. Aluminum Corrosion and Alloy Development

The in-reactor corrosion test of aluminum-clad fuel elements in C-1 Loop at pH 4.5 with H_3PO_4 and 260 C outlet temperature was concluded. The fuel elements were discharged after 58 days at high temperature operation. The cladding temperature, as indicated by a thermocouple element, prior to discharge rose to an undesirable level after the oxygen content of the loop increased to 0.03 cc/l. The outlet temperature was reduced to 250 C for the last ten days of the test so the upper temperature limit would not be exceeded. High activity levels in the loop after the reactor shutdown and the loop water cooled indicated that considerable crud

and oxide film was released from the fuel element cladding. After a cooling period of 30-45 days, the elements will be sent to Radiometallurgy for examination and weight measurements. This discharge completes testing in C-1 Loop under the Aluminum Corrosion and Alloy Development Program.

9. Metallic Fuel Development

Irradiation of Thorium-Uranium Fuel Elements

Irradiation of three tubular Zircaloy-2 clad thorium - 2.5 w/o uranium 1.0 w/o zirconium fuel elements continued in the ETR-P7 loop. The fuel elements are currently operating at a maximum temperature of 480 C, a surface heat flux of 53 cal/sec-cm² (7.1×10^5 BTU/hr-ft²) and a specific power of 49 watts/gm (150 kw/ft). The integrated exposure is 2.7×10^{20} fissions/cm³ (8000 MWD/T). Fuel swelling continues to be no more than that expected from the solid fission products. The measured volume increase at 8000 MWD/T was 0.8 percent.

Irradiation Testing of Metallic Uranium with Sub-Micron Uranium Carbide Dispersions

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

One capsule has achieved a goal exposure of 0.3 atom percent burnup at a maximum fuel operating temperature of 550 C and is being shipped to Radiometallurgy for examination. The remaining two capsules are operating at maximum fuel temperatures of 600 to 625 C.

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

Thermal Hydraulic Studies

Boiling Burnout with 19-Rod Bundles. All drawings were finished and fabrication was approximately 50 percent completed on the second electrically heated test section for the fog-cooling studies. Detail plans were also made for the steam generator unit to be used

for supplying 100 percent quality steam to the test section flow mixer. The unit will consist of 30 Inconel 3/4 inch OD by 0.065 inch wall tubes, each about 30 feet long, arranged in electrical parallel. Each set of three tubes will be connected in hydraulic series, while the ten sets will be in parallel. It will be possible to remove sets of tubes (two sets at a time) at low flow rates if higher mass velocities are desired. With all tubes in place, the heat flux will be less than 75,000 Btu/hr-sq ft at 2700 kw while the mass velocity will be 230,000 lb/hr-sq ft at 10,000 lb/hr.

Analyses were also continued on coolant mixing in 19-rod bundles. An analysis was made on the basis of two channels (one hot and one cold) in a 19-rod bundle and attempts were made to assign mixing rates to the Hanford 19-rod bundles so that Hanford burnout data would agree with those of APED (seven- and four-rod bundles) and of Columbia University (12- and 19-rod bundles).

No reliable quantitative mixing rates (defined as the ratio of mass rate of cross flow per unit length to total mass flow) have been obtained. Qualitatively, mixing rates decrease with a decrease in rod spacing, as would be expected.

For a given rod spacing, the curve of mixing rate versus relative length where bulk boiling begins goes through a minimum in the region of moderately subcooled exit enthalpies. (Note: When exit bulk fluid is subcooled, the relative length where boiling begins is greater than unity.) This minimum is explained by the fact that under these conditions bulk boiling could occur in the hot channels and not in the cold channels resulting in even greater discrepancy in the flows in the hot and cold channels. On the other hand, under bulk boiling conditions, bulk boiling likely occurs in both the hot and cold channels and the distribution of flow in the channels will be better than when two-phase flow occurs in the hot channel and single-phase flow occurs in the cold channel. A similar argument applies for the highly subcooled case in which single-phase subcooled liquid flows in both hot and cold channels.

11. Conceptual Reactor Design Studies

Segmented Fast Reactor (SFR)

SFR core physics calculations have used flux trap enrichments and proportions somewhat similar to those used in the FSPPR design. However, preliminary consideration of the possible fuel cycle schemes for the SFR indicates that it is probably desirable to employ a partially graded fuel cycle for the core, and that the flux

trap fuel cycle would probably be optimized independently of the core. It should thus be possible to lower (or perhaps eliminate) enrichment of the flux trap region and reduce plutonium inventory while still having acceptable power distribution and power shift values. The range of fuel cycles which will need to be considered is currently being studied.

The current problem of high fuel temperatures in SFR cores III and IV has pointed out a need for a more detailed temperature analysis in parametric studies. To do this a computer program is currently being set up for the IBM 7090 to do parametric studies on a specific core geometry, hexagonal core with hexagonal fuel subassemblies and pin type fuel, that will include fuel surface and center line temperatures. It will also include the previous parametric study computations which established flows and core cross sections for specified core power, hot channel factors and maximum cladding temperatures. The feasibility of combining the thermal hydraulics calculations into this program is also being investigated.

Work sheets were completed on the reactor building plan and sections.

Safety of Mixed PuO_2 - UO_2 Fuels

Some very rough estimates of the time required for fuel slumping to occur in oxide fuels whose density is less than theoretical have been completed. The assumption is made that the interior of a fuel rod melts and the fuel flows downward as a viscous liquid filling a void. Kinetic pressure and surface tension effects are neglected. Results obtained indicate that fuel displacement is slowest for smallest diameters. For example, a total displacement of 5 centimeters was calculated to require 100 milliseconds for 1/8 inch diameter and 40 milliseconds for 1/2 inch diameter. Thus, small fuel rods, in addition to having a smaller thermal time constant, should also be more stable against slumping.

A formal report summarizing all of the work to date on the safety of mixed oxide fuels has been completed. The report, An Investigation of Neutron Kinetics Problems Associated with Mixed Oxide Fuels, HW-81259, provides an evaluation of Doppler, self-shielding, and fuel slump reactivity effects.

12. Critical Flow at High Pressures and Temperatures

Experiments were performed to obtain information necessary for the development of a critical discharge correlation for flow of steam-water mixtures through pipes with elbows at the discharge end. It was established earlier that available theories

and data correlations for straight pipes alone are not always applicable for the case where the pipe is followed by an elbow. It was found that at low pressure and qualities, the critical pressure corresponding to any enthalpy and flow rate was generally lower than predicted and observed for straight pipes.

The present experiments were performed on a length of 1/2-inch schedule 40 pipe which had a welding ell welded to the discharge end. Located at various positions along the test section were pressure taps to determine the axial and circumferential distribution of pressure. Steam-water mixtures of desired enthalpy were made by mechanical mixing of steam and hot water. These steam-water mixtures then flowed through the test section and were discharged to the atmosphere. Because of equipment limitations, maximum pressure in the test section was limited to about 175 psia. The experiments were performed by holding upstream enthalpy constant at either 300, 500, 600, 700, 800, 900, or 1000 Btu/lb and varying flow rate. At each flow rate, pressures at all wall taps were noted.

In developing a preliminary correlation, the following two factors were noted:

- (a) Due to separation and centrifugal effects, a "critical pressure" found by conventional extrapolation techniques would probably be meaningless.
- (b) Even if it was possible to define a "critical exit pressure," the two-phase flow characteristics of elbows are not well enough known to allow the use of this data in practical design and analysis.

Therefore, an attempt was made to correlate the data with respect to a pseudo-critical pressure upstream of the elbow. In this manner, both the critical flow phenomenon and the two-phase flow characteristics of the nozzle can be combined. The point of pressure reference was arbitrarily chosen as one pipe diameter upstream of the elbow. At this point, no circumferential pressure gradient resulting from the elbow could be observed.

It was found that for constant enthalpy, the critical mass velocity was an approximate linear function of the pressure at the reference point. The effect of enthalpy was to change the slope of the linear relation.

13. Upstream Boiling Burnout

Additional boiling burnout experiments were conducted with the 0.444 inch ID test section described in the previous report period. It was found in these experiments that changing the inlet piping between the preheater and the test section (from about 40 feet of 2-inch and three feet of 1/2 inch pipe containing several short radius ells and several dead legs to 40 feet of 1/2 inch OD 0.035 inch wall tubing with no dead legs and only smooth tubing bends) caused a decrease in the magnitude of the pressure oscillations within the test section. Burnout heat fluxes and pressure oscillations obtained subsequent to the inlet piping change have been quite reproducible, whereas those obtained prior to the piping change were not. Burnout heat fluxes with the new piping and without quench water introduction at the test section outlet are up to 2.7 times those obtained previously. Pressure oscillations within the test section, as measured by fast-response recorders, are significant during portions of the power increase approach to burnout heat fluxes are achieved. The present data obtained at $G = 1 \times 10^6$ lb/hr-sq ft show less than 11 percent variation in burnout heat flux for inlet temperatures over the range 95°F to 340°F or outlet qualities over the range 4 to 34 weight percent steam.

An interesting situation was recorded wherein an increase in inlet coolant temperature from about 95°F to 140°F at constant heat flux of about 1.0×10^6 Btu/hr-sq ft caused about 20° decrease in test section outer surface temperatures. The test section surface temperature decrease was accompanied by a decrease in the magnitude of the pressure fluctuations within the test section. The 95°F inlet condition corresponds to bulk outlet subcooling. Thus, significant decreases in pressure fluctuations occurred within this range. This might correlate with observations of other investigators at higher pressures wherein increase in heat flux produces a small decrease in surface temperatures.

14. Phoenix Fuel Program

Phoenix Fuel Experiment

A study to determine the suitability of the MTR as a test bed for a Phoenix type, high exposure plutonium-fueled core was initiated. Present calculations have been concerned with identifying maximum capabilities of several individual parameters (e.g., metal-to-water ratio, core loading, heat flux) as part of the parametrizing study. For the purpose of this study the following criteria have been assumed:

1. Core loadings at 50-70 kilograms plutonium. The MTR normally operates with 4.5 Kg U-235.
2. Local metal/water ratios between 0.5 and 2.5 with emphasis on the higher figure. The local metal/water ratio for the MTR is presently 0.43.
3. Power densities at least as high as the standard MTR loading - 400 Kw/liter.
4. Zircaloy fuel cladding with 20 w/o Pu-Zr alloy fuel.
5. MTR plate type fuel elements with an investigation into rod types.

At the present time effort is being directed toward defining the limits on the core and fuel element parameters from an engineering standpoint.

15. Nuclear Rocket Fuels Studies

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

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.

Six ambient-temperature irradiation capsules, each containing 36 polycrystalline molybdenum tensile specimens, have been submitted for irradiation. Three exposures were selected: 1×10^{17} , 5×10^{17} , and 1×10^{18} nvt ($E > 1$ Mev). These specimens will be subjected to post-irradiation annealing prior to tensile testing. Annealing temperatures will correspond to those at which significant microstructural changes have been observed by transmission electron microscopy. Other annealing treatments will be chosen such that there will be a correlation with irradiation temperatures to be employed in future elevated-temperature irradiations.

Considerable effort has been expended in the development of experimental equipment. A low-frequency internal friction apparatus is nearly completed and vibrational noise measurements are in progress. A purification system for removal of interstitial impurities from molybdenum is under construction, as is a system for the addition of known quantities of carbon to molybdenum (utilizing a $C_2H_2 - H_2$ atmosphere).

High-purity molybdenum foils deformed by predetermined amounts after annealing have been irradiated to 5×10^{18} nvt ($E > 1$ Mev). Undeformed annealed foils were also irradiated in the same capsule for comparison measurements. X-ray lattice parameter measurements show that the undeformed lattice increased from 3.1471A to 3.1479A as a result of the irradiation. Samples deformed to the yield point increased from 3.1473A to 3.1480A, while those deformed five percent increased from 3.1473A to 3.1479A. Foils deformed 20 percent increased from 3.147A to 3.1479A. These measurements are believed precise to 0.0001A. It appears that the annealed foils show a greater fractional increase than the cold-worked foils. It may also be of significance that the post-irradiation lattice parameters are nearly independent of pre-irradiation cold work. The same foils are to be further examined by transmission electron microscopy.

High-purity molybdenum foils irradiated to 1×10^{20} nvt ($E > 1$ Mev) have also been examined. Lattice parameters are slightly smaller than those of similar foils irradiated to 1×10^{19} nvt, and the X-ray lines are much broadened. These results are in agreement with very early observations that lattice parameters reach a maximum value at about 5×10^{19} nvt exposure and then decrease for higher exposures. This interesting result will be the subject of further investigation.

The presence of spots and dislocation loops in irradiated molybdenum foils has been reported in previous monthly reports. The exact nature of these radiation-induced defects has been the subject of some controversy. A metallurgical stage has been installed in the Philips EM-200 electron microscope and may aid in resolving this controversy. The stage permits tilting the sample 30 degrees in two directions from the horizontal position. Techniques have been developed whereby an interstitial loop can be differentiated from a vacancy loop by measuring the change in apparent size of the loop as the sample is tilted through a large angle. Specimens of irradiated molybdenum have been photographed and will be studied in an effort to determine whether the loops are interstitial or vacancy in character.

A hot stage and tensile stage have also been procured for the electron microscope. These stages will permit dynamic changes to be observed as the sample is being heated or deformed in the microscope. One attempt to anneal an irradiated molybdenum specimen in the microscope, utilizing the hot stage, resulted in oxidation of the sample at 250 C (482 F). An inert atmosphere is presently being provided to retard oxidation. Suitable irradiated specimens are being prepared for the tensile holder in an effort to observe deformation modes.

The density and width of slip lines in irradiated molybdenum single crystals are observed to increase with increasing deformation, as measured by the radius of curvature on the bent samples. The increase in the number of slip lines suggests that new channels are constantly being formed. The increased width of the slip line probably means the channels are getting wider due to glide on planes adjacent to the existing channel and not to increased glide through the original channel which could give an apparent increase in the slip line width when observed on a surface replica.

Thin sections have been cut perpendicular to the primary slip plane and slip direction on one of the irradiated and subsequently bent crystals for transmission electron microscopy.

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 those properties.

Phase Transformation Studies

The existence of a C in the T-T-T curve of the $\beta \rightarrow \alpha$ transformation of plutonium has been confirmed. Experiments were performed to establish whether or not rapid quenching from the beta to the low alpha, -196 C (-321 F), coupled with rapid removal of heat, would result in rapid transformation.

Specimens in the form of wafers 0.125 mm thick were quenched from the beta phase at 110 C (230 F) into ethyl alcohol at -115 C (-174 F) and then into liquid nitrogen at -196 C. Incubation times for beginning of transformation were six hours and longer. Specimens treated in this manner transformed within seconds if they were warmed to temperatures between -20 and -40 C (-4 and -40 F). The experiments confirmed the C type T-T-T curve with the nose of the curve being at -20 to -40 C. The apparent fast transformation rate of thicker electrorefined specimens (1 mm thick) which were quenched from the beta phase into liquid nitrogen is not due to a high cooling rate but actually a slow rate. The rate is so slow that the nose of the T-T-T curve is not missed, and transformation occurs at temperatures much higher than the quench temperature, -196 C.

Deformation Studies

The LASL electrorefined plutonium which had been drop cast in MgO crucibles was found to have a density of 19.57 g/cm^3 . The castings were 0.180 inch thick, significantly thicker than it has previously been found possible to roll. However, no difficulty was encountered in rolling this material to an overall reduction of 92 percent. Rolling was done with the tables and rolls at 70 C (158 F). Single pass reductions of a constant 0.010 inch were taken on the 6 x 8 inch Stanat mill operated at 16 ft/min.

In order to test further the extent to which self-damage affects the deformation character, one-half of the casting which was successfully rolled has been set aside to be aged some ninety days. After this period, an attempt will be made to roll this material under the same conditions which had been found satisfactory for the freshly cast portion of the ingot.

The work on the pole figures for this heavily deformed material has been initiated. Specimens presenting both the rolling surface and the transverse surface 90 degrees to the rolling plane have been prepared for use on the goniometer. The data derived to date serve to indicate the complexity of the problem. It is obvious that several lines will have to be investigated in detail in order to establish the orientation resulting from the rolling operation and to evolve an explanation for the crystallographic mechanisms involved in the deformation process.

An inert fluorochemical, heptacosafuorotributylamine ($\text{C}_{27}\text{F}_{51}\text{N}$), is being evaluated as a displacement fluid required for density measurements of plutonium. This liquid appears to have excellent characteristics for density determinations of plutonium between -20 C and 150 C (4 F and 320 F). Densities with a precision of $\pm 0.003 \text{ g/cm}^3$ over extended periods of time should be readily obtained.

E. CUSTOMER WORK

1. Radiometallurgy Laboratory

The results of routine examinations and measurements are, or will be, reported as part of the sponsoring research and development programs. During the period June 29 to July 28, 1964, Radiometallurgy Laboratory output included:

Metallography samples processed -----	68
Photomosaics -----	4
Autoradiographs -----	9
Replicas (for electron microscopy) --	18
Replicas (silicone rubber) -----	2
Burnup dissolutions -----	52
Fission gas sample collections -----	8
Vacuum induction furnace runs -----	8
Decladding dissolutions -----	2
Rockwell hardness tests -----	22
Density determinations -----	26
X-ray analyses -----	2
Negatives processed -----	571

Equipment

Tensile Tester Furnace. A furnace has been installed on the tensile tester in the Physical and Mechanical Properties Testing Cell. Initial tests on unirradiated control samples have been carried out at temperatures up to 650 C.

Annealing Furnace. Operational checkout of the complete furnace system was satisfactorily completed. Temperature distribution curves were obtained and the equipment was installed in D-Cell.

Remote Impact Tester. This equipment was shipped to the vendor for inspection and calibration services.

High Temperature Tensile Testing Machine. Installation of the testing machine in H-Cell, including all electrical and piping connections, was completed. Design of a tensile sample loading jig was completed and fabrication was initiated in Technical Shops. Design of a heating element protection device was initiated. This device is required to protect the furnace elements if vacuum is lost at elevated temperatures.

"E" Cell Metallographic Facilities. Electrical and piping installation work was completed. Completion of the cathodic etcher operational tests illustrated its ability to etch at high voltage and low argon pressure with no re-deposition of metal. There was no indication of arcing over the full range of etching pressures.

"I" Cell Micro Hardness Blister. Installation of the remotely operated micro hardness tester in the blister was completed. Operational checkout of the complete system was initiated.

Strain Gage Spot Welder. Design was completed for equipment required to remotely spot weld strain gages on tubes pressurized in the Burst Test Facility. Review of assembly and detail drawings was initiated prior to their issuance for fabrication.

2. Metallography Laboratories

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

During the report month 558 samples were processed, a total of 762 macrographs taken, 2104 negatives printed, and 7484 prints processed.

The initial attempt to thin metal for transmission electron microscopy was partially successful. Stainless steel, Type 304, with an initial thickness of 0.020 inch was the material thinned. The electrolyte (40% sulphuric acid, 60% ortho-phosphoric acid) was directed against the sample as a jet 1/16 inch in diameter with 5/16 inch between the cathode terminal (nozzle) of the jet and the anode sample. Five minutes on each of the two opposite surfaces of the specimen were required to achieve penetration using 50 volts and 0.25 ampere. Following examination in the electron microscope, it was concluded that proper evaluation of the material will require larger areas of properly thinned metal.

3. High Temperature Lattice Test Reactor (HTLTR)

Construction work on the HTLTR large mockup is essentially complete. The only work remaining is that of painting the structure. Startup testing is expected to commence in August.

Laboratory operation of the first HTLTR prototype vertical safety rod continues to be satisfactory; re-design of the vertical safety rod to accommodate the wider control element is complete; and preliminary design of the control element is complete.

Compatibility of Structural Materials with the HTLTR Environment

Tests were completed on the insulating materials proposed for use in the HTLTR to determine their tendency to readsorb gases after initial outgassing. The diatomaceous earth brick underwent a 0.3 per cent weight gain in a 24 hour exposure to the atmosphere after 500 C vacuum outgassing and continued to gain weight at a slow rate over a period of two weeks. Since in normal reactor use the insulation will be periodically exposed to the atmosphere, the above characteristic of the diatomaceous earth could result in prohibitive amounts of impurities in the nitrogen atmosphere during reactor operation, and a design change to replace this material was implemented by the responsible groups. An aluminum brick insulation to be used in the high temperature zone of the reactor was similarly tested and found to have a 0.06 percent weight gain in two weeks, which is considered acceptable.

A 500 hour test to determine the effect of insulating brick material on graphite corrosion at 1200 C is being conducted. Initial preparations were started on environmental tests of fuel and control rod cladding materials.

4. EBWR Fuel Fabrication

As of July 1, 1964 all 1500 EBWR UO_2 - PuO_2 fuel rods as required for various physics experiments at Hanford were delivered to Reactor Physics Operation. After completion of these experiments 1000 of the fuel rods will be shipped to Argonne. These and another 500 to be fabricated in August will be assembled at Argonne National Laboratory for the early critical tests and later full power operation in the EBWR. The remaining 500 fuel rods will be retained at Hanford for further critical experiments in the PRCF.

Preparation of EBWR Fuel Materials

The first test lot of UO_2 -1.5 PuO_2 using high fired UO_2 was processed. The mixed oxide had an average density of 98% of theoretical. The results agreed closely with those from test runs using UO_2 only. The exceptionally fine particle size of this UO_2 made it more difficult to densify and increased the wrinkling of the Nupac container. However, no container rupture problems did occur and continued excellent experience in contamination control was maintained. Crushing yield was 90%, comparable to that with fused oxide.

The newly installed outgas furnace was placed in operation July 8. Approximately 280 kilograms of $\text{UO}_2\text{-PuO}_2$ for the PRTR and EBWR were subsequently outgassed. Water and oil analyses of the outgassed $\text{UO}_2\text{-PuO}_2$ show the system performs satisfactorily, and the shortened outgas cycle (maximum of one hour at 250 - 350 C) to be adequate.

Twenty-six kilograms of EBWR $\text{UO}_2\text{-1.5% PuO}_2$, initially rejected because of high carbon content, were heat treated at 1550 C for eight hours in a 6% wet hydrogen - 97% argon atmosphere.

EBWR Fuel Element Cladding

A shipment of 117 Zr-2 EBWR cladding tubes was received from the vendor as a partial replacement of previously rejected tubes. Ultrasonic examination revealed 10 tubes with defects deeper than 0.001 inch.

As a part of a joint effort to correlate inspection methods, 23 EBWR cladding tubes were sent to Hanford after examination at ANL with pulsed eddy current test equipment. Sixteen of these tubes were ultrasonically inspected using two, 15 megacycle, 3/16 inch diameter crystals with 1/4 inch radius spherical focused lenses. In the ANL tests, only one defect was found that exceeded the 5% localized reduction in wall thickness specification. However, in the Hanford tests, eight tubes were found to have internal defects deeper than one mill, with six deeper than two mils. Examination of the defects revealed enlargement by the etching which had been performed on the tubing. In some cases these defects appear as micro-cracks propagating on a 45-degree shear angle.

5. Other Customer Work

Phoenix Fuel

Approximately 6,000 20 wt% Pu-Al disks, 0.020 inch thick have been fabricated to close tolerances by the recently developed "spiral machining" process. Isotopic content of the disks range from 8 wt.% Pu-240 to approximately 26 wt.% Pu-240.

The third Al-20 wt.% Pu alloy, containing 27 wt.% Pu-240, was prepared by reducing PuO_2 with aluminum in the presence of cryolite. More than 2 kilograms of PuO_2 were reduced to form the alloy. The yield of the initial reductions was 85% but a subsequent reduction increased the yield to more than 90%.

Irradiation Samples for Phillips Petroleum

Irradiation samples consisting of gold-aluminum and lithium-aluminum alloys are being fabricated by a coextrusion process. All alloys have been extruded and final assembly work is in progress. An eddy current test is able to delineate the clad from the Al-Li alloys, which are similar in density to the cladding and cannot be differentiated by radiography. The chemical analysis of the lithium alloys (0.1% - 0.8% Li) indicated that the average variation in lithium content between samples was less than one percent.

Physics Test Elements

Highly loaded (70 wt.% UO_2) graphite- UO_2 pellets were fabricated. The pellets will be used for chemical compatibility tests to determine suitability for HTLTR control rod design. A phenol-formaldehyde resin was added directly to blended graphite- UO_2 powders; and the resulting mix was blended, crushed, and cold pressed into pellets. The pellets were cured at 165°C and then slowly heated to 1350°C to carbonize the resin and set the resulting binder carbon. Several heating cycles and particle sizes are being investigated to enhance the mechanical properties of the dispersion.

For Manager

Reactor and Fuels Laboratory

FW Albaughjd

PHYSICS AND INSTRUMENTS LABORATORYMONTHLY REPORTJULY 1964FISSIONABLE MATERIALS - O2 PROGRAMREACTORN-Reactor Lattice Parameter and Spectral Measurements at Startup

The data from the January and April irradiations have been reduced to activity ratios. These ratios together with the detector pin positions and the irradiation and counting conditions are being prepared for documentation. The data are being analyzed to determine ρ , β , ϵ , the neutron temperature and the r -value of the epithermal flux.

Flux Ratios in Thulium Oxide (Th_2O_3) Adjacent to KVE Fuel

Relative $1/v$ flux ratios are desired for KVE fuel vs. two Th_2O_3 and graphite wafer mockups. This will permit evaluation of total induced activity in these mockup elements by irradiation in a production reactor for Boeing. The experimental portion of this work has been completed and all data have been reduced to the required $1/v$ fluxes. Graphs of relative fluxes are complete, and work is progressing on the preparation of a report.

Utilization of Plutonium Fuel

A series of PCTR experiments are being planned to measure the voiding coefficient and the Doppler coefficient as a function of temperature for Pu-Al fuel with an I & E geometry similar to production reactor fuel. Two different Pu-240 concentrations are to be studied. An acceptable set of fuel dimensions has been formulated. The graphite lattice to be used is the 8 inch square EGCR lattice. The one-half inch diameter Pu-Al rods from previous experiments will provide the buffer fuel. Special I & E fuel will be made only for the single, central test cell.

NPR - Utilization Studies

Work on the physics of fuel cycle analysis for Phase III operation (power only) of the NPR is continuing. Basic parameters for the enriched ThO_2 cycle calculations have been selected. The enriched UO_2 calculations have also been started. The previous NPR utilization studies have been completed and a

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classified document, HW-83193, is being issued.

Instrumentation

Two solid state preamplifiers were designed and fabricated for experimental testing with the subcritical monitors for use at N Reactor. Several other circuit modules from the sub-critical instrumentation were modified to improve performance of the system.

Bids were reviewed and orders placed for a recorder, counting instrumentation, control valves, and scintillation detectors for use at the experimental reactor fuels testing loop installed at PRTR. The ordered equipment represents the final items needed for the system at this time.

System Studies

The N Reactor simulation was used to make special runs to study the change in surge tank parameters during scrams with higher main steam header pressure and larger friction drops in the dump condenser condensate exit piping. These runs are a continuation of the new surge tank design studies that are being made in order to provide N Reactor personnel with information needed to make final design decisions on the surge tank modifications.

A task force has been set up at N Reactor for the purpose of tuning up the reactor control system so the reactor may be operated at higher power levels. Systems Research assisted the task force to make the simulation perform in closer agreement with the actual scram recordings made to date. To achieve this end two approaches were made: (1) Recorders were taken out to the reactor and hooked onto various controllers, recording both input and output. When the recordings are complete, an analysis will be made in order to determine how the controllers react to various frequency forcing functions. (2) Frequency response tests are being performed on our control system simulator to make sure it is functioning according to design. The rough draft of the report describing the N Reactor simulation is complete and reviews are being made. A report was issued containing a description of the simulation and the effects of various controller settings along with charts showing typical computer runs.

Additional information for the N Reactor cold water injection hazard was requested and runs were made on the EASE 1132 analog computer. The results were given to the customer for further analysis. Additional information concerning these simulations was written up and will be published together with other results as soon as possible.

Information gathered for the reliability study of the 3X ball drop system in the small reactors was written and a rough draft submitted for approval. Since future setups are to be patterned after K Reactor circuits, the presently used K Reactor circuits will be used as a standard.

The reactor xenon study is designed to simulate the conditions relating to power level oscillations caused by xenon transients and to explore the control aspects of the system. Some difficulty was experienced in obtaining suitable numerical values for the constants. This simulation is now ready to go on the computer.

SEPARATIONS

Critical Experiments with Plutonium Solutions

Criticality experiments were continued with $\text{Pu}(\text{NO}_3)_4$ solutions in an unreflected 15.2-in. diameter sphere of 30.2 liter volume. Pu concentrations in the nitrate solutions were in the range of 39-45 g Pu/l, with an acid molarity of about 0.4. The critical concentration in the full sphere was measured to be 39 g Pu/l (critical mass 1.18 kg Pu). The H/Pu atomic ratio was 662, with a total nitrate concentration of 64 g/l.

Experiments were performed to determine the effect on criticality of the 48 mil stainless steel vessel wall. The effect of reflectors proximate to the vessel, such as the steel table base and sphere neck supports, etc., were also investigated; these effects were found to be small, < 0.2 liter correction to the critical volume of 30.2 liters.

The critical concentration in the sphere, when reflected with up to 0.3-in. S.S., was 34 g Pu/l which compares with 39 g Pu/l for the 48 mil thick unreflected vessel. The following values were derived for a completely unreflected sphere of solution having a 30.2 liter volume.

Critical Values for Clean 15.2-in. Solution Sphere

<u>Critical Pu Conc.</u>	<u>Acid Molarity</u>	<u>Sp.Gr.</u>	<u>Total Nitrate</u>	<u>H/Pu Atomic Ratio</u>	<u>Critical Volume</u>	<u>Critical Mass</u>
0.1 g Pu/l	0.4	1.08	63 g/l	644	30.2 l	1.21 kg*

* Includes 4.6 w/o Pu^{240}

The above data will be very useful for checking theory on an unreflected Pu solution assembly since few criticality data exist on Pu solution systems of this kind.

An analysis of gold foil irradiations yielded an effective extrapolation length of 2.0 ± 0.4 cm for the bare solution sphere which agrees with extrapolation distances given for uranium solutions. The critical buckling for the sphere is then $21,820 \pm 500$ μB .

In one series of experiments, a block of Lucite 18-in. x 18-in. x 6-in., was positioned at various distances from the sphere and criticality determined. The effect on the criticality of the sphere was surprisingly small. Varying the position of the reflector from 2-in. off the surface to complete removal caused less than a 1% change in critical volume. It may be concluded that personnel approaching to within one foot of an assembly this size (even if it were delayed critical) would not cause the unit to become prompt critical by their reflection of neutrons into the assembly.

Theory and Methods of Computing Criticality Parameters

Previous efforts to calculate criticality of homogeneous plutonium systems using the S_n method and cross section data obtained from the GAM-I code have been unsuccessful. A comparison of the GAM-I cross sections to those of Hansen and Roach (LASL-16 Group) indicates appreciable differences in the transport cross sections. The reasons for these differences are not clear, but the difficulty is thought to lie in the manner GAM-I computes the cross sections and diffusion coefficients. These differences are being investigated.

A new computer code, DTF, was received during the month and is now being debugged. DTF uses both the S_n approximation from transport theory and the diffusion theory approximation to handle multigroup eigenvalue problems.

SMC, a Monte Carlo code for spherical geometry, was successfully used to compute the critical radius of a bare sphere of δ phase Pu metal. The result, which agrees with experiment, provides a checkpoint for the code on a fast system. The code will now be applied to the Pu solution systems under study.

Miscellaneous Calculations for Nuclear Safety Applications

The analyses of recent critical data from homogeneous PuO_2 -polysytrene assemblies having an H/Pu atomic ratio of 15 have given a value for the critical mass of a water-reflected sphere which is ~ 60 percent larger than the previous best estimates. Also, the critical thickness of an "infinite" water-reflected slab is ~ 40 percent larger. It thus appears that the curves of critical mass, and dimensions for Pu, will be considerably revised in the region of low moderation, $0 < H/X < 20$, as a result of these experiments.

Critical Mass Laboratory Instrumentation

Tests were performed by a vendor representative jointly with personnel of Critical Mass Physics on the neutron generator received last month. These tests showed that the instrument fell short by a factor of 100 on neutron yield, contrary to statements in the bid. The unit has been rejected for failure to meet purchase specifications.

Consulting Services on Nuclear Safety--Criticality HazardsNuclear Safety in HL

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

- a) Specification L-1 for Equipment Development Operation covering N-Reactor fuel elements was revised.
- b) Specification S-1 for Testing Methods Engineering was issued covering slightly enriched uranium.
- c) Specification T-1 for Waste Disposal and Decontamination was issued covering the Waste Disposal Tanks at the 300 "Wye" burial ground.
- d) The void date on temporary specification No. 2 for Metallography Development covering the fabrication of $\text{PuO}_2\text{-CH}_2$ blocks was extended to 12-31-64.
- e) Specification M-5 for PRCF was issued covering the handling of Pu-Al alloy fuel rods.

The nuclear safety of a proposed annular concentrator for plutonium nitrate solution was reviewed for Critical Mass Physics. The design of the concentrator is unique in that the heating elements are located around the inside surface of the annulus rather than on the outside.

The annulus is 1.56-in. thick; the inside diameter of the annulus is 10.4-in. Cadmium sheet will be fixed to the outer wall of the annulus to reduce the effectiveness of any hydrogenous reflector. Under the condition of water flooding, k_{eff} will be < 0.9 for plutonium concentrations up to 800 g/l. The mass limit on the dissolver will be such that for concentrations above 800 g/l (i.e., the dissolver accidentally boils dry), the system will remain subcritical.

Nuclear Safety in CPD

A meeting was held with personnel of Purex Process Engineering to discuss the nuclear safety limits in dissolving $\text{PuO}_2\text{-UO}_2$ PRTR fuel elements. One of the problems is that during dissolution the UO_2 dissolves at a faster rate than PuO_2 . Nuclear safety requirements, therefore, become more stringent, being based principally on the criticality of PuO alone. A further study is being made of this problem.

Nuclear Safety in NRD

Six meetings were held with N Fuels Engineering to establish nuclear safety rules for processing 1.95 w/o enriched uranium in the 306 and 333 Buildings. The rules for 306 Building have been approved and issued; the rules for the 333 Building are about 30 percent complete. To date, the following 333 Building specifications have been reviewed and revised for 1.95 w/o uranium:

Area 1	Area 10	One-shelf carts
Area 3	Area 11	Billet boxes
Area 6	Area 15	Finished fuel box
Area 7	Area 16	Drums
Area 8	Exemptions (section 205)	
Area 9	Two-shelf carts	Fuel Storage Rack
		Scrap shipping box

A meeting was also held to discuss methods of shipping 1.25 w/o and 1.95 w/o U metal scrap and U solutions from Hanford to the National Lead Company of Ohio. Studies are under way to determine the most economical method of shipment.

Nuclear Safety in Shipment of Fissionable Materials

Three off-site shipments were reviewed and approved for nuclear safety.

- a) 731 lbs. of 3.063 w/o uranium rods
- b) 800 lbs. of 1.007 w/o and 1120 lbs. of 1.6 w/o uranium metal
- c) 3.4 kg of 93 w/o dilute UO_2F_2 solution

Separations Instrumentation and System Studies

A formal report explaining the ANN (Aluminum Nitrate Nanohydrate) recovery process and analog computer simulation of the process was completed. Technical Publications is preparing the report for issue. Arrangements were made with Simulation Councils, Inc. to review the report for publication in Simulation.

Fabrication of the shielded detector assembly was completed for use with the Pu-239 17 keV X-ray liquid sample counting instrument. With exception of the scintillation detector wiring and assembly, the instrument is essentially completed. Detailed laboratory tests will be conducted before the instrument is moved to the field.

METALLURGY - Nondestructive Testing

N Fuels Testing

1. X-Ray Fluorescence Test Development

The prototype X-ray fluorescence tester in 333 Building, used to measure uranium contamination on the fuel ends, has been cleaned up and updated. The transistor count rate meters have been added and the shielding and mechanical features modified. New shielding parts for the sensing crystal have been designed and are being evaluated. The initial results look promising. From the apparent need for detection of smaller areas of contamination the aperture has been reduced in half and the signal to noise ratio has remained constant. Preparation of the operation manual is under way. New standards are being designed in cooperation with N Fuels.

A reject alarm circuit was breadboarded and tested for operation from the count rate signal. Tests show the circuit to perform well and reliably; three units will be fabricated for use in the prototype station.

Design of an evaluation test for the use of an isotope source replacing the X-ray source presently used is under way. Possible advantages include maintenance, cost, and higher sensitivity.

2. Uranium Surface Contamination Testing

The alpha counting surface contamination tester generally operated well during the past month. Maintenance assistance was limited to only one problem. Completion of the service manual during the month should help on the maintenance; however, more training of the maintenance forces is required.

Progress was made on the new model AC-III to replace the present prototype unit. The electronics are now being worked on while further work is proceeding on the design of a faster, more easily operated test chamber.

3. Irradiated Fuel Testing

Thirty-two more internal N fuels were tested during this past month. Three more cracked fuel cores were found; this makes the percentage of cracked inners at 11 percent. The cracks were all at the very ends of the fuel varying in lengths from 1/4 inches to about 1 inch. Experiments were run to determine if the core cracks were caused by accidental dropping. Test fuels which were dropped several times gave no indication of core cracking.

No unbonds of any kind have been detected on any of the irradiated fuels. It is planned to have samples of the cracks and blistered fuels examined destructively in the irradiated examination facility.

N Reactor Testing

1. Zircaloy Hydride Detection

The fabrication of the balance circuit chassis and dual channel chopper stabilized tester chassis were completed in the electronic shop. Checkout of the system was begun and the basic circuitry appears to be in good shape. A probe design study was conducted to determine the best approach to N Reactor probe design including temperature control. It appears that pressurized air would be a promising coolant to control the temperature of the cables, motor, rotating coupling, and probe coils without giving leakage problems which water would give. A nonrotating checkout probe was built using 75 feet of cable similar to that which would be anticipated for reactor use. This was connected to the electronic component to provide a laboratory mockup for evaluation of the following: (1) Checkout of the basic tester concept, (2) Evaluation of air cooling the probe and cable, (3) Provide a method of evaluating noise stability and sensitivity, and (4) Provide a basis for evaluation of modifications.

Fabrication of the ultrasonic rotating probe was completed and the basic principle appears to be sound. A water leak and other problems with water seals prevented complete checkout; however, the basic water cell principle was demonstrated and the rotating probe and coupling worked well.

Development of circuitry for the ultrasonic prototype is being concentrated on a wide band amplifier. A design utilizing nuvistors is being investigated.

2. Measurement of Fuel Spacer Motion for N Reactor

Development of a test for measurement of the amplitude of fuel spacer rattling in N Reactor process tubes has been initiated. This rattling is a variable affected by temperature and water flow and had been detected through audible noise. This rattling can lead to severe fretting corrosion on the inner walls of the process tube and N Reactor Department is conducting a program in an attempt to eliminate the spacer rattling. Both ultrasonic and eddy current techniques are being evaluated as possible methods of measuring the spacer motion.

Preliminary testing conducted at the hot loop in 189 Building indicated spacer movement of less than one mil can be detected using a pulse echo ultrasonic technique. Work is proceeding to provide a usable prototype to be used for correlation with N Reactor experiments. Present design is directed toward a test for the hot loop only which allows use of the ultrasonic technique. Some work is also being done on investigation of eddy current techniques which could be used under actual N Reactor conditions.

3. Internal Gas Pressure in a Fuel Element Approaching Rupture

Tentative design of a pressure sensor transducer to measure gas pressure as part of an experiment designed to test fuel element rupture pressures was completed. Investigation of similar commercial transducers determined that some would also work if modified. A cost estimate was given.

AlSi Fuel Testing

1. Bond Test Development

The evaluation for determining the precision of the new bond test for use on the MERCY program has been completed. The data have been run through the computer and results are ready to be summarized. A rough draft of the report has been completed and is awaiting the MERCY analysis before being issued. Since the preliminary analyses appeared favorable, work has been started on prototype equipment for further evaluation. This will consist of new circuitry designed to be as maintenance free as possible.

2. Hot Die Sized Fuel Testing

The operation and maintenance manual for the hot die sized fuel tester has been completed and issued.

Nondestructive Testing of Poison Splines for IPD

An ultrasonic test was developed to detect laminations in the poison splines used in reactor flux flattening and startup operations. The feasibility was demonstrated in the laboratory and a testing jig and handling apparatus mocked up in the testing facilities at White Bluffs. Tests are being run to determine the correlation between the ultrasonic transmission properties of the material and the laminations. In addition to inspecting this material for laminated sections, further development effort has been requested to provide a test capable of monitoring other parameters such as boron carbide dispersion, work hardening and other properties affecting the serviceability and usability of the splines. Significant savings would be possible if a reliable test can be provided. Application of the test at the vendor's plant as well as at Hanford would appear to be a feasible method of quality control and quality improvement.

NEUTRON CROSS SECTION PROGRAMTriple-Axis Neutron Spectrometer

The triple-axis neutron spectrometer at 105-KE has now been modified to allow the use of the adjoining beam hole 4B for slow-neutron time-of-flight spectroscopy. With this modification the triple-axis spectrometer will be used in a different configuration than in the past. The maximum range of motion of the first axis monochromator is now 43.5 degrees in 2 θ Bragg and is in the opposite quadrant than previously used. These modifications have required a realignment of the complete spectrometer system which is now nearly complete.

Scattering Law for Polystyrene

The triple-axis spectrometer has been used to make several preliminary investigations of the slow-neutron inelastic scattering from polystyrene. These investigations have consisted of measurements of the energy spectra of neutrons scattered at a fixed angle. The purpose of these measurements is to identify the energy transfers which will make significant contributions to the scattering law. In preliminary measurements covering energy transfers from 0.04 eV to 0.15 eV significant scattering has been observed for transfers from 0.08 eV to 0.15 eV with a small peak in scattered intensity indicated for 0.075 eV transfers. These observations correspond approximately with energy levels of polystyrene determined from Raman and infra-red absorption measurements but are not of sufficient statistical accuracy for positive identification as yet.

Time-of-Flight Spectroscopy for Slow Neutrons

The mounts for the monochromating section of this system have been installed and aligned at the 4B hole of 105-KE. Installation of the required additional shielding pieces is in progress. A spherical aluminum crystal has been mounted in a rotor assembly and aligned with neutrons for initial usage as the rotating-crystal pulsed monochromator for the system.

Fast-Neutron Cross Sections

Work continued during the month on the reprocessing and analysis of previously obtained MeV total cross sections. The tape library of LRL - Livermore has been used with the program LIL NED to compare Hanford results with other data contained in the library.

REACTOR DEVELOPMENT - 04 PROGRAMPLUTONIUM RECYCLE PROGRAMPRTR Burnup Experiments

The data from four UO₂ fuel elements (fuel elements 1006, 1501, 1041, and 1101) are being analyzed. The fuel elements were irradiated in the PRTR to exposures varying from 39.2 to 149.8 MWd. A total of 96 samples were taken from the four fuel elements and the samples were analyzed for Cs-137 content (indicative of the number of fissions), plutonium content by alpha counting, and isotopic composition. With the exception of one sample, the isotopic composition data were within the expected uncertainties (0.1 to 1%) when the U-235 vs. U-238 and Pu-240 vs. Pu-239 data were plotted. However, when the atom percent U-235 is plotted against the atom percent Pu-239, ten data points are outside the error limits(1%). Six of the samples have apparently been interchanged. The samples are being rerun since the data are used in subsequent analyses.

The Cs-137 and plutonium by alpha counting data (error limits of $\pm 3\%$) have a greater scatter than the isotopic data as expected.

The atom percent U-235 depletion was calculated from the formula

$$D^{235} = \frac{N_o^{25}/N_o^{28} - (N^{28}/N_o^{25})(N^{25}/N^{28})}{N_o^{25}/N_o^{28}}$$

where the N's refer to final atom densities, N_o's refer to initial atom densities, 25 refers to U-235, and 28 refers to U-238. The term N^{28}/N_o^{28}

is not known with certainty, and its value is being determined by two methods. However, the term N^{28}/N_O^{28} is very nearly unity and raises the value of D^{235} by about 1-1/2 percent.

The experimental data from 79 samples of 8^4 from H_x -Pu-Al fuel elements have been received. The analyses of the data have shown that these data are more consistent than any taken thus far. Percent burnup of the initial plutonium extends to 50%, and was calculated assuming that Cs-137 yield from Pu-239 and Pu-241 is the same.

The dissolution of mixed oxide (UO_2 - PuO_2) fuel samples has begun. The work is being monitored carefully to insure that the experimental data taken continues to be consistent.

Mixed Oxide Reactor Survey Calculations

In an attempt to gain a better understanding of plutonium-fueled light water reactor systems, a study of several mixed (PuO_2 - UO_2) light water lattices under a variety of reactor conditions has been undertaken. The range of conditions was selected to "bracket" the regions of interest concerning light water (either pressurized or boiling systems) power reactors.

The fuel rods are 3/8" diameter containing 2 w/o PuO_2 - UO_2 (natural) with 8% Pu-240 and clad in 27 mils of Zircaloy. Three lattice spacings (0.60, 0.70, and 0.80 inch) pertaining to undermoderated, near optimum, and overmoderated conditions were chosen. Temperatures were selected to cover the various ranges appropriate to current power reactor systems; fuel ($20^\circ C$ to $500^\circ C$), moderator ($20^\circ C$ to $260^\circ C$). Void fractions covering the range from 0 to 30% voids were also selected to simulate boiling water systems.

Infinite multiplications for all systems were determined along with the migration area such that an approximate critical mass for any of the systems can be determined for any specific reactor geometry. Temperature, Doppler, and void coefficients were also determined along with the effects the plutonium has on each.

Code Development

1. Hanford (RBU) Basic Library

Review, evaluation, and updating of cross section data contained in the RBU Basic Library is continuing. The reviewed and updated data will comprise the new Hanford Basic Library. Isotopes through R_a -224 have been updated and a final check for obvious errors is being made. A preliminary update of certain isotopes of the fissionables has been

made with a more detailed analysis to follow in the near future.

2. RBU

Logic flow diagrams (about 115 sheets) of the Monte Carlo portion of the RBU system have been drawn, reviewed at three levels of detail, and are now ready for submission to photography for inclusion in the second RBU document. The text portion of Vol. II has been reorganized to more aptly serve as a reference manual, and roughly 75% of the revamped text is ready for first review.

A revised schedule for theory-experiment comparison of burnup and other models used in RBU is prepared and implementation of the schedule is expected shortly.

3. Exploratory Use of Fortran-IV Compiler

Evaluative exploration of the reactor-analysis improvement-potential provided by recent revisions of the Fortran-IV Compiler (Version 12) has begun. The work has progressed through familiarization study and conversion of a representative nuclear analysis source deck to Fortran-IV language (GE-HL Program Alchemy-II, Time-Variant Isotopic Transmutation). The limited experiment accrued thus far consistently favors further exploitation effort.

Variable block-dimensionality flexibility in Fortran-IV, for example, provides a substantial extension of basic analysis capability, directly relevant to alleviating memory-demand limitations in nuclear fuel-cycle analysis work; and the mnemonically-addressed implicit-format input-data loader of Fortran-IV significantly reduces the likelihood of input error, by providing card-format flexibility matching closely that of hand-computation work.

Conversion work appears to be quite simple and fast. Conversion of the 2000-card Alchemy source deck, consisting of a typically intricate blend of Fortran machine programming and Fap hand programming, required only one man-day of work. Conversion consisted principally of rephrasing the first three words of all Fortran READ and WRITE statements, and rephrasing the first and last word of each Fap routine to fit the overlay entry and return logic of the Fortran-IV and Map compilers.

Phoenix Fuel Program

1. MTR Plutonium Loading Analysis

Further calculations have been carried out for the Pu loaded MTR Cycle 108. A +10 mk correction to the estimated "rods-out" multiplica-

tion of the MTR power configuration has been computed. The original value of 1.120 had been based on measured rod worths for the reactor physics configuration. The decreased plutonium loading of the power core (8% less plutonium) presents a less absorptive environment to the control rods, and their worth is, therefore, increased.

A comparison of computed rod worths for the two configurations shows that a rod worth of $0.120 \frac{\Delta k}{k}$ in the reactor physics configuration increases to $0.130 \frac{\Delta k}{k}$ in the power configuration.

An attempt has also been made to analyze the burnup experiment conducted on the power core. The multiplication decrease computed is two-thirds of that observed ($0.072 \frac{\Delta k}{k}$) during the burnup to 262 MWd.

The one-dimensional slab model of the reactor, used in the burnup calculation, is weak in describing the conditions of the experiment. This model ignores the important consideration of control rod and follower fuel movement during burnup as well as the influence of piece-by-piece detail in the core and reflector. Some improvement in both areas is possible and is being worked out.

2. Zirconium Hydride Study

Results have been obtained from the first SPECTRUM calculations for zirconium hydride at 20°C. Values of k_{eff} for a TRIGA-type core will be computed for various temperatures. The TRIGA core has been selected for this study since approximate values of the prompt temperature coefficient are available. This type of core is particularly interesting due to the mixed water-zirconium hydride moderator.

An examination of the THERMOS code has been undertaken in an attempt to modify the input parameters to permit the use of the code for the single energy transfer level case which occurs in zirconium hydride below 693°K. THERMOS makes provision for the rigorous treatment of mixed moderators and the calculated values can be computed with those obtained using SPECTRUM which only provides for a single moderator.

3. Evaluation of Calculation Methods

A. Reactivity Effects of Transplutonium Isotopes

In previous Phoenix core calculations the effect of the transplutonium isotopes on reactivity has been ignored. The purpose of the present study is to identify the most important trans-

plutonium decay and capture processes. In the first calculations, only the effects of Am-241, Am-243, and possibly Am-242 will be considered.

B. Reactivity Effect of Finite vs. Infinite Medium Cross Section Averaging Schemes

In previous Phoenix studies infinite medium cross section averages have been used in the burnup calculations. For a typical Mark I core, fueled with 80% Pu-239 and 20% Pu-240, a comparison has been carried out using infinite and finite medium group constants. The results show that for this type of core, essentially no difference in the reactivity lifetime curve arises. The results are tabulated below:

<u>Hours</u>	<u>EFPH</u>	<u>Infinite Med. σ's</u>	<u>Finite Med. σ's</u>
		<u>k_{eff}</u>	<u>k_{eff}</u>
0	0	1.15068	1.14671
2000	1840	1.11639	1.11243
4000	3660	1.08575	1.08181
6000	5454	1.05637	1.05249
8000	7212	1.02482	1.02094
10000	8920	0.98495	0.98120
12000	10555	0.92496	0.92145
14000	12074	0.82027	0.81731

C. Comparison of Cross Section Averaging Frequencies

The effect of various cross section averaging frequencies for a typical Mark I core (80/20 fuel) have been compared. In the first run, new concentrations were calculated at every time step in the normal manner using ZODIAC I. Thus, at every time step new macroscopic cross section values were used in the HFN calculation for k_{eff}. In the second run, new microscopic cross section values were calculated at every other time step. In the third run, they were calculated at every third time step.

One of the major objectives of this study was to determine if a significant decrease in machine running time could be achieved. The average machine time needed to complete one reactor time step has been determined. The original burnup used 6 minutes, 14 seconds per time step; the cross section recalculation at every other step took 5 minutes, 7 seconds per time step; and the recalculation at every third step took 5 minutes, 14 seconds. The discrepancy in

the last two figures can be explained by the extra time involved in NORMAL MODES concentration calculations if cycle status problems occur. It would appear that there are no significant savings in time for the cross section schemes considered. If schemes of this type were tried on ZODIAC II which uses ALCHEMY to replace NORMAL MODES, possibly larger differences in running time would occur.

The difference in the k_{eff} over the lifetime of the reactor for these schemes is quite large, particularly in the early part of the reactor life.

4. Pu-Al Light Water Experiments in the PCTR

The total effective "cross sections" of borated and unborated polyethylene disks are being measured with the PCTR by period measurements. It is hoped that these measurements will resolve the disagreement between the nominal boron content, the chemically analyzed boron concentration, and the previously measured cross sections. Preliminary results indicate that the boron content is fairly uniform from disk to disk, and that its magnitude is closest to the chemical results. Efforts are being made to find a vendor for new disks. All other preparations for the experiment are essentially complete.

Isotopic Analyses of PRTR Samples

Isotopic analyses were provided on 15 plutonium and 2 uranium samples of PRTR-irradiated fuel elements in support of the Plutonium Recycle Program. Of these, 12 were burnup samples from Al-Ni-Pu element number 5109, 4 were reruns of macrodrill samples from UO₂ elements numbers 1101 and 1006, and one was a rerun of a burnup sample from Al-Ni-Pu element number 5103.

Instrumentation and System Studies

Multiplier phototube testing continued in an effort to establish a satisfactory tube for use in the PRTR fuel rupture monitor. Tube types tested have included RCA-6199, CBS-CL1012, Amperex-150AVP, EMI-9524B, and EMI-9536B. Considerable data regarding dark current noise, gain, stability, and drift have been obtained and the results are being analyzed. No conclusions have been reached as yet.

Discussions were held with Ceramics Research and Development regarding the use of small solid state alpha detectors for delineating migration of plutonium in experimental fuel elements.

Modifications are being incorporated in the detector shielding of the PRTR underwater fuel element gamma scanning facility to provide an entryway for a calibration source. In addition, a method is being devised to

permit partial closing of the lower aperture of the collimator.

PRTR Test No. 92, Measurement of "Reactor Noise" in PRTR, was completed. Variations in the moderator level and the flux level were recorded on tape while the reactor power level was held constant. The tests were performed at two power levels; 6.5 and 70 Megawatts. The information was recorded for one hour during the 6.5 MW test, but only for 45 minutes at the 70 MW power level. The reactor was shut down at the end of 45 minutes due to an indication of a leak in the primary system. The data will be analyzed using cross-correlation techniques to yield β/λ^* curves at the two levels.

Preparations were started for testing the automatic controller at the PRTR using the analog computer in the 3707-C Building. The analog computer will be used to simulate the reactor, allowing the controller to be tested throughout its startup mode of operation while the reactor is shut down. Phone lines were connected between the PRTR and the analog computer facilities in the 3707-C Building for the transmission of signals. At the present time two pairs of lines are installed, but it is anticipated that four pairs will eventually be used during the test. The two lines now connected appear to provide the necessary transmission media when operational amplifiers are used with terminating resistors on each end of the phone lines.

EBWR EXPERIMENT PROGRAM

Approach-to-Critical Experiments Using EBWR Fuel

Experiments with the 0.55 inch lattice spacing were completed. The number of fuel rods for critical was 1487 with a buckling of 48.0 m^{-2} . The extrapolation distance was 8.4 cm.

Each of the six cadmium control and safety rods were measured to be worth 8.2 fuel rods. Fuel rods substituted in the control rod positions and displacing water from these positions increased the critical mass by 3.43 fuel rods for each rod substituted.

PRCF Experiments

The effects of major voids were measured by displacing water with foamed plastic. This styrafoam formed a void one cell thick, four cells wide, and eight inches in length. Holes in the styrafoam allowed the fuel rods to be in place during the measurements. A set of four measurements were made, one in the center, the other three on various radii extending to 75% of the critical radius. A vertical traverse with a void 0.585

inches in diameter and 8 inches in length was made in the empty central fuel column. Samples of "Lexan" and "Lucite" were used to displace water in the maximum flux region along the central fuel column. These samples contained holes to prevent them from displacing fuel rods. The "Lexan" samples were worth six to seven times more in negative reactivity than the "Lucite" samples.

The kinetics experiments involving the rapid insertion of poison were completed. The poison, a boron laden arrow, was inserted by a bow made of spring steel. The worth of the poison was 1.3 mk.

EBWR Spectrum Measurements

Twenty 0.50 x 0.005 inch palladium foils have been received. Some of these will be activated in order to test their purity and establish techniques for counting Pd-109 using a 256 channel analyzer. Pd-109 has a large resonance at 33.1 eV, and will be used to define the epithermal neutron spectrum. There are six stable isotopes of palladium. Pd-109 has activities of 4.8 minute and 13.6 hour half life. Three isotopes need not be considered in counting because they are stable, have very short half lives, or have no γ activity. The three activities to consider have half lives of 5.5 hours, 13.6 hours, and 17 days. Counting may be done either to subtract out the 5.5 hour and 17 day activities, or possibly window counting techniques may be used.

Neutron filters which are made of an alloy of gadolinium and stainless steel are about half completed. These filters will cover a variety of pins for irradiation in the EBWR lattice. More fabrication than first expected has to be done using the electrojet cutting machine.

Lutetium pins were used in measuring the neutron spectrum in the vicinity of a void in the EBWR 0.71 inch lattice. These pins have been counted and the data are being analyzed. The preparations are complete for the vertical, radial, and cell traverses using cadmium covered lutetium on the outside of the fuel. The counting data are being analyzed from the vertical and radial traverses using bare lutetium on the outside of the fuel.

A radial distortion was noted in the first flux traverse from the EBWR 0.71 inch lattice. These measurements were made using bare copper wire. The distortions were caused by having the central fuel rod removed and the partial insertion of a control rod during the irradiation. The central fuel rod was removed to insert the "Lucite" holder for the vertical traverse using bare copper wire. Two more bare copper radial traverses were made with all fuel rods in and control rods nearly out and symmetrically posi-

tioned. These traverses showed that the flux had the same shape at the two vertical positions and showed no radial flux distortion.

HIGH TEMPERATURE REACTOR PHYSICS PROGRAM

An experimental study has been made of the effluent gases from heated insulating materials and other materials that are being considered for use in the HTLTR. In one type of test, samples of a few grams were heated, in steps, up to about 800°C, and the emitted gases analyzed. In another type, kilogram samples, more comparable in size with blocks to be used in the reactor structure, were heated for several hours under vacuum and the weight loss measured. Both methods gave consistent results insofar as total loss of material is concerned. From the detailed data of the small sample tests, which showed the major emitted gas to be CO₂ and H₂O, estimates were made of the maximum quantity of graphite that may be expected to be lost from the 100,000 pounds of moderator in the HTLTR over a ten-year operating period. Losses caused by contaminants from the four main constituents--nitrogen, graphite, alumina brick, and diatomaceous earth, were calculated separately. The estimates are 100, 40, 600, and 3400 pounds, respectively. The figure for diatomaceous earth is based on a preheating treatment in which 90% of the contaminant gases are permanently eliminated prior to the insulator being placed in the reactor. Even so, the losses from it are too large to be tolerated and a substitute for it will have to be used. Fiberfrax and Tipersul have been suggested for this purpose.

Some design and operating steps have been suggested that would help to reduce the effects of the remaining contaminants. These include redirecting the rod coolant gas so that it does not have to pass through the reactor; directing the purge gas flow so that it purges the insulating materials; keeping the room relative humidity low; and permitting larger, controlled, purge rates just before cooldown and when contaminant concentrations are high.

NEUTRON FLUX MONITOR PROGRAM

The formal report draft was reviewed and corrected for the plutonium regenerating detector technique report.

For the uranium regenerating detectors, the enriched U-234, which will be used for the coating material in two matched chambers, was shipped to the fabricator. In addition, design was completed on the irradiation equipment to be required for onsite in-core testing of the chambers when they are completed.

All cables were received for the in-reactor evaluation of the cable-generated background noise signal problem on the boron-11 neutron flux monitors. The required portable power supply and cable-testing circuitry were fabricated and tested satisfactorily. All required parts of the chambers, which will contain the B-11, have been fabricated; however, in-reactor tests of the various special mineral-oxide cables will be conducted prior to assembly of the chambers. Plans were established for the irradiation testing.

Scheduling of the irradiation facility prevented further microwave neutron flux monitor in-reactor tests. The He-3 gas being used in the plasma capsules was analyzed for impurity content and was determined to be satisfactory. The oxygen content was less than 0.002 percent and other impurities, such as CO₂, Ar, N₂, CO, H₂, D₂, and CH₄, were at acceptable levels. To further reduce the possibility of contamination of the He-3 during capsule filling, a glassware cold trap apparatus was designed and assembled.

NONDESTRUCTIVE TESTING RESEARCH PROGRAM

Electromagnetic Testing

Preliminary tests of the multiparameter eddy current tubing tester operating simultaneously at two frequencies, 200 Kc and 6 Kc, indicated the need for refinements to further simplify adjustments for calibration and for discrimination against unwanted parameters. Circuit changes are being made to add two additional test frequencies, 22 Kc and 70 Kc, to permit the elimination of the probe wobble parameter. Probe wobble will be eliminated on each frequency channel by a phase discrimination technique prior to the final summing and parameter separation operation. The new arrangement also includes a balanced detector circuit which eliminates the need for bucking batteries used in the original circuit. The batteries were used to compensate for a large unbalanced dc signal due to the rectified reference signal.

A simple Colpitts crystal oscillator circuit has been developed which operates at frequencies from 6 Kc to 750 Kc by simply changing crystals and the value of one capacitor. The circuit differs from the usual Colpitts circuit in that a feedback potentiometer control has been added which permits near sinusoidal output.

Laboratory tests of the Model 1004 eddy current tubing tester on samples of N Reactor dump condenser tubing (70-30 CuNi) showed that anomalous indications, probably due to I.D. diameter variations, could be discriminated against by careful adjustment of the tuning of the test coil assembly.

The quadrature channel signal due to these variations is large and will interfere with the use of the quadrature channel signal in estimating depth of flaws. This problem could be overcome by application of multiparameter techniques for tubing inspection.

An eddy current test is being developed for Fuels Testing and Analysis to locate the end boundaries of aluminum inserts in a developmental tubular AlSi extrusion. Of interest this month was the detection of AlLi inserts having lithium in the range 0.11 to 0.86 percent. It was determined by eddy current tests that a sample of AlLi with 0.27 percent lithium had slightly less electrical conductivity than the AlSi extrusion (2 percent Si) material. This makes this particular alloy very difficult to detect.

An AlLi alloy having about 0.22 percent lithium is estimated to have the same conductivity as that of the AlSi (2 percent Si) used in the extrusions. The aluminum inserts having 0.11, 0.42, 0.56, 0.72, and 0.86 percent lithium should be readily detectable. Equipment sensitivity is being increased in an attempt to locate the 0.27 percent lithium insert. The feathering of the edges of the inserts during the extrusion process reduces the accuracy of location by the eddy current method.

A cathode ray tube display is being developed for displaying the location of flaws detected by the multiparameter eddy current tubing tester. This display will facilitate the development of the multiparameter tubing test and will serve as a useful accessory to both it and the Model 1004 tester when used with a rotational scanning test arrangement. A test assembly has been built comprising an external drive motor and flexible shaft for driving a rotating transformer and probe within the tubing. A resolver is mounted at the motor to give shaft position information for the cathode ray tube display. The whole system is being built for initial use on samples of N Reactor process tubes.

Fundamental Ultrasonic Studies

Shear-wave attenuation measurements were continued. Considerable difficulties were experienced in reliably bonding the shear transducers to the test specimens. It was necessary to bond two identical transducers on opposite surfaces of the test samples in order to measure the insertion loss due to the bond layer and the transducer since this loss is not a part of the true attenuation. This method, when used with a material of known attenuation such as fused quartz, also then measures the beam spreading or diffraction loss which is also not a part of the true attenuation loss.

Bonding these transducers to position them exactly opposite necessitated

the design and fabrication of an accurate positioning fixture. The first fixture did not prove acceptable although a subsequent design appears to be functional. A clamping mechanism which was fabricated earlier was used to clamp the test-sample-transducer combination while about 14 lb/in² load was used to insure a uniform thickness of bond layer. This load was also sufficient to properly dampen the transducer pulse oscillations, thereby solving a problem encountered in previous shear wave measurements.

Phenyl salicylate was used as a bonding agent and since it melts slightly above room temperature, the transducers could be removed and rebonded to determine the reproducibility of obtaining shear-wave attenuation measurements by this method. Though the bonding techniques were controlled as carefully as possible, no better than approximately ± 5 percent reproducibility was obtained in the preliminary data.

Previous longitudinal-wave attenuation measurements on aluminum samples tended to indicate a low frequency cut-off below which the attenuation was very low and an approximately linear dependence with frequency above this cutoff. However, subsequent measurements on stainless steel, Zircaloy-2, and other aluminum samples did not exhibit a low frequency cut-off and attenuation was found to increase with frequency in a nonlinear manner. Shear-wave attenuation is also expected to vary non-linearly with frequency. Previously, it was thought a linear dependence would be most desirable from an analytical standpoint. However, recent studies by Applied Mathematics have shown the cut-off may make mathematical solutions difficult. Therefore, contrary to original thoughts, the absence of the cut-off is desirable and, although a nonlinear attenuation frequency dependence requires an involved numerical treatment, solutions appear possible by the use of computer techniques. The computer program is being written for pulses having a band of frequencies which are propagating in attenuating media. This program is about 50 percent complete and will be tested pending completion of the attenuation measurements.

Ultrasonic pulse analysis through the use of electronic spectrum analyzers is essential to experimentally study the effects of pulse shape changes due to attenuation and diffraction. The pulse gating equipment which was ordered to facilitate this work has been received. This equipment will also be used as a part of the initial electronics for multiparameter analysis of such things as ultrasonic echos from imperfections in metals.

Heat Transfer Testing

Further experiments with the thermal pulse transducer have shown that a simpler arrangement than the infrared temperature sensor and flash lamp heat source is possible. A new experimental transducer was fabricated using

a thin sheet of aluminized mylar. Heat energy was produced by discharging a capacitor through the aluminum layer, and the resulting thermal transient was detected by recording the change in resistance of the layer. Theory shows that application of a uniform instantaneous heat source to the surface of a homogeneous, semi-infinite solid results in a surface temperature behavior that depends on the thermal diffusivity. Thus, the thermal transient recorded at the transducer can be used to measure thermal diffusivity of a substance.

A crude prototype of the new transducer was used to measure the thermal diffusivity of aluminum, graphite, quartz, Lucite, and styrofoam. These measurements showed that differences could be detected between the different materials. However, the reproducibility was not yet good enough for reliable detection of the difference between aluminum and graphite or between quartz and Lucite. Power produced by discharging a capacitor through the aluminum layer was increased in an attempt to increase sensitivity, but this resulted in burning out the aluminum film. A more rugged thermal pulse transducer is now being fabricated using fine wire as the transducer element.

Fatigue and Residual Stress Detection

A decision was made to use high purity aluminum and copper, in addition to stainless and carbon steels, for producing fatigue specimens to use in developing and evaluating nondestructive fatigue detection methods. The high purity materials were selected because it should be possible to more closely predict the number of cycles required to produce a given amount of fatigue. Selection of stainless steel is based on the variety of detectable changes that can occur as a result of fatiguing and cold working. For example, precipitation of a ferritic phase occurs in austenitic stainless steels during cold working. This should be detectable using eddy current techniques. Since cold work and fatigue are similar in the early stages of low cycle fatigue it is felt a similar precipitation may occur during low cycle fatigue. Another example is the fatigue produced acceleration of carbide precipitation at grain boundaries in 15-15 and 18-8 stainless steels at elevated temperatures; high temperatures can be self-produced by a metal during fatigue. Ultrasonics might be used to detect such a precipitate. Carbon steel samples were chosen due to their widespread use in pressure vessels. In addition, their magnetic permeability is a structure sensitive property which may change by a detectable amount early in the fatigue process, thus having an effect on eddy current test results.

Aluminum samples were prepared from 99.99 percent pure stock. Copper samples were prepared from standard stock, since high purity material was not immediately available. However, the copper was reasonably pure since only trace amounts (0.01 percent or less) of silver, iron, magnesium, lead, and silicon were found in it by spectrographic analysis. The aluminum was

air annealed at 400°C for one-half hour, and the copper was salt bath annealed at 725°C for 15 minutes prior to machining.

Due to the importance of the surface condition in fatigue samples, it is desirable to produce smooth, uniform, reproducible initial surfaces. To accomplish this, an attempt is presently being made to electropolish the as-machined samples. It is also desirable to use samples that are free from initial flaws. Fluorescent dye penetrant and ultrasonics are being used to check the samples prior to fatiguing.

In order to more reliably determine the capabilities of ultrasonic critical angle tests for fatigue detection, it is essential to eliminate as many variables as possible. Accordingly, representative samples of these materials are being used to examine and evaluate the test variables. This work will also help establish critical angle test procedures prior to, and following sample fatiguing.

Nondestructive Testing of Isotope Containment Cells

Testing service was provided on several two-inch diameter spherically shaped prototype containment cells. The units were radiographed in the x, y, and z planes providing wall thickness measurements plus additional information on the core material. The units were also measured for thickness ultrasonically. Results from the ultrasonic thickness measurements were then plotted to provide wall thickness profiles along two planes.

Design work on basic electronic circuits for a prototype containment cell ultrasonic tester has begun. Experience gained while testing prototype containment cells is being used to determine tester requirements. Since the final requirements are not known, the circuitry is being designed for maximum versatility. A mechanical system for rotating the cylindrical or spherical cells and thus providing a scan over the entire surface is also being designed. The system will be portable and suited for inspection of only the prototype cells which are not radioactive.

The different types of containment cell cladding materials are being investigated for ultrasonic properties before and after the loading process. On one Inconel cell excessive ultrasonic attenuation and ultrasonic noise was experienced; therefore, this unit could not be inspected with ultrasound. Photomicrographs of this unit are being prepared to determine the cause. Very large grain size or the metal working which occurs in the manufacturing process could be contributing factors. Present plans are to anneal the samples to duplicate the thermal conditions which will be present when the cells are loaded with isotopes, then to retest the samples to look for possible changes in ultrasonic properties. In the event that

large grain size, which causes high attenuation of the ultrasound, is the contributing factor, the frequency of the ultrasonic transducer must be decreased. As the frequency of the transducer is decreased, its resolving power also decreases so that many of the commercially available lower frequency transducers could not resolve a 100 mil thickness of metal or measure its exact thickness. Low frequency transducers with exceptionally high damping, which will make them capable of measuring thickness in large grain size material, are being fabricated.

USAEC/AECL COOPERATIVE PROGRAMNondestructive Testing of Sheath Tubing

The USAEC/AECL program to develop improved methods of ultrasonically inspecting thin walled tubing was terminated at the end of FY 1964 with program objectives being fully accomplished. Terminal reports, HW-81955, HW-81956 and HW-81957 are now being issued. A significant highlight of the program was development and fabrication of equipment which was selected for display at the Third International Conference on the Peaceful Uses of Atomic Energy at Geneva, Switzerland.

BIOLOGY AND MEDICINE - 06 PROGRAMAtmospheric Physics

Four additional field experiments designed to measure the dispersion of materials released from an elevated source into stable atmospheric density stratifications were completed during the month. One additional experiment was successfully completed using an elevated source during unstable meteorological conditions. The source of zinc sulfide particulate suspended in trichloroethane was located at an elevation of 185 feet on the meteorology tower, and samples were obtained to a distance of 25 miles.

An information exchange and field workshop on advanced design atmospheric turbulence measuring devices was held at Hanford on July 14-17, in cooperation with the Department of Atmospheric Sciences, University of Washington. Devices compared included the improved wind component meter, the University hot-wire and sonic anemometer systems and micrometeorological profile measuring systems. Methods of data analysis were reviewed and application of analog and digital computer systems discussed. Turbulence data were obtained for both daytime and nighttime conditions over a wide range of atmospheric stabilities.

In studies of the Area-Dosage relationship from sources near ground level, proper accounting for the temporal and spatial variation of the wind field

has improved the correspondence between experimental determinations and those predicted from theory. The area enclosed within a given dosage isopleth shows a greater dependence on the atmospheric stability than found in previous studies. In addition, the data obtained over the distance range 2 to 16 miles now agree more closely with data obtained over the first 2 miles.

Radiological Physics

Preliminary data from whole body counting of Eskimos at Anaktuvuk Pass indicate Cs^{137} body burdens are much higher this summer. The highest burden measured was $2.4 \mu\text{Ci}$ and the average for the adult males is about $1.4 \mu\text{Ci}$. Body burdens appear to have about doubled since March.

Preliminary results with a 3 inch crystal located at the groin and with the upper body bending over it show promise as an inexpensive and portable method of determining whole body burdens of Cs^{137} . Data taken at Anaktuvuk Pass on 13 Eskimos show a good correlation with measurements made with the shadow shield.

The absolute sensitivity of the plutonium X-ray counter has been determined for measuring Pu^{238} in rat feces and urine samples from biology experiments.

Work began on a calibration technique for the shadow shield based on Evans' one meter arc method. This method, if feasible, will allow calibration of the shadow shield without requiring an individual with a known body burden for comparison. The technique uses a standard source placed on the bed and counted both with and without a subject between the source and detector. Preliminary results show a good correlation with shadow shield data.

The positive ion accelerator has been modified so that the development of the ion separator can continue. Suitable power supplies have been developed and installed in the Van de Graaff and most of the vacuum problems have been solved. One of the beams has been tentatively identified as He^{++} ions. However, nuclear interactions must be used to positively identify this beam.

Krypton has been used to replace the xenon in our proportional counter neutron spectrometer. The krypton has caused very little loss of resolution and appears to be a much better counter gas.

Work on the U of W spermatogenesis project has been temporarily interrupted while U of W and Washington State fire marshals resolve the fire hazard problem presented by the paraffin. The shield has been disassembled and

put in storage. Work is continuing with some of the dosimetry problems.

An IBM computer program was used to determine the optimum thermopile design for the small calorimeter. The optimum design was modified slightly to give a total resistance that experiment shows will result in good galvanometer stability.

The disassembling of the shield for the U of W spermatogenesis project has allowed work to resume on the pulsed X-ray machine. The electrical wiring was completed and a shielded facility for operation of the tube has been completed. Test pulses without the tube in place were all satisfactory.

Instrumentation and System Studies

Satisfactory performance is being achieved at the Inhalation Toxicology Laboratory with the completed alpha energy analysis air monitor. The Pu-239 alpha detection sensitivity is approximately 10 MPC-Hours with a 6 CFM air flow rate. In addition, modifications were incorporated to provide three additional beta-gamma scintillation detectors. During experiments involving animal inhalation of beta-gamma emitters, the added detectors are attached to the instrument to provide monitoring.

Field testing of the smoke inhalation control system, for use in canine experiments, continued during the month. One of the canine masks was modified with a transducer of longer time constant to provide a longer time delay prior to reset following smoke inhalation.

The scanner-drive system for the Biology canine counter was completed and installed. Provisions were incorporated to automatically start and stop signal information to the electronic scalars at the beginning and end of scanning. The scanning speed is variable up to 10 in/min; however, the usual speed will be from 0.5 to 2.5 in/min. Scintillation detector changes are being devised.

Initial gamma spectra measurements were carried out at the Biology aquatic fish facility located at the KE Reactor area. The investigations are to determine the predominant isotopes. These data will be used in the development of a monitoring system to determine the dose rates to which the experimental fish are subjected.

Fabrication was essentially completed, except for installation of a few minor parts, on the experimental radiological analyzer and field monitor for use in biological field studies. The completed portions of the solid state instrument are performing satisfactorily.

Due to unavailability of the positive ion Van de Graaff until September, only specific neutron sources can be employed in the investigations regarding solid state neutron detectors for the combination neutron-gamma monitoring system. When available, the Van de Graaff will be employed to provide required monoenergetic neutrons from about 100 keV to 10 MeV. Until then, efforts are being concentrated on the development of other portions of the system.

Development work was accelerated on the sub-carrier oscillator and thyroid uptake measurement portions of the experimental animal physiological function and dose telemetry system. The voltage controlled sub-carrier oscillator, which employs a unijunction relaxation oscillator and a tuned tank circuit, provided a frequency change from 3.27 Kc/sec to 3.09 Kc/sec for an input dc voltage variation from 0 to 25 mV. Tests were continued on various miniature G.M. tubes to determine an appropriate type for use in measuring thyroid uptake of I-131. The G.M. pulses control a bistable multivibrator which, in turn, gates a sub-carrier oscillator. Initial tests have produced satisfactory results.

Development of solid state amplifier and integrator circuits was carried out for the peak pulse reader instrument, which is to be used in reading out accumulated dose from miniature ion chambers. The developed integrator performed properly in driving the digital voltmeter. Further amplifier development is being done to correct apparent nonlinearities encountered in the coverage of the four decades of pulse amplitude range. The necessary logic circuitry has been designed and will be fabricated following completion of the pulse amplifier.

Efforts were continued to accelerate the fabrication of five more data stations for use in the Atmospheric Physics radiotelemetering system. The five new stations, in addition to the two prototype units, are nearly completed and checkout procedures were started. The sub-chassis for the radio portion, the scanner, radiation detection, voltage controlled oscillator, and the wind speed integrator have completed satisfactory checkout and testing. A tester for the radio sub-chassis was designed, fabricated, and is being tested for proper operation.

Minor circuitry modifications were completed on the punched paper tape drive circuit of the Atmospheric Physics portable mast instrumentation system. The modification corrected the paper tape punching difficulties and the system is, once again, performing correctly.

A series of multiplier phototube tests were conducted with Amperex 56 UVP and 56 AVP tubes to determine the pulse shape of the dark current pulses. The work is being done in conjunction with the development of a single

electron counter to be used in dosimetry studies. Rise times, half-maximum widths, and fall times for the pulses were all in the order of two nanoseconds as measured with a sampling oscilloscope.

Meteorological and climatological measurements and observations at Atmospheric Physics installation are recorded on continuous and multipoint recorders. The measured parameters are later transposed from the recordings to punched cards for processing on a digital computer in the 700 Area. Visual weather observations are also made and entered on punched cards. A study is under way to evaluate these routine data measurements and observations in an effort to make recommendations for a special purpose data system to handle the requirements.

WASHINGTON DESIGNATED PROGRAM

Isotopic Analysis Program

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

The digital computer which is to become a part of the instrumentation for a mass spectrometer arrived this month. It is the model PDP-5 computer with the 4096 12-bit word memory made by Digital Equipment Corporation of Maynard, Massachusetts. It is intended that the computer will be made to control the operation of a mass spectrometer, acquire and process data from it. Some of the benefits to be gained are:

1. Versatility in analytical mode of operation of the mass spectrometer, new hardware not being required every time a new mode of operation is desired.
2. Objectivity in operation which will avoid operator error and assure consistent quality of analyses.
3. Rapid data reduction which will permit evaluation of analytical results before a sample is removed from the mass spectrometer.

Design of the interface arrangement between the computer and mass spectrometer as well as design of computer controllable instrument components is in progress.

A program is being written to process digital data in the form currently outputted by the mass spectrometer for this program.

Tests were initiated to determine which components of mass spectrometer "B"

might introduce systematic errors of mass discrimination. No source of systematic error has been located yet.

EXPERIMENTAL REACTOR PHYSICS FACILITIES

PCTR Operation

The PCTR operated routinely during the month, but there were two unscheduled shutdowns; one was caused by electronic failure, and one by incorrect bypassing technique. Measurements were completed to measure the flux peaking in thulium oxide. Tm-170, produced by irradiating normally occurring Tm-169 is being considered as an isotope heat source. An extended series of reactivity measurements were completed in preparation for Phoenix program lattice experiments. Reactivity measurements were made in a thermal flux of polyethylene, borated polyethylene with varying amounts of boron, and of similar disks of copper and gold. The Final Safeguards Analysis report for the PCTR (HW-82673) was completed, and forwarded to the Atomic Energy Commission.

TTR Operation

The TTR was not operated this month. Approval was received for a change in the TTR safety circuit and rewiring was completed. It is now possible to check the behavior of the neutron sensitive channels as the neutron source is run in and out. When in the test position, the switch automatically drops and immobilizes the safety sheets and rods. The Final Safeguards Analysis report for the TTR (HW-73611) was completed and forwarded to the Atomic Energy Commission.

Critical Approach Facility

The critical approach and exponential experiments were completed using EBWR fuel rods in an 0.55 inch lattice with light water moderator. These rods are 1.5% PuO₂ in UO₂ containing 0.22% U-235 and are clad in Zircaloy.

COMPUTER FACILITIES

A three parameter optimization of an algebraic system using random variations of the parameters was adapted to the new analog computer. The new computer is ideal for this purpose since some unconventional memory circuits are used which are easily implemented as a result of the computer control philosophy.

Beckman Instruments provided a modification kit for the iterative control units on the new analog computer. This modification was designed to make

the units usable until they can manufacture new decade scaler boards for the units. The modification was made and it seems to correct the problem of synchronization between the two units. One problem with the control units remains to be corrected: The SINGLE CYCLE mode of the slave control remains inoperative.

The computer utilization was as follows:

<u>EASE 1132</u>	<u>EASE 2133</u>	
168	148	Hours Up Time
21	37	Hours Scheduled Down Time
<u>0</u>	<u>4</u>	Hours Unscheduled Down Time
189	189	Hours Total

The time shown above includes 21 hours of computer tests which are made daily between 7:00 and 8:00 A.M. This makes it possible to have full 8-hour days of use time.

Problems considered during the month were:

1. N Reactor.
2. N Reactor Cold Water Injection.
3. Reactor Model Gas Loop.
4. Parameter Optimization Techniques.

CUSTOMER WORK

Weather Forecasting and Meteorological Services

Meteorological and climatological services included: 1) Transmitting of meteorological records relative to a wind-damage claim for AEC, 2) support for solvent explosion experiments to HL, 3) support of an unusual volume of burial activity for CPD, and 4) meteorological data for use by bidders for waste handling facilities at Hanford for AEC.

River forecasting support for work on reactor outfall piping was provided IPD for the period July 7-15.

Weather Summary

<u>Type of Forecast</u>	<u>Number Made</u>	<u>% Reliability</u>
8-Hour Production	93	86.9
General	62	83.2
Special	157	85

Although there were several heat waves during July, temperatures for the month as a whole averaged below normal. This was the fifth consecutive month with below normal temperature. It was also the sixth month in the last seven with below normal precipitation. In spite of a wet June precipitation for the first seven months of 1964 totalled only 1.50 inches, the lowest amount of record for the period.

Mass Spectrometry

Isotopic analyses were provided on four uranium samples in support of HAPU U^{233} -production studies. Six uranium samples of standards to be used with the enrichment detector were analyzed as a service to the Metal Fabrication Development Unit.

A summary of the isotopic analyses performed on NBS Standard Sample 948, including the minor isotopes, was reported (HW-81969 1).

Instrumentation and System Studies

Fabrication was nearly completed on the scintillation detection and solid state circuitry aerial gamma monitor developed for use by Environmental Monitoring. The five-inch diameter NaI(Tl) crystal was repaired by the manufacturer and returned. Bench tests of the completed portions of the system have been satisfactory.

The mask outer surface scintillation beta-gamma detector for use with the mask monitor, as designed for use at the Hanford Laundry Facility, was nearly completed. Tests with the finished inner detector probe continue to show satisfactory results. Sketches were prepared for fabrication of the required stand and hardware which will be used to hold the complete mask probe assembly.

Tests were conducted on the U-235 fuel enrichment monitor developed for use by Metal Fabrication Development. The tests were made to determine the effects on the measured ratio information relative to the size and shape of the pieces being monitored. At present, samples differing in enrichment by 0.5 percent can be separated at a 99 percent confidence level regardless of size, shape, or cladding. For enrichment differences in the range of 0.2 to 0.3 percent, a known sample must be employed for comparison to achieve satisfactory results. Further adjustments and modifications will be continued.

A solid state trip-annunciator circuit was designed for use by Testing Methods.

The simulation of the high temperature gas loop for Reactor Fuels was mechanized on the EASE 1132 analog computer. Initial studies show the design of the control system is satisfactory. However, careful consideration must be given the control of the water cooled heat exchanger. The area available for heat transfer is limited and, as a result, the control range is limited. The initial studies used four simulated three-mode controllers. Arrangements were made to obtain one of the three-mode Honeywell controllers used in the process for incorporation into the simulation. In addition, four Bailey controllers were incorporated into the simulation in place of the simulated controllers.

The first of a series of planned tests to determine the optimum controller settings for the Physical Metallurgy calorimeter controller was completed. The purpose of the test was to find the open loop response of one of the sample heaters. A 1/4 amp current step was applied to the heater and a record of the change in temperature was kept. The results of the test will verify previous calculations of starting point controller settings.

Filter capacitors to be used on all cables to the logic circuits of the creep data logger arrived and were mounted. A steel bay was constructed which encloses the noise sensitive logic circuits of the system. The effectiveness of the above procedures in reducing radio frequency interference in the system will be checked.

The UT-3B testers for measuring the resin level in the Purex columns were delivered for installation in the 202-A Building cell. Upon checkout it was found that the only available transducer had failed. Previous difficulty with transducers had been experienced frequently and Testing Methods was given the program to develop improved transducers for this application. Two of the problems were insufficient loop gain and accumulation of bubbles on the transducer face. A workable flat face transducer in a stainless steel housing was assembled and put into interim operation.

The substitution of glass for stainless steel face and the use of a conical shaped stainless wire mesh on the transducer face to deflect bubbles is being evaluated. The glass does provide an increase in gain from less attenuation. The use of the wire mesh cone has yet to be resolved as large bubbles are deflected with only about 30 percent decrease in sound transmission, but very small bubbles tend to adhere, causing loss in sound transmission and false signals. Further experimentation will be necessary. Modification of the UT-3B circuitry is now necessary to indicate when the resin column is empty. This is a change from the original intent.

The scoping of a nondestructive testing facility for the waste solidification storage tanks will be an effort of about one man year during 1965.

Work is starting on the development of a nondestructive test to monitor the integrity and wall thickness of the storage tanks, with secondary efforts directed toward the inspection of contents, homogeneity, void, and stratification of the material within the tanks.

The eddy current motion analyzer developed for use in studying the fuel assembly vibrations encountered in the PRTR has been the object of a study. Due to operational difficulties a series of experiments were designed and performed in conjunction with Mechanical Development Operation. The tests were on specific component parts used in the fabrication of the specially designed fuel element assembly. Temperature tests were performed to test the sensing coils and the high temperature cables. Results showed that the sensing coils performed with specifications. However, the lead wires at the elevated temperature were highly erratic, and show that this cable is unsuitable for the application. As a result of these tests, a new fuel element assembly will be fabricated and Testing Methods will be responsible for the electrical and electronic portions of the instrumented fuel.

Optics

Gears were installed on the pan bore camera and film drives to give more positive action. The film takeup spool was driven with a flexible band. A hundred feet of film was loaded for tests of the mechanical characteristics of the camera. Film transport is smooth and the mechanical action is good.

A test stand has been devised to calibrate the N Reactor traverse mechanism. Transducers and readout equipment ordered six months ago from the low bid company have been delayed in delivery due to the inability of the company to make the equipment until some engineering problems were worked out. This company had low bid but because of their delay in delivery, the contract is being cancelled and an alternate company is being given the order.

During the period covered in this report, the following shop work was performed:

1. Ten quartz windows were fabricated for laboratory glassware.
2. Thirty quartz bell jars were tested for window flatness.
3. The Purex crane periscopes were serviced. The service included installation of new lenses and prisms in the slave crane periscope and in two main crane periscopes as well as the repair of one three-power head.
4. A binocular microscope was modified to give a 12 to 14 inch working distance.

5. Several hundred stainless steel pins were coated with aluminum.
6. A microscope was repaired.
7. Two quartz lenses were fabricated.
8. A laser reflector and five laser crystals were coated with silver.
9. A rectile was repaired in a magnifier for the 234-5 Metrology Lab.
10. Manipulators for positioning ultrasonic crystals were fabricated for Physical Testing.
11. A plate adapter was fabricated to permit use of polaroid film on a 308 Building metallograph.

Physical Testing

Transmitted sound was used as the parameter to measure the condition of the underground export water line between the 100-D and the 100-F Areas. The line was first accurately located and plotted with a new version of the metal finder, then sound measurements were taken to determine the presence of any leaks. Many leaks were found in valves and fittings attached to the export water line, but no leaks in the line itself.

Samples representing the three heats of Inconel tubing used for retubing Steam Generator 4-A have been examined by eddy currents, ultrasonics, fluorescent penetrant, and metallographic methods. All indications were verified as minor amounts of impressed metal or stringer inclusions open to the surface; nothing of a deleterious nature was found.

Assistance in the offsite procurement of one inch, thick walled, stainless tubing was extended to resolve the differences between the supplier and the ultrasonic inspection laboratory. The tubing is being purchased against the stringent Hanford ultrasonic standard. Two samples were delivered to Hanford for a complete ultrasonic inspection and metallographic examination to find the origin and extent of the high noise level. Ultrasonic signals from both large grains and intergranular surface corrosion are sufficiently high to cause rejection.

Instrument engineering assistance has been expanded to include the development of automatic control in the sputtering process used in plutonium metallurgy. Circuits have been developed to automatically interrupt and restart the process upon incipient arc-over conditions to continuously deposit the metal. Early results are promising.

A series of meetings have been concluded with the Atomic Energy Commission, General Electric, Kaiser Engineers, and Combustion Engineering on the subject of the steam generators at N Reactor. Purpose of the meetings was

a review of the extent of damage, possible mechanisms or causes of the damage, and the effect on future operation, to effect a final settlement and condition of warranty. Significant residual chlorides contained in the film between the tubes and the tube sheet has been confirmed on all units, which provides the condition for possible future stress corrosion cracking, similar to that exhibited in Unit 3-B. An invitation was extended to develop a nondestructive inspection procedure to detect the beginning of stress corrosion cracking in the generators.

Splines, made of aluminum and boron, for reactivity control in the old reactors, have been submitted for a program of ultrasonic inspection after receipt from the supplier and before each re-use. The splines have been splitting from laminations and also breaking in two in the reactor. Fatigue resistance during fluttering in the water stream is also being measured.

The program of meticulously inspecting, and the sheath tubing for the Zircaloy clad fuel elements manufactured for the Experimental Boiling Water Reactor has been concluded. Rejection rates on the tubing ran from approximately 10 percent to 60 percent on the various lots. Defect size prescribing rejection was one mil deep by fifteen mils long. Radiography was used to inspect the welds on the final fuel assemblies.

INSTRUMENT EVALUATION

Preamplifiers and EMI-9536-B multiplier phototubes have been installed in three of the offsite fabricated combination alpha-beta-gamma hand and shoe counters and calibration tests were initiated. Counting efficiencies for the standard Ra D-E-F test source are 5.5 to 6.5 percent for the hand probes and 2.0 to 2.5 percent for the shoe probes. These values reflect considerable improvement over the prior probe configurations. The seven counters fabricated by a different company have been calibrated and are either in service or ready to be placed in service. For the units in use, the only difficulties to date have been a few, easily corrected minor light leaks. General operation has been quite satisfactory.

Acceptance tests were nearly completed on 100 new CP-type portable exposure rate measuring instruments.

A commercial gamma radiation (area) monitor was evaluated and an attempt is being made to modify the circuit to provide an alarm-signaling adjustment span from 0 to 100 mR/hr.

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CHEMICAL LABORATORY
RESEARCH AND ENGINEERING

FISSIONABLE MATERIALS - O2 PROGRAM

IRRADIATION PROCESSES

Uranium Metal Surface Studies

The Production Fuels Section has been interested for some time in developing a nondestructive test which would distinguish between "transformed" and "untransformed" uranium metal fuel cores. Recent laboratory tests have pointed to the possibility of developing such a test. In a preliminary experiment, it was found that a light anodic etch (in $\text{H}_3\text{PO}_4\text{-HCl}$) produced a much rougher surface on transformed than on untransformed metal. The resulting difference in area was easily detected by measurement of the electric current generated when the sample was set up as the anode of a galvanic cell. The required etch appeared to be shallow enough as to permit easy reclamation of the core.

Previously reported laboratory work has shown that the porosity of nickel coatings electroplated onto uranium metal can be reduced significantly by using an $\text{H}_2\text{SO}_4\text{-HCl}$ anodic etch in the surface preparation process, rather than the customary $\text{H}_3\text{PO}_4\text{-HCl}$ anodic etch. Adherence of the resulting plate has now been given a preliminary test, with good results. Three segments of a fuel core, given the $\text{H}_2\text{SO}_4\text{-HCl}$ pretreatment and coated with 9.7, 11.0 and 12.5 micron nickel plates, were put through the IPD hot-die-size process. The standard IPD adherence test showed all samples to have plate adherence as good as that of the standard 18 micron plate. The over-all results with the $\text{H}_2\text{SO}_4\text{-HCl}$ etch have been judged to be good enough to warrant pilot-plant testing of the revised process.

In another approach to the problem of evaluating the various types of nickel plating solution used in electroplating uranium, attempts were made to determine the reactivity of uranium metal to these solutions. EMF measurement techniques proved unsuccessful. Measurement of the current generated by a galvanic cell using a uranium metal sample as the anode and the plating solution as the electrolyte, however, showed marked differences between solutions. An order of reactivity for the solutions tested was determined as follows: Watts bath (pH 2.0, 50 C) > Sulfamate bath (containing chloride, pH 3.0, 60 C) > Sulfamate bath (containing bromide, pH 3.0, 60 C) > Watts bath with bromide in place

of chloride (pH 2.0, 50 C). The Watts (bromide) bath was about 60 percent less reactive than the Watts (chloride) bath. These observations tie in with previous conclusions that the Watts (bromide) bath produces a less porous coat than the Watts (chloride) bath because the uranium has a more uniform surface activity in the bromide bath.

SEPARATIONS PROCESSES

U²³³ Support Studies

With transfer of responsibility for thorium processing from the Redox plant to Purex, the process technology which is desired for Pa-233 isolation has shifted from fixed-bed adsorption to a carrier precipitation which could be carried out in the Purex Head End centrifuges. Most previous protactinium studies have been made with rather acidic solutions. Purex thorium feed, however, will be acid deficient (to improve solvent extraction decontamination). Feasibility of scavenging protactinium from acid deficient thorium nitrate solutions is accordingly being explored. To date, results have been much inferior to those obtained in acidic solutions. Decontamination factors are low, and (in the case of MnO₂) precipitate volumes excessively large.

U-233 Detection

Studies were performed on in-line detection of U-233 in Purex process streams. Alpha counting appears promising, even though emission rates are about seven times less than those from Pu-239. Gamma counting was also studied, by means of a spectrographic analysis of a U-233 sample. The sample was several years old and the gamma spectrum yielded energy peaks that were primarily from the U-232 daughters that have built in. Adaptation of recently developed in-line plutonium monitors is a potential means of providing instrumentation for process and critical mass control at an early date.

Thorium Studies

Spray calcination denitration of thorium nitrate produced an oxide containing 11,000 ppm nitrate. The oxide had a crystallite diameter of 169 Å compared to 176 Å for oxide produced at ORNL and 306 Å for oxide produced at MCW. Efforts are underway to reduce the nitrate content to that measured for the MCW oxide (< 300 ppm) and to prepare an oxide sol.

Agitation and dissolution characteristics for sol gel thoria in pot and in annular-type dissolvers are being determined for CPD. Flow characteristics in a packed bed of thoria were measured to supply data for solvent recirculation in the annular dissolvers.

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Dissolution of Thoria

Sol gel thoria prepared by Mallinckrodt, ca. 20-200 mesh, dissolves rapidly in 12.3 M HNO_3 -0.025 M HF -0.1 M $\text{Al}(\text{NO}_3)_3$ at boiling, if thorough agitation is provided. One molar thorium can be reached in about one hour when dissolving to 50 percent heel, and in about 5.5 hours when dissolving to no heel. Current studies are attempting to define the dissolution rate in terms of quantity of thorium removed per unit area per unit time for non-agitated thoria.

Chromatographic Ion-Exchange Recovery of Americium

Recovery of about a kilogram of americium from Hanford Plutonium Reclamation Facility waste is planned by CPD. Use of compact-band chromatographic ion exchange is being evaluated as one possible means for recovering and purifying this americium. Flowsheet and equipment would be virtually identical to that used for promethium processing. Three tracer level laboratory runs (one each with EDTA, HEDTA and DTPA) were made during the month to determine the behavior and elution order of americium. Plant feed is estimated to contain: Am, 2-10 mg/l; Al, 10 mg/l; Fe, 130 mg/l; Ca, 50 mg/l; Mg, 50 mg/l; HNO_3 , 0.32 M; plus lesser, but significant concentrations of Pu, Ce, Th, U, La, Ni and Cr. Besides the above constituents, Er, Sm and Nd were added to the synthetic laboratory feed to serve as points of reference in establishing the elution position of Am and Pu. With all three elutriants, complete separation was accomplished from Fe, Ni, Cr and Th. Separation from plutonium was complete with either EDTA or DTPA, whereas Pu and Am appeared to elute closely together in the HEDTA system. Aluminum spread throughout all of the elution samples; however, its concentration in the americium product is so low that it would not be expected to carry down in the subsequent oxalate precipitation isolation step. On the basis of these very promising results, runs are being undertaken with macro concentrations of americium.

Extraction of Po-210 from Molten Bismuth by Molten Salts

Work performed at North American Aviation Laboratories indicate that 99+ percent of the Po-210 is extracted when molten irradiated bismuth is equilibrated with molten caustic in evacuated sealed ampoule. This work was checked by three extraction runs at 450, 500 and 550 C using 1:1, 1:1 and 1:10 phase ratios of bismuth to molten NaOH-KOH eutectic. The equilibrations were performed in 304-L stainless crucibles under flowing argon. Run times were 40-90 minutes.

Analysis of metal and caustic phases indicated a substantial fraction of the Po-210 had entered the caustic phase, e.g., from 20-60 percent,

but overall recoveries were low, and appreciable Po-210 activity was found in the off-gas line. Thermodynamic considerations are not favorable for the extraction of polonium by molten caustic, and it was concluded that the Po-210 was simply distilling from the bismuth and being trapped preferentially in the caustic phase, which floats on the bismuth and preferentially wets all surfaces. In a sealed, agitated and evacuated ampoule, such as was used at NAA, trapping by caustic would have been quite efficient. In this instance, some Po-210 distilled on through the caustic phase and reached the off-gas line.

The experiment was repeated at 400 C and at 525 C using 1:1 $\text{NaNO}_3\text{-KNO}_3$ in place of molten NaOH-KOH . Essentially the same result was obtained.

It is concluded that molten salt trapping of Po-210 volatilized from molten bismuth is the correct explanation for the apparent extraction of Po-210 reported by NAA.

Polonium-Bismuth Separation - Volatility Studies

Attempts to measure the vapor pressure of bismuth oxide in a new cell designed so that the gas stream would have a better chance to become saturated with the bismuth oxide were not successful. As in the case with the previous cell design the amount of bismuth oxide transported was extremely small when the temperature was 750 C and when the time of the run was one to two days. A check using the original cell design to determine the vapor pressure of liquid bismuth metal at 834 C gave a result within 30 percent of the reported vapor pressure.

Purex 1BX Column Development

A high capacity cartridge for the Purex 1BX column was developed in the Cold Semiworks solvent extraction pilot plant. The new cartridge contained a mixture of stainless steel nozzle plates and fluorothene sieve plates, all with 3/16-inch holes, 23 percent free area. The maximum stable volume velocity obtained with the cartridge was in excess of 1620 gph/ft², at a pulse amplitude of 0.85 inch and a frequency of 68 cycles/minute. In comparison, the maximum capacity obtainable in the pilot plant with the Plant's 33 percent free area stainless steel sieve plate cartridge was 1090 gph/ft².

A program is now underway in the above column to determine the optimum point to introduce sodium formaldehyde sulfoxalate (SFS), a proposed replacement for ferrous sulfamate plutonium reductant. Preliminary tests indicate that this point may be about 6 to 9 feet from the bottom of the cartridge.

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Trilaurylamine Extraction of Np and Pu from Purex 1WW

A 0.3 M TLA-Soltrol 170 solution was contacted continuously with an equal volume of current Purex 1WW solution for one week. Estimated exposure to the solvent was $2-4 \times 10^8$ r. The amine titer of the irradiated solvent, as well as the neptunium and plutonium extraction behavior, was the same as for fresh solvent. These results differ markedly from those obtained in an experiment in which solvent was irradiated in a Co-60 source while being contacted with synthetic 1WW. After 48 hours (estimated exposure 2.9×10^9 r), the solvent contained no titratable amine and did not extract neptunium or plutonium. Reasons for the different results are being sought.

Ion Exchange Hazards Tests

Thermal testing of Permutit SK anion exchange resin in nitric acid 4-inch pipe diameter systems has been completed. Conclusions derived from the test program are as follows:

1. Unconfined 7 M nitric acid wetted anion exchange resin is not flammable.
2. Prompt, complete, pressure relief at 600 psig or less will quench anion resin exothermal reactions in a 4-inch pipe diameter system.
3. Inadequate pressure relief in a 4-inch diameter system during an anion resin exothermal reaction can result in excessive pressures and charred resin.
4. At least one flammable gas, hydrogen cyanide, has been detected following resin pyrolysis. Dry resin which had been previously equilibrated with 7 M nitric acid produced flammable gases during auto-pyrolysis, or charring, which did not always spontaneously ignite.
5. The critical wall temperature for a 4-inch pipe containing Permutit SK anion exchange resin, equilibrated with 7 M nitric acid and drained, is below 120 C. Thorium-loaded resin (78.3 gm/l of resin) may show a slightly lower critical temperature than unloaded resin.

Disposal to Ground

A recent excavation at the inlet end of the Gable Mountain Swamp revealed the presence of basalt bedrock just below the land surface and well above the elevation of the regional water table. The knowledge that basalt exists at this location and elevation provides a more realistic

interpretation of the ground water flow pattern north and east of the 200 East Area, and explains some of the anomalies observed in the pattern of ground water contamination in that region.

Seven wells, located from three to fourteen miles southeast of the 200 West Area, show very low but detectable concentrations of radionuclides. The source of contaminants is probably the Redox waste cribs. Piezometer tubes, recently installed in all seven of the wells, show head differences of up to three feet. It appears that the contaminated ground water from these cribs moved slowly to the southeast and that the ground water flow pattern in and around the monitoring wells in the region prevented the contamination from entering the casings prior to the installation of the piezometer tubes. Additional sampling is scheduled to clarify the picture.

Several attempts were made to evaluate the soil uptake of radionuclides from a mixture of Redox UNH resin column regeneration waste and organic wash (O-2) decant solution by means of soil column tests. A fine precipitate, formed upon mixing the wastes, resulted in the column plugging; therefore, equilibrium-type tests were conducted. Results showed relatively poor removal of most nuclides, probably due to complexing by the oxalic acid present in the regeneration solution. Limited disposal may be possible, however, since the Cs-137 and Sr-90 concentrations in the waste are normally below 0.1 MPC.

A study was made to establish a recommended exploratory program related to the storage of aged high-level wastes in basalt (bedrock) deep beneath the 200 Areas. Five basalt formations varying in thickness from 150 to 200 feet appear to exist at depths above 5000 feet beneath the plant, based on extrapolation of Rattlesnake Hills, Standard Oil Company well logs. The envisioned Phase I portion of the program would consist of three rotary-drilled holes sunk to a maximum depth of 5000 feet and cored from 2000 feet to bottom. Extensive testing in-hole and of the cores would be performed to obtain data needed for the initial feasibility determination. Phase I costs (mainly drilling) are estimated at a maximum of \$400,000. Phase II, undertaken if initial feasibility were established, would consist of drilling and testing of up to ten additional wells.

WASTE MANAGEMENT AND FISSION PRODUCT RECOVERY

In-Tank Solidification

Bench scale testing of immersion heating for concentration of coating wastes was completed. The major purpose of these tests was to determine whether scaling of heater element surfaces would occur in various

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compositions and concentrations of coating waste. In addition, one test was conducted in a cobalt radiation source, receiving an exposure of 3.6×10^7 r. After 2000 hours of operation, no significant scaling occurred in any of the tests.

Cesium Recovery from Alkaline Wastes

Relative magnitudes of the solid and liquid phase mass transfer resistances for the ion exchange removal of cesium with an inorganic zeolite have been determined. The solid-phase resistance, based on the cesium particle diffusion coefficient of 6.0×10^{-7} cm²/sec, is a constant of 72 sec. The liquid-phase resistance is a function of flow rate with values of 66, 40, 84, 100 and 140 sec corresponding to flow rates of 4.0, 2.0, 1.6, 0.5 and 0.25 gal/min/ft². The increase of the liquid-phase resistance at 4.0 gal/min/ft² is attributed to increased channeling.

The document "Ion Exchange Recovery of Cesium from Alkaline Supernatant Waste," HW-83461, has been prepared.

Waste Packaging

The radiation-induced hydrogen-oxygen recombination in zeolites is being investigated. No significant recombination of hydrogen and oxygen was observed at room temperature and atmospheric pressure in zeolite samples stored 30 days in absence of light or radiation.

Full-Level Zeolite Storage Studies

A pressure gauge equipped zeolite storage cartridge was loaded to capacity with fission product strontium about a year ago and a series of observations were made at that time ("Interim Report on Full-Level Zeolite Experiment," H.H. Van Tuyl) before other hot cell work required suspension of heating. Heating was resumed this month. It was soon apparent that the equipment leaked. The gauge was replaced and heating continued over a period of three weeks at successive temperatures of about 290, 370 and 460 C. In each case, the pressure increased on raising the temperature, then slowly declined. This phenomenon was finally traced, at least in part, to condensation of evolved water in the pressure gauge and the tube leading to same. Insulating the tube and gauge proved helpful in reducing the pressure decrease; however, the temperature of the gauge itself is still below 100 C, so possible presence of a leak can still not be conclusively ruled out. Arrangements are being made to test the gauge while continuing observation. In the meantime, all-welded containers are being fabricated and should be ready soon.

Technetium Metal Production

Hydrogen reduction of ammonium pertechnetate to technetium metal powder was completed during the month and the ca. 800 grams of product transferred to the Metallurgy Development Operation for tungsten alloying studies. Analysis showed the metal to contain 60 ppm nitrogen, 44 ppm hydrogen, and 1620 ppm oxygen (all by weight). The oxygen content, although acceptable, is higher than expected and is equivalent to the presence of about 0.5 percent of the technetium as TcO_2 . Arc melting (to produce a massive ingot) should reduce the oxygen content somewhat.

Semiworks Solvent Studies

Laboratory and hot cell investigations were completed, aimed at resolving the problems encountered at the Strontium Semiworks when used solvent was employed in the silver persulfate-D2EHPA process for cerium-promethium splitting.

Radiation tolerances of several Soltrol-type diluents proposed for this use were established. Straight chain hydrocarbons, such as n-dodecane, were found to give best service, although even these degrade in time. A commercially available solvent (termed "NPH" by CPD, for Normal Paraffin Hydrocarbon) was very nearly as good as n-dodecane and much less expensive (ca. \$2/gallon). On the basis of these results, 1000 gallons were purchased for a plant test. Although use of the new diluent should allow several cycles of plant operation before the solvent must be discarded, replacement of the present batch-contact extraction with a continuous pulse column operation would further reduce the radiation exposure of the solvent and greatly extend its life. Continuous counter-current operation would have the added advantage of larger Ce-Pm separation factors.

An interesting side light of the above investigation was the observation of surprisingly large variations in the extractability of cerium [presumably as Ce(IV)] as its concentration was varied from tracer level to macro concentrations. The extraction coefficient (from 2 M HNO_3 , 0.2 M $\text{K}_2\text{S}_2\text{O}_8$, 0.02 M Ag^+ into 0.4 M D2EHPA, 0.2 M TBP, hydrocarbon solvent) increased 100-fold as the cerium concentration was increased from 10^{-5} M to 0.1 M. Cause of this peculiar behavior is being studied.

Kinetics of Ion Exchange on Zeolites

Self-diffusion coefficients were determined for sodium, cesium, strontium and cerium in the zeolites Type X (Linde 13X) and Type A (Linde 4A) at two temperatures. Reaction enthalpies varied from 5.1 kcal/mole for cerium self-diffusion in Type X to 15.9 kcal/mole for strontium self-

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diffusion in Type A. Self-diffusion coefficients are applicable to all systems involving exchange of a tracer level component.

Exchange diffusion coefficients were determined in three systems. Helfferich's exchange diffusion model, postulating a non-linear relationship between the exchange diffusion coefficient within the zeolite and the ionic composition of the zeolite, was found to be applicable to the zeolite systems studied.

Columbia River Studies

The travel times of the Columbia River between Pasco and the Pacific Ocean were estimated from the Na-24 concentration changes during the peak river flow period. This was made possible by the extreme sensitivity of the multi-dimensional analyzer for this radioisotope. Estimates were based on the assumption that no loss of Na-24 occurs other than by decay. Since some loss must occur, these values represent maximum times. Further comparisons with travel times determined by rupture fission product debris will improve the accuracy of these estimates. These data indicate that at 587,000 cubic feet per second (cfs) flow at Vancouver, Washington, the flow time is 77.8 hours. At 627,000 cfs, the time to Vancouver is 75.6 hours. With a flow at Astoria of 656,000 cfs, the flow time is 127 hours.

Late in May, Columbia River water samples from the 300 Area, Umatilla, The Dalles and Vancouver were filtered immediately after sampling and passed through anion and cation exchange resins to determine the forms of some of the radionuclides. About 20 percent of the Cr-51 was on the particles, and more than 98 percent of the Cr-51 in solution was in the anionic form. These results are at variance with earlier studies which indicated a gradual change of the Cr-51 from the anionic to the cationic form. The amount of Zn-65 on particles increased from seven percent to 90 percent as it passed downstream. The Zn-65 in solution remained almost completely cationic.

EQUIPMENT AND MATERIALS

Non-Metallic Materials

A vitreous carbon crucible obtained from the Carbon Corporation has contained an equimolar mixture of molten KCl-NaCl at 900 C in air for 44 hours with no noticeable leakage or apparent damage from oxidation.

Irradiation with fuel element source of a 6-inch cube of Corning No. 8362 (3.2 density) glass was terminated after 1325 hours during which time the glass had received an integrated dose of 3.7×10^7 r. The glass had not discharged.

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Corrosion of Uranus 5 Alloys

Weldments were prepared using Uranus 5 (an 18-14 stainless steel containing four percent silicon) was the parent metal and either Uranus 5 or 308-L stainless steel as the filler material. Exposure of these weldments to pertinent HAP0 process solutions is underway. Preliminary results indicate 308-L is a satisfactory filler material.

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HW 83445REACTOR DEVELOPMENT - 04 PROGRAMPLUTONIUM RECYCLE PROGRAMElectrochemistry of Uranium in Molten Chloride Salt Solutions

Additional points have been obtained for the curves relating EMF to uranyl chloride concentration, melt temperature and melt composition for the reaction

The new points fit the curves already obtained for equimolar KCl-NaCl and LiCl-1.4 KCl. The new points for LiCl-NaCl melts of varying NaCl/LiCl ratio, plotted in terms of values of ΔF for the reaction as a function of NaCl concentration, give no evidence for the "S"-shaped, titration type curve previously observed (reported in HW-75127 C). Rather, the new data show a linear relationship, as found with other melt systems. It is postulated that the previous data, which gave non-linear results, were influenced by contamination of the melt or by the presence of uranyl(V) in the melt.

Studies of Uranium(V) in Molten Chloride Salt Solutions

Attempts to prepare and measure the spectra of various uranium(V) compounds have continued in an effort to gain evidence in support of the conclusion that the species observed in molten chloride salt solutions containing uranyl(VI) and uranium(IV) chlorides is a uranium(V) species such as UOCl_3 . Partial success has been achieved in that the spectrum of a solution prepared by reacting $\text{UCl}_5 \cdot \text{SOCl}_2$ with ethanol, a reaction reported¹ to give UOCl_3 , is indeed quite similar to the spectrum measured in the molten salt. These spectra do not, however, agree with that reported² for solid UOCl_3 , so the issue is still in doubt and will not be completely resolved until a solid compound has been prepared and studied quite extensively.

Salt Cycle Process Engineering Development

Experiments in the High Level Radiochemistry Facility continued during the month with a dissolution of irradiated PuO_2 - UO_2 feed material using

1 D.C. Bradley, et al., J. Inorg. Nucl. Chem. 3,367 (1957).

2 M.D. Adams, et al., J. Phys. Chem. 67, 1939 (1963).

a chlorine sparge. Bath clean-up electrodeposition was undertaken with the intent to remove most of the uranium and fission products, leaving the plutonium undissolved in the melt. Prior to the electrodeposition the melt was sparged with 97 percent O_2 - 3 percent Cl_2 in an attempt to precipitate that plutonium which had dissolved. The electrodeposition step removed 99.4 percent of the uranium in solution, although 7 percent of the uranium in the feed had not been dissolved before electrolysis. The extent of fission product removal has not yet been determined. Not all of the dissolved plutonium was precipitated by the oxygen pre-sparge, and essentially all the plutonium in solution was electrodeposited, representing 24 percent of the plutonium in the feed. The remaining uranium and plutonium in the salt bath was then dissolved and a partition deposition, with a hydrogen chloride sparge, was performed which removed 96 percent of the remaining uranium and only one percent of the plutonium.

In related work, iodine behavior in salt cycle off-gas streams was investigated. Iodine-131 DF's have ranged from 3 to 2700 across a chlorine liquefaction trap at -100 C, and from 570 to 15,500 across the trap and a charcoal adsorber in series. Small scale runs with a liquefaction tube designed such that the off-gas bubbles through the liquid chlorine gave DF's of 10 and 6 at -78 C. The I-131 activity release from the trap varied linearly when plotted as log activity versus reciprocal temperature.

RADIOACTIVE RESIDUE PROCESS DEVELOPMENT

Cold Semiworks Spray Calciner

Simulated high-acid Purex waste modified with colemanite (an insoluble calcium borate complex, nominally $Ca_2B_6O_{11} \cdot 5H_2O$) to form a borate glass was successfully calcined in the 18-inch spray calciner at feed rates of 12 to 15 gal/hr. The small amount of deposits formed on the calciner walls are friable and are held to acceptable equilibrium levels by efficient hammering.

Modifications to the semiworks spray calciner to more closely simulate the proposed Waste Solidification Engineering Prototypes (WSEP) calciner were completed. The new Hastelloy X calciner is 14 inches OD and 6 feet in effective length. Heating of the calciner is provided by the electric resistance furnace modified into two heating zones: an upper 4-foot long zone and a lower zone about 2 feet long. The new calciner is operable in combination with the continuous melter; a 50-hour run was initiated on the combined system.

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Calcine Melter

Two runs were made to study conversion of waste calcine into a glassy solid by simultaneous addition of solid glass-forming chemicals and spray calcined simulated waste as separate feed streams to the melter. In general, melter performance was smoother than with previously tested single feeds.

In the first run, Purex calcine powder without sulfate was fed to the melter at a rate of 1.25 lbs/hr at the same time that $\text{NaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}$ crystals were fed at a rate of 3.1 lbs/hr. The product collected was homogeneous, opaque, green glass except during the latter part of the run when excessive melter corrosion products formed a gray, metallic slag. In the second run, Redox calcine was fed to the melter at a rate of 1.9 lbs/hr, mixing with $\text{Na}_2\text{B}_4\text{O}_7$ glass frit fed at a rate of 3.1 lbs/hr. The product was a dark brown-black glass.

A hole corroded through the side of the overflow valve near the bottom of the melter after 150 hours of service. The resultant leakage of melt reduced the residence time in the melter to the point that numerous gas bubbles were retained in the Redox-based glass product. The walls and bottom of the Inconel melter were replaced with similar parts of Hastelloy X and stainless steel 310, respectively.

Waste Melting Composition Studies

Colemanite-modified Purex waste calcines (weight ratio of calcined waste: colemanite maintained at 3:7) were scouted further in the laboratory in an attempt to obtain fluid, low-melting glasses. The addition of 20 weight percent or more of LiNO_3 crystals lowers the melting point of the colemanite-Purex waste mixture from about 950 C to about 800 C. The addition of litharge (PbO) to the colemanite-Purex waste up to 75 weight percent reduced the melting point by only 50 C.

Modification of simulated Purex wastes with Na_2SO_4 salt additions are not sufficiently fluid for continuous melter operation at temperatures up to 1050 C unless the waste content is held below 5 weight percent. Addition of sulfuric acid to Purex wastes up to 75 weight percent has negligible effect on melting point. Scouting of finely divided silica addition to Purex waste has shown no melts obtainable below 1000 C.

Purex 1WW - Colemanite Melts

About 22 weight percent calcined Purex 1WW waste can be combined with 78 weight percent colemanite to produce a glass-like solid having a melting point of 800 C. Increasing the ratio of 1WW to colemanite in the glass results in increased melting point; a solid containing 53 weight percent 1WW melted at 850 C.

Intermediate Level Waste Treatment

Five scavenging techniques were employed in two stages in a laboratory study on the removal of radionuclides from laboratory type wastes. The precipitates in the first stage were alunm, ferrous sulfate, lime, Guyard reaction ($3\text{Mn}^{+2} + 2\text{MnO}_4^- + 2\text{H}_2\text{O} \rightarrow 5\text{MnO}_2 + 4\text{H}^+$) manganese dioxide, and manganese dioxide formed by the air oxidation of manganous ions in alkaline solution. Each precipitate scavenged approximately 92 percent of the gross gamma activity. The precipitate concentrations were 100 mg/l of waste in all cases.

The primary effluent for each of the scavenged samples was subjected to a second precipitation step. Guyard reaction MnO_2 was employed as the second stage for the alum and Guyard reaction MnO_2 samples. Oxygenation reaction MnO_2 was used for the second stage for ferrous sulfate, lime, and oxygenation reaction MnO_2 . Once again, each precipitation scheme scavenged approximately the same amount of radioactivity (about 95 percent of the gross gamma activity for both stages combined).

The effluents from the two-stage scavenging were passed through clinoptilolite columns for cesium removal. After this ion exchange step, the only significant radionuclide present was Ru-106. The apparent DF for Ru-106 for the two stages and ion exchange was about 50.

CONTAINMENT SYSTEMS EXPERIMENT

Major Facilities and Equipment

The work at T-Plant reached the readiness stage for the erection of the containment vessel. Only the pouring of the footing for the vessel remains as a major work item.

Negotiations with a Struthers-Wells representative on the primary vessel were conducted. Because of the additional quality control and inspection that is desired, the bid price is to be revised. Struthers-Wells is to submit a firm price bid shortly. Questions that arose during the review of the bids were answered satisfactorily by the Struthers-Wells agent.

A program for non-nuclear experimental measuring objectives and proposed approaches was prepared. The program will require a cooperative effort between personnel of Process Control Equipment Development, Instrument Research and Development and Process Demonstration and Analysis.

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Fission Product Simulation and Aerosol Generation and Sampling

Additional tests of silver plated copper screens and copper ribbon beds for the removal of elemental iodine and particles from air were made. The results of the tests are summarized below. To provide a uniform basis for comparison, the values for 14 and 50 mesh have been extrapolated to five layers:

Component		Percent of Airborne Material Retained				
		25 fpm		80 fpm		260 fpm
Mesh	Layers	I2	Particles*	I2	Particles	Particles
14	5	86	0.8	74	0.2	0.2
50	5	99.7		93.2	0.5	
50	5**			96.7		
100	5		1.3	97.6	0.7	
Ribbon, 2", 0.15 g/cc		99.2		97		
Ribbon, 2", 0.3 g/cc			2.4	98.3	1.7	1.4
Charcoal Paper (AC-1)				97		
Ag Colloid Paper				99.7		
Membrane Filter (AA)				3		
Glass Fiber Filter (A)				1		

* 0.2 μ MMD Uranine

** Aged 24 hours at 130 C in air. All other freshly plated.

The iodine removal at 80 fpm by the 100 mesh Ag-Cu screen is marginal and the use of more layers is indicated. The silver colloid paper was made by reducing AgNO_3 with formaldehyde, mixing with cellulose fibers, with subsequent dewatering on a Buchner funnel. The good removal of iodine merits further study. It would, of course, need to be preceded by a particle filter of low iodine retention to obtain the desired particulate-elemental iodine form separation. Testing of the components in air and steam is also necessary.

Instrumentation and Control

Development work was initiated to provide measurement techniques and instrumentation for CSE. Current work is directed toward determination of the rate of water efflux from the pressure vessel following a simulated piping rupture. Calculations have been made on a gamma absorption technique, in which a source is placed at the top of the vessel and detectors along the side. The increase in gamma count rate will indicate the mass of water between the detector and source. Arrangements have been made to instrument an existing semi-works vessel to permit testing and evaluation of the method. Analysis of other CSE instrumentation is proceeding.

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

The curves of permeability versus capillary pressure and saturation versus capillary pressure measured simultaneously on the same soil sample compare very favorably. Estimates of the air-entry pressure (i.e., the capillary pressure at which air first enters the pores of a draining medium) from both curves are identical. Some instabilities are still being experienced with the electronic equipment.

Subroutines have been developed for the extension of Philip's iterative procedure to the solution of transient imbibition problems for two- and three-dimensional radial flow. Programming of this method should be completed by month end.

The initial error analysis, concerned with methods for the determination of permeability distribution, showed extremely small errors associated with obtaining streamlines and evaluating the permeability integral. Relatively large errors, from 2 percent to 150 percent, were associated with the functional fitting of the potential data; therefore, better forms for functional fitting are being sought.

RADIOLOGICAL AND HEALTH CHEMISTRYAnalytical Methods

Interference from iron and copper in the separation of uranium and thorium from tissue samples has been eliminated through a modification of an amine extraction procedure. Uranium and thorium can both be extracted into Alamine 336 (tricaprylamine) in xylene from a heavily salted aluminum nitrate solution. Copper and iron do not extract. Thorium is removed with 7 M HCl and uranium with 0.1 M HNO₃. Uranium recoveries are 86.5 ± 3.7 percent. Direct plating of U-233 spikes separated from liver and urine samples using this method give alpha energy spectra with a resolution of seven percent which is suitable for some distinction between alpha emitters.

Radiation Chemistry

The surface of the human red cell is generally regarded as a mosaic structure consisting of different lipid- and protein-rich areas. Identification of the relative susceptibilities of these areas to radical attack should facilitate the task of chemically protecting the

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cell through use of an agent specific for the most susceptible site. Surface constituents of red cells were selectively extracted with a series of isotonic saline solutions to provide samples of red cells with slightly different chemical structures at their surfaces. The washings were saved for analysis to determine which constituents had been reduced in the cell surface. The samples were then irradiated and the cell hemolysis measured as a function of time. The more washed cells hemolyzed more rapidly indicating that some constituent of a cell which affects its radiation sensitivity was removed by washing. Work aimed at identifying this constituent is in progress.

ATMOSPHERIC RADIOACTIVITY AND FALLOUT

Aerosol Sampling Study

Impaction efficiencies of ZnS particles on membrane filters supported in locally used plastic filter holders were measured for several particle sizes (d) and approach velocities (v). Analysis of the data reveals that impaction efficiency increases with particle size and approach velocity. This is qualitatively as expected; however, the impaction efficiency does not correlate with the product, vd^2 . When vd^2 is plotted against the impaction efficiency, a separate curve for each of three windspeeds, 2.7, 16.5 and 30 mph, is obtained and the curves for these windspeeds are not in successive order of increasing windspeed. Search for possible correlating functions is underway.

Particle deposition on the internal surfaces of the nozzle required to achieve an isokinetic sample rate for the 16.5 mph windspeed was as high as 40 percent for a 25-micron particle. Although frequently used in air sampling systems, tapered nozzles for effecting isokinetic entrance velocity and delivery to a larger filter area must be used with great caution and checked for retained particles.

Curve fitting techniques are being employed to find analytical expressions for particle size distributions. Because the size distributions of materials in use do not follow a normal or log normal plot, some work is going on to derive appropriate expressions. Expressions have been obtained which predict the number of particles in each size range counted. The average discrepancy of completed versus experimental values is about 10 percent. Using the same computer techniques, expressions are being derived for the number of particles in each one-micron size increment.

Aerosol Generation

Silica particles were generated by spraying an ethanol solution of a commercially available colloidal silica using the spinning disc generator.

The solid particles formed by evaporation of drops of this solution exhibited the same high degree of sphericity as the iron oxide particles reported last month. The size uniformity was good, and particles formed from the pure sol alone appeared to be transparent, closely resembling glass spheres.

Organic dyes, uranine and rhodamine-B, added to the solution to be atomized, could be leached from the solid particles using methanol. Thus it appears that particles of several sizes, traced with different dyes, could be used in a single experiment.

Electrical Charges on Aerosols

Several preliminary experiments were performed using the aerosol charge spectrometer. The particles examined in these runs were produced by spraying an ethanol solution of uranine and methylene blue. Extensive results have not yet been obtained, but two preliminary results are: (1) almost all of the particles formed by the spinning disc generator possess a relatively high positive charge; and (2) the sonic jet ionizer effectively neutralizes these charges. Finding (1) above suggests that contact or other stray potentials induce charges on the droplets as they are thrown off the disc.

Fallout Radiochemical Studies

Sodium-24 was measured in three rain samples collected on Rattlesnake Mountain. The values are tabulated below:

<u>Sample Date</u>	<u>Volume, liters</u>	<u>dpm Na-24 per liter</u>
6/15/64	45	0.94
6/17/64	6.64	2.22
6/18/64	14.3	0.59

This nuclide is produced naturally by cosmic ray spallation of the argon-40 in the atmosphere. Its presence was first reported in 1963 by W. Rödel of the University of Heidelberg who chemically separated it from three 200 - 300 liter rain samples to get 0.18, 0.35 and 0.19 dpm Na-24 per liter. These values are the only published values for this cosmic ray produced nuclide. Through use of a multi-dimensional analyzer procedure with its great sensitivity, the determination of this nuclide on rain samples as small as seven liters with only sample evaporation (no chemical separation) was possible.

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ISOTOPES DEVELOPMENT - 08 PROGRAMIsotope Packaging

Six simulated 2-1/2 inch diameter spherical isotopic heat sources were produced by pneumatic impaction. Four of the containers were loaded to a green density of 60 percent of theoretical with strontium titanate and compacted to a final bulk density of from 82 to 90 percent of theoretical. One samarium oxide source was loaded to a green density of 47 percent of theoretical and the other to 58 percent. Both samarium oxide sources were compacted to a final bulk density of 98 to 100 percent of theoretical.

The as-impacted outside diameter of two of the strontium titanate and both samarium oxide sources was 2.50 ± 0.040 inches. The wall thickness of the as-forged sources varied from not less than 0.190 inches at the poles to not more than 0.340 at the equator. The wall thickness of the two strontium sources that were machined to a 2.375 inch diameter was between 0.160 to 0.230 inches.

Manager
Chemical Laboratory

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BIOLOGY LABORATORY

A. ORGANIZATION AND PERSONNEL

R. H. Scott, Specialist - Health and Safety, and J. F. Hawkins, Clerk - Health and Safety, transferred to Physics and Instruments Laboratory on July 1, 1964 after a six-month assignment to Biology Laboratory.

D. H. Willard returned on July 7, 1964 from an educational leave of absence to resume duties as a Biological Scientist in the Inhalation Toxicology Operation.

C. N. Rushbrook, Technologist in Biological Analyses Operation, resigned effective July 8, 1964 in order to accompany her husband, who returned to school.

R. E. Kane, a summer employee at Experimental Animal Farm, terminated July 31, 1964. He was replaced by L. F. Jacques, also a summer employee, who joined the Experimental Animal Farm on July 26, 1964.

B. TECHNICAL ACTIVITIES

FISSIONABLE MATERIALS - 02 PROGRAM

Reactor Effluent Monitoring

Ten weeks of reactor effluent monitoring with young chinook salmon showed 5, 6.6, 11.6 and 20.6% mortality for fish reared in 0, 2, 4 and 6% uncooled effluent, respectively. Fish reared in similar effluent concentration but cooled to river temperatures had 3.4 to 5% mortality, not significantly different from the controls. The average body weight of the fish in 6% uncooled effluent was about 12% greater than the controls; a significant growth acceleration due to warmer temperatures.

Columnaris

First appearance of columnaris disease in the troughs of the 146 Building occurred in the middle of June, approximately two weeks earlier than last year.

BIOLOGY AND MEDICINE - 06 PROGRAM

METABOLISM, TOXICITY AND TRANSFER OF RADIOACTIVE MATERIALS

Zinc

Trout fed a single dose of 200 μ c Zn⁶⁵ retained 7 μ c after 299 days. The effective half-life for long-term retention was about 140 days.

The swimming performance of trout with body burdens of about 1.7 mc Zn^{65} differs little from that of control trout. The experimental trout were force-fed 1.0 μc Zn^{65} /g fish/day, Monday through Friday, for over four months. The total administered dose was about 13 mc. In water velocities of 5.1, 4.1 and 3.5 fps, the fish were able to swim for 1.4, 9.2 and 26.3 minutes, respectively.

Strontium

The gastrolith of the crayfish accumulates 50% of an injected dose of Sr^{90} during pre-molt, a period of approximately 20 days. The concentration of Sr^{90} in the gastrolith at molt is decreased by about one-half as resorption occurs during post-molt. Active resorption of calcium salts in the old exoskeleton during pre-molt is well known; the present work indicates that active fixation or cycling of Sr^{90} also occurs during pre-molt. The total crayfish shows a high retention of 70-90% of Sr^{90} dose, 90 days post-injection.

Based on gross necropsy examination, we previously tentatively identified a "malignant lymphoma" in the tissues of a three-year-old miniature swine which had been chronically fed 125 μc Sr^{90} /day. Histopathological examination confirmed the presence of a malignant lymphoma. Massive lymphocytic infiltration was observed in the lymph nodes, brain, adrenals, heart, uterus, kidney, intestine, ovary, liver and spleen. The animal had a Sr^{90} body burden of $\sim 1200 \mu c$. Maximum radiation dose rates to bone and bone marrow were estimated to be 20 rad/day. This observation is of particular interest since it is the first substantiated case of neoplastic disease in over 150 animals of this age or older maintained on the chronic Sr^{90} study.

Cesium

Current and previous studies of the metabolism and dosimetry of Cs^{137} in sheep have utilized the whole body counter to estimate Cs^{137} body burdens. In these studies calibration of the counter was achieved by injecting various sized animals with known amounts of Cs^{137} and counting them shortly after injection to establish a counting efficiency. Use of this method is based in part on the assumption that the counting efficiency for Cs^{137} in the recently injected animal is the same as for animals with body burdens established over longer periods of time. To check on the validity of this assumption, five animals of various weights were given single intravenous doses of Cs^{137} and whole body monitored at frequent intervals for ~ 30 days. All excreta from these animals was radioanalyzed and total body burdens of Cs^{137} estimated from the excreta analysis. The estimates of body burden obtained by these two methods were very similar.

Comparison of body burdens of sheep administered Cs^{137} orally and those given Cs^{137} intravenously allows an accurate estimate of gastrointestinal absorption. In four cases (where this estimate was possible with animals of similar weight) the gastrointestinal absorption ranged from 70-84%.

With either oral or intravenous administration, approximately 50% of the absorbed Cs^{137} , or that intravenously administered, was excreted in the first 10 days post administration. Approximately twice as much Cs^{137} was excreted in the urine as in the feces.

Neptunium

Dietary and operative manipulations are being tested for their effect on Np^{237} -induced fatty livers in female rats. Included are glucose and antioxidant feedings, adrenalectomy, hypophysectomy, thyroidectomy, ovariectomy, and castration. Glucose and antioxidant feedings and adrenalectomy resulted in a marked depression of the normally observed fat accumulation. Interpretation of these findings must await the completion of associated studies.

Plutonium

The secretion of Pu^{239} in the bile of rats was studied following intratracheal injection of several chemical forms of plutonium. Following intratracheal injection of plutonium citrate, peak bile concentrations were observed after 70 minutes. The maximum concentration was about one-third that observed in earlier experiments following intravenous injection of plutonium citrate. Only trace amounts of plutonium appear in the bile following intratracheal injection of plutonium (IV) nitrate. Following intratracheal injection of plutonium (VI) nitrate, concentrations appearing in the bile were about one-fifth those observed following intratracheal injection of plutonium citrate. These observations no doubt reflect the short-term solubility and absorbability of these chemical forms of plutonium in the lung.

Inhalation Studies

One dog died 51 months after inhalation of $\text{Pu}^{239}\text{O}_2$. The body burden at death was about one microcurie, of which 50% was in the lungs, 40% in the bronchial and mediastinal lymph nodes, 4% in the bone, and 3% in the liver. Fibrosis and metaplasia were present in the lungs, with fibrosis in the bronchial lymph nodes. No neoplasia was observed in this dog. Thus, four of the seven dogs that have died 3 to 4 years after inhalation of $\text{Pu}^{239}\text{O}_2$ have shown primary pulmonary neoplasia.

Eight consecutive weeks of semi-weekly exposures of rats to uranium ore dust were completed. The animals will be examined to confirm the selective retention of thorium in lungs that was observed earlier.

Gastrointestinal Radiation Injury

X-irradiation of the abdominal region of the rat with 1500 r resulted in a loss via feces, during the third day post-irradiation, of bile salts equivalent to about one-half the total body pool. This affords quantitative support for earlier observations of a radiation induced defect in bile salt reabsorption from the small intestine.

Abdominal exposure of the rat to 1500 r was shown to result in a marked migration of bacteria from the colon into the small intestine. A similar effect was produced in non-irradiated rats by treatment with mecamlamine, a ganglionic blocking agent that reduces peristalsis of the intestine. These findings suggest that the bacterial invasion which characteristically accompanies the intestinal radiation syndrome may be a secondary result of depressed intestinal motility, which is also a result of intestinal irradiation.

Thermoluminescent Dosimeters

Several batches of LiF were exposed to gamma radiation and the dose response determined. The response varied between batches and may vary within a given batch depending on treatment. Two batches of LiF (from the same initial lot) were repeatedly exposed to 500 mr. One batch was repackaged after each read-out. (Read-out supposedly returns the LiF to zero levels.) The sensitivity of the LiF increased with each of the first two re-uses and then dropped to a lower sensitivity than the original material. The range of the readings increased from $\pm 10\%$ to $\pm 50\%$. (The variations in the range of reading was probably due at least in part to accumulation of foreign material in the powder.) The second batch was annealed at 400 C for 1 hour prior to each exposure. Contrary to previous literature reports, the sensitivity went down with each re-exposure. The range of the readings also became smaller. After three uses, this latter batch was annealed for 60 hours at 160 C. This has been reported as a means of improving sensitivity; however, in this case, it resulted in the lowest sensitivity of any sample checked.

Terrestrial Ecology

Cheatgrass harvested from standard plots on the Hanford Reservation averaged 17 ± 2 g/m² during the 1963-64 growing season, as compared to 236 ± 9 g/m² during the 1962-63 growing season.

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Barley seedlings grown in the soil taken from the immediate vicinity of greasewood plants showed marked increases in sodium content and reduced potassium content, as compared to seedlings grown in the same type of soil taken at some distance from the greasewood plants. These data provide strong evidence for the importance of mineral cycling on members of a plant community. In contrast to the above, barley grown in the laboratory on soil from greasewood areas, from nongreasewood areas, and in mixtures of these soils, showed little or no difference in uptake of Cs^{137} previously added to the soils.

Microbiology

The rate of RNA synthesis within a given biological system is widely assumed to be dependent upon growth rate per se. Studies with E. coli, using variations in temperature and in nutrients added to the medium, clearly show that the RNA to protein ratio is not entirely consistent when the growth rate is held constant. Addition of amino acids appears to markedly increase the RNA to protein ratio.

Plant Nutrition

Concentrations of Sr^{90} in alfalfa now in its second year of growth were the same in this spring's cutting as in the first cutting following seeding last year.

Alaskan Studies

Whole-body counting at Anaktuvuk Pass during July 6-7, 1964 showed a marked rise in Cs^{137} burdens as compared with similar data obtained one year earlier. Seasonal values for a group of 27 adult residents indicate that summer values tend to be higher than winter values.

Experimental plots were established near Anaktuvuk Pass and Cs^{134} and Sr^{85} applied to lichens. These plots will be sampled during the coming year to evaluate the retention of these radionuclides on the lichens.

Columbia River Limnology

High water during June prevented accurate sampling of periphyton and plankton for radioanalysis. It did appear, however, that the activity of P^{32} , Zn^{65} and Sc^{46} in the plankton decreased substantially, presumably because of increased run-off and increased silt content in the water. Two samples of silt, one from near each shore, were separated from the plankton samples and showed an average activity of .5 nc Zn^{65} and .04 nc Sc^{46} /g dry weight.

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The components of plankton were further evaluated by separation into three size fractions: greater than 50 microns, 5-50 microns, and .45-5 microns. The latter two components comprise the nanoplankton. Chlorophyll a content was measured in these fractions and found to be .8 and .9 mg chlorophyll/liter in the largest and next to largest components, respectively, on May 28, and approximately half this value on July 16. No chlorophyll was obtained from the smallest fraction.

A small sample of scrap fish collected just above Hord Rapids Dam showed no above background content of Zn^{65} . High water conditions prevented obtaining a larger sample which would have been more suitable to evaluate movement of contaminated fish into the Yakima.

A handwritten signature in black ink, reading "R. Thompson". The signature is written in a cursive style with a large, looped "R" and a clear "Thompson" following it.

Acting Manager
BIOLOGY LABORATORY

RC Thompson:sw

TECHNICAL INTERCHANGE DATA
BIOLOGY LABORATORYI. Speeches Presented

a. Papers Presented at Society Meetings and Symposia

Ragan, H. A. Application of miniature goats in ruminant research.
Annual Meeting of the American Veterinary Medical Association,
Chicago, Illinois, July 19-23, 1964.

b. Seminars (Off-Site and Local)

Park, J. F. Inhalation of radioactive particles. University of
Utah Radiobiology Summer Institute, Salt Lake City, Utah.
July 14, 1964.

Rickard, W. H. Radiocology. Montana State University Summer
Institute, Yellow Bay, Montana. July 13, 1964.

Rickard, W. H. Radiocology. Montana State University Summer
Institute, Missoula, Montana. July 14, 1964.

c. Seminars (Biology)

Dr. Madelene Pierce, Chairman, Department of Zoology, Vassar College,
Poughkeepsie, New York. Ecology - basis of modern weed control
in aquatic environments. July 17, 1964.

d. Miscellaneous

None

II. Articles Published

a. Open Literature

Erdman, H. J. Sexual precocity of the male flour beetle, Tribolium
castaneum Herbst, and the influence of temperatures on reproduction
during early adult life. Canadian Entomologist 96:656-59 (1964).

West, J. E. and W. J. Bair. Plutonium inhalation studies. V. Radiation
syndrome in beagles after inhalation of plutonium dioxide.
Radiation Research 22:489-506 (1964).

b. HW Documents

None

III. Visits and Visitors

a. Visits to Hanford

Eight participants in the Public Health summer course of Benton and Franklin County toured Biology facilities on July 8, 1964.

Members of the State of Oregon Radiation Monitoring Unit toured Biology with L.A. Temple on July 9.

Dr. M. Saiki, of the National Institute of Radiological Sciences, Chiba City, Japan, visited Biology and discussed research with staff members on July 13.

Dr. Jacob Shapiro, Department of Industrial Medicine, Harvard University, Boston, Massachusetts, discussed inhalation research with W. J. Bair on July 13.

Dr. Madeline Pierce, Department of Zoology, Vassar College, Poughkeepsie, N.Y. toured Biology and presented a seminar on July 17.

Dr. Joseph Gong, Hospital for Special Surgery, New York, discussed research with R. C. Thompson on July 24.

Drs. James L. Mackin and Joseph D. Terresi, U.S. Naval Radiological Defense Laboratory, San Francisco, California, visited Biology to discuss SNAP device hazards with W. A. Kornberg and staff, July 31.

b. Visits Off-Site

6/27-9/15 - W. G. Hanson conducting biological studies in Alaska.

7/2 - W. Rickard and L. Therhardt collected fallout samples in the Blue Mountains.

7/1-2 - E. H. Eneki presented a lecture at the University of Washington Summer Institute for Radiation Biology in Seattle.

7/6 - L. L. Therhardt collected fallout samples at Packwood.

7/7-15 - D. G. Watson conducted biological studies in Alaska.

7/7-10 - W. A. Kornberg, R. D. McClellan and M. F. Sullivan attended an Aerospace Nuclear Safety Meeting in Los Alamos, New Mexico.

7/15-20 - G. F. Cushing attended symposium at University of Pittsburgh, Pymatuning Lab.

7/20-21 - W. H. Smith presented a lecture at the Summer Institute on Radiobiology, University of Utah, Salt Lake City.

b. Visits Off-Site (continued)

- 7/13-14 - J. F. Park visited the University of Utah, Salt Lake City to present a lecture and discuss chronic toxicity of plutonium in beagle dogs.
- 7/11-15 - W. H. Rickard presented lectures at the Montana State University Summer Institute on Radiobiology in Missoula and Yellow Bay, Montana.
- 7/19-24 - H. A. Ragan presented a paper at the AVMA meeting in Chicago, visited Argonne to discuss research with Dr. Rehfeld, and discussed research with Dr. Taylor at the University of Utah, Salt Lake City.
- 7/24 - W. H. Rickard collected fallout samples in the Blue Mountains, Dayton, In.
- 7/26-8/1 - E. G. Tombropoulos attended the International Congress of Biochemistry in New York City.

IV. Achievements

None

V. Honors and Recognitions

None

VI. Professional Group or Organization Assignments

None

APPLIED MATHEMATICS OPERATIONMONTHLY REPORT - JULY, 1964ORGANIZATION AND PERSONNEL

Joanne K. Fremstad terminated July 10 in order to return to school. D. F. Shepard transferred to Separations Chemistry Lab, Research and Engineering, Chemical Processing Department, July 1, 1964.

ACTIVITIES FOR OTHER HAPO COMPONENTSN-Reactor Department

Assistance was given in the use of equations which apportion the exposure in a tube when the fuel elements are of varying lengths. Assistance was also given in the use of a method of evaluating Pu prediction equations which obviates the direct computation of higher powers of the exposure.

A sampling problem was investigated relative to in-reactor band and baffle wear being experienced on heat-exchanger condenser tubes.

Irradiation Processing Department

A plan was devised to sample process tube flexible-connectors on four reactors with the goal of obtaining data relative to deterioration of the connectors over time.

Manufacturing

Formulae for the reliability of the zone temperature monitoring system have been developed as a function of the reliability of the meter relay components, and a talk was given to engineers of the Plant Equipment Engineering Operation on the development and use of these formulae. Further work is being done to bring other and more reliable components in the system into the formulae. A method is being developed to determine confidence limits in conjunction with system reliability estimates. Further discussions were held with personnel of this group on the problem of estimating component reliabilities determining confidence limits on component mean life to failure values, and presenting the results in a manner meaningful to management.

Production Fuels

Data from the preirradiation measurements of production test IP-677-t to compare the dimensional stability properties of AlSi and HDS fuel elements are

being analyzed in considerable detail. The analysis describes the two fuel element types on the basis of 12 weight and dimensional measurements as well as 10 additional statistics derived from these measurements.

A partially nested ANOVA is being used to estimate the variance components due to differences between ingots, fuel element types, and day-to-day measurement biases.

A considerable amount of data describing the bonding layer diffusion properties resulting from several HDS canning techniques are being studied.

Research and Engineering

The probability of having sustained no catastrophic failures in 120 reactor operating years was determined as a function of various hypothetical failure rates.

The analysis of PT-572 has been completed in which the dimensional stability performance of different kinds of fuel elements in smooth bare tubes has been analyzed.

An analysis of data from PT-546, which compares the dimensional stability characteristics of irradiated HDS and AlSi fuel elements, is being made.

It was determined that several run-to-rupture graphs are still valid.

Assistance was given in the determination of tolerance and confidence limits relating R values to reactor residence time. R values are measures of the outlet water temperature imbalance.

Several recent production tests have taken Latin squares as their basic patterning. Several examples using simulated data have been worked up to show how the analysis would be done. An analysis of covariance on these data, using fuel element exposure versus the covariate, was made on the data and the results comparing the two modes of analysis are of interest.

An analysis of the C-reactor pressure monitor ground detector determined the modifications which would retain existing safety circuit functions under that change of supply voltage required by the installation of the Trip Identification System. These modifications were incorporated into the ground detector and acceptance tests were conducted on July 24.

ACTIVITIES WITHIN HANFORD LABORATORIES

2000 Program

C-Column Computer Control

Documentation continued of the functional programs which will be used to control the operation of the C-column with the GE-412 Process Control Computer.

Ground Water Models

The six basic EDPM program versions of the "shoe box" flow system model have been completed and turned over to the customer as an experimental tool in studying soil permeability.

3000 Program

Power-Roll Forming Studies

Work is nearing completion on an EDPM program which predicts those anomalies to be expected on a power-rolled form as a result of using an imperfect blank.

Numerical Control of Rotary Contour Gauges

Documentation is nearing completion on an EDPM program SPIG which prepares magnetic control tapes for the prototype Sheffield Rotary Contour Gauge.

4000 Program

Radiation Damage to Fissionable Materials

Documentation continued of the Fortran language program SALTY which unfolds an observed two-dimensional particle size distribution into its three-dimensional counterpart. A formal Hanford report is being written which will include the mathematical development leading up to the SALTY program and a description of the use of the program.

5000 Program

Computation and Statistical Analysis

The GEM program is being revised to make it more suitable to the analysis of multidimensional gamma ray spectrometer data. Specifically, the number of channel groups is being increased from 20 to 100 and the number of nuclides from 10 to 30. The GEORGE probability fit program was modified to use arbitrary nuclide configurations in each channel group. Debug testing of the program was completed.

Radiochemical Analysis

Several routines were written to translate TOAD time (laboratory clock time) into its equivalent year, month, day, hour, and minute. The programs were debugged and used to generate reference tables.

Actinide Element Research

Work progressed on the crystal indexing program. Several meetings were held with Professor E. C. Lingafelter of the University of Washington. Professor Lingafelter, who is a Laboratory Consultant, spent one week here giving advice and offering guidance on crystal structure research.

Assistance and advice was provided on analyzing crystalline phases of metal.

6000 Program

Biology

An appropriate model was determined for, and analysis was begun of, data on the swimming performances of Zn^{65} -treated trout.

The analysis was completed of data relative to the fecundity of fast-neutron treated Tribolium castaneum beetles.

OTHER

Statistical analysis was done of the HAPO lost time injury statistics during the period 1948 through 1963 inclusive.

A program to be used in the nested analysis of variance situation has been completed. Work is being done on the case where there are unequal numbers in the various classes.

Acting Manager
Applied Mathematics

RY Dean:dgl

PROGRAMMINGREACTOR PROGRAM - 04 PROGRAMPLUTONIUM UTILIZATION PROGRAMNeutron Losses to the Control System for the MELEAGER Zero Dimension Burn Up Code With Graded Fuel Management

The losses of neutrons into nonfuel material can be grouped as (1) fission-product absorption, (2) cladding and structural material absorption, (3) control system, (4) neutron leakage. The first two categories are properly taken account of by the MELEAGER burn up code. The neutron leakage can be derived by using the dimensional form of MELEAGER, the ALTHAEA code. The ALTHAEA code again has the ability to account for the control system losses but zero dimension codes do not. A perfect graded system (continuous charging and discharging of fuel) would theoretically sustain no loss of neutrons into the control system. This system is impractical for most reactors; thus, some loss of neutrons is incurred in the practical graded system. Excess reactivity is at a maximum when new fuel is added to the reactor system.

With graded fuel management, some fuel elements have reactivity contributions less than unity and other have a contribution greater than unity; while the entire operating system has a reactivity slightly greater than 1. The more burned fuel with less reactivity than unity absorbs excess neutrons from the highly reactive elements acting much like control rods.

Figure 1 shows a typical reactivity curve versus time plot for a fuel element in a reactor simulation with graded fuel management. The graded reactor is fueled with elements whose reactivity history will be identical. The reactor is ready for discharge when the excess reactivity equals zero. At this point, if perfect neutron exchange exists, Regions 1 and 2 balance the reactivity deficiencies of Regions 3 and 4; and, the reactor has no control losses but, at this point, must be refueled. When Region 4 is discharged, Regions 1, 2 and 3 are left resulting in an excess reactivity which can be attributed to Region 1. The excess for a linear reactivity curve would be

$$K_{\text{excess}_1} = K_{\text{max}} \left(\frac{\frac{NR-1}{2}}{\frac{NR-1}{2} + 1} \right) = K_{\text{max}} \left(\frac{NR-1}{NR+1} \right) \quad (1)$$

where NR = number of regions.

LINEAR REACTIVITY CURVEFIGURE 1

When the new fuel is added, its contribution to excess reactivity is simply $K_{\max}$. This excess reactivity is evenly distributed over the entire reactor; thus, $K_{\text{excess}} = K_{\max}/NR$; also, the average excess for a linear reactivity versus time function between refueling is one-half of the maximum. Thus,

$$K_{\text{control}} = \frac{K_{\max}}{2} \left[\frac{1 + \frac{NR-1}{NR+1}}{NR} \right] \quad (2)$$

A more general form of this equation, which is now used in the PROTEUS code, simply integrates the average reactivity worth for each region, instead of assuming linearity as was used in this example. Tabulations in Table I are the average losses to the control system in milli k for various initial enrichments irradiated to reactivity limited lifetimes on a graded cycle. The number of regions in a reactor, or how often a reactor is refueled, is found to be based on a practical time interval between refuelings. The time interval for Table I was chosen to be 11 months. Table I shows the loss of neutrons to a control system derived from Equation (2) is relatively constant over the range of exposures from 12,000-40,000. Deviations from constancy at the low and high exposure ranges are believed due to imperfections in the linear model. These differences are handled more concisely when the integration method is used.

For a single fuel exposure as the number of discharges increases, it would be expected that the loss to the control system decreases. Table II shows a tabulation of this effect based on a changing number of regions and time between discharges.

This system of accounting for control requirement will allow the zero-dimensional code MELEAGER to better simulate the practical graded fuel management. Preliminary comparison with published reactivity limited fuel exposure for multiple region reactor indicated excellent correlation.

Updating of Reactor Simulations Library

An updating of the reactor simulations presently in use has begun utilizing recent Atomic Energy Commission studies of 1000 Mw_e reactors. Those updated to date are (1) Westinghouse Pressurized Water reactor, (2) General Atomics Gas-Cooled reactor, (3) a 500 Mw_e D_2O reactor designed by Savannah River. Initial attempts to match reactivities of the pressurized water and D_2O reactors have been successful, and work is presently proceeding on the gas-cooled reactor.

TABLE I

CONTROL SYSTEM REQUIREMENTS FOR A SIMULATED PWR WITH
ELEVEN MONTHS BETWEEN DISCHARGES

<u>Fuel Exposure Mwd/ton</u>	<u>Number of Regions</u>	<u>K_{max} (mk)</u>	<u>Average Control Requirement (mk)</u>
9,762	1.5	93	40.4
15,495	2.3	159	49.3
24,757	3.8	225	53.9
28,825	4.3	290	54.3
32,662	4.9	320	54.2
36,343	5.5	345	53.5
39,846	6.0	367	52.6
46,515	7.0	402	50.4
52,809	8.0	430	48.0

TABLE II

AVERAGE CONTROL SYSTEM REQUIREMENT AS A FUNCTION OF THE NUMBER OF
REGIONS FOR A SIMULATED PWR FUEL WITH AN EXPOSURE OF 20,000 Mwd/ton

<u>Time Between Discharges</u>	<u>Number of Regions</u>	<u>Average Control Requirement (mk)</u>
11 months	4	53.9
6 months	7	31.8
1 month	42	5.6
1 day	1260	0.2

Cross Section Data

Cross section data from the RBU data tape have been processed to obtain Westcott g and s values for temperatures up to 1600°C. Three separate cross section library tapes will be made so that the minimum practical error in the curve fitted g and s values will result. Tape I having a temperature range from 0 to 600°C will be used for D₂O, BWR and PWR evaluations; Tape II ranging from 500 to 1100°C will be used for sodium-graphite reactors and high temperature PWRs; the third tape with a temperature range from 1000 to 1600°C will be mainly used for gas-cooled reactor studies.

A review of the literature is in progress in order to tabulate thermal cross sections and resonance integrals for the isotopes of interest. The tabulation will also include values used by other computer codes at Hanford and other sites for comparison with RBU values.

Seed-Blanket Studies

The high cross sections of the plutonium isotopes, which are an advantage in uniformly enriched reactors, have been a disadvantage in the seed-blanket reactors studies so far. That is to say, if plutonium is placed in the seed at the same concentration as in U²³⁵ fueled seeds, the power peak is higher and blanket power is lower; while if reduced concentrations are used, the seed loses excess reactivity rapidly and must be recharged more frequently. Seed fuel element designs which are subject to large flux depression such that the effective cross section of plutonium is reduced are being studied.

CODE DEVELOPMENT

QUICK

A reorganization of a subroutine of the QUICK economic code that calculates the cost of separation, SEPO, has been undertaken to clarify the calculational methods and to increase the versatility of separation plant models. One modification has been to add the capability to differentiate between nonseparable U²³⁵ enriched U²³⁸ fuel types and separable fuel types such as plutonium in U²³⁸ and uranium enriched thorium. These fuels may now be handled as outlined in the "Cost Evaluation Handbook."

In addition, the capability to simulate the HIP* type isotopes recovery operations has been added to SEPO. Costs for this plant are entered as a variable type recovery cost (\$/gram) and a fixed plant operating cost (\$/year). The cost for this plant are included in the separation costs.

*Hanford Isotope Plant

JASON-SUPERCASE-MELEAGER

The final debugging of the JASON-SUPERCASE-MELEAGER Chain has been completed and is now operational. For a given lattice configuration and two enrichments; the JASON code calculates the input physics parameters and the flux depression factors for the MELEAGER code. These factors are then stored on an intermediate tape. This procedure can be repeated for many different lattice cells before control is shifted to the SUPERCASE code.

The SUPERCASE code reads the physics parameters and the flux depression factors for one reactor from the intermediate tape and then reads its own control cards. SUPERCASE then causes the MELEAGER code to run a series of burn ups that will produce a good fuel cost curve when the Economics code is applied to the burn ups. This procedure is repeated for each reactor before control is shifted to another link on the Economics Chain.

ALTHAEA

As interest in reactors operating at high moderator temperature increase, it becomes more important to consider the thermal flux distortion due to resonances near thermal energy. A cross section routine which shields resonances in the thermal spectrum has been written for ALTHAEA and is being evaluated.

A new control option has been added to ALTHAEA to permit study of zoned spectrum or spectral shift reactors. Both the maximum moderation condition and the minimum moderation condition are supplied so that unit reactivity can be achieved by interpolation between them.

for Acting Manager
Programming

OF Hill:bwc

RADIATION PROTECTION OPERATION
REPORT FOR THE MONTH OF JULY 1964

A. ORGANIZATION AND PERSONNEL

Claire W. Leonard retired from Radiation Monitoring effective July 31. R. D. Burnett, Radiation Monitoring, terminated July 2. R. A. Wonacott joined External Dosimetry on July 20, replacing R. L. Pierce who transferred to Facilities Engineering on July 22.

B. ACTIVITIES

Occupational Exposure Experience

Six incidents involving seventeen employees required special bioassay sampling for plutonium analysis. The following is a brief description of the one significant incident:

A Hanford Laboratories technician received a plutonium contaminated injury at approximately 2:10 p.m. on July 10, 1964 while working at the Plutonium Metallurgy Building (231-Z). The employee, assisted by a second employee, was performing an operation on a coupon of plutonium metal. As approximately 230,000 psi pressure was applied to the 1/2" x 1" x 0.053" coupon, the outer rim apparently shattered, scattering plutonium metal radially from the press. Two fragments penetrated the employee's upper left arm. One piece, which was visible, was removed at the 231-Z Building. Four excisions were made of the tissue around the wound. After the fourth excision, an estimated 0.3 μ c plutonium remained at the wound site. The open wound was then washed with 4 liters of normal saline solution containing 0.1% DTPA. The amount remaining at the wound site after the flushing was ~0.16 μ c. DTPA is being administered intravenously to increase the amount of plutonium excreted.

One new plutonium deposition case was confirmed by special bioassay analysis during the month. The total number of individuals who have received plutonium depositions at Hanford is 345. With the termination of one employee having a confirmed deposition, there are currently 245 employed at Hanford.

Considerable radiation monitoring was necessary during handling of a pig in the Biology Laboratory that had received an oral feeding of 200 mc of cerium-144. The feeding operation was done remotely with whole body dose rates to personnel not exceeding 5 R/hour.

Environmental Experience

Efforts to eliminate the radiation problems associated with the cooling water swamps for the Purex Operation continued through July. New inlets have been provided for both swamps and the old, highly contaminated, inlets backfilled. Backfilling was not quite completed for the B Swamp at the end of July. However, the portion of the old ditch that presented the most significant dose rates had been covered over. The contamination levels in the swamp water continued to drop and were less than 5×10^{-4} $\mu\text{c/cc}$ at the end of the month.

Continued high river flow rates and seasonal low concentrations of stable elements in the river resulted in usual low concentrations of all radio-nuclides in the river and in fish.

The average concentrations of fallout materials in the air of the Pacific Northwest was about 1 pc β/m^3 during July. The concentration has been slowly decreasing since the first week of June when peak values of about 3 pc β/m^3 were observed.

Studies and Improvements

Special stack samples were taken during a test at the PRTR wherein 2 mc of I^{131} was released into the primary ventilation duct upstream of the main stack filter. Analysis of the stack air samples indicates that about 5% of the original activity was actually exhausted from the stack.

The equipment to convert the PRTR stack air monitor from a moving tape to fixed filter device was received and is being installed.

The integrated water samplers at the reactor 107 basin outlets have been installed at 107-B and C. Sample collection will begin during the first week of August. The 107-D sampler was installed but failed to operate; probably due to a crushed sample line caused by floating debris in the basin. Repairs to the sampler will be made during the next outage. The 107-KE and 107-KW samplers are scheduled to be installed during the next outage.

The plutonium wound counter was modified to achieve better reproducibility, following difficulty in interpreting a plutonium wound case. A plaster cast was made of the employee's arm to allow insertion of the wound counter into an aperture directly over the wound site. The wound counter itself was streamlined to remove base weight and allow its insertion into the cast. This apparatus has decreased the uncertainty in reproducing the same counting geometry from count to count.

Design specifications for a new type plutonium wound probe were forwarded to Nucleonic Instrumentation. This probe will consist of a 1/4" x 1 mm NaI crystal, mounted on a 1/4" x 1-1/8" light pipe and phototube. This device, along with a standard plutonium wound counter probe and associated electronics, should provide improved capability to locate plutonium in wounds.

Calibration of the whole body counter for lung depositions of neptunium-237 was completed during the month. This project was carried out principally by a technical graduate, as part of his training assignment with Internal Dosimetry Operation. The detection level for Np^{237} is approximately 0.5% of the MPBB.

The EDP Program for automatic selection of plutonium urinalysis sample schedules, based on payroll suffix and job classification code, was put into operation during the month. A summary report, showing plutonium urinalysis schedules for all GE personnel under the old and new systems, has been run. Examination of this report revealed outdated or inconsistent sample schedules that have been eliminated by the new system. Primarily involved are IPD and NRD personnel who formerly were scheduled annually or, in some cases, quarterly for plutonium urinalysis even though they are never exposed to significant quantities of plutonium.

A complete review is underway of all calibration standards used by Internal Dosimetry. Either the activity of these standards will be verified by the Analytical Laboratories or new, freshly prepared standards will be obtained from the above source. Several revisions are also being made in methods for storing, handling, and routinely replacing or recalibrating standards.

The Radiological Design Criteria Manual was reviewed and modifications to update and clarify the manual were provided as necessary. Final draft of a report on radiological factors in handling and processing thorium was completed. Radiological engineering consultations on the PRTR Storage Basin facility continued. Consultations were also provided for the design of the waste transport system to provide for rail transport of waste between the 300 and 200 West Areas. Increased liquid pumping capacity, railroad spurs and two railroad loading and unloading stations are to be provided.

Density readings provided by the mechanized densitometer were observed to vary by 8 to 10 densitometer units. This range was reduced to three densitometer units by providing more stable mounting of the light source. Repetitive readings are now consistent to three units or about 2 mR. Random or intermittent performance difficulties were traced to faulty connector and cables. Remedies were provided by strengthening the cable clamps, removal of all extra connectors in the cables and adjustment of the contact pressure at the cable sockets. Films from personnel dosimeters to be exchanged

on July 31 will be evaluated by processing through both densitometers. The dose evaluations will be calculated by the two separate programs and the results compared.

The G.I. Tract Dose Monitor was installed at the Richland Water Plant on July 17. Switching transients from the heavy equipment at the Water Plant introduced some performance problems. The monitor is being checked out and adjusted to provide satisfactory operation.

Testing of the constant flow Filtronics air mover was completed during the month. This air mover is a long neck horizontal face air sampler that will be used to study long-term plutonium air concentrations in the Weapons Fabrication facilities. Seven of the air samplers were ordered this month and are scheduled for delivery in August and September. The model tested is on loan from the Hanford Laboratories Plutonium Fabrication Pilot Plant. The test consisted of checking flow rate maintained through a variable pressure drop of from 0 to 20 inches of mercury. The air flow was maintained automatically to within ± 5 per cent of one CFM. The membrane filters mounted in disposable filter holders were received. These were tested in one-week sampling periods in the laboratory atmosphere to see if the dust loading would cause a greater pressure drop than the air mover could tolerate. The Gelman 2-inch diameter filter with about a 12.6 square centimeter active area seemed to be superior to the smaller Millipore filter for our usage. The air sampler was moved to the Weapons Fabrication facility and sampling initiated at one location late in the month.

Six air filters were received from the Plutonium Metallurgy facility (231-Z) for particle size analysis. These air filters from various rooms in the building indicated high airborne concentrations of plutonium as a result of an unusual incident on June 10, 1964. The short time period autoradiographic exposures indicate the presence of some larger particles (5 to 10 microns). The long term (200 hour) NTA film exposures have not been completed.

In order to determine the energy dependence, several dosimeters were exposed to 16, 23, 34, 58 and 100 Kev X-rays in addition to Co^{60} at doses of 100, 200 and 300 mR. The light emitted per dose was found to vary from a minimum of 0.565 reader units per mR for Co^{60} radiation to 0.736 reader units per mR for 23 Kev X-rays. For doses of 100 mR to 500 mR, the light emitted per dose was found to be approximately constant, but increased slightly for higher doses.

One problem in TLD is the wide variance in powders. Quite a difference was observed in the readout between powder from different manufacturers, as well as a difference in powder between shipments from one company. Annealing the LiF powder between readouts has a pronounced effect upon the powder; however, a detailed examination into the effects has not been carried out.

Dosimeters in groups of five with 25, 50, 75, 100 and 125 mg of LiF were exposed to 500 mR. The light emitted at readout was approximately proportional to the weight of the powder for 25 and 50 mg and then the light per gram decreased. The maximum light emitted was at 100 mg, and the maximum light per gram was at 50 mg. The light per gram decreased sharply between 100 mg and 125 mg.

A gamma monitor, with audible and visual alarms, has been installed in the storage basin area of the PRTR. The alarm point is manually adjusted and can be set from 7 mR/hour to 60 mR/hour. This monitor will aid in preventing inadvertent exposure from material that is lifted from the storage basin.

Research Studies

Effect of Reactor Effluent on the Quality of Columbia River Water

The study on the effect of reactor effluent on the temperature of the Columbia River continued. Additional temperature traverses for correlation of mean vs. point temperatures at selected locations were made during the month. Additional measurements of reactor effluent dilution immediately below the outfalls were also taken at the higher river flow rates that prevailed.

Mechanisms of Environmental Exposure

The available dietary and body burden information necessary for a correlation program were assembled and the data were transferred to punch cards for entry into a permanent computer file. Other information will be added from other data files to complete the assembly needed for dietary correlations.

Nuclear Facilities Monitoring Guide

Many changes were made in the plan and the text of the Guide as a result of a visit by the principal investigator in late June and early July to four power reactor stations and two AEC offices. The changes were made for the purpose of more closely reflecting the actual and changing requirements and practices of operating plants. In particular, an attempt is being made to predict the requirements imposed as a condition of license approval.

C. RELATIONS

There were no minor injuries and no security violations during the month.

No new suggestions were received. Three suggestions were evaluated; one was adopted, two were rejected. Two suggestions are outstanding.

On July 7 an explosion occurred inside a muffle furnace in the 747 Building. This muffle furnace is used for routine dry ashing of all plutonium urinalysis samples processed by the Bioassay Laboratory. Several minutes prior to the explosion, a chemical analyst had placed four beakers containing urine salts in the muffle furnace and these salts were the evident source of the explosion. The force of the explosion discharged broken glass from the furnace door and buckled the walls of the furnace. No one was injured in the incident. A full safety investigation was conducted and a detailed report issued.

The final report on the Radiation Monitoring Refresher Course was issued. Examination papers were returned to the examinees, and all but three were issued pocket cards signifying satisfactory completion of the course.

A lecture was presented to personnel of the Photography Operation of HUPO. Material covered included the philosophy and criteria of radiation zone control, release of equipment from radiation zones, the various kinds of contamination problems, and the general methods used in internal dosimetry measurements.

J. W. Spoonmore completed the CPD Nuclear Safety Training Course.

A talk on radiation protection was presented to 20 personnel of the Ceramic Fuels Development Operation.

Radiation protection orientations were presented to 3 employees at the 308 and 309 Buildings.

A lecture on radiation protection standards and controls, film badge exchange frequency, and personnel exposure estimates was presented at a safety meeting attended by Engineers in the Maintenance and Equipment Engineering Operation, PRTR.

D. SIGNIFICANT REPORTS

HW-80892 6 - "Radiological Status of the Hanford Environs for June 1964" by R. F. Foster, July 13, 1964.

HW-79073 - "Environmental Effects of a Fuel Element Failure" by R. B. Hall, dated September 27, 1963. (Secret)

HW-83538 - "Radiation Monitoring Operation Monthly Report, July 1964" by A. J. Stevens.

<u>Whole Body Counter</u>	<u>Number of Examinations</u>			
	<u>747-A WBC</u>	<u>1964</u>	<u>Mobile WBC</u>	<u>1964</u>
<u>Subject</u>				
GE Employees				
Regular	73	326	30	598
Incident Cases	23	85	0	7
Terminations	50	157	0	0
New Hires	29	224	0	0
Special Studies	6	59	0	10
Non-Employees	<u>6</u>	<u>27</u>	<u>0</u>	<u>0</u>
Total	187	878	30	615

<u>Bioassay</u>	<u>Current</u> <u>Reporting Limit</u>	<u>Results Above</u> <u>Reporting Limit</u>		<u>Samples Assayed</u>	
		<u>July</u>	<u>1964</u>	<u>July</u>	<u>1964</u>
Plutonium	2.2×10^{-8} $\mu\text{c/sam}$	43	498	475	3829
Fission Prod.	3.1×10^{-5} $\mu\text{c/sam}$	0	0	0	0
Strontium	3.1×10^{-5} $\mu\text{c/sam}$	0	11	0	60
Tritium	5.0 $\mu\text{c/l}$	249	1453	412	2126
Uranium	0.14 $\mu\text{gm/l}$	0	0	182	1214
Special Studies		0	0	16	180

<u>Calibrations</u>	<u>Number of Units Calibrated</u>	
	<u>July</u>	<u>1964</u>
<u>Portable Instruments</u>		
CP Meter	1115	7658
Juno	286	1898
GM	520	3680
Other	223	1652
Audits	<u>109</u>	<u>736</u>
Total	2253	15,624
<u>Personnel Meters</u>		
Beta-gamma film	972	6326
Rings	15	495
Other film	<u>352</u>	<u>2158</u>
Total	1339	8979
<u>Miscellaneous Special Services</u>	592	1739
Total Number of Calibrations	4,184	26,342

UNCLASSIFIED

G-8

HW-83445

<u>External Exposure Above Permissible Limits</u>	<u>Current Month</u>	<u>Year to Date</u>
Whole Body Penetrating	0	3
Whole Body Skin	0	1
Extremity	0	1

Hanford Pocket Dosimeters

Dosimeters Processed	5,767	33,907
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Hanford Beta-gamma Film Badge Dosimeters

Film Processed	8,898	61,555
Results - 100-300 mrad	189	1,070
Results - 300-500 mrad	52	154
Results - Over 500 mrad	25	63
Lost Results	55	94
Average Dose Per Film Packet - mrad (ow)	6.7	8.1
mr (s)	3.0	4.4

Hanford Film Badge Dosimeters

Slow Neutron

Film Processed	345	4,389
Results - 50-100 mrem	0	25
Results - 100-300 mrem	0	29
Results - Over 300 mrem	0	5
Lost Readings	0	5

Fast Neutron

Film Processed	345	4,025
Results - 50-100 mrem	10	105
Results - 100-300 mrem	49	305
Results - Over 300 mrem	1	5
Lost Results	0	3

Hand Checks

Checks Taken - alpha	52,248	276,549
beta-gamma	30,404	368,413

Skin Contamination

Plutonium	29	167
Fission Products	32	336
Uranium	2	10
Tritium	0	0
Thorium	0	0

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Environmental Monitoring

<u>Samples</u>	<u>July</u>	<u>1964</u>
Air		
Filters	327	2367
Scrubbers	269	1724
Water		
Raw	30	292
Sanitary	104	612
Process	25	165
Vegetation	139	782
Test Wells	162	1732
Fish	143	869
Food Products	78	374
Beef Thyroids	35	300
Waterfowl	13	109
<u>Measurements</u>		
Control Plots	171	512
Aerial Monitoring	0	10
Ionization Chambers	228	1618

Manager
RADIATION PROTECTION

AR Keene:np

FINANCE AND ADMINISTRATIONACCOUNTINGCost Accounting

Financial Plan #1 for FY 1965 was received from the Commission during the month. Following is a summary of the research and development funds allocated to HL:

(Amounts in thousands)

02 Program	\$ 542
04 Program	15 620*
05 Program	1 444
06 Program	3 570
08 Program	290

*Excludes \$275,000 for proposed work (Pu and U-233 Fueling of a Fast Compact Reactor - \$40,000, Phoenix Fuel - \$140,000, Disposal of Reactor Off-Gas in Soil System - \$30,000, Engineering Field Tests - \$50,000, and Reactor Safety Analysis and Evaluation - \$15,000).

Currently, we are operating under a "Continuing Resolution" passed by Congress. Work cannot be started on new programs until the FY 1965 Congressional Appropriations Act is passed.

The HAPO General Manager has restricted HL charges to the Assessment Pool to \$3,539,000, which is \$39,000 less than the HL budget.

Activities for which special accounting codes were established are described below:

.5H - Westinghouse Thermal Hydraulics Work - \$158,000. The AEC waived the depreciation and 15% adder on this work. Because of the waiver, Westinghouse agrees to publish and make available to the Commission without charge the results of the work. Estimated completion date is July 15, 1965.

.2K - Program for Conducting Compatibility Study Between PuO₂ and Nichrome for General Electric Nuclear Materials and Propulsion Department - \$15,000.

The following identification codes were cancelled during the month:

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<u>Code</u>	<u>Title</u>
.10	Boron Technology
.11	Metallurgical Development
.24	Graphite Radiation Damage
.28	Weapons Research and Development
.31	Aluminum Corrosion and Alloy Development
.48	IPD - Process Technology - AlSi
.51	IPD - Metallurgy
.52	IPD - U-233 Research and Development
.53	IPD - U-233 Fuel Compaction
.74	Reactor Technology Development
.75	Separations Development

New codes were established during the month as follows:

.11	Microwave Detection of Coolant Impurities - 04 Program
.51	IPD - Diversification - Pu Fuels
.52	IPD - Diversification - Thorium
.57	Radioanalytical Methods Evaluation - 06 Program
.58	Radioactive Fallout Rates and Mechanisms - 06 Program
.75	CPD - Innovation

The titles were changed on the following codes:

<u>Code</u>	<u>New Title</u>	<u>Old Title</u>
.16	Columbia River Sediment Studies	Environmental Studies
.63	CPD - PT - FP Recovery	CPD - PT - Strontium-90
.67	CPD - PT - Waste Management Purex	CPD - PT - UO ₃
.77	Nuclear Graphite Studies	Gas Cooled Reactor - Other

General Accounting

Approval Letter No. AT-353 - Assistance to Hanford Work - FY 1965 was approved by the Commission on July 29, 1964. Hanford Laboratories was allocated \$25,000 for the above work.

Agreement AT-29 - FY 1965 Research and Development was accepted on July 13, 1964.

Five requests from the AEC under Agreement No. AT-6 were recorded in July as follows:

FY64-42 Cooperative Research Program - Washington State University and Hanford Laboratories.

- FY65-1 Expenses of A. M. Platt and M. F. Zeutschel to Geneva Conference.
- FY65-2 Graphite Machining Services.
- FY65-3 Westinghouse Thermal Hydraulics Work.
- FY65-4 Toshiyuki Kawada, Japanese National - Proposed Assignment to Hanford Laboratories.

Revised OPG 5.5 - Conflict of Interest was issued during the month.

The HAPO General Manager made the following allocations to HL for FY 1965:

Off-Site Courses and Seminars	\$ 4,900
Attendance at Professional and Trade Society Meetings	49,400

Total investment in Plant and Equipment in Service for Hanford Laboratories at June 30, 1964, was \$78.7 million, compared with \$75.2 million at June 30, 1963, and \$31.2 million at September 30, 1956. The net increase of \$3.5 million during FY 1964 includes additions from transfers from Work in Progress (\$3.5 million), transfers from the AEC (\$.8 million) and other miscellaneous transfers from other departments valued at \$.9 million including \$.2 million capitalized R&D funded equipment and \$.1 million received from excess - other AEC locations. Included in the transfers from Work in Progress and AEC are the following projects: Physical and Mechanical Properties Testing Cell - 327 Bldg., Burst Test Facility for Zirconium Tubes - 327 Bldg., Coolant Systems Development Laboratory - 1706-KEL Bldg., Plutonium Fuels Testing and Evaluation Laboratory - 308 Bldg., Additional Fuel Loading Equipment - 309 Bldg., Additional Air Conditioning - 309 Bldg., and other projects of lesser magnitude. The major offsetting reductions during FY 1964 included retirements (excess and PDR) of \$1.1 million, transfers to other HAPO components of \$.2 million, uncatalogued equipment retirements of \$.3 million and removal of installation charges amounting to \$.1 million.

Following is a summary of Plant and Equipment in Service at June 30, 1964, by major category:

(In millions)

Buildings and Facilities	\$31.2
Fixed Equipment	18.1
Movable Equipment	<u>29.4</u>
	<u>\$78.7</u>

Total investment in Plant and Equipment including RDX equipment and Property of Others is tabulated below by area:

<u>Area</u>	<u>Bldgs. & Facilities</u>	<u>Fixed Equipment</u>	<u>Movable Equipment</u>	<u>RDX</u>	<u>POO</u>	<u>Total</u>
100-B	\$ 29 823	\$ 95 641	\$ 47 413	\$	\$	\$ 172 877
100-D	12 978	1 616 672	529 126			2 158 776
100-F	2 971 389	102 961	898 872		7 958	3 981 180
100-H	15 503		3 109			18 612
100-K	165 819	294 454	650 370			1 110 643
100-N			1 712			1 712
200-E	769 111	149 406	523 143			1 441 660
200-W	2 746 826	127 312	2 605 322			5 479 460
300	23 127 194	14 746 867	22 642 325	1 130 200		61 646 586-1)
700	202 635		294 818			497 453
1100	858		52 713			53 571
3000	237 257					237 257
Gen. Res- ervation	872 004		141 773	2 270	188 043	1 204 090
Off-Site	53 255	561 143	737 280		999	1 352 677
River Land	2 443					2 443
WB	2 361	380 187	279 608		5 355	667 511
Total	\$31 209 456	\$18 074 643	\$29 407 584	\$1 132 470	\$202 355	\$80 026 508

(1- Includes the following major facilities, each worth more than \$1 million and representing 86% of 300 Area investment:

<u>Building</u>	(In millions)
306	\$ 5.5
308	4.7
309	16.7
314	1.5
321	2.2
325	9.6
326	4.4
327	4.4
328	1.7
329	2.4

Hanford Laboratories' investment in materials at July 1, 1964, was:

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	(In thousands)
SS Material	\$27 933
Reactor & Other Special Materials	997
Spare Parts	353
Yttrium	26
Subtotal	<u>29 309</u>
Reserve: Spare Parts \$88	
Yttrium <u>26</u>	<u>(114)</u>
Net Inventory Investment	<u>\$29 195</u>

The cumulative value of nuclear material consumed in research by Hanford Laboratories during FY 1964 is shown below:

02 Program	\$ 93 494
03 Program	331 314
04 Program	<u>675 591</u>
Total	<u>\$1 100 399</u>

The status of Hanford Laboratories' heavy water inventory at July 31, 1964 is as follows:

	<u>Pounds</u>	<u>Value</u>
Beginning Balance	32 762	\$447 572
Acquisitions		
Scrap Returns (SROO)		
Consumption-1)		
PRTR: Loss	(243)	(3 360)
Scrap	<u> </u>	<u>(2 334)</u>
Ending Balance-2)	<u>32 519</u>	<u>\$441 878</u>

(1- Consumption - Scrap reflects amount charged to Cost only.

(2 - Includes 4,576 pounds of heavy water scrap valued at \$55,388.

The physical inventory of Spare Parts taken by C&AO indicated a total statistical surplus of \$2,787 for Hanford Laboratories' holdings.

A review of the depreciation rate for capitalized heavy water (PRTR) was made during the month. The rate .0120 appears to be adequate, at least for the present. The net value of capitalized heavy water is \$13.32 a pound at June 30, 1964, compared to \$13.83 average inventory price.

A new General Ledger Account was established during the month entitled "Exotic Materials for Special Research Programs." The purpose of this new account is to record at cost or other appropriate value, materials obtained

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from other Government contractors at a value established by the AEC for use at HAPO. Materials in this account will be physically located at and controlled by the Laboratory Storage Pool.

A report of the audit of blank One Trip Property Passes in the possession of 58 authorized holders reveals two missing passes out of a total of 646 passes issued for the year, compared to four lost passes out of a total of 819 issued the preceding year.

A FY 1965-66 physical inventory schedule for physically inventorying materials and movable equipment was prepared and forwarded to Section Managers. Effective with the FY 1965 inventory, to start in September, 1964, HL will deviate from the past practice of conducting a complete financially witnessed inventory of movable property within one fiscal year. With the exception of portable health instruments and property of others, which must be on an annual basis, half of the inventory of movable property will be witnessed by Financial in FY 1965, the balance in FY 1966. Movable property not requiring a witnessed physical inventory in any given year will be verified in that year by a certification type inventory taken by custodial personnel. An inventory of reactor and other special materials will be conducted in FY 1965 on a quarterly basis. Again, material not requiring a witnessed inventory at any one quarter will be verified by custodians.

Laboratory Storage Pool activity is summarized as follows:

	<u>Quantity</u>	<u>Value</u>
Beginning Balance	2 027	\$1 493 571
Items Received	177	77 215
Items Reclaimed by Custodians	(8)	(4 522)
Equipment Transfers	(19)	(3 670)
Items Disposed of by PDR	--	--
Items Disposed of by Excess	--	--
Ending Balance	<u>2 177</u>	<u>\$1 562 594-1)</u>

(1- Includes 183 items valued at \$116,916 on loan at July 31, 1964.

Loans & Transfers in
Lieu of Purchases

	<u>Quantity</u>	<u>Value</u>
Loans	10	\$ 5 086
Transfers	<u>19</u>	<u>3 670</u>
Total	<u>29</u>	<u>\$ 8 756</u>

The value of material and equipment in custody of the Laboratory Storage Pool

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at July 31, 1964, totaled \$2.5 million, as detailed below:

Equipment	\$1 562 594
Reactor & Other Special Materials	305 433
SS Materials	154 800
Other Materials	<u>484 162</u>
Total	<u>\$2 506 989</u>

New money was authorized General Electric on projects as follows:

CAH-119	PRTR Storage Basin and Experimental Facilities Modification	\$ 6 000
CAH-137	Temporary Physical Sciences Center	14 000

The following contracts were processed during the month:

CA-449	Velmer Fassel
CA-441 Rev	Pacific Gas & Electric Co. and Willard H. Nutting
DDR-189	Oregon Metallurgical Corporation
SA-355	Comitato Nazionale Per L'Energia Nucleare
SA-357	Sonja Harmon
SA-289-1	Crane Hoist Engineering Corporation
MRO- 75	Ling-Temco-Vought, Inc., Ling Electronics Division
MRO- 76	Textron Electronics, Inc.

HL was authorized to incur during July, FY 1965 obligations for equipment not included in construction projects, as shown below:

<u>Program</u>	<u>Amount</u>
02	\$100 000
03	60 000
04	90 000
05	25 000
06	25 000
08	5 000

HL was also allocated \$30,000 for Capital Work Orders for July. These are interim authorizations pending passage of the FY 1965 Appropriations Act. An additional allocation will be made for the month of August. These amounts have not been reallocated to Sections.

Personnel Accounting

College graduates engaged in research and development activities were categorized according to instructions received from Consolidated Payroll Reports and Statistics Operation in connection with the National Survey of

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Professional Scientific Salaries sponsored by the Los Alamos Scientific Laboratory. The completed five reports were mailed to L. L. Weiss on July 6, 1964. The following indicates the number of degreed employees as reported during the last eight years:

	<u>1964</u>	<u>1963</u>	<u>1962</u>	<u>1961</u>	<u>1960</u>	<u>1959</u>	<u>1958</u>	<u>1957</u>
BS-MS Non-Supervisory	459	425	392	386	410	401	261	264
PhD Non-Supervisory	100	88	79	66	58	59	69	61
BS-MS Supervisory	44	37	34	30	30	34	26	37
PhD Supervisory	<u>39</u>	<u>38</u>	<u>36</u>	<u>37</u>	<u>37</u>	<u>46</u>	<u>36</u>	<u>36</u>
	<u>642</u>	<u>588</u>	<u>541</u>	<u>519</u>	<u>535</u>	<u>540</u>	<u>392</u>	<u>398</u>
Engineers	313	281	237	251	218	200	124	140
Chemists	162	154	140	123	94	149	102	87
Physicists	83	72	75	63	59	75	47	39
Mathematicians	27	21	21	20	13	16	7	11
Biologists	6	6	5	6	10	4	33	--
Metallurgists	17	16	14	15	29	46	65	--
Geologists	5	6	6	5	6	7	5	7
Others	<u>29</u>	<u>32</u>	<u>43</u>	<u>36</u>	<u>106</u>	<u>43</u>	<u>9</u>	<u>114*</u>
	<u>642</u>	<u>588</u>	<u>541</u>	<u>519</u>	<u>535</u>	<u>540</u>	<u>392</u>	<u>398</u>

* Includes Metallurgists and Biologists

In anticipation of the transfer of operations to the new contractor, individual personnel folders were prepared for each of the 1,831 employees on the active payroll. Each folder includes a copy of the addition to payroll form, a copy of adjustments of continuity of service date, a copy of proof of birth, and a job and salary record.

Claire W. Leonard and Adella B. Rouse retired effective August 1, 1964.

Patent awards were made to the following employees:

J. F. Fletcher	HWIR 1482	Nuclear Reactor Control
G. S. Allison	HWIR 1645	The Field of High Surface Area to Fuel Volume Ratio Nuclear Fuel Elements of a Wide Range of Materials and Operating Temperatures

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HW-83445

Personnel statistics follow:

<u>Employee Changes</u>	<u>Total</u>	<u>Exempt</u>	<u>Nonexempt</u>
Employees at beginning of month	1 831	827	1 004
Additions and transfers in	21	12	9
Removals and transfers out	<u>26</u>	<u>16</u>	<u>10</u>
Employees on payroll at end of month	<u>1 826</u>	<u>823</u>	<u>1 003</u>

<u>Overtime Payments During Month</u>	<u>July</u>	<u>June</u>
Exempt	\$ 7 362	\$ 7 084
Nonexempt	<u>27 575</u>	<u>35 023</u>
Total	<u>\$ 34 937</u>	<u>\$ 42 107</u>

<u>Gross Payroll Paid During Month</u>		
Exempt	\$ 837 437	\$ 810 453
Nonexempt	<u>577 464</u>	<u>747 970</u>
Total	<u>\$1 414 901</u>	<u>\$1 558 423</u>

<u>Participation in Employee Benefit Plans at Month End</u>	<u>July</u>		<u>June</u>	
	<u>Number</u>	<u>Percent</u>	<u>Number</u>	<u>Percent</u>
Pension	1 672	99.3	1 676	99.3
Insurance Plan - Personal	397		403	
- Dependent	1 398	99.7	1 393	99.8
U. S. Savings Bonds				
Stock Bonus Plan	150	35.5	149	34.8
Savings Plan	68	3.7	68	3.7
Savings and Security Plan	1 221	86.8	1 226	87.6
Good Neighbor Fund	1 310	71.6	1 307	71.5

<u>Insurance Claims</u>	<u>Number</u>	<u>Amount</u>	<u>Number</u>	<u>Amount</u>
<u>Employee Benefits</u>				
Life Insurance	0	-0-	2	\$35 329
Weekly Sickness & Accident	13	1 171	9	793
Comprehensive Medical	64	3 876	57	4 001
<u>Dependent Benefits</u>				
Comprehensive Medical	<u>107</u>	<u>11 431</u>	<u>135</u>	<u>12 621</u>
Total	<u>184</u>	<u>\$16 478</u>	<u>203</u>	<u>\$52 744</u>

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TECHNICAL ADMINISTRATION

Requisitions for 15 nonexempt employees were filled. 28 remain to be filled.

Suggestion Plan activity:

Suggestions received	32
Suggestions adopted	26
Suggestions rejected	12
Suggestions in process	92

Visitors Center activity:

July attendance	2,952
Average attendance per day open	95
Cumulative attendance since 6/13/62	74,873
Conducted Groups	2 (totaling 43 people)

Plant Tour activity:

	<u>Number</u>	<u>Total People</u>
General Public Relations Tours	2	43
Special tours	0	0

Other

Four exhibits were shipped to the National Scout Jamboree at Valley Forge, Pennsylvania.

Three of the four Hanford Laboratories exhibits for the International Conference in Geneva have been completed and shipped. Completion of the one remaining exhibit was delayed because of translation errors in the technical Russian, French and Spanish copy. These errors have been corrected and local art and photography work is expected to be completed early in August.

Overall recruiting results for July are as follows:

Offers extended	7
Offers accepted	5
Offers rejected	6
Added to roll	8

Advanced Degree - Six Ph.D. applicants visited HAPO for employment interviews. Six offers were extended; three acceptances and four rejections were received. Four offers are currently open.

BS/MS (Direct Placement) - No offers were extended. There were no acceptances or rejections received. There are no offers currently open.

BS/MS (Program) - One offer was extended. Two offers were accepted and two offers rejected. One offer is currently open.

Technical Graduate Program - Five Technical Graduates were placed on permanent assignment. Three new members were added to the roll and none terminated from the roll. Current Program numbers 44.

FACILITIES ENGINEERING

At month end, Facilities Engineering Operation was responsible for eleven active projects having total authorized funds in the amount of \$10,566,500. The total estimated cost of these projects is \$11,415,000. Expenditures through June 30, 1964 were \$4,165,000.

The following summarizes project activity in July:

Authorized projects at month end-----	11
New projects authorized-----	0
Projects completed-----	0
New projects submitted to the AEC in July-----	0
New projects awaiting AEC approval-----	3
CAH-114, Critical Mass Laboratory Addition	
CAH-123, Laboratory Fire Protection System	
CAH-146, Atmospheric Physics Building	
Project proposals being prepared-----	5
Biology Utilities Extension - 300 Area	
Geological and Hydrological Wells - FY 1965	
Power Supply - Million Amp Welder	
Shielded Creep Test Facility - 3707-C Building	
Variable Spectrum Test Reactor	

The status of active projects follows:

CAH-916 Fuels Recycle Pilot Plant

Construction is 69 percent complete compared to a scheduled 54 percent. Placement of concrete and installation of doors and door frames in the walls of the Hot Pilot Cells is continuing. Tanks have been installed in the Low Level Vault. Window wall liners have been installed in the Hot Metallurgy Cells, and the cell liner sections are being welded together. Some difficulty has been encountered fitting the window liners into the wall. Siding was installed on the walls of the Cold Canyon. Installation of the second and third floor piping is continuing. Installation of heating and ventilating duct work and sprinkler piping is approximately 50 and 30 percent complete respectively.

CAH-962 Low Level Radiochemistry Building

Construction is 14 percent complete and on schedule. About 80 percent of the basement walls and 50 percent of the basement and main floor slabs and support columns have been poured. Underslab piping has been installed and tested. An area west of the building was graded and forms were set in it ready for pouring concrete tilt slabs.

CAH-977 Facilities for Radioactive Inhalation Studies and
CAH-982 Addition to Radionuclide Facilities - 141-C Building

The Commission has decided to proceed with relocation of these facilities from 100-F into the site of the budgeted 300 Area Biology Laboratory. It is anticipated the cost to rescope and redesign these facilities for operation in the 300 Area will be about \$10,000. A separate project will be required to provide utilities for these projects. A letter has been sent to the Commission outlining the modifications necessary for relocation of these projects to the 300 Area site.

CAH-100 High Temperature Lattice Test Reactor

Design is 78 percent complete compared to a scheduled 77 percent. Vitro's estimate of the cost of total design is \$290,000. Progress has slowed significantly during the past month. All drawings and specifications for Phase I construction have been issued for approval. Some of the Company's comments and corrections must still be incorporated. Vitro is proceeding on the Phase II design.

Company R&D experiments indicate the use of diatomaceous earth (Superex) in the reactor structure appears undesirable because of the large amounts of impurities released during outgassing.

CAH-114 Critical Mass Laboratory Addition

The project proposal submitted to the Commission on November 4, 1963 is still awaiting action by Washington-AEC.

CAH-116 PRTR Decontamination and D2O Cleanup

Design is 90 percent complete. It was scheduled to be completed on June 15, 1964. Thirty-four drawings have been received for comment. Comments by PRTR operating and engineering components have been numerous and significant.

Vitro was authorized an additional \$2,000, increasing the authorized design funds to \$42,000.

CAH-119 PRTR Storage Basin and Experimental Facilities Modifications

Vitro was authorized an increase in design funds from \$31,000 to \$36,500. Design was scheduled to be complete on June 15, 1964; Vitro estimates the actual progress at 90 percent complete. Fourteen architectural and structural drawings of the basin addition have been approved. It is estimated J. A. Jones forces will start construction early in August. On July 10, 1964 the Company was authorized \$6,000 for preparation of functional purchase specifications and related services for procurement of underwater equipment.

CAH-123 Laboratory Fire Protection System

No action was taken by the Commission during the month.

CAH-126 Waste Transport System

Commission and Vitro representatives met with the Company and visited the proposed construction site on July 15, 1964 prior to initiation of design by Vitro.

CAH-136 Service Addition - 327 Building

A Title I drawing and cost estimate were submitted to the Company for comment on July 17, 1964. Comments were returned to the Commission. Detailed design is scheduled to start on August 10, 1964.

CAH-137 Temporary Physical Sciences Center

A Work Authority dated July 14, 1964, authorized the Company \$14,000 for procurement and installation of a PABX switchboard and related telephone tie-ins. The Plant Telephone Operation is currently preparing purchase specifications for the switchboard.

Vitro has initiated design of building alterations and is currently designing three stairways to satisfy fire code requirements.

CAH-146 Atmospheric Physics Building

The project proposal was approved by the RLOO project review board on June 11, 1964 and was forwarded to Washington on July 10, 1964.

CAH-151 Office Addition - 308 Building

Vitro was requested to perform Titles I, II and III services on this project, and was authorized to expend funds in the amount of \$11,000. Design is approximately 12 percent complete. There is no official schedule. The Company has received two architectural information drawings.

G. H. Bauer, Senior Engineer, transferred to G.E., Huntsville, Alabama, 7-31-64.

Engineering Services and Plant Engineering

Engineering work was performed in support of design and construction on active projects, project proposals, preliminary planning and design criteria for new projects. Principal work items included: (1) field consultation and review of vendor drawings for projects CAH-916, FRPP and CAH-962, Low Level Radiochemistry Building; (2) engineering consultation on Vitro design of CAH-100, HTLTR and review of ventilation drawings and procurement specifications; (3) review of Vitro ventilation flow diagram design on CAH-106, PRTR Storage Basin Addition; and (4) commented upon a lighting plan for the Containment Systems Experiment.

Facility planning and budget study work included: (1) a study on plans and cost to put building 209-E in a stand-by condition; (2) preparation of a design criteria for the services and support facilities for the proposed Biology complex in the 300 Area; (3) drafting of a design criteria for a PRTR replacement deaerator and starting of preparation of a functional purchase specification for underwater equipment to machine irradiated PRTR fuel elements; (4) upgraded the budget study data sheets on the D2O upgrading plant; and (5) two projects, CAH-982, Radionuclide Facilities and CAH-977, Radioactive Inhalation Facilities, are being rescoped for construction southeast of PRTR and a project proposal for utilities to service them is being prepared.

Engineering and consulting work was provided to research and development personnel as requested. Major work items included: (1) assistance in determining motor control center additions for waste calcination power loads in the 324 building, also four electrical drawings were prepared

in connection with this work; (2) an electrical elementary diagram and equipment listing was developed for the 209-E building PuO₂ concentrator; and (3) electrical scoping work is being provided for the new alarm system associated with the central annunciator in the 325-A building.

Plant engineering work during the month included: (1) planning a lunch room facility on the second floor of the 329 building; (2) preparing a sketch for a canopy and exhaust over a physics test reactor in the 326 building; (3) preparation of specifications for the purchase of a second compressor for the 340 building; and (4) checking the floor loading for equipment placement in the 306 building.

Consulting service for other departments included assistance on: (1) test procedures for the High Temperature Gas Loop; (2) instrumentation problems for the HTLTR mock-up; (3) a study of the 109-N ventilation problems in the Heat Exchanger Cells; and (4) the americium installation in the 234-5 building in connection with the radiation meter installation and alarm system.

Pressure Systems

Indications are that Chicago Bridge and Iron will ask for a thirty day extension, to February 10, 1965, to their contract on the containment vessel for the Containment Systems Experiment.

A Struthers-Wells representative was here to discuss negotiations on the simulator vessel for the Containment Systems Experiment. Struthers-Wells Company will submit their proposal on this vessel for review early in August.

The Travelers' Insurance Company third party inspector inspected the 314 building gas loop. Results of his work are expected next month.

Information was supplied to the third party inspector for his review concerning the 271-CR testing vessel.

At the request of the Standards Laboratory, Facilities Engineering investigated the pressurization of mercury batteries used as reference batteries in portable counting instruments. A potential hazard exists from pressurization and suitable disposition of the batteries was recommended to the HL Safety Engineer.

Facilities Operation

Costs for the month of June were \$133,000, which is 96 percent of the forecast for the month. Fiscal costs for twelve months are \$1,874,400, which represents 97 percent of the predicted. Again this month, the amount of credits together with difficulties in returning to a full maintenance schedule kept the expenditures below forecast.

Waste Disposal

The following table summarizes the Waste Disposal Operation:

<u>Item</u>	<u>May</u>	<u>June</u>
Concrete waste barrels disposed to 300-wye burial ground	0	10
Concrete waste barrels disposed to 200-W burial ground	12	9
Loadluggers of dry waste disposed to 300-wye burial ground from 300 Area sites other than the 325 building	20	21
Loadluggers of dry waste disposed to 300-wye burial ground from the 325 building	3	4
Loadluggers of dry waste disposed to 200-W burial ground from 300 Area sites	5	7
Containers of high level dry waste disposed to 300-wye burial ground vertical pipes	86	89
Crib Waste Volume, gal.	380 000	270 000

The increase in volume of dry waste continued this month. WD&D averaged working four days per week again this month at 300-wye burial ground.

None of the retention basins exceeded the Class II activity levels during the month.

The retention waste flow meters in the 325 building have been placed in operation. Installation has not been completed in 326 and 329 buildings. The pH recording system for tanks #1 and #2 at 340 building has not been completed. Installation of the two large dry waste disposal tanks at the 300-wye burial ground has not been completed. This will be completed during August.

Building Operations

Most of the buildings have required maximum cooling during the month of July. Maintenance has been preparing the ventilation systems for fall and winter operation.

New fan base mounts were received for #1 fan, 329 building. Maintenance is working on installation.

Maintenance has installed new motor to provide increased air flow to the first and second floor offices in 328 building. Increased flow is about 6,000 cfm.

The "B" unit freon leaks were repaired in 325 building. The scheduled outage for steam, air and water was completed without delay while the contractor completed the connections for new facilities.

Drafting

The equivalent of 136 drawings were produced during the month for an average of 28 man-hours per drawing.

Major designs in progress are: (1) a powder processing glove box line; (2) diagrams of all air service lines in the 309 building; (3) an ultrasonic tester for irradiated fuel elements, N-Reactor; (4) a high temperature furnace, 306 building; (5) FRPP service piping to waste calcination equipment; (6) underwater measuring equipment, N-Reactor; (7) electrical work for waste calcination equipment in FRPP; and (8) a shielded shipping container.

Drafting service is also supplied in support of other laboratories engineering programs.

Construction

	<u>No.</u>	<u>Unexpended Balance</u>
Orders outstanding beginning of month	66	\$173 429
Issued during the month (inc. supp. & adj.)	228	463 167
J. A. Jones expenditures during month (includes C.O. cost)	--	159 828
Balance at month end	72	476 768
Orders closed during month	222	229 014

Maintenance Work Orders active - 6 Face Value - \$18 014

Major nonproject jobs in progress during the month were: (1) preparation for placing a contract for the crib waste leak detection program in August; (2) installed third floor partitions in the 108-F building; (3) completed miniature swine feeders in the 141-F building; (4) remodeled the dog pens in the 144-F building; (5) revised electrical services in the 146-FR

building; (6) installing a fire detection system in five 100-F buildings; (7) modifying a dark room in the 1706-KEL building; (8) relocating a stairway to the mezzanine of the 189-D building and installing additional electrical services; (9) constructed a new pasture and sprinkler system near the meteorological tower; (10) a concrete beam and column have been removed from the 221-T building cell and decontamination is in progress for the containment systems experiment; (11) completed installing an air conditioner and duct work in the 306 building, also in process of installing a new rectifier for an arc melt furnace in this building; (12) installing hydraulic snubbers and constructing access manholes in the 309 building; (13) constructing autoclave pit and storage area, structural housing for EDEL II loop in the 314 building; (14) installing electrical circuits for a computer, and air conditioner in the 321 building; (15) constructing personnel change and survey station for the 340 building; and (16) installing magnetic flow meters and radiation meters in the retention lines.

Well Drilling Program

A design criteria is being prepared for FY 1965.

Crane Safety Inspection

This contract has now been completed. A total of 99 cases of equipment were inspected for Hanford Laboratories and a modification was made to the contract to cover work done for other HAPO departments. Negotiations for a new contract will be started about January 1, 1965.

Waste Solidification Prototype

All fabrication work is on schedule.

3201 Building

A preliminary survey of existing piping indicated that several heating and plumbing lines were frozen during the winter. Eleven fin-type radiators will have to be replaced for the same reason.

GENERAL

There were no reports of inventions or discovery during the month.

Acting Manager
Finance and Administration

DS Parsley:RDT:lg

REACTOR DEVELOPMENT - O4 PROGRAMPLUTONIUM RECYCLE PROGRAMPlutonium Recycle Test ReactorOperation

Reactor output for July was 1367 MWD for an experimental time efficiency of 76% and a plant efficiency of 63%. There were ten operating periods during the month, five of which were terminated manually, four were terminated by scrams and one continued through month-end. A summary of the fuel irradiation program as of July 31, 1964, 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	0		8	1694.4	77	12296.0			85	13990.4
Maximum				317.3		322.1				
Average				211.8		159.7				
In Basin	7	572.5	25	2673.1	44	4469.9			76	7715.5
Buried							1	7.3	1	7.3
Chem. Process.	<u>68</u>	<u>5465.8</u>	<u>35</u>	<u>1965.8</u>	—	—	—	—	<u>103</u>	<u>7438.6</u>
Program Totals	<u>75</u>	<u>6038.3</u>	<u>68</u>	<u>6333.3</u>	<u>121</u>	<u>16765.9</u>	<u>1</u>	<u>7.3</u>	<u>265</u>	<u>29111.8</u>

(Note: (MWD/Element) X 20 $\approx$ MWD/TU for UO₂ and PuO₂-UO₂.)

Heavy water loss and indicated helium loss for the month were 1,081 pounds and 115,319 scf., respectively.

Seventeen shipments of irradiated PRTR fuel elements were shipped to Rolox for storage during construction of Project CAH-119.

Equipment Experience

A total of 90 reactor outage hours were charged to repair work. Main items were:

- Nozzle to tube regasketing
- Repair HX-1 level transmitter
- Helium compressor repair
- Rupture loop repairs

Preventive maintenance required 143 manhours, or 2.3% of the total maintenance effort.

Improvement Work Status (Significant Items)Work Completed

Storage Basin Work Platforms
Thermal Barrier Support Modification

Work Partially Completed

Corrosion Loop Installation
Primary Water Sample Station
Shim Rod Shroud to Top Cap Modification
Installation of New Alarm Annunciator
Vibration Snubbers for Earthquake Protection
Supplemental Emergency Water Addition
Voltage Off Normal Detection and Alarm for 24 Volt Battery System
Gas Moisture Detection System Blower Exchange

Design Work Completed

New Limit Switch Actuators
Mark III Shim
Installation of Second Generation Shim Rod

Design Work Partially Completed

Additional Fuel Storage and Examination Facility
Decontamination Building and D₂O Cleanup Facility
Flux Wire Scanning System
Gamma Scanner Cask Modifications
Thermal Barrier Seal and Hoist Improvements
Pneumatic Irradiation Facility
PRTR Experimental and Building Facilities Addition
PRTR Increased Power Level
Creep Test Facility

Process Engineering and Reactor Physics

PRTR Test 92, Measurement of Reactor Noise in PRTR, was performed during the month to measure the delayed neutron fraction. Tape recordings of the fluctuations in ion chamber current were made at several power levels. The data are being analyzed by Systems Research personnel.

PRTR Test 97, Effect of Shutdown Valve on Moderator Level, was performed during the month. The test results show that the present shutdown valve is too large for its intended purpose of reducing the reactivity without scrambling the reactor.

Hydrogen addition to bulk helium storage under PRTR Test 93 was continued during the month. Oxygen control in all systems was good with the exception of the gas balance system. In this system, oxygen and deuterium built up significantly during one operating period. It was suspected that this was the result of insufficient "exchange" or flow of hydrogen-charged gas into the gas balance system. During the following outage, steps were taken to improve flow between the gas balance system and the gasometer. This resulted in excellent oxygen control in the gas balance system in subsequent operating periods.

During equilibrium operation pH phosphate control using monosodium phosphate was excellent. During startup transition periods, it is necessary to provide pH control by periodic sampling, which adds to the operations startup burden.

A study was completed on the HX-5 High Outlet Temperature instrumentation override of the pressurizer level control instrumentation. The results indicated that the override ability could create more hazards to the primary system than protection afforded by the override ability. It was therefore decided that the override feature be removed.

Experimental Reactor Services

The status of the various test elements at the end of July 1964, is shown below. Those elements which had reached their assigned goal exposure or had been permanently discharged for other reasons prior to July 1, 1964, have been deleted from this table.

Test No.	Channel Location	Element Number	Description	Date		Approximate Accumulated MWD
				Initial Charge	Date Discharged	
14	1956	5097	Moxtyl-Swaged	4/2/62	--	200.9 repad
14	1352	5098	Moxtyl-Vipac	5/8/62	--	302.1 repad
14	1758	5099	Moxtyl-Vipac	5/8/62	--	212.8 repad
48	1156	5150	Moxtyl ($\frac{1}{2}$ " x $\frac{1}{2}$ " pads)	8/1/62	--	209.9
54	1542	5116	Moxtyl (clip on pads)	5/8/62	--	220.2
54	1554	5118	Moxtyl (clip on pads)	5/8/62	--	322.1
61	1249	5185	Moxtyl-Physics	5/28/63	--	212.1
61	1354	5186	Moxtyl-Physics	5/28/63	--	205.7
61	1445	5192	Moxtyl-Physics	6/13/63	--	210.7

67	Basin	5119	Moxtyl (Repaired wire)	10/20/63	7/7/64	119.9
67	1047	5117	Moxtyl (Repaired wire)	10/20/63	--	173.3
80	1544	5214	Moxtyl (1% PuO ₂ , Swaged)	11/18/63	--	156.5
85	1855	5230	Moxtyl (1% PuO ₂ , Vipac)	1/30/64	--	99.6
37	1548	1098	UO ₂ -Physics	5/12/62	--	196.4
37	1550	1097	UO ₂ -Physics	5/12/62	--	210.4
37	1552	1099	UO ₂ -Physics	5/12/62	--	179.4

Element 5233, a 1.0% Moxtyl having approximately 94 MWD production, failed during the month.

A total of 21 fuel elements were inspected in July. Six elements were partially disassembled and three rods from each of three elements were shipped to Radiometallurgy for examination and testing.

Plutonium Recycle Critical Facility

EBWR fueled experiments continued. A moderator void was simulated by a piece of specially shaped styrofoam, and its worth was measured as a function of core radius. A vertical traverse measurement was made in the center lattice position with a void approximately one half inch in diameter by eight inches long. The kinetics experiment using the boron arrow apparatus was completed using an arrow worth approximately 1.3 mk.

The PRCF core was discharged on July 13th, and the fuel rods were moved to 305 Building for an approach experiment which required essentially all available fuel. The total interruption was six working days. During this outage, 180 manhours of maintenance was performed on the PRCF.

The second H₂O core being fabricated for the PRCF will provide for testing of four foot long single rods of PRTR type in a 0.800 inch triangular lattice. Component fabrication is nearly complete. Installation has been rescheduled from mid-August to early September to permit the performance of additional experiments.

Fuel Element Rupture Testing Facility

Early in the month, the Rupture Loop was returned to service following replacement of the cleanup ion exchangers. Initial testing of these units revealed that the pressure drop increased with time at normal flow rates with only the resin bed supporting anthrafilt in place. This was attributed to compaction and flaking of the anthrafilt. The coal was subsequently removed and replaced with rounded and graded high density gravel. These exchangers now exhibit satisfactory pressure drop characteristics with the gravel resin bed supports.

FERTF Test #9, Irradiation of a Water Tube Cluster was performed. Initial operation was with a test section outlet temperature of about 110 F. At the end of the month, the temperature was increased to as high as 500 F, but temperature cycling problems limited the average temperature to about 350 F.

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TECHNICAL SHOPS OPERATION

Total productive time for the period was 22,240 hours. This includes 13,765 hours performed in the Technical Shops, 5,729 hours assigned to J. A. Jones Company, and 2,746 hours assigned to off-site vendors. Total shop backlog is 20,871 hours, of which 90 percent is required in the current month with the remaining hours distributed over a three-month period. Overtime worked during the month totaled 977 hours or 5.0 percent of the total available hours.

Distribution of time was as follows:

	<u>Man Hours</u>	<u>% of Total</u>
N Reactor Department	1 930	8.7
Irradiation Processing Department	3 324	14.9
Chemical Processing Department	354	1.6
Hanford Laboratories	16 632	74.8

LABORATORY MAINTENANCE OPERATION

Total productive time was 20,200 hours of 23,200 potentially available. Of the total productive time, 91% was expended in support of Hanford Laboratories components, with the remaining 9% directed toward providing service for other HAP0 organizations. Craft overtime worked during July was 3% of total available hours.

Manpower utilization (in hours) for July was as follows:

A. Shop Work		2 200
B. Maintenance		7 400
1. Preventive Maintenance	2 200	
2. Emergency or Unscheduled Maintenance	1 900	
3. Normal Scheduled Maintenance	3 300	
C. R&D Assistance		10 600

WD Richmond

WD Richmond:bk

UNCLASSIFIED

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.

INVENTORTITLE OF INVENTION OR DISCOVERY

J. E. Minor and W. F. Brown

The field of welding using a duplex method of projection welding and brazing to effect a continuous metallurgical bond over large interface areas between similar or dissimilar metals and alloys.

J. D. Smith and L. D. Williams

Use of Cross Bow for Step Reactivity Changes

Manager, Hanford Laboratories

END

**DATE
FILMED**

4 / 13 / 93