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HANFORD LABORATORIES
MONTHLY ACTIVITIES REPORT

SEPTEMBER, 1963

OCTOBER 15, 1963

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HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

GENERAL ELECTRIC

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Robert M. Stan 8/25/92
By DG Kuesner 10/16/92
PM Eich 10-20-92

Compiled by
Section Managers

October 15, 1963

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

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PRELIMINARY REPORT

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Table I - Hanford Laboratories Force Report

Date: September 30, 1963

	At Beginning of Month		At Close of Month		
	Exempt	Salaried	Exempt	Salaried	Total
Chemical Laboratory	147	131	144	126	270
Reactor & Fuels Laboratory	197	191	201	187	388
Physics & Instruments Laboratory	108	81	100	73	173
Biology Laboratory	44	65	42	63	105
Applied Mathematics Operation	21	5	18	5	23
Radiation Protection Operation	45	93	44	93	137
Finance & Administration Operation	154	120	150	117	267
Programming Operation	15	5	16	3	19
Test Reactor & Auxiliaries Oper.	56	307	58	314	372
General	3	4	3	4	7
TOTAL	790	1002	776	985	1761

BUDGET AND COST SUMMARY

September operating costs totaled $2,697,000, a decrease of $103,000 over the previous month; fiscal year-to-date costs are $7,914,000 or 24.5% of the $32,269,000 control budget. Hanford Laboratories' research and development costs for September compared with last month and the control budget are shown below:

(Dollars in thousands)	COST Current Month	Previous Month	To Date	Budget	% Spent
HL Programs					
02	$ 80	$ 89	$ 239	$ 1 180	20%
03	40	42	107	250	43
04	1 196	1 208	3 414	13 485	25
05	127	133	369	1 456	25
06	275	269	798	3 604	22
08	9	15	39	100	39
	1 727	1 756	4 966	20 075	25
Sponsored by					
NRD	174	167	462	1 761	26
IPD	68	63	187	660	28
CPD	108	113	338	1 668	20
Total	$ 2 077	$ 2 099	$ 5 953	$ 24 164	25%

RESEARCH AND DEVELOPMENT

1. Reactor and Fuels

Irradiation for two months in a high pressure loop did not significantly change the bulk density of eight experimental lithium-aluminum target elements.

Postirradiation examination of fluted tubular elements of the N-inner size, which were irradiated to 2000 Mwd/ton in cold water, indicated density losses up to 7% - primarily by grain boundary tearing. A normal tubular

element would probably have failed at a much lower volume increase by clad necking.

Postirradiation examinations of KSE-5 elements, irradiated to 1070-1350 Mwd/ton at temperatures from 525-600 C, showed a 2.3% volume increase and evidence of systems of parallel microcracks within isolated uranium grains. Further examination will be required to establish the extent to which these microcracks have contributed to the measured fuel volume increase.

Brittle fracture tests on N-Reactor pressure tube sections containing milled slots 1.5 in. in length and 80% through the wall thickness resulted in failure at stress values more than six times the proposed reactor operating stress.

In-reactor tests on Zircaloy-2 confirm that the creep rates during irradiation approach a steady state value which is independent of path. That is, the steady state creep rate during irradiation is a function of temperature, stress, and neutron flux only. This result is predicted by the dislocation model developed to explain in-reactor creep behavior of Zircaloy-2.

Preliminary examination of data from an electrically heated test section representing the downstream half of an N-Reactor fuel train and process tube indicates that the pressure drops during boiling conditions are not as great as calculated, and flow instability should be a lesser problem than anticipated.

Graphite burnout monitors in B-Reactor indicated no increase in burnup rate using a gas atmosphere containing up to 60% carbon dioxide. Savings from reduced helium losses should result.

An alternate design (ring supported) Mark I PRTR fuel element continues to resist fretting corrosion after 184 days of severe testing in an out-of-reactor facility.

Seventy-six PRTR fuel rods were fabricated by the Nupac-Vipac process. The homogeneity of the PuO_2-UO_2 densified by the Nupac (impaction) process makes decontamination operations simpler than those involving physical mixtures of the oxides.

Capsule irradiation of earlier prototypic EBWR fuel (depleted UO_2-2.5 wt% PuO_2) demonstrated better performance (more uniform plutonium and fission products distribution) in impacted fuel than in physically mixed fuel.

PRTR pressure Tube 6115 has been cut into 10 pieces in the PRTR storage basin. One of the pieces will be burst-tested to determine the hazard potential of flaws on the inside surface. This tube is the eleventh to be discharged for the PRTR pressure tube surveillance program.

Calculations for PRTR operation at a power level of 105 Mw indicate that convective cooling would be sufficient to cool the fuel elements following a loss of electrical power to the recirculating pump.

Three tubular Zircaloy-2 clad thorium - 2.35 wt % U^{235} - 1 wt% Zr fuel elements have been irradiated to 3400 Mwd/ton. The irradiation is continuing. Weight measurements made at this point indicate a total volume increase of 0.5% for the highest exposure element and 0.3% for two lower exposure elements. This very low volume increase represents the theoretical minimum density change attributable to the fission products.

The use of a finely dispersed second phase to improve the already favorable swelling resistance of metallic thorium fuels is under study. Aluminum or beryllium additions (500 to 2000 ppm) have been made to thorium base alloys containing uranium and uranium plus zirconium.

The study of metallic uranium fuel modified by "shot forming" to produce an extremely fine carbide dispersion has shown that the carbide particles obtained are 1 micron or smaller even after beta heat treatment of the fuel.

[redacted]

Finely dispersed intermetallic particles have been successfully delineated metallographically in 9 of the 31 dilutely alloyed uranium samples under study for their swelling resistance.

Stress-strain rate tests on molybdenum at room temperature indicate the existence of a rate-controlling, thermally activated deformation mechanism. The effect is slightly more pronounced in cold-worked material.

Molybdenum seed crystals have been prepared for growing single-crystal rods. Orientations selected are those for which resolved shear stresses will be a maximum for {110} planes and for {112} planes.

Diffraction micrographs have been made from (110) and (100) faces of a zone-refined molybdenum single crystal. The (110) photographs show what appear to be regions of lattice curvature. Photographs from (100) faces show only a pattern of faint, finely spaced lines resembling slip traces.

The combined effect of reaction rate and compressive load on transformation strain during the $\alpha \rightleftharpoons \beta$ transformation of plutonium is being investigated.

The respective steady state creep rate of beta phase unalloyed plutonium at 150 C under compressive loads of 2300, 1300, and 800 psi was 2.4×10^{-5}, 7×10^{-7}, and less than 10^{-7} per minute. The steady state creep rate at 130 C (266 F) at 2300 psi was 6×10^{-6} per minute.

The increase in yield strength of Zircaloy-2 as a function of neutron exposure has been compared for neutron irradiations both at 60 C (140 F) and 280 C (540 F). For integrated exposures less than 10^{20} nvt, there is no significant difference in the rate of damage accumulation for the two irradiation temperatures, and a linear function exists between yield strength and log nvt for several conditions of prior cold work. At integrated exposures greater than 10^{20} nvt, the higher irradiation temperature results in a higher rate of damage accumulation in annealed Zircaloy-2. At exposures greater than 10^{20} nvt, the yield strength of cold worked Zircaloy-2 begins to decrease with irradiation,

indicating the occurrence of radiation-induced recovery. The rate of recovery is higher for the higher temperature of irradiation.

A series of sintered ThO_2-PuO_2 fuel specimens were fabricated and shipped to NRTS for irradiation tests. Fuel compositions are typical of a crossed progeny fuel cycle.

A sound, stainless steel - 26 wt% PuO_2 cermet (97.5% TD) having uniform plutonium distribution was prepared by impaction. Evaluations will include both long and short duration irradiations.

A tungsten-molybdenum billet has been successfully extruded on a low speed press employing only 170 of the available 700 tons pressure. Success may have been largely due to the unique use of a pyrolytic graphite sleeve as a combined insulator and lubricant for the billet. This successful extrusion represents a major step in the program of developing a tungsten clad, tungsten-UO_2 honeycomb fuel element by coextrusion techniques.

The first irradiation test at 3000 C of an impacted, W-clad, W-20 vol% $U^{235}O_2$ cermet fueled plate was successfully conducted. The fueled plate remained intact during the four-hour irradiation, and UO_2 loss through nonclad areas appeared minor. Other, longer irradiations of W-50 vol% UO_2 and Mo-UO_2 cermet rods were successfully conducted.

A series of reactions was visually observed in a 50 wt% W-UO_2 cermet during heating between 800 and 1900 C.

Vibrational compaction equipment was isolated and modified for compaction of UO_2 into beryllium tubes supplied by CEN, France.

End closure welds were successfully made on test pieces of beryllium employing the magnetic force welder.

Two wt% and 10 wt% Sm_2O_3 specimens were pneumatically impacted with micronized UO_2. Samples were prepared for analysis of Sm_2O_3 distribution.

Tungsten clad, tungsten-UO_2 cermet plates were successfully butt welded. There was no cracking.

Beta-Pu_2O_3 was found to be compatible with tungsten, molybdenum, tantalum, niobium, and vanadium at 1650 C in helium at one atmosphere pressure for 24 hours.

During irradiation to a high burnup a specimen of fused PuC fractured extensively and released 22% of the fission gases.

Pressure drop measurements for an electrically heated 19-rod bundle test section were examined and equations were developed to correlate the results. An equation was developed to give the overall pressure drop for the bundle combining single phase, local boiling, and bulk boiling flow conditions.

When irradiated at 30 C, a series of graphites made from different petroleum fillers expanded in the direction transverse to the extrusion axis at about the same rate as conventional nuclear graphites; however, one material made with iron oxide addition showed significantly better dimensional stability.

Electrical resistivity of graphite for possible High Temperature Lattice Test Reactor use was measured for 25 C to 940 C. A minimum was observed at 550 C.

A gas chromatograph claimed by the vendor to be sensitive to 1 ppm of O_2, N_2, H_2, methane, CO, and CO_2 is under evaluation. Initial quantitative results indicate a sensitivity of 10 ppm is attainable and with further cleanup of the carrier gas the claim of 1 ppm sensitivity may be achieved.

2. Physics and Instruments

Exponential pile experiments in an overbored C-Reactor lattice were completed this month. Information was obtained on the effect of adding one column of enriched uranium (0.947% U^{235}) to each eight columns of natural uranium.

The PCTR was used to obtain information in support of operating K-Reactor with KVNS fuel pieces in Zircaloy-2 tubing.

Assembly of N-Reactor startup instrumentation is being accelerated. Water cooled thimbles have been designed for the installation of ionization chambers with which neutron flux measurements will be made. Sample line changes were made on the gamma energy spectrometer at KE loops 1 and 2 to permit adjustment of the sample delay time from 40 to 80 seconds.

Installation of reactor fuels test loop at PRTR is moving rapidly ahead. Pneumatic line, electric lines, and voltage controllers have been installed. Water sample lines have been extended to the cell room; flow transmitters have been installed; and connections have been made to the sampling glove box.

N-Reactor pressurizer simulation test runs have revealed new data that confirm the need for addition of the derivative (rate) mode to the pressurizer level control system. Scram induced pressure surges were evaluated with a proportional-plus-reset control, and it was determined that addition of rate action reduced severity of the pressure surges by providing a negative error signal to the reset mode. A second model of the N-Reactor primary flow system has been developed; it appears to circumvent difficulties with the first model. The steam generating system has been simulated with a mathematical model now ready for the computer.

New results were obtained in the Critical Mass Laboratory from experiments applicable to nuclear safety problems associated with wet powders, precipitates, slurries, polymers, etc. Plutonium oxide-polystyrene compacts were used having a hydrogen-to-plutonium ratio of 15. When this material was used without a neutron reflector it was found that a block 12 x 12 x 12.66 in. would chain react. This corresponded to a critical mass of 34 kg. With a reflector of lucite in place, a cube 9 x 9 x 8.38 in. corresponding to a mass of 12.6 kg, was critical. Criticality data were obtained also on a 6 x 7 in. column. Neutron lifetimes and temperature coefficients were also measured.

[redacted]

The high accuracy, cylindrical interaction code INTERSET was distributed to CPD and HL customers. This completes the scheduled work on the interaction problem. The mathematical interaction model postulated in this code has advanced the art considerably beyond that in common use throughout industry. This is the first known description of interaction between cylinders with different heights, different nuclear characteristics, and external reflectors. Since little or no experimental data with these variables exist, the possibilities for such experiments are being informally explored.

Nuclear safety consulting services continued. Participation in the hazards review for the Z Plant Waste Treatment facility was completed. Two lecture series on nuclear safety were begun to train Chemical Processing Department personnel.

Studies of the scattering of slow neutrons by 95 C light water continued. This month the reduction of raw data from previous measurements was completed. Theoretical calculations were performed to compare theory with experiments. At the moment the comparison is rather unsatisfactory. A step plug which will serve as a neutron beam shutter for a new time-of-flight spectrometer for slow neutron scattering studies was completed.

Another series of total cross section measurements for neutrons of 3 to 15 Mev energy were completed. Five elements were studied for which no data previously existed. Measurements were repeated on six other elements.

Experimental studies of the nuclear physics properties of Pu-Al rods in light water continued at a rapid pace. Buckling and critical mass data have now been obtained on four different lattice spacings. Work on a fifth lattice spacing is under way.

A major goal was attained on September 13 when the first irradiated PRTR fuel cluster was moved into the Plutonium Recycle Critical Facility (PRCF) for physics measurements. This fuel element was a Pu-Al cluster

which had been cooled for a long time. It was possible to override the photoneutron production from the fuel element without exceeding the current operating limits for the PRCF. Thus, for long cooled fuel elements it appears that techniques can be worked out to obtain worthwhile physics measurements in spite of the photoneutron production problems.

The burnup data from the destructive testing of PRTR element 5108 are complete. Element 5108 is a high exposure Pu fuel element, Pu^{240}, 16 at.% which has received an exposure of 30 Mwd.

In the analysis of PRTR burnup experiments, improved values for the fuel cross section ratios have been obtained using fitted polynomials to describe the atom density changes as a function of burnup.

Extensive work on other reactor physics codes was also under way. Development and/or checkout of RBU, BARNS, HRG, and PHYSICS CHAIN was carried out. Modifications of some of the cross section constants for the one-dimensional burnup code ALTHAEA were formulated.

Members of a committee appointed by the ANS Mathematics and Computing Division met at Hanford to plan a Master Cross Section Library Processing Computer Code to process data from the Brookhaven Master Data File in a form useful to all reactor organizations.

Progress was made on the development of the High Temperature Lattice Test Reactor. A 200 hr corrosion test in nitrogen atmosphere did not turn up any severe visible corrosion or carburization on materials contemplated for use in the HTLTR.

Work on advanced reactor concepts was considerably expanded during September. The Phoenix core survey was extended to include various M:W ratios from 0 to 2, and core sizes ranging from 250 to 1000 liters. A brief study assessing the accuracy of current fast reactor cross section sets was completed.

Reactor tests to experimentally evaluate the B^{11} neutron flux monitor were inconclusive because of beta current assumed to be generated in the electrical lead-in cable. The use of isotopes other than B^{11} is being considered which permit measurements over extended energy range, and which simplify probe construction. Continuing experiments are being made to confirm the magnitude of cable induced errors.

The use of ultrasonic boundary waves as a method of detecting zirconium hydride was suggested to Testing Methods, N-Reactor. Early experimental results by that organization suggest this technique may be one of the most promising methods investigated to date. Experiments are continuing in HL for studying this application, in addition to the possible use of these waves for bond strength determination.

A significantly improved ultrasonic tester for thin wall fuel sheath tubing was made operational and is now in use for routine testing. Defects down to 1/20th of the wall thickness in depth by one wall thickness in length, both axial and circumferential orientation, are consistently detected and automatically recorded in terms of defect location and depth.

An excellent information exchange and field workshop on advanced-design atmospheric turbulence measuring devices was held at Hanford on September 9-13, in cooperation with the University of Washington. Devices compared included the Hanford wind component meter, the University hot wire anemometer and sonic anemometer systems. The University systems received field testing before use this winter on the International Indian Ocean Expedition.

The summer's whole body counting work in Alaska was completed. An average increase of about 50% observed at Anaktuvak Pass is probably the best indicator of the general trend of fallout conditions in Alaska. At the other villages the increase was modified by other effects that will be better understood when Biology Section completes the analysis of the dietary and other information collected this summer.

[redacted]

Further study of the urinalysis method of determining average Cs^{137} body burdens continued to give good results. Fabrication of the plutonium X-ray scintillation counter was completed. An experimental method of spectroscopy of low energy fast neutrons was chosen and fabrication of apparatus started.

Intrathoracic air pressure on an experimental animal has been successfully achieved. Sensitivity was equivalent to 1.5 mm of water. Experiments are being made to produce animal anesthesia by electrically exciting probes placed on animal temples at 700-900 cps, at a power level equivalent to 12-50 ma.

At their request, equipment and professional assistance were provided Combustion Engineering to assist them in the further evaluation of the eddy-current tests applied to the N-Reactor heat exchanger.

Our delivery commitment for the second 1200 Zircaloy process tubes for K-Reactor retubing was met ahead of schedule. These tubes were tested and inspected and given the Laboratories developed grit-blasting process which reduced the failure rate of Vanstone flares on the reactor to around one-half percent. This flare failure rate is one-half that experienced on the previous 1200 Zircaloy tubes, and both rates are substantially less than that experienced with ductile aluminum process tubes formerly used.

3. Chemistry

Comparative tests of aluminum coatings under out-of-reactor conditions showed reduction in uptake of phosphate by a factor of four for teflon coating and by a factor of 20 for a coating of black marking ink ("Marks-a-Lot" brand).

In-reactor tests with the experimental water treatment plant showed that 0.2 ppm "CatFloc" (a cationic polyelectrolyte) could be substituted for

[redacted]

ca. 10 ppm of alum, yielding a floc of zero zeta potential (desirable for easy removal of colloids) and without adversely affecting removal of ionic phosphate. In similar tests with activated silica, conditions were not found which allowed simultaneous removal of both colloidal material and ionic phosphate.

In-reactor tests with deionized water have allowed estimates to be made of the separate corrosion rates for process tubes (corrosion of which releases Ga^{72} and Na^{24}) and fuel cladding (corrosion of which releases Ga^{72}, Na^{24}, and Ni^{65}). Studies which started with new aluminum process tubes showed an initial apparent combined corrosion rate some tenfold higher than that observed after 5 or 6 fuel changes, indicating some passivation of the process tube with use and time. The film which builds up on the process tube is an important factor in the corrosion of the fuel jackets.

A lead-bearing sludge which had accumulated in the CR vault strontium storage tank proved readily acid soluble after metathesis with 10% caustic, which converts the sludge to Pb_3O_4 (red lead).

Sugar treatment to destroy nitric acid was shown feasible on waste solutions containing 1M aluminum. The efficiency is actually promoted by the presence of aluminum, which exhibits an apparently catalytic effect essentially identical to that previously observed for wastes containing 1M iron.

Laboratory studies showed excellent technetium recovery with the same feed and resin used in a recent apparently unsuccessful field experiment. The poor result reported in the field experiment is believed due to either poor geometry or hydraulics in the resin-filled cask or poor analytical data.

Exploratory studies are underway to determine the feasibility of producing Tl^{204} in high specific activity via a modified Szilard-Chalmers effect, recently reported successful in producing high specific activity Co^{60}. Tl^{204}, a beta emitter with a 4-year half life, is an isotopic heat source potentially competitive with Pm^{147} and Pu^{238}.

Upon development of the necessary improved analytical methods for chloride in uranium dioxide, it has been found that conditions readily achieved in laboratory electrolyses produce uranium dioxide containing less than 5 ppm chloride. Such conditions have not yet been achieved in pilot-scale equipment; however, the chloride contents in these preparations is of the order of 100 to 200 ppm.

Hot cell runs testing addition of phosphate to spray calciner feed to achieve a microcrystalline "pseudo glass" were completed without incident. Inclusion of phosphate in the feed had no discernible effect on ruthenium volatilization.

Studies of iodine emitted from separations plant stacks continue to show strong evidence that there are a multiplicity of iodine species present, certain of which are relatively nonreactive and therefore not retained by caustic scrubbers or silver mesh but are retained by activated charcoal absorbents.

Chloride ion, often present at substantial concentrations in biological systems, has been shown to be important when determining the nature and amount of radiation damage suffered by organic chemicals in solution when exposed to gamma radiation. Although the protection index for chloride ion is small (ca. 0.0003), the large excess of chloride over other solutes in biological systems makes its effect important.

An experimental comparison of two chromatographic cation exchange flowsheets (one a Hanford development, the other an ORNL development) for purification of promethium showed as the main advantage of the Hanford approach, better separation of promethium from lead and yttrium. The study suggests that substitution of HEDTA for the EDTA used in the Hanford flowsheet might yield a flowsheet retaining the major advantages of both approaches.

If 0.1M oxalic acid is used to strip plutonium and neptunium from 0.3M TLA-Soltrol (proposed as an extractant to recover plutonium and neptunium values from Purex acid waste) the oxalic acid must be destroyed before adding it to the neptunium-plutonium separation cycle (3A-3C) to avoid high neptunium losses.

A "sandwich" cartridge using thin (3/32-in.) fluorothene appears at least as efficient as 3/4-in. polyethylene plates in the Purex 2E column. After six weeks' exposure to Purex HAX at 70 C, samples of perforated polyethylene plates were severely embrittled, in agreement with the short life observed for polyethylene plates in Purex plant columns.

The use of phosphoric acid to remove strontium from Purex waste sludges appears promising.

Installation of equipment in C-Cell of the High Level Radiochemical Facility for processing 30-lb batches of PRTR fuel by the Salt Cycle Process has been completed. Cold runs were in process at month end.

A solvent extraction pilot plant demonstration of the cesium purification process proposed for the Hanford Isotopes Plant was highly successful. Cesium losses of 0.08% and 0.14% were obtained for the extraction and stripping columns and the overall sodium decontamination factor was 4000.

Laboratory tests indicate that a recycling of cesium product from the ion exchange recovery process can eliminate the need for an ammonium salt scrub, provide a product of higher purity, and permit higher cesium loading (ca. 2 meq Cs/g) in the zeolite storage package.

Preliminary laboratory studies were made with a six-membrane electrodialysis unit processing acid condensate waste to aid in evaluation of ruthenium behavior. Ninety percent of the ruthenium was removed from the solution; however, the distributions of ruthenium species could not be determined because of sorption interferences.

A thin bed ion exchanger-prefilter is being evaluated for use in an integrated process for condensate decontamination. An acceptably low pressure drop was achieved with 50-80 mesh Decalso.

A comparative cost analysis for ion exchange decontamination and a one-stage evaporation process for Purex Tank Farm condensate indicated that the ion exchange process would be at least $9.50 per 1000 gal less than the evaporation cost.

Evaluation of the recent geophysical seismic surveys of selected Project sites yielded favorable conclusions. Combined refraction profiling and rotary drilling, with thorough logging of drilled holes, appears fastest, most definitive, and most economical.

4. Biology

Special agents for cleaning N-Reactor tubes continue to be tested for toxicity to fish. Dowell F-33 is one of the latest. Although the LD_{50} for 72 hr is about 20 ppm, loss of equilibrium occurs in young fish at concentrations as low as 1 ppm. The effect of loss of equilibrium on survival under river conditions is obvious.

Another substance being used is trisodiumphosphate, and this is also being tested. It causes loss of equilibrium in fish at 400 ppm, with 600 ppm causing mortality in half-an-hour.

River water temperature has risen from 67 to 72 F during the past 30 days. This is unusually warm and has increased the incidence of columnaris and mortality among rainbow trout held in troughs. At 4 F above normal river temperature, observed was a 50% increase in mortality (control about 7%); columnaris infection was about 50% above controls. Oddly enough, 4F below the river temperature resulted in about the same mortality as the river temperature itself, with columnaris infection above controls. Ultra-violet treatment of the water definitely decreased the incidence of columnaris, but the mortality of fish was the same as in water at the river temperature.

From results observed among pigs fed 625 μc Sr^{90}/day, it appears that this amount is about borderline for killing after nine months.

DTPA administered with zirconium colloid or India ink was no more effective than DTPA alone in removing plutonium deposited in rats 7 days prior to treatment.

[redacted]

Among dogs, at least, it appears that DTPA is more toxic than previously believed. Some of the levels tested for the removal of $Ce^{144}O_2$ in dogs caused vomiting and death. The treatment given to each dog was the following: 1 g DTPA iv on day 1, followed by 0.5 g DTPA each on day 2, 3, and 4. Calcium gluconate was also given on the second day. These levels are close to those administered to humans.

Iodine-131 labeled PVP is being found as a useful indicator of gastrointestinal radiation damage. Following intravenous injection of PVP, the material is excreted into the intestine dependent on X-ray and fission neutron dose. Cysteine decreased intestinal permeability of neutron irradiation, but did not decrease mortality, since the death was probably due to hematopoietic injury.

Yeast cells grown in D_2O show decreases in RNA, DNA, and proteins. This is probably due to reduction of nucleic acid content in the cells. When the cells are removed from the D_2O and placed in a medium containing ordinary water, protein and nucleic acid contents return to normal in less than one cell generation.

It appears that I^{131} deposited on plants from the atmosphere will gradually evaporate off with a biological half life of about eight days. A considerable amount of the radioiodine seems to penetrate to the center of the rye leaves used.

Whole-body counting of northern Alaskan residents was completed with the examination of 120 people at Point Hope and 157 people at Kotzebue. The monthly report shows averages and maxima observed during 1962 and 1963. The threefold increase in Cs^{137} among residents at Point Hope (1962-1963) is attributed to the greater availability of caribou and greater Cs^{137} concentrations in caribou flesh during 1963 as compared to 1962.

5. Programming

The effects of specific power and variations in the AEC use charge rate on fuel cost were each investigated for six different fueling schemes in a water reactor simulation. Results are available in graphical form.

A number of presentations were made to the Technological Hazards Council during its meeting at Hanford the week of September 9. The PRTR pressure tube surveillance program was reviewed for the Council along with (1) recent PRTR operating experience, (2) the use of the PRTR automatic controller, and (3) the effect of nonuniform distribution of plutonium in mixed oxides fuels.

Probable selling prices of separated fission product radioisotopes were estimated and reported for the proposed Hanford Isotopes Plant. For the assumptions used, which are considered reasonable for profit-making operation of the plant, the following prices resulted: Sr^{90}, $0.20/curie; Cs^{137}, $0.19/curie; Ce^{144}, $0.02/curie; Pm^{147}, $0.08/curie.

Thorium oxide samples irradiated to 1,850 and 3,500 g of U^{233} per ton were analyzed for U^{232} content. Results show that in high concentrations (approaching 100 ppm) Th^{230} contributes markedly to the formation of U^{232} contamination in the U^{233} generated.

TECHNICAL AND OTHER SERVICES

No new plutonium deposition cases were confirmed by Bioassay analysis this month. Re-evaluation of a case previously reported as less than 1% of the maximum permissible body burden (MPBB plutonium with bone as reference as 0.04 μc) revealed that no plutonium deposition had occurred. This resulted in a reduction of one in the number of deposition cases that have occurred at Hanford. The total number of individuals who have received internal plutonium deposition at Hanford is 324 of which 235 are currently employed.

[redacted]

A total of 62 curies of I^{131} was released from the Purex Plant stack over the three-day period from September 2 to September 4, 1963. The maximum concentration of I^{131} found in milk as a result of this emission was between 300 and 500 pc/liter. The total radiation dose that would have been delivered to the two-g thyroid of an infant drinking this milk throughout the month of September was estimated to be only 0.05 to 0.08 rem.

Calibration curves were developed for estimating two wall thicknesses from chart readings obtained on the probolog instrument. In addition, data from tests were analyzed to determine the effect of factors such as probe speed, water flow in tube, and air pressure in the bellows on probolog chart readings.

Further data are being analyzed to compare the process control characteristics of fuel elements canned by the AlSi and hot-die-sizing process.

A study was made of the probability of a spurious scram as a function of the number of individual tube signals which fail within a temperature monitor zone. Present results are tentative. A more complete analysis is being planned.

In anticipation of onsite field tests considerable effort was devoted to debugging and checking out the computer program to prepare magnetic tape input for the prototype Sheffield rotary contour gage.

Recent theoretical and experimental developments in the field of sound wave propogation and attenuation in visco-elastic media were discussed with Professor Leon Knopoff at the UCLA Institute of Geophysics. These discussions were motivated by modeling difficulties which arise in the study of nondestructive materials testing techniques.

Primary results from the Monte Carlo based diffusion study exhibits desirable characteristics not previously found in other models.

Considerable progress has been made in defining an appropriate numerical solution for the boundary value formulation of the nonlinear system of second order differential equation expressing mass transfer in a pulse column.

SUPPORTING FUNCTIONS

Plutonium Recycle Test Reactor output for September was 1359 Mwd, for an experimental time efficiency of 79.2% and a plant efficiency of 64.7%. There were four operating periods during the month; one was a continuation of an August operating period. Two operating periods were terminated for scheduled refueling and planned maintenance; one was terminated by a scram; and one continued through monthend. A summary of the fuel irradiation program as of September 30, 1963, follows:

	Al-Pu		UO_2		PuO_2-UO_2		Other		Program Totals	
	No.	Mwd	No.	Mwd	No.	Mwd	No.	Mwd	No.	Mwd
In-Core	24	2118.4	0		61	5840.1			85	7958.5
Maximum		144.9				149.8				
Average		88.3				95.7				
In-Basin	19	1216.8	66	5702.8	16	554.2	1	7.3	102	7481.1
Chemical Processing	32	2309.3	1	78.0	—	—	—	—	33	2387.3
Program Totals	75	5644.5	67	5780.8	77	6394.3	1	7.3	220	17826.9

A total of 70 reactor outage hours were charged to repair work. Main items were:

D_2O and helium leaks	17 hours
Helium compressors	15 hours
Instrument air leaks	10 hours
Injection pumps	8 hours

The September heavy water inventory indicates a loss of 1654 lb for the month.

[redacted]

Installation of the motorized switches at the PRTR, 13.8 kva, incoming line was completed during the month. This change permits remote switching from one leg of the 13.8 kva loop to the other leg, should a local fault occur.

The first irradiated fuel measurement in the Plutonium Recycle Critical Facility was completed on September 13. Two complete cycles of irradiated fuel handling were performed with a full-sized PRTR element (Pu-Al) and with D_2O coolant. Crude worth data were obtained from these preliminary measurements. Biological shielding integrity was again checked and found to be adequate.

Seven hot operating runs were conducted during the month in the Fuel Element Rupture Test Facility. Most of the runs were of fairly short duration and were terminated under controlled conditions for maintenance work. Only one run was stopped because of conditions which would have caused a reactor scram; this was a high pressure condition caused by failure of the pressure control valve positioner. A more reliable positioner has been installed.

Operation of the Gas Loop at design temperature of 1500 F was achieved during the month in the Pressurized Gas-Cooled Loop Facility.

Total productive time in the Technical Shops Operation for the period was 24,068 hours. Distribution of time was as follows:

	Man Hours	% of Total
N-Reactor Department	3 212	13.35
Irradiation Processing Department	3 606	14.98
Chemical Processing Department	247	1.02
Hanford Laboratories	17 003	70.65
Hanford Utilities and Purchasing Operation	--	--

Total productive time for the Laboratory Maintenance Operation was 17,400 hours of 19,200 hours 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. Manpower utilization for September was as follows:

A. Shop Work		1800 hours
B. Maintenance		6100 hours
1. Preventive Maintenance	1800 hours	
2. Emergency or Unscheduled Maintenance	1600 hours	
3. Normal Scheduled Maintenance	2700 hours	
4. Overtime (Included in above figures)	830 hours	
C. R&D Assistance		9500 hours

The heavy water inventory at the end of September 1963 showed a loss of 1654 pounds ($22,738) for the PRTR and a loss of 99 pounds ($1,361) for the PRCF. Heavy water scrap generated during the month amounted to 3976 pounds, resulting in a $4059 charge to operating cost. Heavy water accumulated at September 30, 1963 for return to SROO amounted to 17,218 pounds ($216,675).

Visitor activity is reflected in the following numbers:

	Number of Visitors	
	In September	Since 6-13-62
Visitors Center	2242	56,625
Plant Tours	259	n.a.

[redacted]

HAPO professional recruiting activity this month is summarized below:

	Plant Visits	Offers Extended	Acceptances Received	Rejections Received	Open Offers at Month End
Ph.D.	7	3	0	3	4
BS/MS (Direct Placement)		2	3	0	1
BS/MS (Program)		0	0	0	0

Ten technical graduates were placed on permanent assignment. Nine graduates joined the program, two terminated to return to school, and one transferred to APED. Current program members total 75.

Authorized funds for nine active projects total $6,739,500. The total estimated cost of these projects is $10,584,000. Expenditures through August were $1,134,000.

W. H. Reas
for Manager, Hanford Laboratories

HM Parker:JEB:mhs

REACTOR AND FUELS LABORATORY MONTHLY REPORT

SEPTEMBER 1963

TECHNICAL ACTIVITIES

A. FISSIONABLE MATERIALS - 02 PROGRAM

1. Metallic Fuel Development

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

The target elements which were discharged from Loop 1 after 61.2 days at full reactor power were "weasled". The results indicated that the relative exposure of the individual elements varied approximately 15%. The bulk density of the target elements was measured and compared to the pre-irradiation test values. The differences noted were within experimental errors. Examination of the elements is under way in Radiometallurgy. With the exception of a reddish-brown deposit previously reported, the elements, as received in Radiometallurgy, appeared unchanged as a result of irradiation. Post-irradiation measurements indicated the diameters of the element were unchanged. However, a slight increase in length was observed.

Fluted Fuel Element Irradiations. Two fluted N-Reactor size single-tube fuel elements have completed six cycles of irradiation in the ETR M-3 facility. These fuel elements have operated at a maximum specific power of 130 kw/ft with a corresponding maximum fuel temperature of 520 C. The accumulated maximum exposure is currently 1200 MWD/T and the measured volume increase is 0.5%.

High Temperature Irradiation of I&E Fuel Elements. Four Hanford tubular I&E fuel elements have been irradiated in the GEH-4 loop facility in the MTR to investigate the susceptibility of these elements to the grain boundary tearing phenomenon. The maximum fuel temperatures and burnups varied from 700 to 50 C and 3130 to 350 MWD/T, respectively. A maximum diameter increase of less than 1% was observed, indicating that little or no grain boundary tearing occurred. Metallographic examination of fuel sections for possible evidence of grain boundary tearing is under way. Some bumping of the outer and inner cladding was observed, as was a slight warping of all four elements.

Fluted Fuel Element Examination. The post-irradiation examination of the N-inner size fluted elements which were irradiated to 2000 MWD/T in cold water in the KE-Reactor was completed. In addition to the observable gross swelling which occurred near the ends of the elements, a considerable volume increase had taken place throughout the length of the element without damage to the Zircaloy-2 cladding.

A density determination on a three-inch long section from the center of one element indicated a volume increase of 7% had occurred. The swelling was the result of a "grain boundary tearing" phenomenon related to the anisotropic growth of uranium which has been seen previously in high exposure uranium irradiated in cold water.

Although the fuel failure which occurred in this irradiation test was probably associated with the gross swelling observed at the end caps, it is noteworthy that the central section of the fuel element swelled some 7% without evidence of cladding instability. A normal tubular element would probably have failed at a much lower volume increase due to localized instability (necking) of the cladding.

Examination of High Temperature Tubular Fuel Elements. Post-irradiation examinations of KSE-5 elements is in progress in Radiometallurgy. These elements were irradiated in a KER loop facility to an exposure of 1070-1350 MWD/T at maximum fuel temperatures in the range of 525 to 600 C. A metallographic examination of one fuel element which showed 2.28% volume increase during irradiation has revealed evidence of parallel microcracks within isolated uranium grains. A detailed examination will be required to establish the extent to which these microcracks have contributed to the measured fuel volume increase.

Cladding Deformation Studies. Thirty-six NaK capsules containing a total of 94 Zircaloy-2 clad uranium rods have been irradiated to provide data on the strain capabilities of Zircaloy-2 cladding as a function of cladding thickness uniformity, temperature, and exposure. A total of 54 samples have been examined visually and diameter measurements completed. On all samples with one, two, or four 0.008-inch deep striations in a nominal 0.025-inch thick cladding, necking or splitting of the cladding has occurred. The minimum cladding strain on these samples is approximately 1%. On the samples with 0.004-inch deep striations in a nominal 0.025-inch thick cladding, the results are not wholly consistent. On some samples no instability is observed even up to 1.8% cladding strain. Also, on some samples necking is observed at locations other than the intentional striations. Metallography of transverse cross-sections from certain of these irradiated samples is planned.

Macrophotography and diameter measurements have been completed on three, 6-inch long samples which were irradiated to provide qualitative data on the plastic flow of uranium under irradiation. Two of these 0.6-inch diameter rods have nominal cladding thicknesses of 0.020-inch and the other a nominal cladding thickness of 0.040-inch. One end of each of these rods is open, thus presenting a surface which offers no resistance to longitudinal movement of the uranium fuel. Measurements made from the photographs of these samples showed that plastic flow of the uranium reduced the swelling-induced cladding strain for 1.25 inches on the rod with the 0.040-inch thick cladding and for 0.9-inch on the rods with the 0.020-inch thick cladding. The diameter increase beyond the stress relieved section was calculated to be 4% on the rods with the nominal 0.020-inch thick cladding and approximately 2% on the rod with the 0.040-inch thick cladding. The estimated average cladding temperature on these elements is 400 C.

Fuel Fouling Detector. Fabrication of eight fuel fouling detectors was completed. These one-inch diameter probes were prepared from a coextruded rod of Zircaloy-2 clad thorium-uranium fuel alloy. Four of the probes have Zircaloy-2 clad thermocouples in which a Be-Zr braze joint was used to effect the thermocouple seal and four utilized stainless steel clad thermocouples in which a compression seal is used. Following final autoclave testing one of the probes with a Zircaloy-2 clad thermocouple will be irradiated in the ETR P-7 loop to evaluate its performance in high-temperature pressurized water.

Destructive examination of sections of the double-sheathed Zircaloy-2 clad thermocouples used in the fabrication of the above probes continues to indicate that the outer 20-mil thick sheaths are sound. The defects indicated in eddy current tests have so far been associated with the thinner inner sheaths.

Target Material Development. The vacuum melt furnace has been modified to permit longer melts as part of the preparation for the Poison Column and Physics Test for N-Reactor. This modification will permit up to 60 lbs of aluminum to be melted at one time. Graphite molds have been fabricated for making extrusion billets. These molds will make a 120-lb extrusion billet in a double pour. A total of four aluminum billet shell castings for pre-extrusion, six aluminum-1% lithium direct cast ingots, and six pre-extruded extrusion billets will be cast. Of these, the four aluminum billet shell castings have been made and machining has started. This material will be coextruded in the 333 press cold.

Weld Development. A study to evaluate unbonded end caps is being conducted in NRD. To prevent any argon gas which might be trapped during TIG welding an unbonded cap from becoming a factor, it was decided to electron beam weld the first P.T.

Sixteen elements were welded. A step joint was formed by leaving the end cap ~ 0.040-inch longer than the clad. NRD testing of the welds included x-ray, metallographic section, and, because of some concern over lack of fit between cap and element, an end loading test to determine if the weld would fail if excessive pressures were encountered during charging. The elements passed all of these tests.

N-Reactor Fuel Support Development. A test was run to determine the effect of reactor thermal cycling on the growth of hydrides in supports. Inner supports which were attached to elements, autoclaved, solution annealed, and sized up according to the current manufacturing procedure were heated to 260 C and furnace-cooled to simulate a reactor thermal cycle. No deleterious growth of hydrides was observed in the microstructure of the Zircaloy-2. The effects on the compressive fatigue strength of the sized-up supports is being evaluated.

Fretting Corrosion of N-Reactor Fuel Elements. Five fretting tests on N-Reactor fuel elements in high temperature flowing water have been completed during the year on elements with soft-sized and hard-sized buggy spring inner element supports. During portions of the tests, induced vibration is being impressed on the outside of the horizontal process tube. Fretted areas up to 18 mils deep were found on the soft-sized element after a one-day exposure at 41 cps and six days at 54 cps. No fretting was found on the hard-sized elements during the four remaining tests when the induced vibration frequency was less than 60 cps. Whenever the frequency was increased over 60 cps (up to 83 cps), severe fretting occurred between the inner element supports and their contact areas on the outer element cladding. Tests on elements with microcracks in the buggy spring supports (prior to testing) showed that all supports would fail by a combination of fatigue and fretting corrosion whenever induced frequencies above 60 cps were employed.

Rupture Testing of Irradiated N-Reactor Fuel Elements. One fuel element, irradiated to 1730 MWD/T in KER-4 at a water temperature of 262 C, was predefected at Radiometallurgy and tested in the Irradiated Rupture Prototype (IRP). After nine hours at 300 C, no reaction had occurred. It was concluded that the defect was not deep enough to penetrate to the uranium and the element was returned to Radiometallurgy for redrilling.

Another fuel element irradiated to 1200 MWD/T in K-4 at a water temperature of 228 C had an incubation time of 45 minutes at 300 C in the IRP. The temperature was held at 300 C for five minutes and then cooled at the N-Reactor programmed cooldown rate which is about 3½ C per minute. The activity as indicated in the two micro filters increased very slowly for the first few minutes after the start of the rupture and then increased rapidly (from 45 mr/hr to 800 mr/hr) for several minutes. Thereafter, the corrosion rate decreased as the temperature decreased. The filter activity stopped rising at 1500 mr/hr, when the temperature dropped down to 220 C. The fuel element was discharged into the 242-B Basin for examination and weighing. Weight loss was 12 grams; the rupture consisted of a single raised and torn mound, about 3/4" in diameter.

These N-Reactor outer fuel elements were the first to be handled in the 242-B Basin facilities. The facilities worked satisfactorily for underwater loading and unloading of casks, canning ruptured elements, examination and weighing.

Decontamination of the loop was performed after backflushing the filter (backflushing reduced the filter activity from 1500 mr/hr to 310 mr/hr). A single decontamination solution, peroxide-peracetic-oxalate, reduced the filter activity to 60 mr/hr after 30 minutes at 35 C.

2. Corrosion and Water Quality Studies

Continuous In-Reactor Corrosion Measurement. Probes for continuous measurement of aluminum and steel corrosion were installed in the outlet ends of in-reactor channels at the 1706 Single-Pass Facilities SP-5, 6, X, and Y (currently evaluating quachrom glucosate inhibitor). Corrosion is measured indirectly by change in electrical resistance of wire specimens. Recording instrumentation installed on these probes provides a continuous record of corrosion during both reactor operating and shutdown periods. Measurements from these probes show the periods of relatively rapid corrosion rate as reactor coolant temperatures increase during startup or decrease during shutdown. Typical measurements from one probe during this initial exposure showed a penetration of 1.40 ± 0.10 microinches in a one-hour period just prior to reactor shutdown, and 0.80 ± 0.11 microinch in the next hour (immediately after shutdown). These measurements correspond to corrosion rates of 1.01 ± 0.07 mils per month, and 0.58 ± 0.08 mil per month, respectively, during these one-hour periods. Coupon samples are in place immediately upstream from each of these probes.

Anodized Aluminum Nozzles. Six types of anodized aluminum (candidates for color identification of special reactor nozzles) have been exposed eight days in cold process water and six days in 90 C process water without showing visible corrosion. A seventh coating (sulfuric acid anodized-chromic acid) showed nearly complete color fading.

High Velocity Corrosion Effects. X-8001 and X-8003 aluminum coupons were discharged from the high velocity test section after 12 days of exposure to 95 C process water at a bulk velocity of 42 fps. The coupons were coated with a uniform brown film. After removal of the film, visible erosion, corrosion effects were discernible, particularly on the X-8003 alloy. The quantitative results were as follows:

Aluminum Alloy	Penetration (mils)	Film Buildup (mg/cm^2)
X-8001	0.72	3.3
X-8003	0.66	3.1

Other coupons of these alloys remain in the operating facility and will be discharged after longer exposures.

A variable velocity coupon holder was placed in the system during September. The X-8001 aluminum specimens are subject to a linear velocity gradient from 16 fps to 42 fps over a length of five inches.

N-Reactor Steam Generators. Tests are continuing to determine if the fumes given off from charred purge balloons and charred or uncharred vapor phase inhibitor (VPI) will cause stress-corrosion cracking at room temperature or at elevated temperatures. To date, no cracking has occurred after $2\frac{1}{2}$ months of exposure at room temperature to uncharred VPI or after $1\frac{1}{2}$ months to specimens exposed to charred purge balloon or VPI vapors.

Tests were run to determine if localized carbon pickup in the steam generator tubing could have been a factor in the intergranular attack. Samples containing residual amounts of several types of lubricants were heat-treated at 1150 F and then exposed to a Huey test. There was no increased corrosion at the areas contaminated with the lubricants.

Passivation of Carbon Steel with Tri-Sodium Phosphate. Laboratory tests on the passivation properties of tri-sodium phosphate on carbon steel have shown that complete passivation is maintained in air for about one week. Passivation in a 0.5% TSP solution was

maintained for an entire month, at which time the test was concluded. There was no waterline pitting on the samples exposed half immersed in the TSP solution and half in air. Waterline pitting was found on samples removed from the TSP, and then exposed half immersed in tap water and half in air.

Examination of the N-Reactor primary piping two weeks after flushing with a TSP solution has revealed only a few spots less than 1/8" in diameter of very thin surface rust.

Development of Crud Detector Elements. A series of in-reactor tests is being conducted to determine the feasibility of using ammoniated coolant for pH control in the N-Reactor primary system rather than lithiated coolant. One of the major unknowns with ammonia pH control is the rate of crud deposition on fuel elements during the irradiation. The most direct, available method for measuring crud deposition rates is to measure the change of metal surface temperature with a thermocouple fuel element or crud detector. To avoid previous deficiencies in crud detectors which resulted in early failures, a new design was prepared by packing enriched UO_2 powder to 65% theoretical density in a stainless steel can, welding, attaching thermocouples, slip-fitting into a Zr-2 jacket and attaching supports. Each element had three stainless steel thermocouples located about the periphery of the stainless steel can.

Two of the new crud detectors were charged into K-1 Loop, one element was placed in the front and one in the rear of the charge. This is the first time that two thermocouple elements have been charged into a single reactor tube. On startup, all eight thermocouples were operating, although two seemed to give abnormally high readings. The reactor was shut down twice after very short operating periods and resumed operation after minimum outages. These power fluctuations did not adversely affect the operation of the crud detectors.

Evaluation of Ammoniated Coolant. Operation of the K-1 Loop at pH 10 with ammoniated coolant was resumed when the reactor tube outage was completed. The loop charge includes heater elements, and upstream and downstream instrumented crud detectors.

Ex-reactor operation of the loop was resumed two days prior to startup of the reactor to investigate the effects of the extended wet layup period with ammoniated coolant. Prior to startup of the pumps, the loop coolant was very clear, with no indication of solids in the samples. Within 30 minutes of pump startup, the solids (principally magnetite) concentration increased to a high level. Evidently, the magnetite film on the piping did not retain its adherent characteristics during the

extended wet layup period with ammoniated coolant. A different layup treatment procedure will be required to minimize this problem.

The process tube was flushed with high purity, ammoniated coolant to remove process water before the loop resumed in-reactor operation. In-reactor recirculation was resumed about 24 hours prior to reactor startup, and the coolant quality was within the limits considered normal for ammoniated coolants at startup.

Operation of the loop since startup has been sporadic due to reactor operating problems. Three separate operating periods of approximately 1, 2, and $2\frac{1}{2}$ days duration have been experienced to date. Of special interest is the fact that even with the frequent temperature transients encountered, no problems were encountered with high solids concentrations or pH control in the coolant. An improved sampling system was used for these tests to obtain more representative samples of the actual coolant stream than those collected previously. The ammonium hydroxide injection system was also modified to prevent loss of ammonia to the atmosphere. This change has resulted in better control of the ammonia (and pH) in the coolant.

Formation of H_2O_2. Hydrogen peroxide is formed as an intermediate product during radiolysis of aqueous coolant streams. When radiolysis is significant, peroxide concentrations of 5-15 ppm may be encountered in the coolant. Tests were conducted to determine the amount of interference encountered in the manual procedure for dissolved oxygen measurement as a function of the peroxide concentration. The results confirmed that peroxide does interfere and indicated an interference factor (ppm O_2/ppm H_2O_2) of 0.42-0.45 compared to a predicted value of 0.47 based on decomposition of peroxide to water and oxygen. The discrepancy between observed and predicted values is attributed to problems involved in preparing accurate peroxide standards in the oxygen analysis equipment, and to operator error in analysis. The predicted interference factor is considered accurate for analysis of sample streams containing peroxide. Tests are now in progress to determine the extent of peroxide interference with the continuous analyzers that will be used for oxygen measurement at N-Reactor.

In-Reactor Capsule Irradiation of Lithium-Aluminum Target Alloy. Rates of tritium evolution from irradiated aluminum-lithium alloys were determined by withdrawal of helium-tritium gas mixtures from an in-reactor capsule; tritium concentrations were determined by mass spectrometer analysis.

Tritium evolution rates at temperatures between 500 C and 390 C indicate an activation energy of 44 kcal for the process. This activation

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energy is slightly higher than the range of activation energies reported for hydrogen permeation of aluminum. On the other hand, the activation energy reported in DP-743 for ex-reactor tritium outgassing of Al-Li alloys is 140 kcal. This extremely high apparent temperature coefficient probably results from swelling and fissuring at the high temperatures of the duPont outgassing experiments. The value of 44 kcal is more likely to be typical of evolution rates at relatively low temperatures (200-400 C) where swelling effects are apparently less than 1% (DP-744).

A second capsule has been fabricated and will be charged on the next reactor outage, probably near the first of October 1963. The second capsule has provisions for water cooling and has two sets of heating coils. After suitable irradiation, tritium outgassing rates will be measured at controlled temperatures with and without the reactor in operation to study the effect of radiation on tritium evolution rates.

Erosion-Corrosion of Aluminum Alloys. Studies of accelerated aluminum corrosion are being conducted at relatively low temperatures (90-95 C; 194-203 F) in deionized, reactor process, and 300 Area sanitary waters. Four-inch diameter aluminum disks are rotated in water at peripheral speeds up to 90 ft/sec. In 72-hour tests at pH 8.5-9, an attack occurs in 300 Area water which strongly resembles groove pitting observed on aluminum in-reactor. The attack produces groove pits near the periphery of the disk; the attack becomes less pronounced toward the center of the disk as the effective velocity decreases. Addition of 1.8 ppm sodium dichromate did not prevent the pitting attack in 300 Area water. Rotational speeds up to 75 ft/sec in deionized water and deionized water with 10 ppm chloride ion failed to initiate pitting attack. Pitting also did not occur in a single run in reactor process water. The pH rose from 6.8 to 8.4 during the run, due to water losses from the tank, which apparently caused scaling. A series of runs are now under way to investigate the effect of pH on the initiation of pitting. Carbon dioxide is used for pH adjustment. Pitting did not occur during 72-hour runs at pH 6.7-6.9 and 7.5-7.7. Increasing the peripheral speed from 75 to 90 ft/sec at pH 6.7-6.9 did not initiate pitting in a 72-hour test. The groove pitting attack seems to be associated with combined effects of sample velocity and water chemistry, with pH being the most important single chemical parameter. To date, the results of the test point to possible local increases in pH as a contributor to in-reactor initiation of groove pits.

Corrosion of Aluminum in Neutral Deionized Water. An experiment was run to determine the effect of oxygen content in high temperature water on the oxidation of two aluminum alloys, X-8001 and KYZ. Coupons were exposed for two, seven, and 30 days in a 350 C (662 F)

static autoclave. No effect of oxygen on corrosion was observed.

3. Gas-Atmosphere Studies

Graphite Burnout Monitoring. About the middle of July, B-Reactor began operation under a test authorization which permitted partial replacement of helium with carbon dioxide and an increase in graphite temperatures (HW-77827). The purpose of the test was to demonstrate reduction in He losses (which amounted to about 1.8 million dollars last year (HW-74705)), without significantly increasing graphite burnout rates.

At the start of this production test the usual burnout monitoring channel, 3461, and a new channel, 1081, were charged with small TSGBF graphite monitors. The reactor stack itself is composed of KC-type graphite which is less pure and oxidizes about 1.2 to 3 times as fast according to laboratory tests.

The monitors showed very low burnout rates - the highest measured rate was about 0.5%/KOD (viz., per 1000 operating days), on the basis of KC-type graphite. Moreover, there was no peak near 80 inches into the stack, indicating no air in-leakage during the test. There were some weight gains of monitors in the end of channels, a fact previously interpreted as due to the disproportionation of CO.

During most of the test the CO_2 concentration in the reactor gas was about 40%. During the last three days it was greater than 60%. Helium losses were reduced about one-third, the improvement attributable entirely to the change in gas composition.

Monitors were also discharged and replaced in channel 3580 at F-Reactor. For the period from January 29 to August 5, 1963, the highest burnout rate was about 0.4%/KOD.

Kinetics of the Reaction of Carbon Dioxide and Hydrogen at 840 C. Study of the kinetics of the reaction of carbon dioxide and hydrogen has continued. In recent work the rate was found to vary linearly with the first power of the CO_2 concentration leading to the following complete rate expression when CO and H_2O concentrations are small

$$\frac{d(H_2O)}{dt} = \frac{d(CO)}{dt} = k(CO_2)\,(H_2)^{1/2}.$$

The specific rate constant based upon 16 runs at 840 C is 4.0×10^{-2} liters$^{1/2}$ moles$^{-1/2}$ sec^{-1} with an average deviation of ± 10%.

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The rate expression is in agreement with published results (Graven and Long, J. Am. Chem. Soc., 76, 2026, 1954), but the rate constant is lower by a factor of three.

Effect of Precipitated Hydride on Hydrogen Absorption of Zircaloy-2. The August 1963 Monthly Report reported that the rate of hydrogen absorption of Zircaloy-2 during corrosion in 400 C (752 F), 1500 psi steam was only slightly affected by an initial hydrogen content of 410 ppm. Metallography of samples corroded for 294 days showed the additional 234 ppm hydrogen added during corrosion (655 ppm total) was uniformly distributed throughout the sample with no layers detected under the oxide.

4. Process Tube Development

Tube Burst Studies. Brittle fracture tests have been performed at room temperature on N-Reactor pressure tube sections containing milled slots up to one and one-half inches in length and 80% through the wall thickness. The stress at which fracture occurs decreases with increasing crack length, being 100,000 psi at one-half inch; 91,000 psi at 5/8 inch; 80,000 psi at 0.81 inch; 71,500 psi at one inch; and 55,000 psi at one and one-half inches. The lowest of these values is more than six times the proposed reactor operating stress.

Speed of crack propagation was measured by an electronic method on one of the tests in the series mentioned above. Copper wires 0.022-inch in diameter were cemented to the tube wall at one-inch intervals across the path to be followed by the crack. The wires were connected to a circuit network in such a way that as they were successively broken by the advancing crack they produced a pulse on an oscilloscope screen. Spacing of the pulses indicated the velocity of the moving crack tip to be 2750 ft/sec, comparing well with a value of 2100 ft/sec reported earlier as measured by high speed photography.

Stress-Rupture Facility. This facility has continued to operate at capacity during the past month. New over-temperature shutdown instrumentations have been installed to prevent the loss of tests when a malfunction in the temperature control occurs. A new series of tests upon the stainless steam generator tubes for the N-Reactor was begun. To date, 25 sections of this tubing with flaws in excess of 80% of the wall thickness have each undergone 232 hours at 300 psi internal pressure and 300 C (572 F). No measurable dimensional changes have occurred in these specimens. Twelve samples were burst-tested at elevated temperatures.

5. Thermal Hydraulic Studies

N-Reactor Studies. Experiments were continued in the heat transfer laboratory to investigate the pressure drop at the entrance to the N-Reactor rear nozzles as affected by the orientation of the spacer pieces. Since the spacer pieces have holes between the annular and inside flow channels, the angular position of the most downstream spacer piece determines the degree of alignment of holes in the spacer piece with the flow channel in the exit of the rear nozzle. Previous experiments by Equipment Development, IPD, showed that when holes in the spacer piece were in line with the nozzle exit, the pressure drop was considerably less than when these flow passages were not in line. As a result, the spacer pieces were modified by drilling additional holes to allow better chances of alignment of flow passages.

Results of experiments showed the variation in pressure drop with angular position to be much less for the modified spacers than for the original spacers. However, the pressure drops with the modified spacers were approximately equal to those for the original spacers in their most restrictive position. For example, at a flow of 200 gpm the pressure drops with the modified spacers ranged from 9.3 to 10.2 psi, compared with 7.4 to 10.4 psi with the unmodified spacers.

It was noted that these pressure drops were substantially lower than those obtained in the Equipment Development loop with unmodified spacers. In the Equipment Development loop at 100 F and 200 gpm, the pressure drop at the outlet nozzle ranged from 11.2 to 16.3 psi. Thus far, the difference in results from the two experimental loops has not been explained.

Outlet nozzle pressure drop measurements were also made with a different type of spacer in the outlet nozzle. This spacer consisted of 2-inch long sections from the ends of a normal spacer separated by a centered 15-inch length of 1/2-inch pipe. Outlet nozzle pressure drops using this spacer were about 55% less than those obtained with the modified spacers.

Heat transfer experiments were started with a full scale electrically-heated model of a half column of N-Reactor fuel elements to determine various thermal hydraulic characteristics of the N-Reactor. One hundred and twenty-three sets of measurements were made to determine the pressure drop-flow relations of the fuel train and hydraulic connectors during heat generating conditions. Data were taken at 1200 psig for heat generation rates of 2600, 2500, 2250, 2000, 1500 and 1000 kw

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with outlet conditions ranging from 8% steam by weight at 2600 kw to 30% at 1000 kw. Data were also taken at 850 psig for heat generation rates of 2000, 1500, 1000, and 500 kw with outlet conditions ranging from 11% steam by weight at 2000 kw to 35% at 500 kw.

The test section used in the experiments consisted of a heater rod of N-Reactor geometry, together with prototypical outlet piping beginning with the downstream spacer charge and continuing to the outlet riser. The heater rod is a tube-in-tube element of the following dimensions:

Outer tube	OD	2.390 inches
	ID	1.775 "
Inner tube	OD	1.220 "
	ID	0.440 "

The active length of the heater rod is 17.5 feet and is made up of materials of various resistivities to represent the cosine power distribution of the downstream half of an N-Reactor fuel column. The heater rod is housed in a 2.70-inch ID pressure tube. Ceramic supports attached to the inner and outer tubes in the same pattern as the actual fuel supports serve both to support the heater rod and electrically insulate it from the pressure tube. Flow to each of the three flow channels is separately controlled and measured, and since there is no inner junction flow between the channels, the flow remains separate until it recombines upstream of the downstream spacer charge. Pressure taps at each end of the heater rod active section permit the pressure drop of each channel to be measured. The heater rod is instrumented with 16 thermocouples equally divided between the inner and outer tubes. Half of the thermocouples are located at the outer surface of the tube and the other half are located at the "adiabatic" radius of the tube.

The piping downstream of the heater rod consists of a length of 2.70-inch ID pipe containing the support charge of two short and four long supports, an N-Reactor nozzle, a 47-foot run of connector piping, and a diversion valve discharging into a 4-inch riser. Pressure taps are located along the piping system to provide pressure drop measurements across selected components.

Burnout indications were not observed at any of the 1200 psig operating conditions. However, at 850 psig, a flow instability in the hole channel of the heater rod was observed at a condition of 1500 kilowatts and an outlet quality of 21%. This flow instability had the magnitude of a 50% swing-in flow and a 100% swing-in

pressure drop across the hole channel. A thermocouple located at the "adiabatic" radius between the inner and outer surface of the inner tube had a swing of 40 F.

No detailed analyses of the experimental results have been made as yet. However, a preliminary examination of the data indicates that at 1200 psig the increase in riser-to-riser pressure drop due to boiling during a flow reduction at constant tube power would be less than calculated. At 30% outlet quality, the estimated riser-to-riser pressure drop was less than 10% greater than at zero quality, and well below the pressure drop at normal operating flows. Under these conditions, flow instability should not occur.

Hydraulic Tests of Spline Insert Modifications. In recent months a number of scrams in the present production reactors have resulted from failure of the poison splines used in individual tubes for reactor physics purposes. These failures were attributed to fatigue failure from vibrations induced by the high velocity water stream entering the nozzle and impinging on the spline. The nozzle cap inserts have been redesigned to allow greater support and protection of the poison spline and thus reduce the vibration and the number of spline failures in the region of the front nozzle.

Hydraulic tests were conducted to determine pressure drop relations for the redesigned nozzle insert when used in a new K-Reactor nozzle of the extruded type which has a perforated plate over the nozzle inlet port. (The perforated plate design was intended for use in nozzles on nonribbed tubes which would be charged with self-supported fuel.) The test results show that the new tapered insert has slightly lower pressure losses than the old blunt shape insert which did not support the poison spline in the critical area.

Further tests were conducted to determine the effect of not perforating a portion of the perforated plate insert in the extruded nozzle. This nonperforated portion would protect the poison spline from the high velocity water where it enters the nozzle. Use of a perf plate with a blanked portion did result in increased pressure losses across the front nozzle. Quantitative results of these tests are presented in HW-78883.

6. Shielding Studies

MAC Code Cross Sections. The 31 group MAC cross section library is completed except for the removal cross section compilation. These cross-sections are currently being calculated. A 15 group MAC library has been set up, and calculation of these group cross sections

[redacted] [redacted]

are well under way. The group structure consists of 13 equal groups of lethargy width 1.15, a 14th group of lethargy width 2.30, and a thermal group. A report is being written to explain the origin and use of these cross section libraries.

N-Reactor Shield Experiment Preparation. Equipment required to perform the evaluation of the N-Reactor primary shield is being tested in the exponential pile laboratory. The majority of testing time to date has been spent with the He^3 neutron spectral analysis system. The He^3 detector has been operated satisfactorily with noncoincidence electronics, however, without sufficient resolution for actual spectral measurements. A coincidence pulse analysis system is being set up to improve the detector resolution. Currently, this system is being adjusted for pulse shapes and delay time to allow proper processing of the detector pulses.

Other work being accomplished in support of the N-Reactor shield evaluation includes: planning the experiments in detail; designing apparatus to facilitate placement of foils and detectors in the reflector; working out details for placement of experimental equipment and for cable access through the biological shield and containment; and calculating foil and detector exposure required to obtain desired experimental results.

7. Graphite Studies

N-Reactor Graphite Irradiations. The two third-generation capsules, H-4-3, in the series of long-term irradiations of N-Reactor graphite continue to operate satisfactorily in the GETR. The third-generation capsule, H-6-3, has been constructed and will replace H-4-3 in the reactor during the cycle 48 shutdown the last week in September.

B. WEAPONS - 03 PROGRAM

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

C. REACTOR DEVELOPMENT - 04 PROGRAM

1. Plutonium Recycle Program

Fuels Development

Remote Fabrication Studies. In cooperation with Chemical Development personnel, a product container was designed for salt cycle UO_2. Four product cans were built to fit the three-ton Radiometallurgy transfer cask. Each product can will hold approximately 20 pounds of UO_2.

A new plier-type resistance welder was used to join two pieces of wire end to end by spot welding a sheath first to one wire and then to the other, using current of approximately 1600 amperes.

Wire Enriched Fuel Element. A four-rod cluster fuel element (GEH-4-88) containing natural UO_2 pellets enriched with a coaxial Pu-15 w/o Zr alloy wire was fabricated and shipped to the NRTS for irradiation. This novel enrichment scheme reduces the complexity of the fabrication process for a plutonium-containing fuel element since the plutonium enrichment can be added immediately prior to making the final end closure. Data obtained from this test will be applicable to the investigation of heterogeneously enriched fuels, and to fuel element rejuvenation studies.

Fuel Element Design Studies. The UO_2-Mark I fuel element with ring-type end brackets designed to reduce fretting corrosion has now accumulated 184 days of exposure in the TF-7 loop facility operated at PRTR coolant conditions. No process tube wear and only superficial wear of the bottom end bracket has occurred during this time. The excellent performance of this end bracket design warrants tests in the PRTR.

Cladding Alloy Procurement. Submitted bids are being evaluated for the procurement of Zr-2 tubes for the fabrication of Mark II, PRTR nested tubular fuel elements.

PRTR Fuel Element Fabrication. Three-hundred-eight kg of UO_2 - 1 w/o PuO_2 was impacted for PRTR fuel elements. Three-fourths of the material was crushed to size fractions suitable for vibrationally compacted rods; the remaining material was further crushed to make swage compacted rods. The impacted UO_2-PuO_2 mixture is easier to decontaminate than the mechanically mixed UO_2-PuO_2. The homogeneity of the plutonium distribution is apparent in gamma scan traces of the fuel rods, which show no variation in plutonium distribution.

Seventy-six PRTR fuel rods, containing UO_2 - 1 w/o PuO_2 Nupac core material, were fabricated by vibrational compaction. Seven of these rods which did not meet density specifications were reclaimed, either by decontaminating the rod and adding additional core material, or removing the core material, adding additional core material and refabricating in a new fuel tube.

Two slightly different designs of 4-inch double wall impaction cans were made by scaling-up the 2½-inch diameter, double wall cans currently being used for the impaction of PuO_2-UO_2 ceramics. One design utilizes the same inner and outer wall thicknesses as for the 2½-inch cans (25 mil and 1/16-inch, respectively); the other involves 1/16-inch walls for both inner and outer cans. Six of these cans were impacted with loadings of uranium dioxide, and are now being examined to determine whether design modifications will be required.

ThO_2-PuO_2 Fuel Irradiations. Twenty capsules containing hydrogen-sintered ThO_2-PuO_2 fuel pellets (0.50-inch diameter, 96% of theoretical density) were fabricated and sent to the MTR/ETR for irradiation. ThO_2-PuO_2 fuel is of interest for the production of U-233 in crossed progeny thermal reactor fuel cycles, and of the isotopic heat source Cm-244. The irradiation performance of five different fuel compositions will be evaluated under various conditions. Maximum fuel temperatures will be above melting (2600 C). The requested irradiation conditions are summarized as follows:

Fuel Composition (w/o)	Power Generation w/cm	(kw/ft)	Surface Heat Flux w/cm²	(Btu/hr-ft²)	Calc. Max. Center Temp. (°C)
ThO_2-2.23 PuO_2	556	(17)	120	(390,000)	1850
	720	(22)	158	(500,000)	2650
ThO_2-5.47 PuO_2	590	(18)	130	(410,000)	1850
	750	(23)	167	(530,000)	2600
ThO_2-8.80 PuO_2	655	(20)	145	(460,000)	1800
	850	(26)	190	(600,000)	2600
ThO_2-14.74 PuO_2	720	(22)	158	(500,000)	1750
	985	(30)	218	(690,000)	2600
ThO_2-18.48 PuO_2	850	(26)	190	(600,000)	1850
	1180	(36)	260	(825,000)	2750

The high thermal neutron absorption cross-section of plutonium causes a variation in the flux depression which depends upon the PuO_2 concentration. For example, the specific heat generation rate at the surface of the ThO_2-18.48 w/o PuO_2 will be approximately 10 times greater than at the center line. This radial specific power variation alters the temperature profile for samples with different PuO_2 concentrations. Radial temperature profiles were computed on an IBM-7090 digital computer using the CHEAT code. The effect of PuO_2 concentration on the relation between rod power and center line fuel temperature is illustrated in the table. For example, a rod power generation of 720 w/cm produces a maximum core temperature of 2650 C in a ThO_2-2.23 w/o PuO_2 sample, while 1180 w/cm is required to produce a comparable center temperature in the ThO_2-18.48 w/o PuO_2 samples.

Post-Irradiation Examination of PRTR Fuel Elements. Two swage-compacted UO_2-Mark I fuel elements were examined in the Fuel Element Examination Facility. Other than the usual minor scratches and clinging particulates, Fuel Element 1024 (3700 MWD/T) appeared to be in excellent condition and will be recharged into the PRTR. The spiral bundle wrap and some of the rod wire wraps on Element 1049 (3950 MWD/T) were severely worn at points of contact with the process tubes. Wear was more severe near the ends of the element, and some of the wires were worn approximately one-half of their diameter (0.070 inch). Other than the worn wires, there was no obvious reason why this particular element should have behaved in an abnormal manner and caused excessive process tube wear. It will not be recharged without repair.

High fission product activity was detected in the PRTR primary coolant during depressurization following a 10-day continuous operating period. Failure of a new vibrationally compacted, Mark I, UO_2-1 w/o PuO_2 element (Fuel Element 5203 with 200 MWD/T) containing impacted fuel material was indicated by streams of gas bubbles issuing from the top end cap regions of seven of the 19 fuel rods. There were no fuel failure indications until four hours after shutdown of the reactor; however, external coolant pressure may have prevented the escape of fission gases since there were no reactor power fluctuations to cause gas bursts. Corrosion, cracking, and embrittlement of the cladding in the heat affected zone of the end caps appear similar to those seen in a previously failed element (5174). The previous failures were characterized by internal corrosion of the Zircaloy in the crevice between the end cap and the cladding tube. Traces of water on the UO_2 particles and of fluoride on the Zircaloy components are suspected as the cause of failure. Swaged elements have not failed; it is believed that the end cap

design of these elements may make the difference. There is no crevice as there is between the end plug and cladding of vibrationally compacted elements.

Corrosion and Water Quality Studies

Concentration of Zirconium in Primary Coolant. The program to monitor routinely the total zirconium concentration in the PRTR primary coolant was continued. Grab samples were collected and emission spectrographic techniques were then used to obtain the analytical data.

The analytical results obtained indicate the zirconium concentration was generally within the 0-1 ppb range considered normal for this system. On one occasion the concentration increased abruptly to > 10 ppb and remained high for three days. This high concentration occurred during startup operations following an extended outage and may have resulted from charge-discharge and/or tube inspection work.

The analytical technique was improved by completely evaporating the acidified heavy water to dryness instead of to 1 milliliter. This results in increased emission intensities for both zirconium and the indium standard.

Development of Continuous Zirconium Monitoring Procedure. Investigation of the continuous spectrophotometric procedure (using Arsenazo as the indicator) for measurement of ionic zirconium concentrations in water was continued. The results indicate the procedure is satisfactory for routine laboratory analysis of concentrations as low as 10 ppb with a reproducibility of ± 15%. At present, the procedure is not satisfactory for continuous operation, however, due to hydrolysis and/or adsorption of the zirconium in the standard solutions which results in a continuous decrease in the concentration with time.

Fretting Corrosion Studies. Fretting corrosion studies on a PRTR element with a 360° ring support have indicated only superficial fretting will occur between the supports and the pressure tube based on tests in TF-7 for 192 days at PRTR conditions. Fretting still occurs between the individual rod wire wraps and the pressure tube, however. To date, several locations on the wire wrap have worn up to 50% of the diameter. These tests are being conducted with induced vibration.

PRTR Corrosion Studies. Portions of the exterior area of three PRTR shroud tubes have been examined by borescope. The tubes are covered with a thin uniform oxide layer with no evidence of severe attack in either the water or gas covered areas of the tubes.

The lower six inches of the top shield is covered by a heavy layer of red rust. No evidence of localized corrosion was seen. The thickness of the rust layer could not be determined.

Examination of the stainless steel cone assembly from the interior of the PRTR feedwater deaerator (secondary system) revealed extensive cracking and failure. Cracks were predominantly associated with the metal immediately adjacent to the weld beads. Metallurgical examination of failed surfaces showed a single major crack with minute amounts of side branching. The extent of cracking and the amount of branching were less than is generally seen in stress corrosion cracking of austenitic stainless steels. The probable mechanism of failure was corrosion fatigue possibly accelerated by a few stress corrosion cracks.

It has not been possible to adjust the pH-phosphate relationship in the PRTR boiler while using disodium phosphate additions. This is an undesirable situation since it poses the possibility of caustic corrosion cracking in areas where the caustic could be concentrated. One possible solution to this problem is the use of monosodium phosphate addition. Since this chemical makes a more acid solution, it is necessary to determine the effect it will have on the chemical addition piping.

A test is being run on stressed stainless steel coupons to determine the corrosion rate and stress corrosion cracking susceptibility of stainless steel in an NaH_2PO_4 solution of PRTR addition concentration (one-half pound/gal). Chloride is being added to the solution in the amount required to simulate the chloride concentration in technical grade NaH_2PO_4 (700 ppm in the phosphate). The test is being conducted in a static autoclave at 275 C. The samples show a rough, etched surface, but the corrosion after 250 hours of exposure appears relatively uniform. After a high initial weight gain (145 mg/dm^2 in 12 hours), the samples have shown low weight gains. No samples have yet been stripped to determine the relationship between weight gain and metal penetration.

Reactor Components Development

PRTR Pressure Tubes. Using underwater handling techniques at the PRTR storage basin, PRTR pressure tube number 6115 has been cut into 10 pieces. One of these will be burst-tested as soon as possible to determine the hazard potential of flaws on the inside surface.

This tube is the eleventh selected for destructive examination for the PRTR pressure tube surveillance program. It was discharged upon completion of a reactor operating month after the tenth tube was removed.

Selection of tube 6115, from channel 1358, was made from a group of seven candidates. Each candidate had flaws 10 mils or more deep. At the most recent in-reactor monitoring, tube 6115 was reported to have two flaws - one 12 mils deep and one greater than 20 mils deep at approximately 11 feet, 5 inches from the flanged end. It is these flaws which will be evaluated by the forthcoming burst test.

The bursting properties of unirradiated cold-worked PRTR pressure tubes have been measured at room temperature, 149 C (300 F), and 316 C (600 F). The values of ultimate hoop strength and hoop elongation obtained were compared with similar values for K- and N-Reactor Zircaloy-2 pressure tubes. The ultimate hoop strength of the PRTR material at the lower temperatures was the same as the ultimate hoop strength of the K and N material, but at the higher temperatures the PRTR material strength was about 6% greater than the strength of the K and N material. Ninety-three Centigrade (200 F) is the temperature at which the PRTR material became noticeably stronger. Fifty-one Centigrade (125 F) is the temperature at which the PRTR material became noticeably less plastic than the K and N material. The elongation of the PRTR material varied from 11% at room temperature to a maximum of 17% at 121 C (250 F) and then to 8% at 316 C (600 F). The maximum elongation of the K and N material was about 22% at 121 C (250 F).

Pressure Tube Monitoring. Fifteen process tubes were visually examined this month. While all of the process tubes inspected this time exhibited new areas of fretting corrosion, none of the fretted areas was severely deep. Two of the tubes examined this month exhibited large numbers (approximately 20) of fretted areas at both the upper and lower fuel element support locations. In these two process tubes the fretted areas are approaching about 30% to 40% of the circumferential area of the tube at the upper and lower fuel element locations.

The tube in process channel 1348 was again inspected this month to confirm the presence of blister type defects in this tube. This examination disclosed three defected areas of which two were known to exist from previous examinations. The severity of these defects, one of which was at least 20 mils deep, was deemed a sufficient basis for removal at this outage and subsequent destructive examination.

Shim Rod Development. The use of permanent magnets to stop uncontrolled coasting of the single control element in the revised first generation (Mark-I-A) PRTR shim assembly was successfully demonstrated in the environmental test facility. The advantage of the magnetic brake is its relative ease of installation on the as-built shims.

Fretting Corrosion Investigation. No fretting was visually detected in a PRTR pressure tube (being tested in EDEL-I facility) after 52 hours of prototypical service using an old style (narrow pad) urania fuel element. Continued vibration measurements were made under several conditions. A frequency of 16 cps with an amplitude of 3-5 mils was measured at the center of the pressure tube with no fuel element at full flow. At the same point with the fuel element installed, the vibration was 34 cps with 0.3 to 0.5 mil amplitude.

Design Analysis

PRCF-EBWR Safety Studies. A preliminary evaluation of the time delay in the Doppler effect in mixed PuO_2-UO_2 fuels resulting from a heterogeneous distribution of plutonium was completed. Calculations are based on a simple conduction model in which it is assumed that heat is generated in a particle of PuO_2 residing at the center of a spherical domain of fuel. Particle sizes of 0.2, 0.15, 0.1, and 0.05 millimeter in diameter (which correspond to -70 to -325 mesh) are considered. Two values of enrichment, also investigated, are 1.5 and 3.0 w/o PuO_2.

The time constant for UO_2 heating and hence for the Doppler effect to be effective is found to be a strong function of the fuel diffusivity. For PRCF-EBWR fuel and using what appears to be reasonable values for the diffusivity, a time constant of about 10^{-3} second is obtained. This is short enough to assure an effective negative temperature coefficient for periods accidentally encountered less than prompt critical. The shortest credible period for the PRCF with EBWR fuel is calculated to be 0.2 second. However, additional refinement of these calculations and data are needed to evaluate possible prompt critical excursions, which may be credible for the EBWR. Additional experimental data on diffusivity and particle size distribution are being obtained for the EBWR fuel to compare the validity of the calculational model and the diffusivity values used. Subsequent calculations will include any changes needed in these factors, together with heat transfer by radiation and fission fragment deposition, which are neglected in the present study.

The above information was presented to the G.E. Technological Hazards Council this month. The council is expected to request analysis of the additional variables discussed above.

Thermal Hydraulics Studies

Work has been directed toward the solution of two problems associated with a possible power increase of the PRTR:

1. The ability for the primary system to be cooled by convection cooling after a complete loss of electrical power and a scram.

2. The pressure transient resulting from the loss of pumping power where the reactor would fail to scram until a high pressure trip is reached.

A review of the past calculations and pressure transient computer program was made with the thought of simplifying the calculation method.

Primary system convection cooling calculations have been made for the reactor operating at 106 Mw with coolant flows of 9,000 and 11,500 gpm. Inlet and outlet temperatures were set to give a 5 F margin below boiling in the hot tube with a 10% reduced flow at steady state. During the pump coast-down a constant reactor inlet temperature was assumed and the inlet temperature was that of the heat exchanger steam during the convective cooling. A pump coast-down curve was used which complied with the minimum PRTR process specifications. In both cases boiling should not occur as more than a 10 F margin below boiling exists for the hot tube at the worst time (65 sec) during the transient. The case of the smaller flow has a higher margin. More detailed calculations will be made when operating parameters have been fixed more firmly.

Review of the method of calculation for the pressure transient indicated that a simpler and more direct method of calculation would be desirable. The equations for an approximate thermodynamic model have been derived to give the time rate of change of system pressure. The model assumes that the pressure increase is the same everywhere in a constant volume system which consists of the volume of the entire primary coolant before the transient. The only mass transfer out of the system is that discharged from the pressurizer safety relief valves. The subsystems include the subcooled liquid, saturated liquid and saturated vapor. The model is applicable only for the first part of the transient, but this is sufficient time to obtain the peak pressure. Numerical work is yet to be done to check the prediction of this model with previous calculations.

2. Plutonium Ceramic Fuels Research

Preparation of PuO_2-SS Cermets. PuO_2-SS cermet (26 w/o PuO_2) was fabricated by pneumatic impaction with a density 97.5% of theoretical. Photomicrographs revealed that the -60 +200 mesh PuO_2 particles were uniformly dispersed throughout the continuous, crack-free stainless steel matrix. Autoradiographs of the PuO_2-SS cermet verified the uniformity of PuO_2 dispersion. No evidence of reaction between PuO_2 and stainless steel was observed.

The latest modification of a split die for impacting cermet pellets was successfully tested. Six 97.5% TD UO_2-SS pellets were made in a die that had been flame sprayed with Al_2O_3. The die was easily opened, and the six pellets remained intact. The one-inch long pellets were ground to a finished diameter of 0.481 inch.

Beta-Pu_2O_3 Compatibility. Equimolar mixtures of beta-Pu_2O_3 powder and each of several refractory metal powders (W, Mo, Ta, Nb, V, Hf, and Re) were pressed and sintered for 24 hours in helium at 1650 ± 50 C. Visual observations indicated the only incompatible pairs were those containing rhenium and hafnium. More definite conclusions will be drawn after completion of metallographic and x-ray analyses.

Irradiation of Plutonium Carbide. A specimen of fused PuC (GEH-14-408) irradiated for 41.8 days to an estimated average exposure of 1.5×10^{20} fissions/cc (36,500 MWD/T_{Pu}), released 22% of the fission gases. The 0.450 gram sample fractured extensively during irradiation, principally at the grain boundaries.

3. Ceramic (Uranium) Fuel Research

Short-Term Irradiation of Cermet Fuels. The third in a series of tungsten-50 w/o UO_2 cermets was successfully irradiated four hours to study the dimensional and chemical stability of the system. Cladding temperature was greater than 2000 C.

Examination of two previously irradiated tungsten-50 w/o UO_2 cermet capsules was completed. Metallographic examination showed the tungsten clad cermets were chemically and dimensionally stable. Autoradiographs show a uniform distribution of fission products in the cermet.

The first fuel specimen was clad in 0.063 cm (0.025 inch) wall tubing made by spark discharge machining of hot swaged tungsten rod of random grain structure. The second cermet was clad in 0.030 cm

(0.012 inch) wall tungsten tubing produced by vapor deposition, a process which produces tubing with a radially oriented, columnar grain structure. The thin wall 0.030 cm (0.012 inch) tubing developed a crack, probably because of differential thermal expansion of fuel and cladding. Minor fuel loss occurred through the crack. No defects were found in the other tungsten capsule.

Irradiation of Mo-UO_2 Cermet Fuel. A cladding temperature greater than 2500 C was attained during irradiation of a vacuum insulated, Mo-clad Mo-UO_2 cermet (GEH-14-416) in the ETR. Melting of the Mo cladding and of the continuous Mo phase in the cermet allowed egress of contained UO_2. Destructive examination revealed that nearly all of the released UO_2 was deposited dendritically on the outer surface of the Mo cladding near the point of penetration, while only a thin (~ 0.001 inch) UO_2 film was found on the inner surface of the outer, stainless steel can. The integrity of the stainless steel can was not compromised by the release of UO_2 from the inner cladding.

Irradiation of Tungsten-UO_2 Cermet Fuel Plate. A W-UO_2 cermet fuel plate was successfully irradiated four hours under conditions designed to allow a surface temperature greater than 3000 C (5500 F). The pneumatically impacted, tungsten clad plate (1" x 7/8" x 0.030"; 20 v/o 93% enriched UO_2 plus 80 v/o tungsten) was suspended inside an evacuated, gold-plated stainless steel sheath to attain the desired temperature. Initial post-irradiation examination showed that tantalum (melting point 2996 C), molybdenum, and niobium wires embedded in the thin plate had melted or otherwise disappeared. Minor loss of fuel was suggested by UO_2 dendrites deposited around the holes through which the temperature monitor wires were originally threaded. Otherwise, the fuel plate remained intact.

Beryllium Clad UO_2. Vibrational compaction equipment was isolated and modified for compaction of UO_2 into beryllium tubes supplied by CEN, France. Because of the possible brittleness of the beryllium cladding, bottom coupling to the tubes will be used. A special chuck to hold the beryllium tubes during vibrational compaction was designed and fabricated. A resistance heater was also installed, capable of bringing the vibrator chuck and beryllium cladding up to temperatures from 150 to 200 C, in case heating is necessary to avoid cracking.

End closure welds have been made on test pieces with the magnetic force welder. There was not sufficient test material to provide for establishment of parameters which would repetitively produce top quality welds. Metallographic examination of the latest welds indicate that the material from the sintered bar is more suitable

for magnetic force welding than the material from the arc cast bar. Recent dye penetrant examination of the four remaining tubes has shown that one tube has a crack about 3/4-inch long on the ID.

Burnable Poison Fuel. Two w/o and 10 w/o Sm_2O_3 in micronized UO_2 was pneumatically impacted. Samples were prepared for analysis of Sm_2O_3 distribution.

Materials and Information Exchange. Ten UO_2 single crystal specimens were prepared and characterized for Rice University, where they will be used in studies of reaction rates.

Electron Microscopy Studies of Cermets. A series of reactions occurring in a 50 w/o W-single crystal UO_2 cermet has been disclosed by reflection electron microscopy. Several different crystallizations and vaporization phenomena took place in both tungsten and UO_2 between 800 and 1900 C in vacuum.

Rapid reaction of UN with oxygen, without noticeable effect on the tungsten in a 50 w/o W-UN cermet, was demonstrated using a low pressure gas reaction device with reflection electron microscopy. Subsequent hydrogen treatment on the oxidized specimen caused no further change in either component.

Thermal Diffusivity Measurements. The thermal diffusivity of a single crystal UO_2 specimen was determined at temperatures from 700 to 1200 C, using pulsed energy from a ruby laser. Thermal conductivity values calculated from these data were in close agreement with previous results by other methods. Of particular interest in the curve is the confirmation of the peak in the thermal conductivity between 950 and 1050 C.

Compatibility Studies. A capsule has been designed for use in investigating the compatibility of salt cycle UO_2 with Zircaloy and other claddings. This capsule will be capable of reproducing the temperature and pressure conditions encountered in the PRTR.

the weld interface, but the tungsten cladding was not bonded. Some UO_2 in the immediate area of the joint appears to have vaporized, leaving small voids.

A cross was fabricated by welding one piece of tungsten clad, tungsten-UO_2 cermet to each side of a third piece. Initial attempts resulted in a 50% bond on one side only.

4. Basic Swelling Program

Irradiation Program. Two general swelling capsules are being successfully irradiated in a reactor at respective control temperatures of 500 and 575 C (932 and 1067 F). The tandemizing of two additional capsules was completed and the capsules were placed in a shipping box for transporting to the reactor. Two others have been completed and will be bench-tested shortly. Redesigned sample holders for two more capsules have been constructed which will accommodate specimens of varying size and shape. These capsules are about 10% complete.

Capsules recently constructed contain high purity uranium specimens of varying enrichment, size and shape as well as uranium containing Fe + Si and Fe + Al. Several heat treated conditions are represented.

Post-Irradiation Examination. Electron microscope examination of a uranium specimen irradiated to 0.2×10^{20} fissions/cc (0.03 a/o B.U.) at a temperature of 525 C (977 F) has been completed. This specimen was beta-quenched prior to irradiation. Extensive porosity has developed in one leg of the half cylinder obscuring the general microstructure. On the other half of the specimen porosity was observed to exist in patches. The individual pores are arranged in rows which are perpendicular to twin bands. Grains contained wide deformation twins which were essentially free of pores. Preferential porosity was not observed at grain boundaries. Many of the pores show a raised rim about their circumference similar to observations made several years ago on specimens annealed after irradiation. A nonirradiated uranium specimen was processed in the Radiometallurgy facility for metallographic comparison with irradiated specimens. The replicas of the specimen were examined in the electron microscope and no artifacts due to polishing or etching were noted.

Post-Irradiation Annealing. A systematic study of the swelling of high burnup, clad and declad uranium as a function of post-irradiation pulse annealing has continued. Replicas of the unclad wafers which had been annealed at 550 C (1022 F), 600 C (1112 F), and 650 C (1202 F) for one-half hour and an unclad wafer which had been annealed at 600 C (1112 F) for five hours have been processed for quantitative

metallography. Replicas of clad wafers annealed at 600 C and 650 C for one-half hour have also been prepared. Qualitative observations indicate that there is an increase in volume and an increase in observable porosity as the temperature and time of annealing are increased. This is accompanied by an increase in the extent of recrystallization.

Thorium. The two irradiated thorium specimens previously discussed are being processed for metallography, density and hardness subsequent to a one hundred hour vacuum anneal at 950 C (1742 F). Preliminary optical examination of a polished and cathodic vacuum etched surface indicated that the specimen irradiated to 1.5×10^{20} fissions/cc (0.92 a/o B.U.) had developed considerable porosity whereas the specimen irradiated to only 0.6×10^{20} fissions/cc (0.18 a/o B.U.) had not. Examinations are continuing.

Second-Phase Distribution in Dilute Alloys of Uranium. Electron metallography has been completed on nine of the 31 dilutely alloyed uranium samples currently being studied to determine the size distribution of second-phase particles. Finely dispersed intermetallic particles have been successfully delineated in these samples, which include six dingot uranium samples with dilute Fe-Si additions, and three ingot uranium specimens dilutely alloyed with Fe-Si and Fe-Al.

Twelve random photographs at 15,000 X were obtained for quantitative metallographic analysis of each sample. The particles have been measured and the raw data are being processed through a computer program which was previously developed on this program.

Several of the completed specimens were mechanically polished using the Syntron polishing technique outlined in the previous monthly report (August 1963). Samples which had received similar polishing and etching treatments, and which had been prepared by both the Syntron and the hand polishing methods, were compared by electron metallography. Specimens prepared with the Syntron exhibited more uniform surface conditions. This attainment will greatly aid in defining a general electropolishing treatment for the remaining specimens, since the initial surface condition is important in determining the polishing characteristics of each sample.

Intermetallics present in the alloyed ingot uranium samples are readily delineated by electropolishing for 60 seconds at a closed circuit potential of 18 volts, followed by electroetching at a potential of five volts for 120 seconds. The electrolyte is the same as that discussed in the August 1963 monthly report.

A similar technique has been employed on the dingot uranium samples and has yielded very sporadic results. In some cases acceptable microstructures were obtained after three to five polish-etch cycles while a similar treatment of other samples rendered the surface completely unacceptable for electron microscopy.

The large difference in specimen size and geometry, as well as the differences in metallurgical history, undoubtedly contribute to this observed variation of polishing characteristics. Current-potential curves of the electrolytic cell were determined for both types of samples. Closed circuit potential of 12.5 volts was selected for the electropolishing of dingot samples. Preliminary investigation indicates improved results. Further study is necessary for defining the proper electropolishing conditions for the remaining specimens.

5. Irradiation Damage to Reactor Metals

Alloy Selection

Procurement of materials to be used as test specimens for the Irradiation Effects on Reactor Structural Materials Program is continuing. Additional quantities of AISI 304 SS, Zircaloy-2, AM-350, A286 and 406 were received during the past month. Final shipment of the AISI 348 SS was made during the week of September 16, 1963.

Specimen quadrants from the ETR hot water loop facility containing Hastelloy N, Inconel 702, R-235, Inconel 625, Inconel 718 and R-27 have arrived on-site and are presently being examined in Radiometallurgy Laboratory. In addition, capsules from the ETR G-6 cold water facility containing tensile specimens of R-235, R-27, Hastelloy N, and Inconel 625 exposed to 1.8×10^{20} nvt (fast) and Cb - 1 Zr, Cb-752, and Ta - 10 W exposed to 1×10^{20} (fast) were received on-site. These materials will be examined to determine the effects of irradiation upon their mechanical properties and microstructure.

Four graphite boats containing specimens of Inconel 600, Incoloy 800, Inconel 625, AISI 406, Hastelloy X, AISI 348, R-235, Hastelloy N, Inconel 702, Inconel 718, and TD Nickel were delivered to the reactor for irradiation. These alloys will be irradiated at an estimated temperature of 600 C (1112 F) to different exposures in a gaseous environment. Similar boats irradiated at 525 C (977 F) are scheduled for discharge during the next reactor shutdown.

In-Reactor Measurements of Mechanical Properties

The two in-reactor creep tests on 20% cold worked Zircaloy-2 started last month were continued. Creep rates were determined after completion of a long reactor outage during which the tests were stopped. The observed in-reactor creep rates were 1.04×10^{-5}/hr at 320 C (608 F) and 35,000 psi (2450 kg/cm^2) and 1.25×10^{-5}/hr at 365 C (688 F) and 25,000 psi (1750 kg/cm^2). These rates are slightly lower than those found during irradiation before the outage. The slightly lower rates were expected as neither test reached a steady state condition before the outage. After the creep rates were measured, the temperature of both tests was increased to provide additional steady state data. Creep rates found are as follows:

Stress (psi)	Temp., C	Creep Rate, $\frac{1}{hr}$
25,000	377 (711 F)	3.0×10^{-5}
25,000	395 (743 F)	4.2×10^{-4}
20,000	395 (743 F)	3.2×10^{-5}
35,000	345 (653 F)	1.0×10^{-4}

All of the above data plot well on the Arrhenius plot. The activation energy for this plot is 86,000 cal/mole, while ex-reactor the activation energy for creep is 60,000. The excess activation energy is attributed to the formation and annealing of radiation produced creep obstacles.

The in-reactor creep behavior of Zircaloy-2 is becoming well defined. At the present time it is possible, with the aid of the Arrhenius plot, to predict in-reactor steady state creep rates over a wide range of temperature and stress. It is also possible to predict the magnitude of the creep rate increase during a reactor outage as well as the time required to initiate such an increase. Only three more in-reactor creep tests are required to complete the study of Zircaloy-2. These will be completed in about three months.

Irradiation Effects in Structural Materials

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

A cask containing 21 GEH-20 quadrants discharged from the G-7 hot water loop and nine GEH-14 capsules discharged from the ETR G-6

ambient water position was received by the Radiometallurgy Operation at Hanford. Irradiated materials included in this shipment consist of refractory metal alloys, nickel-base alloys, stainless steels, and Zircaloy-2.

Three central flux monitors of a new design containing continuous dosimeter wires were fabricated and shipped to the ETR for insertion in the G-7 loop. The purpose of these new central monitors is to obtain continuous flux data over the entire length of the reactor core as opposed to the intermittent measurements currently obtained. The flux monitor assembly is designed to reduce handling time and to eliminate hot cell disassembly.

A Magna-Gage has been obtained for determining relative magnetic susceptibilities of various stainless steels. Preliminary measurements show that this gage is sensitive to changes in ferromagnetic constituents in austenitic stainless steel resulting from cold work and heat treatment.

A vacuum furnace utilizing an induction current concentrator has been designed for high temperature tests of nickel-base and refractory alloys. This furnace is being employed to measure the high temperature stress-rupture properties of Haynes Alloy-25 and the recrystallization temperature of various refractory alloys. The furnace has been equipped with automatic temperature control and is being modified for hot cell use with a remotely operated Instron tensile frame.

The increase in yield strength of Zircaloy-2 as a function of neutron exposure has been compared for neutron irradiations both at 60 C (140 F) and 280 C (540 F). For integrated exposures less than 10^{20} nvt, there is no significant difference in the rate of damage accumulation for the two irradiation temperatures, and a linear function exists between yield strength and log nvt for several conditions of prior cold work. At integrated exposures greater than 10^{20} nvt, the higher irradiation temperature results in a higher rate of damage accumulation in annealed Zircaloy-2. At exposures greater than 10^{20} nvt, the yield strength of cold worked Zircaloy-2 begins to decrease with irradiation, indicating the occurrence of radiation-induced recovery. The rate of recovery is higher for the higher temperature of irradiation.

Ambient temperature irradiations of various program materials are being conducted in the ETR G-6 and other core positions to provide comparative data for the elevated temperature irradiations at 280 C (540 F) in the G-7 hot water loop. Nine capsules containing

refractory alloy tensile specimens and Zircaloy-2 notched beam specimens were assembled and shipped to the ETR for insertion in Cycle 58. Nine matching capsules for the ETR critical facility were also shipped. This brings the total number of specimens inserted for low temperature irradiations over the past four months to 200, of which approximately one-third have been discharged and are awaiting testing.

A program has been initiated to study the effects of pre-irradiation conditioning by mechanical working and thermal treatment on the stress-rupture and tensile properties of irradiated Hastelloy X-280, Inconel 600, and Inconel X-750. In addition, basic studies will be conducted to determine the effects of irradiation on solution-hardened and precipitation-strengthened nickel-base, binary and ternary alloys. Sixty-two Hastelloy X-280 tensile specimens for this program have been discharged from the G-7 hot water loop and have been returned to HAPO for testing. The specimens were given various aging treatments prior to irradiation. Additional examinations will include hardness and weight-gain measurements and metallography.

Recent evaluations of notch tensile tests on Zircaloy-2 specimens containing 0, 10, 20, and 40% cold work and irradiated in the G-7 hot water loop have been made. Specimens containing lower amounts of cold work (0, 10, and 20%) have retained considerable notch ductility and resistance to fast crack growth after irradiation to 2.6×10^{20} nvt, the highest exposure evaluated to date. Irradiated material containing 40% cold work exhibits good ductility and resistance to crack propagation parallel to the longitudinal direction. However, a serious decrease in notch ductility and resistance to fast crack growth sets in at approximately 8×10^{19} nvt for crack propagation parallel to the transverse direction. Ductility is nearly zero at 2.6×10^{20} nvt for crack growth in this direction, and an extrapolation of the data shows that the nominal stress for failure will be less than the yield point after an exposure of 4×10^{20} nvt.

Damage Mechanisms

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

Tests on the strain rate sensitivity of the lower yield stress of Ferrovac "E" iron were completed for the strain rate range of 0.003 inch/min to 2 inch/min. The results indicate that only one deformation mechanism is operative under the temperature and strain rate conditions of the test according to the Gilman and Johnson theory.

An examination of the fracture surface of the Battelle zone refined iron sample tested in liquid nitrogen showed the presence of a few twins. The intergranular nature of the fracture surface prompted an investigation of the grain boundaries using electron microscopy. Small precipitate particles were observed along some of the grain boundaries.

Initial experiments to determine activation volumes of iron were begun with tests at room temperature using strain rate changes of a factor of 10 between the strain rates of 0.002 inch/min and 0.02 inch/min, and between 0.02 inch/min and 0.2 inch/min. The activation volumes (xLB) were found to lie in the range 20 to 65 b^3, where x is the distance a dislocation moves during a thermal activation over a barrier to slip, L is the length of dislocation taking part in the thermally activated jump, and b is the Burgers vector (about 2.5 A in Fe).

Environmental Effects

ETR G-7 loop water analyses have continued to show oxygen concentrations below one part per million.

The G-7 loop downstream out-of-flux specimen exposure chamber was fabricated, examined for defects by use of radiography and fluorescent dye penetrant and shipped to Idaho Falls, Idaho. Four coupons of Zircaloy-2 plate 6497 were loaded into the internal sample holder for exposure to irradiated loop water during ETR Cycle 58. Two of the coupons are in the bright etched condition and the remaining two have a 48-hour, 360 C (680 F) water autoclave precoat. Water transport time from the active zone to the exposure chamber is expected to be on the order of one second.

As a consequence of the observed higher rate of weight gain shown by irradiated Zr-2 specimens as compared with unirradiated specimens of the same plate material during the initial two-week exposure of a 39-day autoclave test in 1500 psig steam at 400 C (752 F), a 24-hour autoclave test was conducted to confirm the observation. The 24-hour test comprised both irradiated and unirradiated Zr-2 with half of the specimens of each type pre-heat treated for 24 hours at 400 C (752 F)

in vacuo. The purpose of the vacuum heat treatment was to explore the possibility that annealing of radiation-induced defects during autoclaving may have caused oxidation rates of the irradiated material to approach normal rates during extended autoclaving. No significant differences in specimen weight gains attributable to irradiation or annealing effects were observed at the end of the 24-hour period, but all weight gains were 30 to 100% greater than the "expected" Lustman and Kerze value of about 10 mg/dm^2. All specimens were reloaded into the autoclave for an additional 13 days at temperature.

Metallography on a sample cut from in-reactor coupon 87-10, 40% cold work, 125 days in-core at 540 F (282 C) 7.6×10^{13} nv (fast) and 8.2×10^{20} nvt showed an average oxide thickness of 0.313 mil equivalent to a weight gain of 129.3 mg/dm^2. The measured weight gain of this specimen was 135.6 mg/dm^2. Hydrogen content of this 50-mil thick specimen was found by analysis to be 188 ppm, and this was confirmed by micrographs showing a hydride distribution equivalent to about 200 ppm.

ATR Gas Loop Studies

Helium Corrosion Studies. Single rows of Hastelloy X and Haynes 25 specimens were exposed to 190 ft^3 of flowing A Grade helium at 1038 C (1900 F) over a period of 10 days. Lead samples of Haynes 25 gained weight while downstream samples lost weight, though all the samples were oxidized. The Hastelloy X specimens appeared to have a more tenacious oxide film than the Haynes 25 alloy and did not lose weight; however, the lead samples gained the most weight.

Weight losses of Hastelloy X descaled electrolytically in a molten $NaOH-Na_2CO_3$ bath, corresponded to penetrations of 0.06 mil to 0.13 mil for the rear samples and lead samples, respectively. For the Haynes 25 specimens the average penetrations were 0.08 mil to 0.15 mil for the rear and lead samples, respectively. These measurements do not take internal oxidation into account.

In order to calculate oxide losses during the test, it was assumed that the molecular ratio of metallic constituents in the scale was the same as in the metal.

Calculations based on this assumption show that during exposure to the high temperature helium, the Hastelloy X specimens lost little or no oxide, compared to at least 25% loss for the Haynes 25 specimens. Metallographic examination to determine the extent of internal oxidation in the two materials is now in progress.

Helium Purification. A helium purification system is necessary to maintain gas purity in the ATR gas loop. Correct sizing of the purification system depends on the amount of contamination initially present in the gas and in the system, and on the amount of contamination continuously introduced because of leaks.

On startup, the time required to attain a given low impurity level in the loop gas can be estimated by the relation

$$t = -\frac{V}{G} \ln \left(\frac{z-x}{y-x}\right)$$

where t = time required, hr.
V = total volume of gas in loop, ft^3
G = flow rate through helium purification plant, $ft^3/hr.$
z = impurity concentration in loop gas, vpm (viz., volume parts per million).
x = impurity concentration in effluent from helium purification plant, vpm.
y = initial impurity concentration in loop gas, vpm.

Upon attainment of steady state conditions, at which time the helium purification system is maintaining system purity against a constant in-leakage of contaminant, the by-pass fraction may be estimated by the relation

$$\frac{G}{H} = \frac{Q}{Q-x+z}$$

where G = flow rate through gas purification system, $ft^3/hr.$
H = total flow rate through loop, $ft^3/hr.$
Q = the in-leakage occurring in the time required for the gas to make one cycle, vpm.
x = impurity concentration in purified helium, vpm.
z = aim impurity concentration in loop gas, vpm.

The helium purification system must be designed to handle the heavier of the two types of loads, i.e., initial gas purification in a reasonable time, and maintenance of purity against constant in-leakage.

Gas Analysis. A gas chromatograph was received which utilizes a new ion cross section detector which the vendor claims will detect one ppm of oxygen, nitrogen, hydrogen, methane, carbon monoxide, and carbon dioxide in helium. This detector is unique in its ability to detect hydrogen as well as the other gases. This instrument was installed in 326 Building for evaluation and calibration. A number of startup difficulties were encountered including a very troublesome feedback

problem in the control circuits which prevented satisfactory temperature control. These installation problems have been solved, and initial testing shows that the detector responds well to oxygen, nitrogen, and carbon monoxide. Carbon dioxide and methane have not yet been checked. Initial quantitative results indicate a sensitivity of 10 ppm is attainable and with further cleanup of the carrier gas the claim of one ppm sensitivity may be achieved. The new detector is far superior to a thermal conductivity detector for hydrogen and appears at least equal for the other gases.

Strain Cycling Loop Materials. A test configuration has been designed, and some candidate loop materials have been ordered for strain cycling tests. The tests will be run in helium atmosphere. The materials that have been ordered are Hastelloy X, Haynes 25 and 304 SS. Other materials which will be tested are Inconel 600, Inconel 702, and 316 SS.

Insulation Studies. Refinements have been made in the fabrication method developed for the large castable Fiberfrax insulating blocks to be used between the hot helium containing superalloy inner pipe and the cooler pressure bearing stainless steel outer pipe on the model gas loop. The combination of stainless steel wire and mesh as reinforcing material in the block interior has overcome the tendency of the blocks to crack during thermal cycling. Studies on the outgassing and load bearing characteristics of the Fiberfrax insulating blocks at service temperatures expected in the model loop are under way.

Test Section Construction. Construction of the Mark I test section for the model loop has started. The pressure bearing type 347 stainless steel tubes for the test section shell and the Grayloc flange for the opening at the top of the test section are on hand.

Germinative Grain Growth in Superalloys. Large grains such as those often produced by germinative type grain growth can have detrimental effects on the tensile, impact and corrosion properties of metals. A study is under way to determine if there is a critical strain for the model loop metals Hastelloy X and Haynes alloy 25 which, upon annealing, will result in germinative grain growth. A strain range of about 0-10% is being investigated for temperatures from 927-1177 C (1700-2150 F) for Hastelloy X and from 927-1240 C (1700-2265 F) for Haynes alloy 25 for annealing times of one and 24 hours. Samples with varying amounts of strain were made by rolling slightly tapered thin plates. They were sealed inside a quartz tube in a helium atmosphere for thermal treatment.

Results thus far indicate that there is no germinative grain growth for Hastelloy X or Haynes alloy 25 when strained over the range of about 0-10% and annealed at 927, 1010, and 1093 C (1700, 1850, and 2000 F) for one or 24 hours. Further, the original grain size of ASTM 7 for the Hastelloy X and ASTM 3-4 for the Haynes alloy 25 did not appear affected by the rolling and thermal treatments.

Heat Transfer Program. The computer program prepared for calculating interface temperatures and heat losses for the doubly contained pressure piping with insulation between pipes has been expanded to include alternative construction materials. The program can be used to calculate temperatures for up to eight layers of material plus the inside and outside film drops using either helium or water. Structural materials include the refractory metals, 316 and 347 stainless steel, Hastelloy C and X, carbon steel, Zircaloy-2, TD Nickel, Inconel and Inconel X, Rene 41, and aluminum. Insulators include carbon felt, silicon carbide, Fiberfrax, Micro-Quartz, Refrasil, Zirconia, metallic insulation and molded diatamaceous earth. The program is arranged to permit addition of other material equations and permit modification of material thermal conductivities as more precise data become available.

Tensile Specimen Holder. A report on the "Tensile Specimen Holder for the ATR High Temperature Gas Loop" has been written. This report evaluates a tensile specimen holder designed earlier this year, provides a revised design, compares materials for construction of the holder and indicates areas for further investigation. The revised holder contains fewer parts and is easier to fabricate than the original holder. It is recommended that columbium alloy CB-752, because of its high melting temperature, low creep rate, high recrystallization temperature, ease of fabrication, and excellent welding characteristics be used for construction of this holder. Possible alternate materials are columbium alloy B-66 or molybdenum alloys Mo-0.5 Ti or TZM. Final choice of construction material will be based on further investigation.

Creep-Rupture Tests. A program has been started to evaluate the creep-rupture properties of Haynes 25 at 2100 F (1149 C). This material is being considered for use in the ATR as a structural material for the heater exit piping.

An induction heating furnace has been modified to run short time creep-rupture tests in conjuction with the Instron tensile machine. Temperature is controlled and recorded automatically by the use of a magnetic amplifier and Brown recorder. A compression-type

extensometer is incorporated into the system to measure elongation. A load pan is hung from the lower pull rod and lead weights added accordingly, depending upon the stress required.

To date, two tensile tests and four creep rupture tests have been run. These tests are in agreement with the limited data available in the literature.

Radiation Damage Theory

In HW-68758A, calculations were reported which showed that if a specific material were exposed to neutron spectron of widely different energy distribution, vacancy production by each spectrum would be directly proportional to the flux of neutrons having energies greater than a "limiting energy", E_L. E_L was found to be constant for a given material but varied in a somewhat systematic fashion from material to material.

This concept has been further tested by calculating the vacancy production using the Kinchin & Pease model, the Beeler model and the Beeler model modified to give trivacancy and larger cluster production. Although the weighting of high energy neutrons ($E \geq 1$ Mev) differs by a factor of 10 among the models, correlation of vacancy production with nvt ($E > L_L$) agrees to within 10% in all instances. Relatively low flux in the energy range where theoretical differences occur accounts for the smallness of the error. This result, however, lends more support to the utility and validity of this approach for characterizing neutron flux in damage studies.

6. Gas Cooled Reactor Studies

EGCR Graphite Irradiations. The sixth capsule, H-3-6, in the series of long-term irradiations of EGCR graphite was successfully removed from the GETR on August 17, after completing a four-cycle irradiation period. All 24 samples and 65 flux monitors were recovered and sample measurement, flux monitor analyses, and temperature determinations are now in progress. Maximum neutron exposure is estimated to be 16×10^{21}, $E > 0.18$ Mev.

Low Temperature Irradiations. Graphites prepared with eight different petroleum-coke fillers have been irradiated to an exposure of 8300 MWD/AT_K at 30 C. Three nuclear graphites, CSF, KC and TSGBF, were included for a comparison of dimensional stability. All graphites were graphitized at 2700 to 2800 C with the exception of TSGBF graphitized at 2450 C. Samples were 0.426 inch diameter x 4 inches long.

In the transverse direction all samples expanded. The range was 2.21 to 4.73% in comparison with 3.34 for CSF and 4.77 for KC. The exception was a graphite prepared with iron oxide addition which expanded 0.50% in the parallel direction. This material expanded only 2.32% transversely and thus shows good dimensional stability.

7. Graphite Radiation Damage Studies

Effect of Long-term Heat Treatment on Graphite. Two transverse unirradiated graphite samples were subjected to temperatures of 800 C for 64 days with intermittent periods at room temperature. Essentially no change was observed.

Electrical Resistivity of Graphite. The electrical resistivity of grade GC-126 graphite, a candidate for HTLTR heating element use, was measured from 25 to 939 C. The sample was 0.5 inch in diameter and 4 inches long. The electrical resistivity at 25 C was 1.23×10^{-3} ohm-cm at 550 C. Above 550 C the electrical resistivity increased about 0.018%/°C and the value measured at 939 C was 1.04×10^{-3} ohm-cm.

8. Boronated Graphite Studies

Analysis of Gas Annulus Capsule. A study was made of a capsule design in which heat would be transferred from boronated graphite samples by gas conduction and radiation only. Calculations of gas annulus spacing for various heat generation rates were carried out and the results were tabulated in graphical form (heat generation versus gas-gap spacing). The results indicate that only 0.5% of the total heat would be transferred by radiation loss.

Burnout of Boronated Graphite. Because the burnout reaction ($B^{10}(n,\alpha)Li^7$, E = 7.6 Mev) is the major source of heat in irradiation of boronated graphite, graphite characteristics were calculated for specimens of varying boron content under typical irradiation conditions. The $B(n,\alpha)$ Li reaction is also important since it contributes to the radiation-induced damage.

During an irradiation in which the boron concentration in the outer 10% of a sample would be reduced from 8% to 4%, the heat generation rate would decrease only 6.5%. Furthermore, the expected total relative heat generation rates in samples containing 6 and 30 w/o boron are only 5% less and 13% more than the rate in an 8 w/o boron sample. Thus, because of self-shielding, the heat generation rate is relatively insensitive to burnout and to initial boron concentration.

Self-shielding also leads to severe reaction gradients in samples with boron concentrations exceeding 3%. For example, the reaction rate at the surface of a 0.426 inch diameter, 8% boron sample is seven times the rate at the center and the difference is even more pronounced for higher boron concentrations. In the case of the 30% boronated samples the reaction rate is reduced by 70% within 0.05 cm of the surface. These data illustrate the necessity for careful design of irradiation tests and laboratory results so that data meaningful to practical application can be obtained.

9. Metallic Fuel Element Development

Irradiation of Thorium-Uranium Fuel Elements. Three tubular Zircaloy-2 clad thorium - 2.35 w/o U-235 - 1.0 w/o Zr fuel elements have completed their fourth cycle of irradiation in the ETR P-7 Loop. At the end of the fourth cycle the maximum exposure achieved was 1.2×10^{20} fissions/cc (3400 MWD/T). Maximum specific power during the fourth cycle was 68 watts/gm (205 kw/ft) with a corresponding maximum fuel temperature of 580 C.

Weight measurements made at the end of the fourth cycle showed a total volume increase of 0.5% for the highest exposure fuel element and 0.3% for the two lower exposure fuel elements. This low observed volume increase essentially represents the theoretical minimum density change associated with fission product generation within the fuel.

Dispersed Phase Thorium Alloys. One phase of the metallic fuel development program for FY-1964 is the study of quarternary additions to thorium base, solid solution strengthened, Th-U-Zr ternary alloys for development of finely dispersed intermetallic compounds in the structure. The dispersed phases are expected to contribute to additional irradiation swelling resistance in these high strength, corrosion resistant alloys.

Initial alloys have been prepared as 100-gram arc melted buttons with aluminum or beryllium additions (500 to 2000 ppm) to thorium base alloys containing 2.5 or 5.0 w/o U and 2.0 or 5.0 w/o Zr. Attempts to hot roll the Th-2.5 w/o U-2.0 w/o Zr ternary alloy and the same composition with Al or Be additions resulted in severe cracking. Heating was done in a neutral salt bath at either 850 or 900 C. By contrast, an arc melted button of Th-2.5 w/o U-1.0 w/o Zr previously vacuum melted was easily rolled at 900 C preheat at 0.010"/pass to 0.125" thickness without cracking. Additional alloy buttons were melted for fabrication work to

determine whether the difficulty in fabrication is due to composition or is related to impurities not removed in the arc button melting (argon atmosphere).

Submicron Uranium Carbide Dispersion in Metallic Uranium. The previous monthly report described the formation of a uranium carbide dispersion, submicron in size, in uranium metal shot; and the simultaneous densification and cladding of the material to form a fuel rod suitable for irradiation testing. Additional examination has been made of heat treated sections of these fuel rods including electron microscopy of cathodically etched specimens. The uranium carbide particles, in electron microscope examination, appear one micron and smaller after beta heat treatment of the fuel. An additional quantity of uranium shot; -10 +30 mesh, containing approximately 650 ppm carbon, has been prepared for additional fabrication study to determine the size of the uranium shot on densification, and carbide size and distribution.

Corrosion Studies on Thorium-Contaminated Braze Alloy. A series of Zircaloy-2 + 5 w/o beryllium braze alloys containing thorium contamination ranging from 0.012% Th to 3.1% Th have been made by arc melting. A large number of corrosion coupons have been machined from the buttons. Preliminary weighing and measurements have been completed, and the initial charge of corrosion coupons are to be autoclaved.

Compatibility of Structural Materials with the HTLTR Environment. A group of candidate materials for cladding and structural components are being evaluated for use in the High Temperature Lattice Test Reactor (HTLTR). The materials being evaluated are Inconel 600, Inconel 625, Nickel-A, TD Nickel, Hastelloy X280, Hastelloy B, and unalloyed molybdenum. In a preliminary test to determine the effect of the reactor atmosphere on corrosion, ductility and microstructure, the materials were exposed 192 hours in nitrogen gas at 1000 C in the presence of graphite. Prepurified nitrogen gas (nominal impurity levels: O_2-5 ppm, A-10 ppm, hydrocarbon - 1 ppm) was passed through graphite at 1000 C and then over the specimens, with one group being in contact with the graphite. The only materials which did not undergo a weight gain after the exposure were Nickel-A and TD nickel. With the other materials, weight gains ranged from approximately 400 mg/dm^2 for molybdenum in contact with graphite to approximately 700 mg/dm^2 for Inconel 600 in contact with graphite. In general, the materials not in contact with graphite had slightly smaller weight gains than the specimens in contact with graphite. Bend test results show a pronounced loss in ductility for the Hastelloys in the nitrogen atmosphere, and for Hastelloy X, Inconel 625 and molybdenum for Nickel-A and TD Nickel in the bend tests.

Tensile tests and metallographic evaluation of samples from this preliminary test are being obtained. Other samples of the above materials, along with ceramic specimens and graphite felt samples, will be evaluated in additional tests.

10. Aluminum Corrosion and Alloy Development

Installation of In-Reactor Loop (C-1). The in-reactor portion of the C-1 Loop was installed in C-Reactor, and the test section was operated on process water cooling.

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

Thermal Hydraulic Studies. Pressure drop measurements for an electrically-heated 19-rod bundle test section were examined to determine the feasibility of correlating the results. Data from 255 runs were examined where the flow rate varied between 0.5×10^6 and 5×10^6 lb/hr-sq ft and the heat flux varied between 0.046×10^6 and 0.468×10^6 B/hr-sq ft.

The analysis of the data was divided into five main areas:

(1) Single-phase nonisothermal flow.
(2) Determination of the start of local boiling.
(3) Correlation of the heat transfer coefficients.
(4) Pressure drop in the local boiling region.
(5) Pressure drop in the bulk boiling region.

For single-phase nonisothermal flow, it was found that the friction factors for the bundle were about twice as great as those for smooth tubes. This is probably due to the presence of helical wire wraps on 12 of the 19 rods to promote mixing and maintain spacing, and also to two rings around the bundle to maintain electrical insulation.

The start of local boiling, as indicated by changes in the relation between surface temperature and heat flux, took place at considerably higher surface temperatures than predicted by the common correlation of Jens and Lottes. While this is unexplained, the possibility of thermocouple errors is being further investigated.

A correlation of heat transfer coefficients for single phase cooling indicated that the Reynold's number had an influence to the 0.6 power rather than the usual 0.8 power. However, this has been found previously for unbaffled rod bundles in heat exchangers and the possibility also exists that the wire wraps would cause such an influence.

It was found that the pressure drop during local boiling could be correlated by the equation

$$\left(\frac{\Delta P_{LB}}{\Delta P_{sp}}\right) = 7.0 \left(\frac{Q/A}{10^6}\right)^{2.5} \left(\frac{G}{10^6}\right)^{-1.25} + 1$$

where ΔP_{LB} = pressure drop during local boiling

ΔP_{sp} = pressure drop during single phase

Q/A = heat flux, B/hr-sq ft

G = mass flow, lb/hr-sq ft.

The bulk boiling pressure drop could be predicted quite well by using Levy's momentum model to calculate void volume and his relation between the void volume and the ratio of pressure drop during boiling to pressure drop for single phase.

Based on the correlations discussed above, an equation was developed to give the over-all pressure drop for the bundle when it combines single phase, local boiling, and bulk boiling. A computer program was written to allow comparison of this equation with the experimental results.

12. Advanced Reactor Concept Studies

Fast Supercritical Pressure Power Reactor. Further physics parameters for the 300 MWe FSPPR have been determined. The Doppler coefficient is calculated to be -2×10^{-5} $\Delta k/^{\circ}C$ for normal coolant conditions and -8×10^{-6} $\Delta k/^{\circ}C$ for void coolant conditions. The value for normal coolant conditions is somewhat larger than those for other fast reactor designs, but this is expected in view of the large amount of H_2O coolant present in the core.

Reactivity as a function of reactor core coolant inventory was calculated for the reference design. The maximum reactivity occurs near normal coolant conditions. If the reactivity at normal coolant conditions is defined as 0 reactivity, then the reactivity at voided conditions is -0.5% $\Delta k/k$ and at flooded conditions -8.8% $\Delta k/k$. Reactivity change as a function of the hydrogen density in the moderator region without control rods has also been calculated. The maximum reactivity loss of -0.7% $\Delta k/k$ occurs when 50% of the hydrogen in the moderator region is lost. Hydrogen losses of up to 80% can be sustained without increasing reactivity. Calculations also show that the void effect will remain negative for a hydrogen loss of up to 50% in the moderator region.

Cost estimates were made by Estimating Operation, HUPO, for several possible power plant arrangements described in very brief form. According to these estimates, there is essentially no difference in the cost of the plant regardless of building arrangement, and the total direct capital cost of the 300 MWe FSPPR would be $32.4 million - identical to the SPPR. More detailed analyses of the plant layout are under way so that more thorough cost estimates can be made. It is expected that a substantial reduction (> $1 million) can be made in the building costs below current estimates.

The cost of fabricating the first fuel loading for the 300 MWe FSPPR is estimated to be $5.9 million. The 42 core elements (including axial blankets and flux traps) cost $4.5 million ($256/kg) of which the Rene' 41 structure accounts for very nearly one-half. The 30 radial blanket elements cost $1.4 million ($85/kg), the Rene' 41 structure representing only one-sixth.

A fuel cycle diagram (suitable for both 300 and 1000 MWe plants) has been drafted. A cost analysis, following the AEC Cost Evaluation Handbook procedures, is nearly complete for the 300 MWe plant's fuel cycle.

The first rough draft of a formal report on the FSPPR is nearing completion, and some sections have been revised. Some redesign is being done on the second pass tubing to reduce the high primary stresses resulting from the tube dimensions selected. Since the combined primary and secondary stresses are well below values, tube wall thickness can be increased slightly.

A presentation describing the FSPPR was prepared for delivery at the ANL meeting on fast reactors in October.

Plutonium-Fueled Rocket Reactor. Preliminary calculations by Applied Physics Operation of power distribution in the rocket reactor indicate an approximately linear front-to-rear variation in average power per fuel plate, with about 10% of the power in the last (fourth) plate. Approximate heat transfer calculations indicate a maximum temperature at the centerline of the fuel webbing of about 5200 to 5300 R, in the third and fourth fuel plates. Work is progressing on obtaining more refined calculations of power distribution and of temperature-pressure relationships. The indicated temperatures are somewhat higher than the desired maximum of 5000 R. If these temperatures are confirmed in more refined calculations, some temperature relief can probably be obtained by skewing the power distribution more strongly toward the

inlet of the reactor. This would also improve conditions at the inlet plate, whose calculated temperature is lower than desired for freedom from hydrogen embrittlement.

A preliminary calculated pressure drop through the reactor at a hydrogen flow of 207,000 pounds per hour (for 1000 Mw power) and with a 1000 psi outlet pressure, is less than 200 psi. The pressure drop is distributed approximately equally across the four fuel plates, with about 10 psi of the drop being contributed by the front reflector. A computer code is being prepared to allow more exact computation of pressure drop.

13. Program Proposals

Ultra-High Temperature Liquid Metals Component Feasibility Experiment. At the request of the AEC, a program proposal (Form 189) has been prepared for an ultra-high temperature liquid metals component feasibility experiment. This experiment had been proposed previously as a "scouting" effort to identify promising areas of development in the liquid metals field and involves the design, development, fabrication, and operation of a bench scale liquid metal flow system with components capable of service to 3500 F. The system would contain models of all necessary process equipment except a nuclear heat source and includes pump, flowmeter, heat exchanger, heater, power converter unit piping and other necessary auxiliaries for an integral operating system.

It is considered that three basic components which make the ultra-high temperature component experiment feasible are (1) a tungsten fully-bonded honeycomb heat exchanger, (2) an electromagnetic pump fabricated with nonferrous materials, and (3) flow system materials of tungsten tubing material joined by advanced fabrication techniques. Development of techniques for the fabrication of tungsten honeycomb structure and tubing is presently under way as part of another program.

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.

The effects of strain rate and temperature on the yielding and flow of high purity polycrystalline annealed and cold worked specimens have been studied at 295 K (72 F). Work performed elsewhere on molybdenum of lower purity has disclosed that the 0.2% offset yield stress varies in such a manner that there are four distinct regions in the curve of yield stress versus log strain rate at room temperature. Results obtained in this program with molybdenum of higher purity, on the other hand, show only two distinct regions over the same range of strain rates (1.67×10^{-6} to 8.33×10^{-3} sec^{-1}). The effect of prior cold work is to decrease the slope of the curve.

Strain rate sensitivity experiments are also being conducted; in this type of test, the strain rate is cycled between two values, usually varying by an order of magnitude, while the test is in progress. Whereas in the case of other body-centered cubic metals (Fe and Ta, for example) tested at 295 K (22 C, 71.6 F), the increase in flow stress for a given instantaneous strain rate increase is independent of the stress level, molybdenum shows a marked stress-dependence. This dependence on stress level becomes more pronounced as the strain rate is decreased.

These experiments are being extended to lower temperatures (i.e., 195 K, 77 K, and 4.2 K) (-108.4 F, -320.8 F, -451 F); 500 specimens are in preparation off-site, and these specimens will be used for similar studies after irradiation. In addition, the work will also be extended to cover single crystal specimens. These specimens are also in preparation; a total of 75 cyrstals of suitable length have been grown and are now being machined by an electrolytic technique reported previously.

X-ray line broadening studies are being carried out on irradiated and unirradiated molybdenum. It is intended that this work be performed with the sample at an elevated temperature, but measurements to date have been made at room temperature. The profiles of the diffraction peaks will be analyzed by the Fourier method to determine the magnitude of short range strains associated with the formation of defect clusters. Data have been collected for a high purity molybdenum foil annealed at 1900 C (3452 F), a similar foil in the as-received condition, and a molybdenum foil containing 10-30 parts per million carbon, all irradiated to 1.5×10^{19} nvt (E > 1 Mev). Analysis of the data is in progress.

Gross structural irregularities in the single crystals may be directly observed by means of x-ray diffraction micrography. These irregularities are recorded on film as variations in intensity of the

diffraction image from regions on the crystal surface. A series of six specimens has been prepared from one single crystal molybdenum rod grown in this laboratory. Three were prepared with (100) faces and three with (110) faces. Diffraction micrographs were made after grinding, metallographic polishing, and electropolishing of the faces. The crystals were then subjected to a second electropolish and again examined. The resulting micrographs are apparently free of surface effects resulting from the grinding operation. No individual subgrains can be observed, but the micrographs made from (110) faces show what appears to be a randomly curved or rumpled texture. The pattern resembles the "deformation bands" observed optically in some deformed metals. Micrographs made from (100) faces show a pattern of faint parallel straight lines making an angle of 10 to 15 degrees with the rod axis. These features are found for each of the six samples, the patterns differing only in minor details. In none of the crystals is there any evidence of subgrains. The crystals are markedly more free of substructure than the crystals obtained from commercial sources. The present sample crystals will be annealed to determine if the substructure can be further improved by such treatment.

Nickel, a face-centered cubic metal, and rhenium, a close-packed hexagonal metal, are being investigated in a manner analogous to the molybdenum studies. Work to date on these two metals has been confined to sample preparation and development of associated experimental procedures.

Forty high purity (99.995%) nickel single crystals, of length suitable for tensile specimens, have been prepared and are being electrolytically machined. Also on hand are 30 polycrystalline nickel specimens machined from each of three lots of nickel foil with purities of 99.997, 99.97, and 99.6%. These foil specimens are 50 microns thick and will be used for tensile testing after quenching or irradiation. A special fixture has been fabricated for foil tensile tests which ensures alignment of the specimen and minimizes actual handling of the specimen.

Twelve rhenium single crystals and 15 polycrystalline Re foil specimens, 99.992% pure, are also on hand. Development of a suitable electrolyte for electrolytic machining of the crystals is in progress.

Electrolytic thinning techniques have been developed for 99.997, 99.97, and 99.6% foils, and for 99.992% rhenium foils. An electrolyte consisting of 23 parts perchloric acid and 77 parts acetic acid was utilized for both nickel and rhenium. An applied potential of 30 volts was used for the nickel foils, while 24 volts proved

adequate for thinning rhenium. It was found necessary to use an electrolytic jet to remove the thinned sample from the foil in the case of rhenium. This was accomplished by painting the area of interest with an insulating lacquer and applying a potential of 100 volts DC between the jet stream and the sample.

Examination by transmission electron microscopy of nickel foils annealed for one hour at 700 C (1292 F) revealed the presence of many dislocations and stacking faults. Second phase precipitates were noted in the 99.6% nickel foils. Rhenium foils annealed 16 hours at 1300 C (2372 F) were observed to be incompletely recrystallized. Additional foils, annealed at the same temperature for 100 hours, are currently under investigation.

2. Plutonium Physical Metallurgy

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

The influence of concurrent phase transformation on the deformation of plutonium is being studied under compressive stresses from 0 to 3000 psi. The total strain during transformation consists of creep strain, transformation strain, and transformation volume change. The unit length change of the latter is 0.030.

The transformation strain is significant at nominal stresses and is at least an order of magnitude greater during the alpha to beta transformation than during the beta to alpha transformation. The transformation strain during the alpha to beta transformation is a nonlinear increasing function of applied stress and a nonlinear decreasing function of the transformation rate. The preliminary investigation showed the transformation strain to be 0.003, 0.026, 0.031, and 0.040 at 150, 650, 1150, and 2150 psi, respectively, at a transformation rate of 0.3 ± 0.2% per minute. Under an applied stress of 650 psi the transformation strain was 0.026, 0.021, and 0.008 at transformation rates of 0.3 ± 0.2, 7 ± 3, and 35 ± 15% per minute, respectively. The transformation rates are average rates which were computed over a time period corresponding to 80% transformation.

The creep strain of the alpha phase was found to be less than 10^{-7} per minute at 120 C (248 F) under a stress of 3100 psi. This creep strain is insignificant relative to the transformation strain. The

respective steady state creep rates of the beta phase at 150 C under compressive stresses of 2150, 1150, and 650 psi were 2.4×10^{-5}, 7×10^{-7}, and less than 10^{-7} per minute. The steady state creep rate at 130 C (266.0 F) under 2300 psi was 6×10^{-6} per minute; at 120 C under 3100 psi it was 9×10^{-6} per minute.

A major effort during the past month has been devoted to the analysis of the textured structure induced in alpha plutonium by rolling. It appears that the (201) plane tends to lie in the plane of the strip after about 90% reduction at 70 C (158 F). This observation is strengthened by the fact that the (020) reflection predominates the diffraction pattern of the surface perpendicular to the rolling direction. The standard (010) projection of alpha plutonium indicates that these two planes are mutually perpendicular in the crystal lattice. The complexity of the diffraction pattern complicates the position identification of these lines in view of the fact that each is paired with relatively strong lines from other planes so that the 2θ values of each pair differ by values of the order of 10 minutes. Annealing studies have been undertaken in an attempt to insure that the residual stresses which might prevent the resolution of these pairs are relieved (as-cast structures can definitely be stress relieved). To date, 200-hour anneals at 100 C (212 F) have not altered the characteristics of the pattern significantly.

In view of the lack of hardening in the as-rolled material together with the absence of significant line broadening, there is reason to suspect that recrystallization has occurred and that the diffraction patterns observed thus far are those representative of a recrystallized structure. Consequently, the patterns are not necessarily indicative of that resulting directly from the rolling operation. For this reason it is not profitable at this time to speculate on possible slip planes and directions which may have been active in the deformation process.

An investigation of the influence of both tensile and compressive stress on the beta to alpha transformation of alpha plutonium has been undertaken. An initial experiment in which a $\frac{1}{4}$ inch diameter plutonium rod has been transformed under the influence of an applied bending moment is currently being evaluated. The metallographic investigation of the longitudinal structure should reveal some evidence of the effects of both types of stress on the transformation process and related grain growth process.

The recently developed application of electron microscopy to fractographic studies of plutonium is being utilized in the study of the

beta to alpha transformation mechanisms. It has been shown that the incubation time of this transformation is a function of the time and temperature of prior beta heat-treatment. Samples are being treated at 120 C (248 F) and 180 C (356 F) for 200 hours. Upon completion of this treatment samples from each temperature will be impact-fractured at 100 C (212 F). Electron microscopic examination of replicas taken from the fractured surfaces will be utilized to determine if beta microstructure can be correlated with the incubation time of transformation.

The electron microscopy of plutonium necessitates the decontamination of replicas. The two stage plastic-carbon replica process requires cleaning of both the cellulose acetate and the palladium shadowed carbon replicas in hydrochloric acid. It has been established that the carbon replica is not attacked and the cellulose acetate is only slightly affected by the acid decontamination. The maximum permissible acid concentration that can be employed is being determined.

E. CUSTOMER WORK

1. Radiometallurgy Laboratory

Examinations and Measurements. Routine examinations and measurements are or will be reported as part of the sponsoring research and development programs; however, items of unusual interest or representing new or different laboratory techniques will be briefly described.

Examination of an irradiated fluted N-Reactor inner element revealed that severe grain boundary tearing and porosity occurred in the uranium fuel. Bulk densities of this fuel material were 15.8 gm/cc compared to 17.0 gm/cc for similar nonirradiated uranium.

Higher crushing loads and increased brittleness were observed by crush tests of buggy spring supports on NIE type fuel elements after irradiation.

An irradiated PuC specimen was found to be badly fragmented when its container was opened. Several fragments were mounted and polished, but their small size prohibited etching. An unidentified second phase was seen in the polished specimen.

Examination of a tungsten clad rod containing UO_2 single crystal pellets and two tungsten clad, UO_2-tungsten cermet rods was completed.

Metallography of two thorium specimens was completed after vacuum annealing at 950 C for 100 hours. Gas voids were observed at the grain boundaries of one specimen.

Vacuum-pulse anneals were completed on a series of clad and unclad uranium samples. Temperature charts and data were submitted to the customer for study.

Approximately 425 test specimens (tensile, notch tensile and bend) were received, sorted and identified for the irradiation damage to metals program.

Metallographic studies of an Inconel thermocouple sheath revealed carbide formation at the exterior surface as a result of sheath-graphite contact and high temperature operation during irradiation.

Four samples (two fused and two unfused) were sectioned from a Li-Al capsule. The three flux wires were recovered and shipped for counting.

Remote Induction Furnace. A stainless steel mercury diffusion pump was added to the induction furnace vacuum system to act as a valve and maintain the pressure over the sample at about 10^{-3} Torr during melting.

Fission Gas Collection. Fission product gas was successfully collected from a $\frac{1}{4}$ inch diameter molybdenum clad tungsten-UO_2 cermet capsule suspended inside a larger capsule. A vacuum seal was made on the outer container and holes were then drilled through the outer wall and the inner capsule wall.

High Temperature Extensometer. A promising commercial device, an electromechanical transducer or distance detector is being evaluated for tensile specimen elongation measurements at high temperatures.

2. Metallography Laboratories

During the report month 251 samples were processed, a total of 765 micrographs and micrographs taken, 2552 negatives printed, and 8801 prints processed.

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

Stereo electron micrograph pairs were made for a series of notched Zircaloy-2 specimens fractured at temperatures between +22 C and -182 C. The specific areas studied were pre-selected by optical examination. The stereo electron micrographs at 5000X magnification show relief that may prove extremely valuable for interpreting the mode of fracture.

Support was given this month to work in behalf of the Boeing Company on experimental spot welding of heavy sections of titanium alloy. The alloy responded very well to the same chemical polish used for zirconium and zirconium alloys. This etch consists of 45 volumes of concentrated HNO_3, 10 volumes of concentrated HF, and 45 volumes of water. Weld specimens approached $2\frac{1}{2}$ x 3 inches in cross section. The weld nuggets were ground through 3/0 emery then chemically polished by rotating the sample in a circular motion on an 8-inch diameter stainless steel plate covered with cotton cloth and wet with the acid mixture. Etching time was from 60 to 90 seconds on most pieces. The sample was then rinsed with warm water and dried. This procedure allowed the entire surface of even the largest sections to be chemically polished to an evenly finished, stain-free surface.

3. N-Reactor Design Testing

N-Reactor Magazine Loader and Tongs. Modifications to the N-Reactor magazine loader have been completed, so that all control and drive mechanisms are now electrically powered. Three charges of 24-inch, 18-inch, and 12-inch long fuel elements were successfully loaded in magazines without damage to the fuel.

The tongs used to move fuel elements from pallet to magazine loader performed satisfactorily following counterbalancing and installation of new gripper pads. The problem of proper positioning of fuel elements on the loader is still under investigation.

N-Reactor Charging Tests. N-Reactor fuel charging tests were continued to define the conditions which result in excessive self-support deformation. For instance, it has not been possible to consistently charge fuel elements against a back pressure of 1500 pounds force without excessive self-support deformation. This amount of back pressure does not represent a normal charge condition and is probably not significant for the initial N-Reactor fuel loading, since prototypical charges have been made (using an eccentric tapered adapter with no back pressure) without damage. In 10 other runs excessive deformation was noted using a concentric tapered adapter at the discharge end of the magazine.

4. High Temperature Lattice Test Reactor Mockup

Detail design of the graphite core blocks and keys for the High Temperature Lattice Test Reactor mockup is 98% complete. Detailed layout of the insulating materials is approximately 40% complete. Support of the ceiling brick has been changed from the "jack arch" to vertical support rods; therefore, permitting testing of a shortened safety rod in a vertical position.

The single pass gas coolant concept has been changed to a recirculating closed system as a result of calculations which indicate nitrogen costs in excess of $6,000 for each two-day cool-down cycle.

Initial scope and layout drawings have been completed for both the safety and control rods. Tentatively, Hastelloy X alloyed with gadolinium has been selected for the poison portion of the rods. Safety rod drop and braking mechanism has been detailed and fabrication of the hardware is 50% complete. Gears and bearings for this mechanism have been ordered and 80% of these items have been received. Initial testing has been completed satisfactorily on the rod release mechanism for initiating scram of the control rods.

5. EBWR Fuel Elements

Irradiation Testing Program for EBWR Prototypic Fuel Rods. Four, irradiated, EBWR diameter fuel rods containing U^{D}*O_2-2.5 w/o PuO_2 were examined, two destructively. Estimated exposure is 0.37 x 10^{20} fissions/cm^3, or 1300 MWD/T of fuel; however, the flux-monitoring wires have not yet been measured. Two of the Vipac capsules (GEH-14-421 and 422) contain impacted $U^{D}O_2$ and PuO_2. Longitudinal autoradiographs of the unopened capsules indicate more uniform radioactivity in the impacted fuel. Two capsules (421 and 424) were returned to the MTR for irradiation to 1.43 x 10^{20} fissions/cm^3 (5000 MWD/T of fuel). The capsules are tentatively scheduled for insertion in the ETR for Cycle 59. The remaining two capsules were sectioned. Little or no sintering was noted, which indicates that the specimens operated below design conditions (Zircaloy surface heat flux of 158 w/cm^2 or 500,000 Btu/hr-ft^2). Autoradiographs of the transverse sections showed uniform plutonium distribution in the impacted fuel and less uniformity in the physically mixed fuel. An autoradiograph of a longitudinal section of the latter capsule revealed a concentration of radioactivity at one end of the capsule. The intense-activity region

*The U^{D} notation signifies depleted uranium.

would be caused by a plutonium-rich area or by a steep neutron flux gradient during irradiation.

EBWR Plutonium Fuel Element Fabrication. Preliminary vibratory compaction studies, using the Plutonium Fabrication Pilot Plant Facility, showed that EBWR-size fuel rods could be compacted to UO_2 densities exceeding 88% of theoretical. These results, obtained while the above facility was still under construction, compare favorably with those obtained using a prototype vibratory compaction facility, where similar fuel rods were multiple loaded and compacted to densities of 88-90% of theoretical.

Cladding Alloy Procurement. A second group of EBWR fuel element cladding tubes was received at HAPO and is being tested by ultrasonic techniques. Altogether, 1187 tubes have been received. The final shipment is expected to be made by 9/30/63.

6. Other Off-Site Customer Work

Tungsten Clad Honeycomb Fuel for SNPO. The month was highlighted by the successful extrusion of a tungsten-molybdenum billet on a low speed, 700-ton press. A composite billet of Mo and W was extruded at a 9:1 ratio on the 306 Building 700-ton press. The billet consisted of a 2-1.8 inch diameter, 1/8 inch wall Mo can with 1/8 inch thick end caps, two nested 1/8 inch wall W sleeves, and a solid Mo core all enclosed in vacuum by electron beam welding. The over-all billet length was four inches. The uncoated H21 hot work steel die had a 90° included angle entrance cone with a 0.750-inch throat diameter. A pyrolytic graphite can with a 1/32-inch wall and 90° cone nose was used as combination lubricant and insulation. In preparation for the extrusion the die and graphite can were placed in the 2.250 diameter container, which was held at 500 C, and allowed to come up to container temperature. The dummy block was fastened to the stem and allowed to preheat in the container. The billet was preheated in argon by induction (3000 cycle) to 2200 C as measured with a tungsten-rhenium thermocouple, and transferred manually to the container. A graphite cut-off was manually placed on top of the billet and the extrusion made at a 60 inch/min ram speed (maximum for this press). Maximum force was 170 tons and dropped to 140 tons minimum. The die was severely washed after about six inches of extrusion and the remainder of the extrusion has an extremely rough surface. Even though there was a long delay* (15-20 sec) between removal of the billet from the furnace and

*The billet bonded to the furnace pedestal and had to be broken loose before charging.

application of load, the evidence indicates the preheat temperature of 2200 C was too high. Subsequent trials will be made at lower preheat temperatures and with zirconia coated dies.

Extrusion Billet Heater. (NASA) The 200 KW induction billet furnace has been tested for heating refractory metals to 2200 C. The alumina outer liner of the furnace cracked from thermal shock at 1500-1800 C. Vycor glass was tried for the outer shell, but softened and swelled out at 2200 C. A zirconia liner was then tried (this material was being used as the inner liner) and appeared to withstand the temperature without cracking. The zirconia is very porous making it difficult to hold a positive inert gas pressure within the furnace. However, as the liner heats, the gas leak through the liner decreases making it possible to hold a positive pressure at the elevated temperatures.

Resistance Welding of Heavy Titanium Alloy Plates. The feasibility of resistance welding heavy titanium plates has been demonstrated for the Boeing Aircraft Company. During the program carried out to date, resistance welds were made which joined $\frac{1}{2}$" plate to $\frac{1}{2}$" plate; $\frac{1}{2}$" plate stacked three high; 3/4" plate to 3/4" plate; 3/4" plate stacked three high; and $1\frac{1}{4}$" plate to $1\frac{1}{4}$" plate. All of these combinations could be joined by the 600 KVA resistance welder while using power outputs well within the capacity of the welder. In many cases void formation occurred in the weld nugget under the arbitrarily selected conditions of initial tests. In each case the flexibility and control of the welder permitted variation of preheat, weld, post-heat cycles, and variations of applied force sufficient to overcome this problem. Study included formation of the basic weld and the study of interaction between adjacent plate edge. Considerable difficulty was encountered with the $1\frac{1}{4}$" plate because of lack of flatness of the plate supplied and the poor surface quality of the metal. These plates were successfully joined after being reconditioned here. Further work in this area will depend upon determination of the customer's requirements.

J. W. Woodfield

For Manager
Reactor & Fuels Laboratory

FW Woodfield:kb

PHYSICS AND INSTRUMENTS LABORATORY

MONTHLY REPORT

SEPTEMBER 1963

FISSIONABLE MATERIALS - 02 PROGRAM

REACTOR

Optimization of Overbore Lattices

A measurement of the buckling of a supercell lattice using the natural and enriched (0.947% U-235) C-pile overbore fuel has been completed. The buckling was determined for a supercell in which one enriched column is surrounded by eight natural fuel columns. From these data the buckling may be interpolated for any smaller number of enriched columns. This measurement completes the work on the overbore fuel program.

K Lattice Experiments Using Zirconium Tubes

Absolute k_∞ values have been determined for KVNS fuel pieces in Zr-2 process tubing in the K-lattice. This work has included both wet and dry cases. An informal report is being written which includes all information obtained during the experimental phase.

Computer program IDIOT has been used to calculate thermal flux traverses which agree to within about 2% of the unpoisoned experimental traverses measured. This has been made possible by using an adjusted neutron temperature as described by D. E. Wood. Computer program GAMTEC has also been used for this purpose, and the P-3 section thermal traverses agree to within about 1% of the unpoisoned experimental work. This program requires an adjusted neutron temperature which is just about one-half as far above room temperature as the IDIOT program. The lower temperature agrees with the methods described in Weinberg and Wigner. The advantage of GAMTEC appears to lie in input control of the source term.

Instrumentation

Development and procurement of special N Reactor startup and physics test instrumentation is being accelerated. On the basis of heat transfer calculations which revealed that thin-walled, air cooled thimbles would not be practical for the ionization chambers with which neutron flux measurements are to be made, a more conservative double walled, water cooled thimble has been designed. Adequacy of the latter design has been analytically

confirmed by Laboratory Engineering, HL, and detailed design drawings have been prepared.

High temperature coaxial cable will be used to permit elevated temperature measurements which are likely to be needed in future tests. Special teflon dielectric will be employed to reduce microphonic noise.

Tests at Loops 1 and 2 at KE Reactor continued on one gamma energy spectrometer and detector of the N Reactor fuel rupture monitoring system. Specific sample line changes were made during the last outage to permit adjustment of the sample delay time over the range of 40 to 80 seconds. In addition, the instrumentation was moved to a new location and was recalibrated. Data will be obtained following completion of the outage.

Procurement and installation of the new reactor fuels testing loop being installed at PRTR was accelerated. Noise filters were installed in the six rack cabinets which have been moved to the installation site. Pneumatic lines and electric power were run to the site, and line voltage controllers were installed. The water sample lines from the loop were extended to the sample cell room, with flow transmitters installed and connections made to the sampling glove box. Flow control valves were received and are being installed. Bids for the spectrometer electronic systems were reviewed and the equipment placed on order. Neutron counting system specifications have been prepared and a purchase order initiated. Stock delivery of both systems is expected. Recommendations have been made that during background testing the process tube be left empty rather than being charged with a dummy fuel element. Logarithmic response count-rate-meter changes were discussed with a manufacturer's representative, in which the need for more instrument sensitivity was pointed out.

The desirability of increased radiological shielding efforts at Hanford are reviewed in a memorandum report just published. Emphasis is given the advantages of coupling computer solutions with experimental studies to determine optimum shielding configurations for particular applications.

System Studies

Additional runs were made on the N Reactor pressurizer simulation to obtain new data on the liquid level and pressure control systems. The data confirm the implications of studies made earlier which indicated that addition of the derivative (rate) mode to the pressurizer level control system would be advisable. Severe pressure surges following a normal scram were obtained with the proportional-plus-reset mode of control. Addition of rate action reduced the pressure surges by providing a negative error signal to the reset mode before the level setpoint is attained, thus reducing the coolant

injection rate. A sufficient number of runs were made to determine the effects of controller time constant and gain settings and their relative sensitivity. Additional data were obtained on the performance of the pressurizer spray system and associated relief values. This completes the pressurizer runs presently scheduled.

A second model of the N Reactor primary flow control system was developed. Difficulty was experienced in getting accurate results from the first model. Debugging of the hydraulic section of the second model is complete. It is being combined with a one-delayed group reactor kinetics model to permit studies of the effects of primary loop flow control system manipulations on reactor power level, coolant flow rate and temperature.

Three mathematical models for the N Reactor steam generator were investigated and one was selected for simulation on the analog. All the necessary problem preparations, with the exception of patching, have been completed. In addition, two of the models have been programmed for the MIDAS system. Both programs are being debugged.

Calculations of reduced delayed neutron groups for the fast fission of Th^{232}, U^{233}, U^{235}, U^{238}, and Pu^{239} and the thermal fission of U^{235}, U^{233}, and Pu^{239} have been completed using a new 7090 code. This code was used to calculate 1, 2, and 3 group reduced delayed neutron constants according to a criterion which makes the asymptotic behavior of the reduced group transfer function agree with the natural group transfer function at low and high frequency. Calculations of the magnitude and phase shift of the transfer functions for all of the above isotopes for 1, 2, and 3 delayed neutron group models have been completed.

SEPARATIONS

Critical mass experiments were continued with PuO_2-polystyrene compacts and the Remote Split-Table Machine. Critical core configurations studied consisted of bare and reflected rectangular prisms with criticality being achieved in three different arrays described below. The concentration of Pu in the polystyrene compacts was 1.14 g/cc with an H/Pu atomic ratio of 15. The Pu contained 2.2 percent Pu^{240} by weight; the critical mass values are given in terms of the total Pu present including the Pu^{240}.

1. The first of these assemblies consisted of a non-reflected rectangular prism of near cubic geometry. The critical dimensions were 12-in. x 12-in. x $\sim$ 12.66-in., and the critical mass of Pu was 34.06 kg.

2. The second assembly was fully reflected with Lucite. Critical core

dimensions were 9-in. x 9-in. x ~8.38-in. The critical quantity of Pu was 12.6 kg.

3. Criticality was also achieved with a rectangular parallelopiped of cross sectional dimensions 6-in. x 7-in. The critical length of the parallelopiped, which was reflected with Lucite on the sides but not on the ends, was ~26.8-in., and the critical mass was 21.0 kg.

Pulsed neutron source experiments were performed concurrently with the critical experiments, and several measurements were made of the "reactor noise" by Dr. Albrecht of the University of Washington. The pulsed neutron source experiments and reactor noise analyses were expected to give independent but similar answers for the neutron lifetimes in the assemblies. The measured lifetime corresponds to the average time that a neutron lives in the finite system once it has been released in fission. Excellent agreement has been obtained between the two methods of measurement. Values of the neutron lifetime are given below for several of the measurements completed this month in which the data have been analyzed.

Critical Dimensions of Assembly	Neutron Lifetime**	
	Pulsed Neutron Source	Reactor Noise Analysis
Bare Rectangular Prism* 12-in.x12-in.x12.66-in.	1.38×10^{-6} sec.	1.21×10^{-6} sec.
Lucite Reflected Prism* 9-in.x9-in.x8.38-in.	13.8×10^{-6} sec.	Analysis not completed

* Pu concentration 1.14 g/cc; H/Pu atomic ratio 15.

** In the calculation of the neutron lifetime, the delayed neutron fraction (β) was assumed to be 0.0021 for Pu.

It is interesting to note the considerable difference in the neutron lifetime between the bare and reflected assemblies (a factor of ten). This is because the lifetime in the reflected case is the weighted average of the core lifetime and the mean time spent by neutrons in the reflector region before returning to the core. (The lifetime of a neutron just in the reflector material itself would be about 200×10^{-6} sec.)

From Monte Carlo calculations the neutron lifetime in the unreflected assembly is estimated to be $\sim 1 \times 10^{-6}$ sec., which does not differ appreciably from the measured value.

Copper and gold foil irradiations were made in each of the first two assemblies (the near cubic arrays) for determining neutron flux distributions. The analysis of the data from these irradiations has not been completed; however, in the bare assembly the measured cadmium ratio with 5 mil thick gold foils and 21 mil thick cadmium was $\simeq 1.091$ indicating the neutron spectrum to be predominantly epithermal.

The self heating from the α particles emitted in the radioactive decay of the Pu was used to determine the effect of temperature changes on the criticality of the PuO_2-plastic mixtures. Reactor period measurements taken at various temperatures in the bare and reflected cubes showed the temperature coefficient of reactivity to be definitely negative in both cases, with the value being larger in the unreflected assembly. The pulsed neutron source technique was also used to measure the temperature coefficient of reactivity, but the results are in poor agreement with those obtained from the reactor period measurements; the reason for the difference has not been determined.

Further measurements of the control and safety rod strengths in these systems have yielded values of about 90 cents for the control rod worth, and about three dollars for the safety rod worth.

The results from these critical experiments provide the first firm critical data on homogeneous Pu systems of intermediate neutron energy spectrum which constitute neither fast or thermal systems. The data will be applicable to wet powders, precipitates, slurries, polymers, etc., which may be encountered in the separation and processing of Pu.

Computational Methods

1. FMC-N Monte Carlo Code for Computing Criticality Parameters

A study is currently being made to determine the feasibility of using an off-plant Monte Carlo program from GE-NMPO, Cincinnati, in the calculation of criticality parameters for complex reactor shapes. This Monte Carlo code, called FMC-N, was written primarily for use in shielding calculations, but can possibly be modified for application to criticality problems. The code does not take molecular binding into account in the thermal region and it also neglects the thermal energy of the target nuclei. These two effects tend to cancel, but the over-all consequences of neglecting both of these needs to be determined. A test case has been run on the 7090 computer.

2. GAMTEC - A Neutron Slowing Down and Thermalization Code for Lattices

A number of minor changes have been made in the GAMTEC code. This code provides multigroup constants for heterogeneous systems for use in multigroup diffusion calculations and also computes the individual criticality parameters of a lattice. A special routine has now been added for calculating the resonance escape probability by empirical methods. When this special routine is used, all of the high energy portion of the code (GAM) is not used. The empirical method is quite satisfactory for survey work and saves considerable computer time.

An option has also been provided in GAMTEC so the microscopic cross sections for the thermal group can be printed out. Therefore, both microscopic and macroscopic cross sections are available over the entire fission energy range.

3. INTERSET Code

The INTERSET high accuracy cylindrical interaction code was distributed to CPD and HL customers. A final code report is being processed, completing the scheduled work on the interaction problem. Theoretical work done over the past eighteen months has advanced the mathematical model of interaction beyond that in common use throughout industry. The previous method considered only the central unit in an interacting system and calculated the interaction by a very simple first approximation to the total solid angle subtended by all other units. The present method considers interactions between all the units, treats the problem as an eigenvalue problem and calculates the geometric contribution to the interaction matrix by a double cosine integral over solid angle, iterating on the system multiplication to eigenvalue convergence. The accuracy of the present method is estimated as ± 5%, a marked improvement over the 75% of the former method. This is the first known description of interaction between cylinders with different heights, different nuclear characteristics, and external reflectors. Since little or no experimental data with these variables exists, the possibilities for such experiments are being informally explored.

4. Buckling of Truncated Spheres

Several delays in complete debugging of the code to calculate the buckling of a bare truncated sphere were encountered during the month. The most snugly concealed bug located so far was found in the integration of the Lagrange fitting terms with the top surface boundary condition: complete loss of significant figures resulted from cancellation of large positive and negative terms. Resorting to double precision for

this portion of the calculation gave reasonable accuracy, but the added instructions overflowed the computer memory. This section of the code has been rewritten as the first link of a chain job.

Instrumentation

Reactor noise measurements were made in two critical, solid systems at the Critical Mass Lab. In one system with alternate moderator and fuel blocks, the prompt neutron lifetime was found to be 8.4 micro-seconds and in an all fuel block assembly the prompt neutron lifetime was found to be 1.33 micro-seconds. The 8.4 microsecond point was corroborated by a pulsed neutron measurement. The 1.33 microsecond point could not be measured accurately using pulsed neutrons but substantial agreement between noise and pulsed neutrons at two slightly subcritical points gives increased confidence in this measured value of lifetime.

Further tape recordings have been made in a completely reflected system with prompt lifetime (as measured by pulsed neutrons) of approximately 15 microseconds. This data will be processed at the University of Washington in order to determine the value of the lifetime from noise measurements.

Development of the Redox counting room programmer was completed. Fabrication will begin upon receipt of the circuit boards which were ordered. This device is designed to produce automatically a typed readout and a punched paper tape containing about 200 characters of information needed to instruct the IBM 7090 in the analysis of pulse-height analyzer data.

An improved rod drop test was performed at the Critical Mass Laboratory to measure the worth of the safety and control rods in the plastic block system. The test, utilizing a fission chamber, showed considerable improvement over a previous test which utilized a scintillation detector.

The magnifying lens for the TV camera at the Critical Mass Laboratory was received and tested. The results showed that a one-sixteenth inch separation of the blocks projected as a one-inch separation on the screen. It is suggested that an additional camera be purchased for this close viewing and the existing camera be used for over-all viewing.

Consulting Services on Nuclear Safety - Criticality Hazards

1. Nuclear Safety in CPD

Participation on the hazards review committee for the Z-Plant Waste Treatment Facility (CGC-912) was completed. Report HW-78577 has been

issued by the committee to cover this review. Both the CGC-912 project and the CAC-880 project were reviewed by the GE Technological Hazards Council on September 9, 1963.

Plans are being made to make pulsed neutron source measurements on the Z-9 crib, located east of the 234-5 Building. The Z-9 crib received CAW and organic waste solutions from the old Recuplex facility before the latter facility was shut down in 1962. Samples of the soil from this crib have indicated the presence of significant quantities of Pu. Pulsed neutron source measurements will be made in an effort to obtain an estimate of the neutron reproduction factor in the crib, and if possible, to determine if these concentrations constitute a potential criticality hazard.

2. Nuclear Safety Review for GE-APD

During the period September 16-20, Mr. C. L. Brown visited GE-APD to perform a nuclear safety review at their request.

3. Nuclear Safety Training and Education Course

Two different lecture series in nuclear safety are currently being given at the Critical Mass Laboratory. The "A" series is designed to introduce technically oriented personnel with the technical bases and computational methods used to prevent criticality accidents. About 16 lectures are required for presentation of the material. The "B" series (short course) is oriented more to the non-technical supervisors and specialists who have need for some understanding of the bases for nuclear safety procedures and operating limitations. The "B" series consists of about six lectures.

These courses have been arranged for the Chemical Processing Department, but to the extent that space permits, personnel from other departments are welcome to attend the lectures. All lectures are presented in the lunchroom of the Critical Mass Laboratory, starting at 10:30 A.M. on Mondays and Thursdays; each lecture lasts about 1½ hours. The "A" series is presented on Mondays, and the "B" series on Thursdays. Both of these series were begun during the week of September 9. A total of 40 students are currently enrolled in the two classes. Another series of technical lectures will be scheduled to start in January, 1964, to accommodate those who cannot be included in the fall "A" series. A second presentation of the "B" series will be given, beginning about October 31; depending on the indicated demand, this series may be presented again in 1964.

NEUTRON CROSS SECTION PROGRAM

Scattering-Law Measurements for H_2O at 95°C

No significant measurements were made on the study of the slow-neutron Scattering Law for H_2O at 95°C during the month due to reactor outages. The reduction of raw data from previous measurements was completed. New indications of systematic errors in the measurement of the neutron scattering from vanadium were identified in these results. Measurements are in progress to attempt to define the source and extent of these errors.

Analysis of the Scattering Law

A series of scattering-law calculations using program LEAP have been made to attempt to fit the Hanford and Chalk River measurements on room-temperature light water. The results are not very satisfactory. When each of the two highest molecular-vibration levels (near 0.48 eV) is given weight equal to that of the lowest vibration level (at 0.2 eV), the calculated surves of S vs. α have peaks which are about 20% low and shifted to high values of α. Reasonably good fits have been obtained only by reducing the weights of the highest levels to zero, a procedure which has not been justified on any theoretical or other experimental grounds.

Time-of-Flight Spectroscopy for Slow Neutrons

Work continued on the development of equipment for a rotating-crystal spectrometer for the measurement of slow-neutron inelastic scattering by time-of-flight. The fabrication of the step plug which will serve as the neutron beam shutter for this spectrometer was completed. The step plug has been vacuum tested, and the testing of the beam-shutter mechanism under expected temperature conditions is in progress.

Fast-Neutron Cross Sections

Another series of total cross-section measurements for neutrons of 3 to 15 MeV energy by time-of-flight techniques was completed during the month. In this series, measurements were made on five elements for which no data previously existed in this energy range; scandium, europium, terbium, thulium, and lutetium. Measurements were also repeated for samples of Be, Si, La, Ho, Er, and radiogenic Pb.

Samples of separated isotopes of W^{182} and W^{186} were received from ORNL for total cross-section measurements.

REACTOR DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Approach to Critical Experiments Using High Exposure PuAl Fuel

The results of the five approaches made to date are listed in the following table. These are not the final values, but are preliminary estimates of the critical number of rods and the bucklings.

Lattice Spacing (in)	Extrapolated to Critical (Rods)	Buckling (Microbucks)	Extrapolation (length-cm)
0.66	1378	4346	8.021
0.75	848	5000	8.192
0.80	796	4967	7.48
0.85	786	4641	7.411
0.90	871	----	-----

Experiments with Irradiated Fuel in the PRCF

Two types of irradiated fuel have been measured in the PRCF. The reactivity of a small PuAl rod 1/2" O.D. and 4" long and a PuAl 19-rod cluster from the PRTR have been measured.

The measurements of the small samples serve two purposes. First, they show how sensitive a measurement can be made and where errors may enter the measurement. Secondly, if measurements on the small samples are successful, it will be possible to compare them with measurements which have been made in an H_2O moderated facility (MTR-ARMF at Idaho Falls). The PuAl sample was measured in a thimble of H_2O in the center of the D_2O moderated PRCF. The sample had lost 103 ± 10 μk because of irradiation in the MTR. This loss was 2/3 of its original reactivity. It was also learned that the more accurate measurements are made with coolant flow in the thimble rather than in static conditions. A coolant coefficient for H_2O coolant was measured as + 30 μk/°C also. This coefficient has the opposite sign of the moderator coefficient because the H_2O is a strong poison in the PRCF and increasing its temperature would decrease the absorption effect.

The measurements of full length clusters are to determine how best to make the measurement in the presence of the photoneutrons from the (γ,n) reaction and to learn how much information can be obtained from the measurement. The PuAl cluster has lost 5 ± 1 mk after being irradiated in the

PRTR for 30 MWD. This loss is ~1/3 of the original worth. The neutron source strength in the PRCF because of the (γ,n) reaction in D_2O and the (γ,n) reaction in the PuAl elements increased by a factor of 4 because of an increase in the (γ,n) source when the irradiated fuel element was added to the PRCF. The irradiated element has been discharged from the PRTR for ~17 months.

Experiments in D_2O Moderator in the PRCF

Measurements were performed in the center of a Pu-Al cluster and in a single Pu-Al rod in a thimble in the center of the PRCF to determine the neutron spectrum in two different environments. The thimble contained no moderator when the cluster was used and contained light water moderator when the single rod was used. The measurements were made by irradiating lutetium foils, bare and cadmium covered, in a plutonium-aluminum sample which was placed in the vertical and radial center of the reactor. The spectral index and Westcott r value were measured to be 317 ± 1°K and 0.0121 + 0.0001 respectively for the H_2O moderator and 380 ± 3°K and 0.070 ± 0.002 respectively inside the cluster. In both cases the temperature of the D_2O moderator was 301°K.

The measurements to determine the sensitivity of the reactor to absorption for each of the environments have been analyzed. The sensitivities vary between 72 and 99 $\mu k/cm^2$ of boron depending on the fission cross section of the sample used for the measurement. The sensitivities were obtained with an uncertainty of ~5%. This uncertainty is only one-half of that which was based on a preliminary analysis and reported earlier.

Scattering Law for Water

Work continued toward reducing the running time of 2GUSWI which calculates the scattering law for water. An asymptotic formula for large momentum transfer has been developed, and currently the methods for evaluating this formula numerically are being worked out.

Modified Heavy Gas Equation

The flux distributions produced by three runs of program PHI for a graphite moderator have been compared to the more exact flux distributions produced by program SPECTRE S. The preliminary results indicate that the modified heavy gas equation breaks down and does not produce a good approximation to the flux distribution of SPECTRE S when a high concentration of plutonium is present. Various parameters, such as moderator temperature, plutonium concentration, and uranium concentration are being varied to determine the range of usefulness of the modified heavy gas equation.

PRTR Burnup Experiments

The experimental burnup data from the destructive testing of three graded exposure Pu-Al fuel elements are essentially complete. These elements are three of six elements initially proposed as PRTR Test Number 13 in HW-71786. The data have been tabulated and include the following:

1. Fabrication information, exposure periods, accumulated exposures, and the analytical results from melt samples.

2. Sample weights (gm/liter) for 1/2" samples cut from three rods, one outer ring rod, one middle ring rod, and the center rod of each element at designated rod positions.

3. Sample weights (gm) for macrodrill samples. These samples are 1/16" drills, 1/2" deep, across the diameter of a 1/2" section taken from center of each rod.

4. Cs-137 activity measurements (d/m/ml) for the samples of (2) and (3) above.

5. Alpha activity measurements (d/m/ml) and Pu content determinations (gm/liter) for (2) and (3) above.

6. Coulometric titration analyses to determine Pu content (gm/liter) of every third sample only of (2) above.

7. Plutonium isotopic analysis for the samples of (2) and (3) above by mass spectrometry.

The spatial distribution of percent burnup of the plutonium in a rod was calculated by the following equations:

$$\text{Percent Burnup} = \frac{\text{Pu fissioned} \times 100}{\text{initial Pu}} \qquad (1)$$

$$\text{Percent Burnup} = \frac{\text{Pu fissioned} \times 100}{\text{Pu fissioned + final Pu}} \qquad (2)$$

where initial Pu of a sample is obtained from the data tabulated in (1) and (2) above, and the final Pu of a sample is obtained from the data of (5) and (6) above. The Pu fissioned is determined by the equation

$$\text{Pu Fissioned} = K \frac{A(t)}{\gamma\lambda\, e^{-\lambda t}} \qquad (3)$$

where A(t) is the Cs-137 activity of (4) above, γ is the yield of Cs-137 from the fission of Pu-239, 6.48%, λ is the radioactive decay constant, $T_{\frac{1}{2}}$ = 29.68 ± 0.05 years, and K is a constant containing conversion factors. For every regular $\frac{1}{2}$" burnup sample, percent burnup was thus determined by two methods and, where the data of (6) above were available, by three methods.

Analysis of PRTR Burnup Experiments

Improved values for the fuel cross section ratios have been obtained using fitted polynomials to describe the atom density changes as a function of burnup. The derived cross sections are dependent on the accuracy of the fitted curves, as well as the assumed value of $\sigma_f^{41}/\sigma_a^{49}(=.84)$, considered constant throughout the burnup.

Code Development

RBU

Preparations for the PRTR 19-rod fuel cluster study on RBU are nearly completed. The mathematical description of the cluster has been done in such a way as to allow estimation of both radial and transverse effects as well as some fine-structure detail in the cluster itself during the burnout period. Some difficulties still remain in treating the heavy water scattering law in the Monte Carlo calculation.

Re-evaluation of the modified gas scattering law may be completed in time for use in the 19-rod cluster study. The KERNEL program has required some revision in the numerical integration calculation because of large accumulative errors. A Simpson's integration was substituted for the original trapezoidal integration and a considerable reduction in error resulted. Despite this, however, it appears that numerical difficulties with KERNEL have not been eliminated completely and additional changes are planned.

The RBU system documentation work proceeded slightly behind schedule due to some required flow-diagram revisions.

Master Cross Section Library

A three-day meeting of the ANS Master Cross Section Library Subcommittee concluded September 20. Some progress was made towards creating a central evaluated source of nuclear data. Preliminary estimates of the time required to establish an operating library system are one to five years. A target date of June 1964 was set for compacting the design of a format for the evaluated data library.

BARNS

In the course of debugging the revisions in BARNS which combine individual isotope data to produce cross sections for elements, additional errors were found in the subroutine for calculating the inelastic scattering matrices. These errors are now being corrected.

HRG

One of the modifications to GAM which has been included in HRG is the formal extension of the GAM resonance integral calculational method to isotopes other than U-238 and Th-232. In applications so far, this method has proved to be very time consuming. In an effort to improve the performance of this calculation, this portion of HRG has been extracted and set up as a separate code to calculate resonance integrals. An investigation of resonance integrals by this method has now begun.

Physics Chain

Physics chain revisions which will permit a burnup case to be run in one pass are approximately 30% complete. SIGMA-3H has been altered to carry required information from GAM and TEMPEST to HFN via the HFN Data Tape. Additions to HFN pass on this information and additional input and output data from HFN to a CLERK II pre-processor called SAM. All changes are apparently operative up to SAM, which is written but not debugged.

Because of space limitations in HFN, it has been necessary to write revised versions of several FORTRAN library programs.

ALTHAEA Cross Section Constants

An interference coefficient array for a 260 C water-moderated reactor has been obtained using the HRG-SPECTRUM chain code. The interference coefficients are for use in the ALTHAEA one-dimensional burnup code to reflect the epithermal shadowing of the various isotopes on other fuel isotopes by means of the following equation:

$$\frac{\sigma_i}{\sigma_i} = \frac{1}{(1 + C_{ji}\, Y_j\, Z_j/SCA)^{1/2}}$$

where:

$\overset{o}{\sigma}_i$ = the effective cross section of the i^{th} isotope averaged from μk T_n to 10^7 ev with the isotope i present in typical concentration,

σ_i = the infinitely dilute cross section as calculated from Westcott (see CRRP-960) parameters,

C_{ji} = the interference of the j^{th} isotope on the i^{th} isotope,

Y_j = concentration of the j^{th} isotope,

Z_j = the height of the major low lying NRIA resonance adjusted for the effects of the other resonances,

SCA = a resonance scattering index reflecting the surface to volume ratio effects of the effective scatterer. This is adjusted to give the correct epithermal reaction rate of the major isotope.

The values of the interference coefficients have been obtained and a library tape processed using these values.

HRG-SPECTRUM Library and Standard Energy Mesh

Several energy mesh spacings have previously been in use with SPECTRUM code, therefore, it was recommended that experiments be carried out to determine if a universal mesh spacing could be devised which would provide the benefits to the user previously attained only by using different mesh spacings emphasizing the portion of the spectrum where greater accuracy was desired. Specifically, one mesh spacing was in use for thermalization experiments, and another was in use for obtaining the effective resonance integral of Pu-239 for homogeneous reactors.

A mesh spacing has been devised which yields results in the thermal or Maxwellian energy group which closely approximate those previously attained with the mesh especially designed for this purpose as indicated by the following averaged cross sections.

Isotope	Pu-239	Pu-241	U-235	Pu-240	O-16	Zr-40
Thermal Mesh	967.37	990.75	567.94	249.17	0.0001784	0.15291
Universal Mesh	963.23	986.85	571.48	249.76	0.0001788	0.15329
% Change	-0.43%	-0.40%	+0.62%	+0.24%	+0.26%	+0.26%

The agreement between the two thermal groups is thus shown to be rather good, where the thermal group extends to 0.18 eV. The next group extends from 0.18 to 0.68 eV, and the agreement for Pu-239 and for Pu-241 is excellent (0.1% approx.), and the Pu-240 agreed to within about 1.0%. The next group from 0.68 to 2.38 eV, which contains the major Pu-240 resonance, agreed to within ±10%; and the dilute resonance integral was closer for Pu-240 to the expected value with the second mesh than for the original mesh.

Transport Theory

Transport Theory Development Work

Reformulation of Hanford's multi-energy transport analysis, to provide rounding logic throughout the entire calculation, progressed through completion of programming and debug work on the new deck (GE-HL program S-XII).

To facilitate decisive evaluation of the effects of replacing truncation logic by rounding logic, other improvements incorporated into the reformulation were limited to meeting immediate needs not affecting the calculational logic. The deck was broken up into a three-link chain (input, main loop, output), for example, to ease memory-capacity limitations; a power normalization option which has been needed in advanced design studies on epithermal reactors was provided; and the space-energy output smear was extended to provide space-energy-material smearing flexibility, in response to off-site requests received from both Los Alamos and Vallecitos.

Advanced Reactor Concepts

Phoenix Reactor Concept Studies

The nuclear parameter survey for the Mark I core has been extended to cover a larger variety of core configurations. Core volumes which previously were confined only to 500 liters, now cover a range from 250 to

1000 liters. The original Mark I, M/W was set at unity. Additional calculations have now been carried out for M/W = 0 and M/W = 2.

Refinements of the burnup calculations are also being made. Many of the previous "life studies" were carried out with group microscopic cross sections characteristic of the clean reactor startup conditions. In the more recent life studies, adjustment of the microscopic cross sections is made at various stages of reactor life.

Evaluation of MTR as a possible irradiation facility for a complete Phoenix core is continuing. Studies of the reactor physics statics have been broadened in both detail and scope over the past month. Two-dimensional solutions of the four-group reactor fluxes, using the code 9-ANGIE, have eliminated a great deal of the geometry idealizations necessary for 1-D calculations. The specification of the core composition in x-y geometry puts the general problem of "core homogenization" on firmer footing. Three areas now being analyzed contain separately 4.4, 10.0, and 20.0 isotopic percent Pu-240 in the unburned Pu-Al fuel. Each core is composed of 27 fuel boxes, several of which contain fuel plates with uniformly 6.4 gms/plate, the remaining boxes having 8.0 gms/plate before irradiation.

Initial (time = 0) cross sections of all pertinent materials for the burnup calculations of these cores have been obtained in four-energy group form using THERMOS for the thermal and Pu-240 resonance groups, and GAM for the two high energy groups. Some supplementary cross section data were obtained from TEMPEST.

Fast Reactor Studies

Nuclear Design Calculations for a Pu-Rocket

Reactor physics statics calculations have been completed on the preliminary model of a small fast spectrum reactor.

The description of the model is as follows:

> The core is 18" high by 12" in diameter, divided axially into four fuel zones, each $4\frac{1}{2}$" thick and containing 40 v/o, 50 v/o, 60 v/o, and 70 v/o void, respectively, starting at the reflected end.
>
> The reactor is reflected radially, and on one end by 4" of Be.
>
> The fuel is a cermet of Pu in W, the Pu containing 5 a/o Pu-240 and 95 a/o Pu-239.

The first results of the calculation indicate that the reactor should contain higher fuel loading than was originally postulated. It does have, however, approximately the desired axial lower distribution. The calculations were performed with HFN in both slab and cylindrical geometry in an iterating procedure in order to specify the vertical buckling as near as possible in the final case.

Assessment of Fast Reactor Cross Section Compilations

The GODIVA (U-235) and JEZEBEL (Pu-239) core were selected to perform a series of check calculations on the validity and accuracy of the plutonium and uranium fast reactor cross sections currently used for criticality calculations. Seven cross section sets were investigated and both diffusion (HFN and G-2), and transport (S-XI) theory codes were used for the calculations.

The cross section sets are designated as follows:

(1)	HRG 228.2288	6 gps
(2)	HRG 228.2288	13 gps
(3)	HRG 239.5607	6 gps
(4)	LAMS 2543	6 gps
(5)	CPRX-LA 2707	13 gps
(6)	YOM	16 gps
(7)	NDT	19 levels

HRG 228.2288 - From RBU Basic Library data.
HRG 239.5607 - From GAM-I data tape.
LAMS 2543 - From the document LAMS 2543.
CPRX-LA 2707 - From the document LA 2707.
YOM - From Fast Reactor Cross Sections, Yiftah, Okrent, Moldauer.
NDT - From the G-2 Nuclear Data Tape.

The results of the calculations indicate a considerable spread between the various cross section sets in use. Re-evaluation of some of the sets seems to be in order.

Mass Spectrometry

Isotopic analyses of samples in support of Plutonium Recycle Program studies were continued. Thirty-two analyses were performed for uranium fractions of PRTR fuel element No. 1101. Twenty-two analyses were performed as additional samples or confirmatory analyses for PRTR fuel elements Nos. 5092 and 5095. In addition, five analyses were provided for PRCF experiments.

Instrumentation and System Studies

The minor circuit modifications desired for the PRTR liquid effluent monitors were completed in one instrument and tests at PRTR were successful. Similar changes will be made on the other units of the system with one unit being converted at each outage.

An attempt to rerun PRTR test No. 35 (kinetics) was only partially successful because of a failure in an ionization chamber. The moderator level measurement was completed, however, and analysis of the spectrum shows the same peaks at approximately 3 and 10 cycles per second which were noticed on an earlier test. A simultaneous measurement of flux and liquid level is required, however, to obtain useful kinetics data.

The PRCF analog computer study for heavy water moderation was completed for use in hazards analyses. A similar analog program for light water moderation was completed and debugging was started.

HIGH TEMPERATURE REACTOR LATTICE PHYSICS PROGRAM

A 200 hour corrosion test in a nitrogen atmosphere at 1000 C has been completed. None of the samples used showed any severe corrosion or carburization upon visual inspection. Samples of nickel, thoria dispersed nickel, hastelloy-X, molybdenum, and inconel were included in the run. All of these are being considered for use in the HTLTR. Physical and metallographic studies of the samples are being made. Another run at 1000 C is being prepared which will last for 1000 hours. In addition to the materials included in the first run will be samples of hastelloy-X containing about 1% gadolinium and some ceramic materials. The hastelloy-X-Gd may be used in control and safety rods. The ceramics to be tested are those considered for use as thermal and electrical insulation in the HTLTR.

The HTLTR mockup, in which prototype items are to be tested up to 1200 C, consists of a 10-foot-long graphite assembly surrounded by insulation and a containment shell for the nitrogen atmosphere. Considerations of the graphite portion have been completed and fabrication will start in about a week. The engineering work on the insulation, shell, gas system, and heating system have not been completed. The drive and release units of the prototype control and safety rods have been considered from the engineering and fail-safe point of view.

The reactor calculations being made for HTLTR have been extended to include a determination of control rod worth. This will be of assistance in selecting the alternate control rod locations.

A study of neutron beam choppers has indicated that a suitable type for use in measuring neutron spectra from lattices in the HTLTR would be a single rotor multiple slit type. For this type the relations between neutron velocity, flight path, rotor angular speed, rotor diameter, slit width, source strength, chopper transmission, counter efficiency, and resolution have been reduced to graphical form covering the region of interest for HTLTR application. The graphical presentation will be useful in setting the various parameters of the chopper system during the design period.

During the course of experimental studies using the HTLTR there will be a need for several types of reactivity data. The null reactivity of the properly poisoned central cell must be determined. Relative reactivity coefficients for various materials must be measured. The reactivity of a sample as a function of position would also be valuable information.

Several techniques are available for measuring reactivities and relative reactivity coefficients. For the HTLTR two oscillators have been proposed. The reported performance of oscillators now in operation is being evaluated to determine if existing equipment and techniques of analysis can be adapted to our needs. The heavy central cell will not be able to move in and out quickly enough to generate a step change in reactivity. The reactivity change will be more like a saw tooth or a sine function. The neutron respone of the reactor to several frequencies of oscillation has been calculated using the zero power transfer function and TRIP-105. Both methods agree within 0.5% thus giving confidence to the use of TRIP for the analysis of more complex reactivity changes.

NEUTRON FLUX MONITORS

A topical report discussing experimental evaluation of the neutron parameters r, T and ø has been completed and made ready for issue.

Three regenerating detector samples, of the 12 being irradiated at KE Reactor, are still awaiting preparation for mass spectrometer analysis. Recent outage at KE Reactor has delayed exposure of the remaining samples. Further investigative efforts will depend on the results obtained by the mass spectrometry tests.

Calculations were made to determine the possibility of using isotopes other than Boron-11 as in-core neutron flux detectors of the beta-current type. Aluminum-27, Vanadium-51, Technetium-99, and Lithium-7 all appear to offer possibilities although none has the desired combination of cross section, half life, and beta energy. A snout facility in the KW Reactor was secured for irradiation of one Boron-11 detector, and in addition, an

Aluminum-27 detector was fabricated and charged into the reactor with the Boron-11 unit. A detectorless cable was also charged into the facility since initial tests indicated that currents resulting from detectors exposed to known flux distributions were inconsistent. Measurements are now being made to determine the extent to which cable induced errors are present in these applications. A special circuit was devised for measurement of the low current levels expected from the beta-current detectors. A commercial voltage-to-frequency converter was modified to a current-to-frequency converter. Tests showed that ±1% accuracy could be achieved for an input current of one nanoampere and ±10% accuracy for 0.1 nanoampere. Input drift currents are in the order of 10 picoamperes after warmup. The complete measurement system includes the modified converter, a commercial frequency counter, and a printer. In use, data points can be obtained every 20 seconds with a 10 second counting time. Variations permit sampling on a 10-second period to a 2-minute period with a 1-second minimum counting time.

A discussion was held with members of Irradiation Testing, IPD, to determine the requirements for shield plugs and reactor test hole facilities for the microwave in-core neutron flux monitor experiments. Prints were obtained for the B-Test Hole at DR Reactor test facility which will be used for the investigations. Since water cooling will be used, a special shield plug will not be required. Preparation was started on the Production Test proposal. Requisitions were prepared for a new higher power klystron, for a ferrite microwave switch, and for some special glass which will be used for plasma containment. All necessary waveguide test sections have been received.

NONDESTRUCTIVE TESTING RESEARCH

Electromagnetic Testing

An invention report was written describing a single frequency, dual channel eddy current tester using the graphical nulling feature. The tester, which evolved during the extensive tests on the N Reactor steam generators, has new features which permit the display of more test information and make it easier to keep in adjustment by the operator. This is made possible by use of the graphical nulling feature, in making phase discrimination adjustments, the use of special circuits, to give a vectorscope presentation having easily recognized patterns for specific test specimen conditions, and the recording of signals which will reproduce the vectorscope presentations for future interpretations of test results.

A commercial eddy current vector impedance locus plotter (VILP) is being evaluated for use in measuring impedances of unknown sources over a range

of frequencies. The performance of the VILP was found to be limited over the frequency range which is desirable for impedance measurements. In order to use the VILP for such applications as metal thickness measurements, it will be necessary to modify the unit with a special amplifier, which is being designed, not having the limitation in frequency response.

Experiments are under way to determine the feasibility of accurately measuring metal thicknesses using a two-coil, transmit techniques in which signal phase shifts are used. In one application it is desirable to measure 0.020 to 0.030 inch thick Hastelloy "C" specimens to within an accuracy of one tenth of one percent. It was found that such precision will be possible if the equipment is properly designed. Existing equipment was found to be accurate to within 0.4% and new designs, which are being considered, should approach the desired precision.

Heat Transfer Testing

The equation describing the diffusion of heat is identical in form to that describing the diffusion of an electromagnetic wave in a conductor. A study is being made to determine the applicability of data analysis techniques, used in electromagnetic testing, to data from heat transfer tests. A review of the differential equations describing heat transfer has shown that there is no direct analog between an electromagnetic wave in space and a thermal wave (with temperature corresponding to electric field and flow rate corresponding to magnetic field). However, it may be possible to apply some of the same concepts and techniques used in analysis of eddy current data to the analysis of heat transfer test data. For example, the attenuation in the amplitude of sinusoidal temperature variation, which is a function of distance, heat capacity, density, thermal conductivity, and frequency of temperature variation, is analogous to that of eddy currents in conductors. Further studies to develop concepts for use in interpretation of data from heat transfer tests are under way.

The heat transfer testing equipment that is being used for development of heating and temperature detection techniques, and for demonstration of testing techniques, has been temporarily dismantled to allow removal of the N Reactor charging machine from the building.

Zircaloy-2 Hydride Detection

Metallographic results from a small section of an N Reactor process tube showed a few hydride platelets and a large number of smaller particles distributed in the matrix metal. The distribution of smaller particles correlated with the relative amplitudes of eddy current signals recorded during tests made on the process tube section prior to the metallographic

work. Although the smaller particles took on the characteristic gold stain of zirconium hydride during anodization, they may not be hydride. Samples taken from the process tube section are presently being analyzed for hydrogen content by the vacuum outgassing method.

Stability and signal-to-noise ratio in the 44 and 455 kc laboratory prototype eddy current detection instruments were determined experimentally in terms of differences in resistivity of Zircaloy-2 samples placed under the probe coils. Drift, during 1/2 hour periods, and noise at the output terminals of either instrument were approximately equal to the change in signal caused by a resistivity change of 0.2 micro-ohm-centimeters in Zircaloy-2 sample having a resistivity of 72 micro-ohm-centimeters. This compares favorably to the 2.5 micro-ohm-centimeter change in the resistivity of Zircaloy-2 which is expected to occur as a result of hydriding to a level of 2000 ppm.

A new temperature compensated probe head for operation at 44 kc was fabricated for use in laboratory tests on short sections of Zircaloy-2 tubes. The new probe is an improvement over the previous design in that it mechanically follows the inner surfaces of the tubes better and reduces the problem of probe lift-off compensation. Tests have shown that better compensation for rapid temperature changes will be needed in probes for in-reactor use than was obtained in the present laboratory model.

Fundamental Ultrasonic Studies

In order to determine the feasibility of using boundary waves for testing bond quality, various small metal samples were prepared for bonding. An induction heater was used for initial attempts to obtain bonds between pairs of metal specimens. This method of bonding was found to be unsuitable for all but a few of the prepared metal samples which had the highest melting temperatures. Efforts were undertaken to obtain bonds and bonding defects by other methods. Boundary wave experiments with regard to zirconium hydride and stressed samples were delayed pending completion of sample holders and other associated equipment. Photographs of various effects related to boundary wave formation and several colored Schlieren photographs of lamb wave propagation were taken for use in poster displays in connection with research studies.

Basic theoretical studies concerning the general aspects of sound wave propagation are being conducted by the Applied Mathematics Operation, HL. It is hoped, as a long-range goal, that any ultrasonic testing model can be eventually explained as the result of this work. Initial studies have dealt with the representation of the general solution to wave propagation at an interface between ultrasonically dissimilar media. Wave attenuation was

taken into account in the form which is given by the differential equation of Voigt, which is commonly referred to as the "Voigt Solid." The not-yet-complete study of the solutions to the equation of particle motion has given rise to some doubt as to the validity of the Voigt model. One solution actually indicated that wave propagation would be in a direction of increasing amplitude: An obvious violation of what physically occurs. Further analysis is essential to bring agreement between the analytical model and the physical phenomena. Also, the Voigt solid may not be the best model for representing the wave propagation as applied in common ultrasonic tests. The assistance of individuals more familiar with these problems has been solicited and an informative visit has been arranged. The rough draft report on the fundamental studies concerning liquid-liquid interfaces is about 95% complete.

USAEC-AECL COOPERATIVE PROGRAM

Nondestructive Testing of Sheath Tubing

Design changes and required additions to the 17 mil wall tubing tester have been completed. The complete test station is operational and is being used to test 27 mil wall Zircaloy tubing of 56 inch lengths. The one, two, and three mil depth by 15 mil length punched notches used as the standard are consistently detected with the tubing rotated at 1800 RPM and scanned at 18 inches per minute. The entire test station has provided good performance on the 200 tubes tested to date.

In order to provide a more versatile test station and simplify both calibration and operation of the equipment, auxiliary readout circuitry was developed. Test information is presented in three separate channels. An internal oscilloscope presents the video waveforms for observation of defect signals and provides a calibrated marker for verifying proper tester operation. The remaining two channels provide outputs from defects only. The dual red light circuit channel may be set at the reject levels required while the analog recorder output channel is used as the input to a strip chart recorder. Prints and parts lists for the complete system have been prepared and components for the final tester electronics have been placed on order.

Although the mechanical system has required modifications to hold the tube more securely and prevent wear and vibration, the basic method of rotating the tube and translating the crystal functions very well. Two steady rests were mounted on the lathe bed to correct the vibration problem while the tank was fitted with ball bearings so that the O-ring seals rotate with the tube. With these modifications wear and vibration problems were solved, producing a durable and precise mechanical system which provides an accurate

ultrasonic scan over the entire tube surface. Future effort will be devoted towards automating the system.

As the hardware design and fabrication is completed, more emphasis will be placed on gathering additional data for the final report. At the present time only Zircaloy tubing from 13 to 30 mils in wall thickness has been tested. In order to establish the full potential of the present test system, standards of stainless steel and aluminum, as well as Zircaloy, are being prepared in various wall thicknesses. The response of the thin wall tubing tester will also be compared to the response of the present tubing test employed by Canadian General Electric Company while gathering data with these standards.

The ultrasonic crystal is also a component of major importance in thin wall tubing tests and in order to realize full potential of an ultrasonic tubing test, an ultimate ratio of ultrasonic beam size to tubing wall thickness must be established. Methods of measuring the ultrasonic beam size have been developed. Various diameter of crystals fitted with spherically focused lenses with varying radius of curvature were measured for beam size and other variables. After the beam sizes of a sufficient number of transducers have been measured, design parameters for obtaining an optimum thin wall tubing test transducer will be established.

BIOLOGY AND MEDICINE - 06 PROGRAM

Atmospheric Physics

An excellent information exchange and field workshop on advanced design atmospheric turbulence measuring devices was held at Hanford on September 9-13, in cooperation with the University of Washington. The Hanford Wind Component Meter was operated along with the University hot wire and sonic anemometers in comparative studies of instrument response and recording systems. The University systems received their final field check-out for use in the International Indian Ocean Expedition starting in December. In addition to the turbulence instrumentation, the Hanford micrometeorological mast was operated in conjunction with the single boom profile device developed at the University.

In Air-Force-supported work, the narrative for a film documenting the Cape Canaveral and Vandenberg Studies was prepared and editing of the film was completed. The draft material will be sent to the Air Force Geophysics Research Directorate for comments and approval prior to final copy.

Substantial progress was made toward summarization and practical utilization of field test data with completion of three reports as follows:

1) "Prediction of Environmental Exposures from Sources Near the Ground, Based on Hanford Experimental Data."

2) "Comparison of Results of Atmospheric Diffusion Experiments with Calculations from Prediction Models." (HW-SA-3220)

3) "Use of Meteorological Measurements for Predicting Dispersion from Releases Near Ground Level." (HW-SA-3176)

Two field tests designed to measure the dispersion of particulate materials released to the atmosphere were attempted during the month. The test conducted during unstable meteorological conditions, using a source height of 61 meters, was unsuccessful due to a change in wind pattern during the experiment. The experiment, utilizing a 23-foot source height during stable meteorological conditions with sampling both in the horizontal and vertical dimensions, was successful. The number of successful field experiments for the year now totals 9 unstable and 16 stable trials.

Data on precipitation scavenging of zinc sulfide particles by falling raindrops underwent further analysis during the month. Full data for correction of air dosage data for anisokinetic sampler error were not available at month end, limiting the data interpretation possible. However, it has become increasingly apparent that electrical charge on the water droplet may be a significant factor in evaluating the collection efficiencies.

Prototypes of both the "Real Time Sampler" and the "Automatic Sample Changer" were received from technical shops during the month. Both units operated satisfactorily during laboratory tests.

Dr. F. I. Badgley, Consultant to the operation, reviewed the atmospheric physics program during the month. Many helpful comments and suggestions were received.

Radiological Physics

Whole body counting work in Alaska was completed. Body burdens of Cs^{137} higher than those observed last year were found at all the villages visited. An average increase of about 50% observed at Anaktuvuk Pass is probably the best indicator of the general trend of fallout conditions in Alaska. At the other villages the increase was modified by other effects that will be better understood when Biology Section completes the analysis of the dietary and other information collected this summer. At Point Hope, for example, the average body burden increased by more than a factor of two. This can probably be explained by a difference in hunting conditions near

that village in the two years with a consequent difference in the amount of caribou in the diet. At the other villages differences in the time between the eating of the last meals of caribou in the spring and the counting of the people in the summer affected the average body burdens observed.

This year calibration data were available for small children, so 69 Eskimo children in the 5 to 15 year age range were counted. The average body burdens of Cs^{137} for these children were about one-third those of the adults in the same villages.

Pooled urine samples for two more groups of Richlanders of 150 people each were counted. With the sample reported last month, the average body burdens of Cs^{137} so determined were 11.5, 11.3, and 11.7 nc. The average body burden for 52 employees counted at the Hanford Whole Body Counter during August was 12.6 nc.

Fabrication of the plutonium X-ray counter was completed. Measurements of the background counting rate with no one in the counter were within the expected range. Measurements of the background with people in the counter are in progress.

The positive ion Van de Graaff performed satisfactorily during the month. It was shut down almost two-thirds of the month for the work described below.

L. W. Seagondollar, professor of physics at the University of Kansas and consultant to Radiological Physics, spent fifteen days at the laboratory to superintend the installation of the helium ion source and charge separator on the Van de Graaff. Extensive changes to the Van de Graaff were necessary. These changes are permanent, although the helium ion source and charge separator must be removed to permit normal operation. The source and separator were tested without voltage on the Van de Graaff and showed what are presumed to be the two charge states of the helium ion beam. Final testing was not possible because a vacuum leak developed in the separator when the Van de Graaff tank was pressurized. While the separator is removed for repairs, an additional voltage supply is being prepared for insertion in the terminal of the machine to permit better control of the separator.

A preliminary study was completed of experimental methods that could be used to establish the importance of low energy fast neutrons in working environments. It was concluded that a method of neutron spectrometry based on proportional counters with gamma ray discrimination should be able to obtain the desired information. A suitable counter was designed

and is being fabricated.

A Pm^{147} sample was placed in the radiation calorimeter to obtain information from which the half-life could be calculated.

Bids for a neutron generator for the University of Washington spermatogenesis study were evaluated for the University. The generator is on order and will be delivered to Hanford. A graduate student has elected to do his M.S. thesis on this study and is spending his Fall Quarter in residence at Hanford for this purpose. Calculations of expected dose distributions are being made.

Instrumentation

Test data obtained with the positive ion Van de Graaff accelerator relating to the characteristics of thermal, intermediate, and fast neutron detectors have been analyzed and are now being documented. In essence, the results showed the integrated output of the three detectors approximated a theoretical response curve which weights biological effectiveness in terms of neutron energy.

The experimental intrathoracic air pressure measurement instrument, developed for use with Biology experimental animals, was calibrated and tested in one animal experiment. Internal pressure changes as low as 1.5 mm of water equivalent can be detected. Experiments showed that for the particular animal used, no anesthesia was required to avoid muscular spasms. This fact may be of particular significance if later experiments prove it to be generally true.

The respiratory control valve, for use at the Biology Laboratory in the measurement of radionuclide deposition in lungs of animals, was successful in its trial operation with an animal. Valve control was accomplished using a special pressure sensing transducer mounted in the nose mask. Minor experimental modifications are necessary prior to completion of the monitor.

Discussions were held with Biology Laboratory personnel regarding the possible use of electrical anesthesia for experimental animals. Considerable interest in the approach has been generated, and a review of available instruments indicates that adequate equipment is on hand for some laboratory experiments. In essence, anesthesia is produced by placing probes on the temples of the experimental animal and electrically exciting the probes at a frequency of 700-900 cycles per second. Anesthesia is produced at currents ranging from 12 to 50 milliamperes.

Considerable testing was carried out on the experimental instrumentation to be used for determining the amount of beryllium entrapped on air filters. A set of calibrated-deposition filters was obtained from Occupational Hygiene, Relations & Occupational Health Operation, and were used for the tests with the 3 curie Po-210 alpha source. Various combinations of both neutron and gamma detectors were employed in the experiments. The tests indicated that the appropriate method would be two neutron detectors with the filter and source sandwiched between the two. Tests with one neutron detector showed that for a background rate of about 4 c/min, the insertion of a filter with 50 μg of beryllium entrapped produced a gross rate of about 30 c/min. With the mounting geometry, this was nearly a 2 π response; therefore, the stated two neutron detectors will now be used to obtain a nearly 4 π response with possible improvement in efficiency. The scintillation fast neutron detectors will be followed by electronics, now fabricated, to provide an anti-coincidence (exclusive OR logic) counting system. This should materially reduce the background effects and permit detection to the 1 to 10 μg levels desired. It should be noted that this approach will be materially less expensive than the neutron, gamma coincidence method originally used and abandoned for lack of sensitivity.

Experimental work was accelerated on circuitry for the experimental animal biological function telemetry instrumentation. At present, the pulse rate information directly amplitude-modulates the carrier frequency, the breathing rate is used to gate on and off a 1 kc/sec subcarrier oscillator, and the temperature information frequency-modulates the carrier. A receiver was developed and tested which separates the three signals.

Experimental fabrication was nearly completed on the final "production" model of the miniature recharging pocket dosemeter for use by plant personnel. The ion chamber and solid state circuitry have been mounted in a thin aluminum box as per request of Radiation Protection Operation, HL.

Economic improvements were achieved for the experimental miniature solid state integrator circuit developed for use with portable radiation detection instruments, particularly of the neutron dose rate type. The field tests were completely satisfactory on the original unit which employs some 30 transistors; however, a rapid market survey indicated that considerably less expensive transistors could be used. This approach was carried out along with the use of several plug-in printed circuit boards in place of the original hard-to-assemble cordwood fabrication method. The developmental circuits were then tested satisfactorily from -25°F to +150°F. Over-all parts cost reduction was about 40%. A final model, using the new approach, will now be fabricated.

Circuit development and direct testing continued on a HAPO Radiotelemetry System data station to further simplify the circuitry and to improve reliability. A special slave station was developed to monitor the telemetry radio channel and print out the transmitted information using a commercial printer. The amplifiers and gate circuits were developed and the necessary scaler printed circuits were commercial items. In the regular data station, the servo system and the 400 cps power supply for wind direction use were replaced by sine and cosine information which was filtered with a six minute RC time constant. This method greatly simplifies the data station circuitry and will increase the reliability. General operation of the one data station so modified continues to be satisfactory. Progress was achieved on complete conversion of the second station.

Good progress was also made on development and assembly of the three in-field, real-time zinc sulfide airborne particle monitors being prepared for use by Atmospheric Physics Operation, HL. Considerable re-machining was found necessary on the detector heads originally fabricated off-site. A successful field test was achieved with the one instrument modified to date.

Methods were developed for terminating long coaxial cables, using special solid state amplifiers, when G-M tubes are used as detectors. A report was prepared and issued.

Debugging continued on the 400-channel analyzer to be used in the positive ion accelerator. The paper tape punch and typewriter readout circuits have been completed and installed in the analyzer. Operation of the punch and typewriter have been checked out and they appear to work satisfactorily. An improved sense amplifier was developed for the memory and is now undergoing testing.

The study of the distribution and radioactive decay of iodine and tellurium in the bodies of animals and man was completed on the GEDA analog computer.

WASHINGTON DESIGNATED PROGRAM

Isotopic Analysis Program

Isotopic analyses were provided on program samples this month in accordance with present schedules.

Studies continued on the scintillation-type ion detector for the mass spectrometer. The high level of background noise previously encountered appears to have been eliminated by modifying the shape of the ion-target electrode such as to reduce the electric field gradient near some auxiliary components. Work is in progress to make the operation of the pulse-height discriminator

of the detector compatible with the pulse-characteristic requirements of the multichannel analyzer.

TEST REACTOR OPERATIONS

The PCTR was operated on an intermittent basis during the month. There was one unscheduled shutdown due to electronic failure. The remainder of the month was spent on scheduled maintenance. The experiment to measure the N-Reactor flux ratios was started during the month.

The TTR was not operated this month.

The critical approach tank was operated on a two-shift basis during the month. The 0.75 inch, 0.85 inch, and the 0.90 inch lattice spacing measurements were completed. All fuel pieces were 1/2 in. 2 w/o Pu-Al rods, 16 w/o Pu-240.

CUSTOMER WORK

Weather Forecasting and Meteorological Services

Consultation service continued on mteorological and climatological aspects of oxides of nitrogen release in the 300 Area. New stack sample data were analyzed in conjunction with the increased stack height and blower changes on the 333 Building. The weather watch for cross-arm changes for Electrical Distribution continued throughout the month. Assistance was given in preparation of CPD Containment Criteria for consideration by the Technological Hazards Council. A weather summary was prepared for use in a recruiting brochure. Meteorological support for GE-AEC activities during the President's visit was provided. Considerable time was spent in assistance to RPO and CET, relating to iodine releases from Purex during the month.

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

Weather Summary

Type of Forecast	Number Made	% Reliability
8-Hour Production	90	86.5
24-Hour General	60	88.6
Special	150	94.0

The past month was the warmest September in 52 years of record, with a mean temperature of 71.1. The previous September record was the 70.0 mean of 1938. The past month was also dry with only 0.02 inch of rain recorded.

Instrumentation and System Studies

An experimental model of the optical scanning apparatus proposed for use as the sensor in a high temperature extensometry system for Reactor Metals Research was built and tested. Experiments revealed the output pulses from the photomultiplier tube to be of sufficient amplitude and possess fast enough rise times to warrant further work on the system. The system will ultimately measure specimen strain at high specimen temperatures with good resolution and accuracy.

Hardware to perform high temperature microformer excitation and readout has been designed and built for Reactor Metals Research in high temperature stress-strain experiments. The hardware will be integrated into the high temperature microformer interrogation and readout system.

An analog-threshold logic circuit was designed and built for use in the creep data logging system to detect out-of-sequence conditions and alarm. Work is picking up on the data logging system with only shakedown and debugging to be completed.

The complex mathematical model for the C-column was simplified. This simplified model was successfully simulated on the analog computer for two of the 52 cases to be studied. A MIDAS program for the simplified model was found to check the analog computer results.

Design work on Chemical Effluents Technology's ground water analog system continued during the month. The system will be used to simulate the ground water conditions in the Hanford area. After considering the possible methods of mounting the resistive analog network, it was decided to use the taper pin block method. This method provides the best reliability and the greatest ease of changing resistors in the network. An adequate number of taper pins and taper pin blocks for the 707 node test model have been ordered for a test model. The design and drawings for the portable mount which will contain the test model network have been completed. Wiring and node identification drawings for the network are being prepared at the present time and a test model mount is under construction by Technical Shops.

The soil moisture measuring probe, which uses a PuBe neutron source, five BF_3 proportional counters, and all solid state amplifier and high voltage circuitry, was nearly completed. A number of neutron detection tests have

been made with satisfactory results. The probe is being developed for Advance Technical Planning, CPD, and Chemical Effluents Technology, HL.

Progress continued on instrument procurement for the U-235 fuel enrichment monitor for use by Metal Fabrication Development, Plutonium Metallurgy, HL.

Changes were made to the alarm relay circuitry of the Columbia River Monitor, as developed for Radiation Protection Operation, HL, and a final report on the system was written.

The plutonium waste container monitoring system, developed for Plutonium Process Engineering, CPD, was completed and is ready for direct testing with known sources at the 234-5 Building. Plutonium Process Engineering, CPD, is to furnish the test sources.

Necessary assembly head portions of three coincidence-count type alpha air filter counters were received and are being assembled. The commercial (solid state) instruments required have been ordered. The counters are being assembled for use by various CPD components. A memo report was prepared and issued stating how, in the future, such counters can be obtained directly through the Electronics Shop, 328 Building. The previous systems placed in service have established the full requirements and details.

The model 1004 single frequency, dual channel eddy current tester was used to determine the feasibility of testing 1/8 inch OD Zircaloy sheathed, chromel alumel thermocouple wire. The sheath consists of coaxial inner and outer layers, 0.0065 and 0.020 inch thick, respectively, both made of Zircaloy. In this application it is required that defects in the outer sheath layer be detected. However, it may also be necessary to examine the sensitivity to inner sheath flaws in order to determine if test signals are actually due to imperfections in the outer sheath. Accordingly, a set of electro-machined notch standards were prepared in a representative sheath sample and from initial tests, it appears possible to detect, and distinguish differences between, internal and external sheath flaws. Improvements are needed, however, to obtain differences which are of sufficient magnitude for test applications. In particular, it appears that a higher frequency than the 200 kc, which was used initially, would be desirable. This would provide greater phase angle differences between signals from inner sheath and outer sheath flaws. The higher frequency would have the additional advantages of increasing the sensitivity to the flaws in the outer sheath, which are most important to detect, and being less sensitive to inner effects such as wire spacing which may give undesirable background signals.

Optics

During the past month a laser head incorporating linear flash lamps and facility for ready interchange of different laser rods has been designed. A spherical output reflector was also designed for use with the laser head pending purchase of a combination total internal reflector beam splitter. The latter device is insensitive to position alignment and operates at efficiencies near ninety-eight percent. It has the further advantage of requiring no periodic reconditioning since it employs no metal or dielectric coatings as partial reflectors.

A two-inch diameter borescope having greater light gathering power than the currently used process tube borescopes is being designed. The design includes all of the features found to be most useful in the earlier borescopes. This is the first time a complete borescope has been designed at Hanford. Hanford drawings now being prepared will permit the purchase of uniform borescopes and replacement parts.

A study was made of photocell characteristics to find photocells suitable for measuring microsecond temperature transients from room temperature to 1000°C. An Indium Antimonide detector under consideration would cover the complete range. A silicon photovoltaic cell also being considered would cover temperature above 500°C. Lenses and mounting have been designed for the silicon cell.

Physical Testing

Services were requested by Combustion Engineering, Inc. to provide testing assistance in connection with N Reactor steam generator engineering studies presently being conducted at their plant locations in Chattanooga, Tennessee, and Windsor Locks, Connecticut. This request was honored by shipping a complete graphical null, eddy current tester and the necessary auxiliary equipment to their plants with a Hanford representative qualified to administer the tests. A study was initiated at these plants to observe the behavior of intergranularly corroded and non-corroded sections of steam generator tubing under simulated N Reactor conditions of pressure and temperature. A related effort at Hanford is maintaining a quantitative testing program to periodically monitor the rate of corrosion propagation during the investigations. At the conclusion of 100 hours of simulated N Reactor exposure conditions, no propagation of corrosion defects was observed. The program is continuing.

An important delivery commitment was met ahead of schedule when 1200 Zircaloy process tubes were shipped to KE Reactor for the retubing program. Continued grit-blasting of the inner tube surface where the Vanstone flange

is turned after reactor installation has further reduced tube failures. The cracking of the Vanstone flares after installation generally requires discarding that tube since it is pre-cut to exact reactor length. Process tubes rejected because of cracked flanges have been reduced to less than one percent, a figure substantially less than that associated with the ductile aluminum process tubes formerly used.

Radiographic testing was successfully applied to the unusual problem of measuring the integrity of 18 inch rubber diaphragms used in the air operated valves on the KER loops. One diaphragm exhibited several internal defects. Special radiographic techniques were also devised to inspect a gold-uranium ingot and to simultaneously inspect inner and outer N fuel closure welds. Normal techniques were employed to assure quality of 1600 slitter blades for IPD tube removal equipment.

A one hundred percent inspection by eddy current methods was completed on steam generator 4-A at N Reactor. The data from the complete inspection of 2-A was compiled and presented in a memo report and distributed as HW-78258-B to those outside companies with contractual interests in the steam generator problem. The techniques and tests procedures were developed to positively and quickly identify an individual leaking tube within a steam generator. The method employs both the ultrasonic translator and a helium mass spectrometer. This test application was made difficult by the fact that the largest leak found was so small that nearly two hours were required to pass one cubic inch of gas. This sample was readily detected at distances of 100 feet from the detecting equipment.

ANALOG COMPUTER FACILITY OPERATION

Problems considered during the month were:

1. N Reactor Pressurizer.
2. N Reactor Primary Loop.
3. PRCF Hazards.
4. Iodine and Tellurium in Man.
5. C-Column.
6. Critical Mass Lab Noise Analysis.
7. HTR (Two-Dimensional Model).

Computer utilization was as follows:

GEDA	EASE	
180	286	Hours Up
30	26	Hours Scheduled Downtime
10	8	Hours Unscheduled Downtime
100	--	Hours Idle
320	320	Hours Total

The latest liaison report indicates that the manufacturer may be somewhat ahead of schedule in the construction of the new computer. Present indications are that the computer will be ready to ship by October 29, 1963, about one week ahead of schedule.

Considerable effort was expended in checking various electronic multiplier testing methods for use as an acceptance test. The work of devising and checking the tests and writing the step-by-step procedures is approximately 25% complete.

A revision of the Modified Digital Analog Simulator (MIDAS) program was received from Wright-Patterson Air Force Base. The program was revised to:

1. Handle algebraic loops.
2. Remove the necessity of repeating constant input data for each run of a parametric study.
3. It also added a curve following function generator component.

The revised MIDAS program was placed on our IBM 7090 SPL Library tape. This allows use of the MIDAS program without submitting a binary deck with each program. Difficulty has been encountered in finding a MIDAS circuit that will differentiate. The conventional implicit differentiation circuits used for the analog computer have been found to be unsuitable for the MIDAS system.

Analog Computer Course

Fifteen students attended the first class on analog computer programming. The class meets every Monday night from 4:30 to 6:30 for ten weeks in the 3703 Conference Room.

INSTRUMENTATION EVALUATION

Acceptance testing of 7 scintillation, solid state, alpha-beta-gamma hand, shoe, and clothing contamination counters which were fabricated offsite is now being done. Several minor circuit improvements, developed after the

contract, are being installed. Three more of these instruments are now being fabricated offsite by a different manufacturer. Other Hanford groups have indicated interest in further purchases assuming the initial seven instruments perform satisfactorily.

Extensive testing continued at 105-B Building on the experimental gamma background compensated beta-gamma hand, shoe, and clothing counter. The tests are being performed along with corresponding standard HAPO counters of the G-M tube detector and vacuum tube circuitry type. To date, the test results have shown the experimental instrument to have superior performance. The compensated instrument can perform satisfactorily in backgrounds from 0.5 to 1 mr/hr; whereas, the standard HAPO counters become unable to detect the required test source when the background exceeds about 50 μr/hr. The counting efficiencies for the standard HAPO test sources were 6.5% and 4.3% for the experimental instrument hand and shoe probes and were less than 1% for both probes of the older counters. Acceptance of the experimental instrument by field personnel has been good.

Review testing was conducted on three Model II Scintrans fabricated in the 328 Building. Several errors and inconsistencies were noted. Approximately 95 Scintrans are now in satisfactory service on plant.

A review was made of Standard J-4-2, Health Monitoring Ion Chambers, for Radiological Engineering, IPD. It was recommended that the basic constant employed be changed from 0.333 picoamps/mr/hr to 0.37 picoamps/mr/hr for the standard HAPO H-M chamber.

R S Paul

Manager
PHYSICS AND INSTRUMENTS LABORATORY

RS Paul:JJF:mcs

CHEMICAL LABORATORY

RESEARCH AND ENGINEERING

FISSIONABLE MATERIALS - 02 PROGRAM

IRRADIATION PROCESSES

Film Adsorption Studies

The adsorption of P-32 labelled phosphate was studied on aluminum surfaces exposed to hot process water at a pH of 6.6. Untreated coupons, laboratory-coated Teflon coupons, commercially-coated Teflon coupons, and black Marks-a-Lot ink-coated coupons were compared. The coupons were exposed to hot flowing process water for three days before the tagged phosphate was added and the uptake was measured by beta counting. Both the laboratory and the commercially prepared Teflon coatings reduced the adsorption to one-fourth that of uncoated aluminum surfaces, but this was much less than the reduction of adsorption by a factor of 20 which was observed with the black Marks-a-Lot ink coating.

A test was completed on the effects of citrate, borate, oxalate and lactate ions on reducing the adsorption of phosphate ion on the surface of aluminum turnings. Although literature reports indicate that under some conditions these materials markedly reduce adsorption, under the conditions of this test (100 ppm additive, pH of 6.6, contact of solution at 93 C with turnings for two days prior to addition of a P-32 labelled phosphate solution) no reduction in adsorption was observed.

Reactor Water Treatment Studies

A cationic polyelectrolyte made by Black Laboratories under the name "CatFloc" was tested in the laboratory for possible use in treating process water. It was found that 0.5 ppm was sufficient to reduce the zeta potential of river water colloids from their approximate value of -16 mv to zero. It requires about 15 ppm of aluminum sulfate to effect this same change. This agent was used in conjunction with alum in the laboratory water treatment plant to produce water with a zeta potential of zero at a pH of 6.6, and the effectiveness of removal of phosphate ion was determined. Up to 0.2 ppm CatFloc (with 5.5 ppm alum) can be used without reducing the phosphate ion removal efficiency. Thus, 0.2 ppm CatFloc can be substituted for about 10 ppm of the alum and the resulting floc will still be at a zeta potential of zero for easy colloid removal, and still the removal of ionic phosphate will not be reduced.

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The use of activated silica as a flocculating agent was also investigated. Following literature recommendations activated silica was substituted for one-fourth of the alum. This resulted in a zeta potential of -14 to -17 mv, good removal of colloidal material, but poor removal of ionic phosphate. Upon increasing the alum to obtain a zeta potential of zero on the floc, poor removal of ionic phosphate was obtained. Under the conditions used in these tests, activated silica does not improve the process water with regard to reducing the radionuclides in the reactor effluent water.

Reactor Tube and Fuel Element Corrosion in Deionized Water

In reactor studies of the use of deionized water as a reactor coolant medium, some interesting estimates of corrosion rates can be made based on the Ga-72, Ni-65 and Na-24 concentrations in the effluent water. With new aluminum tubes and a new fuel charge clad in aluminum, rapid corrosion occurs which rises to an almost steady state. If, after discharge of these elements, a new fuel charge clad in aluminum is loaded, the corrosion rate observed when a steady state is reached is less than with the first charge. Further reductions on charging fuel continue until about the fourth loading, after which the steady state corrosion rate reached is about the same following each new fuel charge. Because the Ni-65 concentration in the effluent is related to the fuel element cladding corrosion rate only, it is possible to show that it is not only the corrosion rate of the tube which changes markedly with time but that the corrosion rate of the fuel charge cladding varies somewhat with the corrosion rate of the tube. With the first fuel charge the combined corrosion rate appears to be about ten times that obtained five or six fuel charges later. Since a similar reduction in Ga-72 activity is obtained when Zircaloy tubes are used, it seems that the film which builds up on the tube is a controlling factor in the rates of corrosion of both the fuel elements and the tube.

Uranium-233 Production Studies

A computational study has been completed on the effect of nuclear and operating parameters on the quality of U-233 which would be produced by irradiating thorium in the Hanford production reactors. The calculations, which are reported in detail elsewhere (HW-78989), led to several interesting conclusions:

1. Additional data on effective cross sections and reactor flux spectra are required for accurate prediction of the various quantities of interest (rate of U-233 production, U-232 content, etc.) and, indeed, even for extrapolation from gram-size samples to full-size slugs.

2. The Th-232 (γ,n) Th-231 process may represent a significant route to formation of U-232. Since both fission gammas and capture gammas from such reactions as neutron capture in aluminum must be considered, the relative importance of this route may be critical in the design of thorium target elements.

3. Ultra-pure thorium, i.e., thorium very low in ionium (Th-230), is not required since other nuclear reactions will contribute U-232 equivalent to that produced by an ionium concentration of about 8 ppm. This prediction was fully verified by the analytical results on the first one-gram size irradiation samples.

These results further emphasize that the best route to very high quality U-233 is probably via isolation and decay of 27-day Pa-233. Both loop-type irradiation, with continuous removal of U-233 and Pa-233, and "close coupled" (short irradiation, short reprocessing and refabrication) schemes would therefore appear to merit special R&D attention.

Laboratory work has also been initiated to establish a flowsheet for hot-cell processing of five kilograms of irradiated thorium from a current IPD test. This five kilogram test has two objectives: (1) better determination, via irradiation of three full-sized slugs, of some of the nuclear and reactor parameters mentioned above, and (2) preparation of highly decontaminated gram-size samples of U-233 low in U-232 ($\leq$ 1 ppm). Plan is to irradiate the aluminum-clad metallic thorium slugs in F Reactor (irradiation currently in progress) for a relatively brief period of time, cool for about one month, and then transfer to B-Cell of the High Level Radiochemistry Facility, where the slugs will be dissolved (in fluoride-catalyzed nitric acid) and processed for separate recovery of the uranium and the remaining protactinium. The protactinium will be allowed to decay for several half-lives and then will be processed to recover a sample of U-233 of ultra-high purity, thus providing samples of two potential grades of product.

SEPARATIONS PROCESSES

Disposal to Ground

No significant changes were noted in the radionuclide contamination status of the ground water beneath 200-East Area during this month. The gross beta-emitter concentrations beneath the 216-A-10 Purex process condensate crib have remained fairly constant at about 4×10^{-3} $\mu c\beta/cc$. Strontium-90 results continue to be less than the routine detection limit of 7×10^{-8} $\mu c/cc$.

Only one significant change was noted in the status of ground water contamination beneath the 200-West Area. During the past six months

the activity in samples from well 299-W22-1 has risen gradually from 8×10^{-7} μcβ/cc to the present level of 1×10^{-5} μcβ/cc. Strontium-90, present in this well at a concentration of 3×10^{-6} μc/cc, evidently is due to the continued drainage of the 216-S-1 and -2 cribs which this well monitors. The 299-W22-2 well, located approximately 25 feet away, has routinely contained low concentrations of Sr-90 due to crib drainage since 1957. These cribs were removed from use in January, 1956.

I-131 in Plant Processes

The I-131 removal efficiency continued to decline for a test cartridge of charcoal through which has passed Redox ventilation air taken just ahead of the sand filter. After 38 days in use the cartridge had a removal efficiency for plant stream I-131 of only 35 percent. This same cartridge, however, showed an efficiency of 86 percent for molecular I-131 introduced in the air upstream of the charcoal. The highly significant increase for molecular iodine removal indicates that adsorptive capability of the charcoal has deteriorated more for the non-molecular form than for the molecular form. If this is true, it must also follow that much of the I-131 in the Redox exhaust air must be other than elemental molecular, yet a species which can be effectively collected on fresh charcoal. The observation has not been satisfactorily explained. One indication is that there may be two separate adsorption mechanisms operating in the charcoal. The one which controls the removal of other than molecular iodine can be interfered with more readily than that which controls elemental molecular iodine adsorption.

Elution tests were completed on charcoal exposed to air from upstream of the sand filter at Redox for 11 days. Elution with laboratory room air containing 20 ppm hexone for 23 days did not remove any I-131. It is unlikely that poor charcoal efficiency results from migration of the I-131 through the bed.

Trilauryl Amine Recovery of Neptunium and Plutonium from Purex 1WW

In the currently favored flowsheet, 0.1 M oxalic acid is used to strip plutonium and neptunium from 0.3 M TLA-Soltrol extractant. Batch contact studies were made to determine the feasibility of routing the oxalic acid solution to the 3A-3C cycle (Purex J-Cell) for separation of neptunium from plutonium and fission products. At pertinent flowsheet conditions, neptunium extraction was significantly impaired when the feed solution contained as little as 0.01 M oxalic acid. Destruction of oxalate prior to J-Cell extraction is indicated if the oxalic acid strip is used.

In other experiments, contact of 0.3 M TLA-Soltrol solution with an equal volume of 0.05 M hydroxyl-amine sulfate for one hour at 60 C removed greater than 99 percent of the plutonium and 92-94 percent of the neptunium present. The utility of this strip solution as a feed to the 3A column is under study.

Purex Plant Capacity Study

Methods of increasing the capacity of the Purex 1C column are being evaluated as part of an overall plant capacity study. It is proposed to replace the existing stainless steel cartridge with a graded, plastic-and-steel "sandwich" cartridge, using linear polyethylene or fluorothene. Linear polyethylene used in plant cartridges has had rather short service life, except for some 3/4-inch plates in the relatively mild conditions of the 2E column. Fluorothene, on the other hand, has a long life expectancy but is prohibitively expensive when fabricated into 3/4-inch thick plates. A "sandwich" cartridge using thin (3/32-inch) fluorothene appears advantageous if its performance compares favorably with that using thick polyethylene. A series of runs in the 321 Building experimental C-column have been undertaken to provide this comparison. Four preliminary runs have been made with each cartridge to determine the approximate location of the flooding curve, approaching the flooding point by increasing the pulsing frequency at about 10 cycles per minute per hour.

Additional runs are now in progress with the approach to the flooding point being decreased to two cycles per minute per hour and additional efficiency observations being made. Based on the results of the preliminary runs, there appears to be no significant difference between the performance of the two cartridges and, if anything, the fluorothene cartridge appears to perform slightly better than does the polyethylene cartridge. Capacities achieved with either sandwich cartridge, as expected, were well above that of an all-stainless steel cartridge.

WASTE MANAGEMENT AND FISSION PRODUCT RECOVERY

Extraction of BAMBP by NaOH Solutions

Measurement of the extraction of BAMBP by sodium hydroxide solutions from organic extractants at room temperature (22-24 C) and at 60 C were continued. Sodium hydroxide solutions (0.025 to 3.0 M) were contacted with an equal volume of either 0.5 M BAMBP-Soltrol or 0.5 M BAMBP - 0.3 M D2EHPA - Soltrol solution. The BAMBP extracted by the aqueous phase was stripped into carbon tetrachloride and determined spectrophotometrically. Loss of BAMBP to the aqueous was also determined from the initial and final concentration in the organic phase. Results by

the two methods agreed to within 80 percent. Without D2EHPA in the organic phase, room temperature extraction of BAMBP increased from about 0.0035 M in 0.023 M NaOH to about 0.023 M in 1.2 M NaOH. Extraction was slightly higher at 60 C.

Extraction of BAMBP was less with D2EHPA present in the organic and ranged from 0.0001 M at pH 6 to 0.012 M in 2.7 M NaOH at both room temperature and 60 C. Sodium hydroxide concentrations given are equilibrium concentrations after the contact.

Strontium-Lead Sulfate Carrier Precipitation

A decant procedure was successfully demonstrated this month on the lead sulfate carrier precipitation process. After digesting the synthetic Purex-type waste with 1 M sulfate, pH 1 for one hour at 80 C, lead nitrate was added at 0.02 M and the resulting slurry pumped through a decant tank which then overflowed into the centrifuge. At an average holdup time of 50 minutes, the supernate from the decant tank contained only 4 percent of the feed strontium. The strontium concentration in the supernate was reduced two-fold on passing through the centrifuge, operated at 1200 G's, five minutes holdup time. Similar results were obtained with a portion of the feed slurry which was cooled to 40 C before pumping through the decant system. In this latter test, reducing the centrifuge speed two-fold had little effect on the final strontium concentration in the supernate, even with the precipitate in the decant tank deliberately stirred up.

Treatment of Purex Stored Waste Sludge

Treatment of Purex process stored waste sludge with water and dilute nitric acid has been shown to dissolve the major portion of the sludge. However, some of the strontium (ca. 20 percent) and most of the iron (70-80 percent) remains undissolved. When residue from Tank 203A sludge, previously leached with water and nitric acid, was contacted with concentrated phosphoric acid at 90 C for two hours, less than one percent of the strontium initially present in the sludge remained undissolved. Diluted (1-1) phosphoric was slightly less effective in removing strontium. Such procedures may be practical for final treatment of the relatively small volumes of residue left after leaching the sludge with water and nitric acid and will be explored further.

Ammonium Carbonate Recovery

Recovery of the ammonium carbonate eluate is required for economical operation of the zeolite ion exchange cesium recovery process. The technique to be employed involves evaporation of the 3 M $(NH_4)_2CO_3$ -

2 M NH_4OH solutions with the volatilization of NH_3, CO_2 and water. Condensation of the volatiles reconstitutes the ion exchange elution reagent. Pilot plant testing of the recovery process is complete and most of the data have been assembled. Cooling of the hot gas stream from the concentrator condenses most of the ammonia, and up to 80 percent of the carbon dioxide along with all the water. Co-condensation of the three components and gas phase reaction of ammonia and carbon dioxide takes place.

Direct absorption in a wetted packing proceeds rapidly in a relatively small packed volume with heats of condensation and reaction largely controlling equipment sizing. By employing a condenser ahead of the absorption tower, the tower size can be reduced to approximately one-fifth that required without a pre-condenser.

The possibility of the equipment clogging with ammonium carbonates was observed on several occasions. A cool saturated solution produced in the condenser during one unsteady state operating period eventually caused plugging and high pressures in the concentrator. Crystalline deposits of ammonium carbonate occur whenever cool (< 140 F), dry surfaces are exposed to high vapor pressures of NH_3 and CO_2. Maintaining all surfaces wetted or at temperatures in excess of 140 F prevents deposits from forming.

In-Tank Solidification

Present plans for in-tank solidification of intermediate level plant wastes call for evaporation of the waste solutions by introducing 1200 F air into the underground tanks. The air flows downward through an annulus, transfers heat to the solution, and induces circulation in the tank, acting as an air-lift circulator. A pilot scale mock-up of the proposed in-tank solidification system has been completed and placed in operation in 321 Building. The purpose of the experimental unit is to provide information needed for design of the full-scale system to be installed in a 200-E Area tank.

Calculations have indicated that the heat transfer coefficient attainable from a straight annular circulator as currently proposed is approximately 8 Btu/hr/sq.ft/°F, which is insufficient to cool the hot gas to the approximately 700 degrees required to avoid entrainment problems. Experimental runs conducted in a model annular circulator have yielded an "h" value in the range 10 to 12. It is concluded that a finned annular surface is needed to reduce the inlet gas temperature to the desired value. Calculations are now essentially complete for the optimum fin design.

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Extraction of Aluminum from Redox Acid Waste with D2EHPA

Further studies on the extraction of aluminum from Redox acid waste by D2EHPA-Soltrol showed that, at 60 C and an 1/v of 0.2, ten to thirty minutes' contact time was required to reach equilibrium aluminum distribution. At three minutes' contact time, measured aluminum E_a^o was 80 percent of the equilibrium value; distribution of aluminum appears sufficiently rapid at 60 C to permit use of countercurrent extraction equipment. In five-minute contacts at 60 C, measured E_a^o values for extraction of aluminum from synthetic acid waste into 0.55 M NaD2EHP - 0.25 M TBP - Soltrol varied from 0.343 at an 1/v of 1.1 to 52 at an 1/v of 0.16.

Cesium Removal from Alkaline Waste

Additional purification of cesium from ion exchange processing of high-level wastes by recycle eliminates an ammonium salt scrub and provides a product of higher purity and thus higher cesium loadings on the zeolite storage package.

The Na/Cs ratio in Redox "SX" waste is about 45,000. One ion exchange cycle produced a solution with Na/Cs ratio of 150 (DF of 300) and a second ion exchange cycle resulted in a Na/Cs ratio of 1.7 (DF of 88). A Na/Cs ratio of 1.7 would provide a packaging load on Linde AW-500 of 2 meq Cs/gram. Only one second-cycle column run per 140 first-cycle column runs would be required.

In the case of Purex "A" farm supernatant wastes, the eluate of the first cycle of ion exchange has a Na/Cs of 8 to 10 which is satisfactory for packaging. However, by use of a second ion exchange cycle, the ammonium carbonate scrub could be replaced by a water scrub which would decrease essential materials costs for the process by about one third as well as eliminate concern for disposition of the ammonium containing waste. With a water scrub flowsheet the Na/Cs ratio in the first cycle eluate is 30 (DF of 190) as compared to 8 to 10 with an ammonium carbonate scrub. The second cycle eluate had a Na/Cs ratio of 0.7 which should yield a packaging load of over 2 meq Cs/gram. For the Purex waste about one second-cycle run per 20 first-cycle runs would be required.

002 Tank Sludge

Samples of a white sludge which has accumulated in the CR Vault strontium storage tank (002) and which is troublesome to the semiworks strontium purification operation were examined and identified as a lead compound. Dissolution was effected by metathesizing with 10 percent caustic to red lead (Pb_3O_4), which readily dissolves in 2 M HNO_3, a procedure which

should be satisfactory for plant use. Most of the Sr-90 associated with the precipitate was removed with a water wash prior to caustic treatment and very little was found in the caustic or acid solutions.

Sugar Treatment - Effect of Aluminum

The effect of aluminum nitrate on the rate and stoichiometry, or efficiency, of the sugar destruction of nitric acid was examined because of Purex Plant interest in possible treatment of certain 1WW solutions containing on the order of 1 M ANN. Aluminum was found to exert very nearly the same effect as iron, 20 moles of HNO_3 being destroyed per mole of sugar in the presence of either 1 M iron or 1 M aluminum (as compared with about 12 moles of acid destroyed in the total absence of catalyst). As expected, there was little increase in efficiency beyond 20 moles/mole for aluminum or iron (or iron plus aluminum) concentrations greater than 1 M.

Technetium Recovery

A plant test was made recently at the Purex tank farm, using a resin-loaded Shielded Transfer Tank (STT), to demonstrate Hanford capability to recover kilogram quantities of technetium from alkaline Purex tank supernate. Although the flowsheet was successfully tested over a year ago with actual waste in the 325-A hot cells, field analyses indicated very poor technetium loading in the field test. Experiments have accordingly been undertaken to resolve the matter and to pinpoint whether the trouble was chemical, mechanical, or analytical. Laboratory column runs have been made on a very small scale with a sample of the actual feed and IRA-401 resin used at the plant, and with larger quantities of synthetic feed. Results have been entirely consistent with earlier hot cell experience. Technetium loading from the plant feed exceeded 90 percent after passage of 25 column volumes. Larger scale runs with synthetic solution gave even better results and indicated (1) that off-standard temperature, a suspect parameter, had little or no effect on loading, (2) that elevated temperature is actually quite beneficial to elution, and (3) that Tc(IV) is absorbed just as efficiently as Tc(VII) [the (IV) may well be rapidly oxidized to (VII) by the nitrate present in the feed]. Ten gallons of tank supernate have been obtained for further studies. On the basis of results to date it seems apparent that failure of the plant test must have been due either to the considerably less than optimum geometric configuration of the STT and/or to analytical difficulties in identifying and determining technetium (whose long half-life and very soft beta energy makes its analysis exceedingly difficult). Modifications have been made to the STT and an early second attempt at loading is planned.

EQUIPMENT AND MATERIALS

Air Pulser Development Studies

As an aid in the future scale-up, design and prediction of operating variables for air pulsers, a study of important operating parameters has been run on a prototype air pulser attached to a 12-foot long, 3-inch diameter, glass column. The measured parameters which were read out on an 8-channel Brush recorder, using two strain gage pressure transducers and a strain gage flow transducer, were: pulse leg dynamic air pressure measured above the water, pressure at the bottom of the pulse leg, and velocity head at the bottom of the pulse leg. Evaluation of the recorded analog data indicates that for a constant pulse frequency, the amplitude varies approximately as the square root of the velocity head, in agreement with hydraulic theory. The information obtained from these studies should be useful in predicting pulse amplitude, pressure wave shape, and phase lag in larger columns.

Air Pulser Control System

The air pulser control system proposed for the Plutonium Reclamation Facility uses a solid state logic unit for controlling the introduction and venting of air to the pulse leg. The logic unit supplies power to operate solenoid valves controlling air flow. The system provides adjustable spans of pressure application, pressure hold, vent and stop vent, and has potential capability of controlling the pulsing pressure wave shape to achieve optimum column efficiency.

A prototype of the plant system has been installed and tested in 321 Building. Performance of the logic unit has been satisfactory. The full amplitude frequency capability of the system was not realized, however, and the problem was traced to excessive pressure drop in the solenoid valves. Replacement of the valves using an alternate design is expected to solve this problem. Other potential difficulties exist in terms of expected solenoid valve life; with the valves operating up to 120 cycles per minute, it may be difficult to attain service life longer than a few weeks.

Radiation Effects on Temperature Sensors

Temperature sensors in plant service have been found to have unpredictable service life in high gamma fields and at high temperatures. A study was undertaken to define the cause of the failures and to relate this to radiation exposure. Two resistance bulbs, with nickel wire resistors, have been irradiated to 10^9 R using a cobalt source. No change in calibration has occurred; however, the insulation resistance

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has decreased by several orders of magnitude (from 10^{11} ohms to 3.5 x 10^7 ohms) in one case. Radiation exposure will be continued to 5 x 10^9 R. An iron-constantan thermocouple failed at 5 x 10^8 R; it was observed that the constantan wire (60-40 copper-nickel) was quite brittle, and that several pieces had broken off, along with the fiberglass insulation.

Corrosion of Mild Steel Weldments in Sodium Nitrate-Sodium Nitrite Solutions

Further study of the severe corrosion of weld metal in a mild steel weldment by 40 percent $NaNO_3$ - 10 percent $NaNO_2$ solution, as reported last month, indicated galvanic attack was responsible for the complete deterioration of one weld pass and the ditching observed in other weldments. The galvanic attack apparently occurred due to stray currents arising from a cathodic protection experiment in progress in the same tank in which the mild steel weldments were exposed. Attempts to duplicate the attack by $NaNO_3$-$NaNO_2$ solutions in laboratory-scale experiments were not successful except when the sample was made anodic to the solution. Even when anodic to the solution, weld metal which retained a cast structure was not attacked. The annealed structure observed in the weld pass which was attacked was also observed in areas where ditching occurred in other weldments. Apparently the cast weld metal, which is relatively high in manganese (ca. 1 percent), is converted, under certain heat treatment conditions, to a structure which is exceptionally susceptible to anodic attack in alkaline nitrate-nitrite solutions. In this case, heat treatment was due to successive weld passes and the proper conditions to produce the susceptible structure occurred only in the one weld pass and in areas of other welds where ditching occurred. Further study to define the parameters leading to the susceptible structure are in progress.

Non-Metallic Materials

Chemical compatibility tests were completed on one neoprene and five silicone rubbers. This completes chemical compatibility tests on rubber samples previously tested for radiation tolerance. Detailed results will be presented in a forthcoming report.

Samples of polyvinylidene fluoride were tested in several solutions typical of the Recuplex process. The material swelled three percent in boiling 72 percent nitric acid; swelled one percent in boiling 37 percent hydrochloric acid, and was not altered in carbon tetrachloride, a 50-50 solution of lard oil in carbon tetrachloride or a 20 percent TBP-CCl_4 solution.

Samples cut from a perforated polyethylene plate have been tested in Purex HAX at 70 C (static and agitated with a small air flow). After six weeks' exposure the polyethylene was severely embrittled. A slight bend will cause surface craks and the coupons break easily.

ANALYTICAL AND INSTRUMENTAL CHEMISTRY

Determination of U-232 and U-233 in Irradiated Thoria

Uranium-233 and the U-232 to U-233 isotopic ratio were successfully determined in samples of irradiated thorium oxide. A measurement accuracy of ± 5 percent or better was obtained. Initial handling, dissolution, and separation were carried out in the Shielded Analytical Laboratory. The refractory thoria was successfully dissolved in 12 N HCl using 0.04 N HF as a catalyst. Uranium was separated from thorium, Pa-233 and extraneous constituents using anion exchange. The purified uranium was assayed for U-233 by two independent methods (isotopic dilution and alpha counting) with a between-method agreement of ± 3 percent. The U-232 to U-233 isotopic ratio was determined by alpha energy analysis using a silicon diode detector. Electrodeposition was used to prepare residue free alpha sources. Essentially complete resolution of the alpha energy peaks was obtained at an alpha ratio of 1:150 of U-232 to U-233.

Controlled Potential Coulometry

Work on the design and testing of an improved mercury-cathode, controlled potential coulometer cell has been brought to a successful conclusion. The new cell, in which the major change from the old HAPO-type cell is an increase in the distance between the isolated electrode and the mercury working electrode, gives much improved performance. A document describing this work is in preparation.

REACTOR DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Salt Cycle Process

Chloride Contamination in UO_2 - The chloride content of many electrolytic UO_2 samples of diverse history has now been determined by means of the highly sensitive amperometric method recently adapted to this purpose. It was found that (1) UO_2 containing less than 5 ppm chloride can readily be prepared by electrodeposition from chloride melts under typical laboratory conditions, but (2) all the samples of electrolytic UO_2 prepared in pilot plant equipment had chloride contents of at least 100-200 ppm after thorough washing, and at least 50 ppm after a pyro-hydrolytic treatment with high temperature hydrogen and steam. The cause of the difference between laboratory and pilot plant results has not been resolved, but is believed to be associated with differences in the level of metallic impurities in the melts. There is some evidence that elements such as aluminum, cobalt, copper, iron and silicon, present in trace amounts in the melt, tend to concentrate in the UO_2. One or more of these elements may carry chloride into the deposit.

Electrochemistry of Uranium in Molten Chloride Salt Solutions - Experimental work on the thermodynamic properties of the reaction

$$UO_2 + Cl_2 = UO_2Cl_2$$

has been completed, and a paper covering this work has been prepared for presentation at the October, 1963, meeting of the Electrochemical Society. The conclusions are summarized below:

1. In general, the precision of the data is good. However, uncertainties in the accuracy due to possible junction potentials, the use of slightly off-stoichiometric UO_2 electrodes, and analytical error are such as to render uncertain any conclusions as to the activity coefficient of uranyl chloride in molten salt solutions or as to the behavior of UO_2(VI) with respect to Henry's Law.

2. A roughly constant value of ΔS was found for the reaction in KCl-NaCl and KCl-LiCl melts of varied composition, inferring the existence of the same UO_2(VI) species in the various melts. Two ΔS values, both different from the value found in the KCl-NaCl and KCl-LiCl systems, were found in two different ranges of melt composition of the NaCl-LiCl system. Thus, one may speculate that at least two UO_2(VI) species exist in the NaCl-LiCl melts, with a third species predominating in the other systems studied. The

existence of two distinct UO_2(VI) species in NaCl-LiCl melts is also indicated by the "S"-shaped, potentiometric-titration type curve obtained by plotting the EMF for the reaction vs. the NaCl concentration in NaCl-LiCl melts of varied NaCl/LiCl ratio.

3. A graph was made of the EMF for the reaction, at constant temperature and UO_2Cl_2 concentration, vs. the reciprocal of the ionic potential of the salt melt. A reasonably linear relationship, over the range of compositions studied, was found for each of the three salt combinations (NaCl-KCl, NaCl-LiCl, and KCl-LiCl). The slopes of the lines were different for the three systems, however, increasing in the order of presumed increase in chloride activity. It is apparent from the results that more precise data, from a simpler electrochemical cell, will be necessary before a serious attempt to study chloride effects can be made.

Engineering Development - Installation of equipment has been completed in C-Cell of the High Level Radiochemistry Facility (325-A Building) for the processing of irradiated, Zircaloy-clad PuO_2-UO_2 fuel from the Plutonium Recycle Test Reactor. The maximum scale of operation will be 30-pound batches of fuel which corresponds to one-quarter fuel assembly per batch. In C-Cell the fuel will be declad, dissolved in molten LiCl-KCl, deposited electrolytically as a PuO_2-UO_2 mixture, and prepared to the correct particle size distribution for vibratory compaction into recycle fuel assemblies. Cold runs were in process at month end.

Materials of Construction - A crucible of Crystalon 63 (Norton Company) was tested as a possible container for fused salt. An equimolar solution of LiCl-KCl percolated through the crucible in less than one hour.

Plutonium Recycle Fuel Processing Economic Study

The initial phase of this study (HW-77397 C and HW-77709 C) covered a comparison of close-coupled vs. central plant processing for a 1000 MW_e station operated at 14,500 MWD/T and graded fuel discharge. Results indicated a savings on the order of 0.25 mills/kwh at a $5 million plant cost, or about 0.10 mills/kwh at an $8 million to $10 million plant cost.

Since then the study has been extended to explore the effect of optimized fuel exposure on the savings potential. It was found that savings are reduced when the central plant and the close-coupled fuel cycles are compared at optimum exposure for each system. In addition, operating revenue for the close-coupled plant is reduced because optimum exposures ranging from 20,000 MWD/T or higher means

reduced reprocessing plant throughput relative to the 14,500 MWD/T case. The net result is that only $2 million to $4 million plant cost can be permitted to provide a 0.20 mill/kwh savings, and only $3 million to $6 million plant cost can be permitted to provide a 0.10 mill/kwh savings.

The effect of low poison decontamination in the recycled fuel has also been partially evaluated. Recycling one-sixth of the fission products in the recycled mixed oxide (approximately one-third of total fuel) reduces allowable plant investment by about $500,000 for a given savings or reduces savings 0.03 to 0.05 mill/kwh for a given plant investment.

A new reactor case is being developed for evaluation that represents an advanced design water reactor. It is believed that higher fuel enrichments will be encountered and (based on trends in previous data) larger incentives for close-coupled processing may be indicated.

Reprocessing PRTR UO_2-PuO_2 Fuels at Redox

Studies aimed at developing a satisfactory procedure for dissolving PRTR UO_2-PuO_2 fuels in the Redox plant were initiated. The studies are based on the probability that some of the plutonium in these fuels will remain refractory during irradiation and be difficult to dissolve. Dissolution rates for non-irradiated PuO_2 powder (-325 mesh, 95 percent theoretical density, prepared by calcining plutonium oxalate 3-4 hours at 950 C) in boiling 8 to 12.7 M HNO_3 - 0.0 to 0.05 M NH_4F - 0.0 to 0.025 M $Al(NO_3)_3$ solutions were determined. The dissolution rate in nitric acid alone was extremely slow; with added fluoride, the dissolution rate was relatively rapid (complete in 30 minutes in 12.7 M HNO_3 - 0.05 M NH_4F); addition of aluminum nitrate to the nitric acid-ammonium fluoride dissolvent (to reduce corrosion of stainless steel equipment) lowered the dissolution rate severely.

RADIOACTIVE RESIDUE PROCESSING DEVELOPMENT

Cold Semiworks Radiant Heat Spray Calciner

Sub-capacity runs were made with an aspirated, shielded thermocouple to obtain better gas temperature profiles in the annulus. Preliminary calculations from initial shielded thermocouple temperature measurements for the shortened (4.75 ft.) draft tube indicate recirculation rates twice as large as those calculated from bare thermocouple temperatures (3500 lb/hr vs. 1500 lb/hr). Bare thermocouple temperatures were 20 to 30 degrees higher than the shielded probe temperatures in the upper portion of the column. However, the two temperatures agree at the bottom, resulting in no change in the previous estimates of capacities.

After the first three runs, a large leak through the cover flange of the reactor was discovered. Tightening the flange resulted in reduced air in-leakage by a factor of six.

Runs made before the leak was discovered were duplicated. Comparison of results indicate that the recirculation rate was not altered, but that comparable gas temperatures were about 40 C lower during the leakage, which indicates that in-leakage may lower reactor capacity.

Calcine Powder Melter

The siphon discharge valve in the melter was tested successfully during a 3-1/2 hour run in which the melt level was raised above the bottom of the siphon cup. A vacuum pulse periodically initiated below the melter was used to start the siphon causing the molten product to be forced out of the valve opening until the melt level had dropped to the bottom of the siphon cup. During this run a powder feed rate of between three and four pounds per hour was used. No attempt was made to reach the melter capacity.

Denitrator-Evaporator

Additional runs were made with simulated Purex waste in the denitrator-evaporator. After 45 hours of boiling at a temperature difference of 40 F, the overall heat transfer coefficient gradually rose from 190 to 225 Btu/hr-ft^2-^{o}F. This rise was later attributed to pitting of the bayonet heater. After a shutdown of three days, solids had settled to 50 percent of the total volume. These solids prevented natural circulation and reduced the rate of heat transfer to 140 Btu/hr-ft^2-^{o}F. The solids were not resuspended by excessive boiling and mild agitation.

Attempts were made at concentrating a type of waste with high zirconium and rare earths content. After concentration to a boiling point of 112 C, the waste was converted to a gel and could not be boiled. One run in the evaporator at 110 C gave a heat transfer coefficient of 80 Btu/hr-ft^2-^{o}F. On a second run the simulated waste began drying out near the heater and solids were baked onto the bayonet due to poor circulation.

These data indicate that careful chemical composition and operational controls are required for the successful operation of a denitrator-evaporator.

Filter Blow-Back Studies

An experimental study of blow-back cleaning systems for the spray calciner off-gas filters has been initiated to define the effects of

various parameters on filter cleaning. Work to date has been aimed at optimizing the filter overpressure (the difference in pressure between the upstream and downstream faces of the filter).

Experimental data were collected using the same type filter and venturi now installed in the cold semiworks spray calciner. In these first runs the effects of distance from the blow-back nozzle to the venturi throat and nozzle size were investigated. Two nozzles (0.41 inch and 0.16 inch I.D.) were compared at constant upstream air delivery pressures and at constant air flow rates. In all cases the overpressure attained a steady value 0.2 seconds after a solenoid valve opened, allowing air to flow through the nozzle. Overpressure was independent of position on the filter face, except within two inches of the top of the filter where the extension of the venturi into the filter probably interfered with air flow to the filter face causing smaller overpressures.

Within experimental error, steady-state overpressure measured at the midpoint of the filter indicates little effect of nozzle to venturi distance when the nozzle is from two to six inches from the venturi throat. At the same flow rate, the smaller nozzle produced greater overpressures than did the larger nozzle. However, the gas velocity in the smaller nozzle was sonic, while that in the larger was sub-sonic.

Calcination Studies

Following several runs in the "cold" laboratory spray calciner to define conditions which would insure melt production, three runs were made in the A-Cell spray calciner. The first run was with acidic Purex waste plus orthophosphoric acid and a modest sodium nitrate addition (0.3 M) sufficient to give a fluid melt at 900 C. The second run was identical except for addition of sugar (100 g/l) to the feed. The third run was similar to the first except for substitution of diammonium phosphate for phosphoric acid. The first two runs were quite smooth but nozzle plugging was troublesome on the third as long as steam atomization was attempted. A switch to air atomization eliminated the plugging difficulty. Volatilization of ruthenium (ca. 1.2 percent) in the first and third runs was about the same as in acidic Purex runs without any additives, indicating little effect of phosphate, whereas less than 1 percent of the rutnenium was volatilized in the run with phosphate plus sugar. This may be compared with 3 percent volatilization for acidic Purex waste plus sugar (but no phosphate) and may indicate a slight, favorable, synergistic effect. Behavior of the other fission products was normal, except for a slight decrease in decontamination across the calciner and its associated sintered stainless steel dust filters, a decrease which probably implies increasing porosity of the filters (due to corrosion). In all cases, the total off-gas decontamination factors, after passing through

the condenser and Cambridge filters, exceeded the detection level of 10^8. The next planned runs will use Redox waste, which is high in aluminum and similar to TBP-25 waste. A cask of Redox waste was received at the end of the month for these studies.

Glass Studies

Calculations were made, in behalf of forthcoming continuous glass making experiments, of the composition and heat generating rates of glasses produced from power reactor fuels of relatively high burnup (20,000 MWD/T). For these wastes, as contrasted to current Hanford Purex waste, the fission products will constitute an important fraction of the waste, and the heat generating rate (short cooled waste) is of the order of 0.5 to 1 watt/cc. On this basis, the diameter of cylindrical storage containers is limited to about 6 inches.

At month's end, the induction heater for laboratory glass studies was operational but certain deficiencies in its design, not previously realized, will require correction in order to obtain adequate control capability. In the meantime, other equipment required for "cold" pilot work is proceeding with November 1, targeted for initiating integrated testing.

Samples of a number of promising high-temperature ceramics have been obtained for testing with phosphate glasses. It is hoped that it may be possible to substitute one or more of these for platinum in melt furnace service.

Thermodynamic Properties of Zeolites

Rational thermodynamic equilibrium constants and standard Gibbs free-energies were determined for several synthetic zeolites and clinoptilolite with the reaction

$$Ca_{zeolite} + Sr_{solution} \rightleftarrows Sr_{zeolite} + Ca_{solution}.$$

The equilibrium constants of the above reaction for Linde 4AXW, 13X, AW-400, AW-500, Norton Zeolon and clinoptilolite were 3.61, 2.55, 0.351, 0.478, 0.376 and 1.78, respectively. Expressed to the nearest 100 cal/mole, the standard Gibbs free-energies were -800, -600, +600, +400, +600 and -300 for 4AXW, 13X, AW-400, AW-500, Zeolon and clinoptilolite, respectively. The equilibrium constant for 4AXW is very high, considering the chemical similarity of calcium and strontium. Just as with the previously reported values for the reaction

$$2Na_{zeolite} + Sr_{solution} \rightleftarrows Sr_{zeolite} + 2Na_{solution}$$

[redacted]

[redacted]

the zeolites with the lower silica-to-alumina ratios (4AXW and 13X) had the highest strontium selectivities.

Low and Intermediate Level Waste Treatment

Batch equilibrium experiments were conducted to determine the uptake of trace ruthenium from steam-stripped Purex tank farm condensate by various anion exchange resins. The resins were based with nitrite ion, the predominant anion (5-10 ppm) in the condensate. The highest ruthenium distribution coefficients were obtained with Duolite A-14, Amberlite IR-400 and Dowex 1 x 8. Ruthenium adsorption by Dowex 1 x 4 was less than that of Dowex 1 x 8 which indicates that increased cross linkage favors ruthenium adsorption from this condensate.

A six-membrane electrodialysis unit was constructed to aid in determining the relative fractions of anionic, cationic and neutral ruthenium species present in an acid condensate stream. The unit was operated so that cationic and anionic ruthenium would be transferred to individual concentrating streams isolated from the electrode compartments to avoid sorption and electrodeposition on the electrode surfaces.

In preliminary experiments 90 percent of the ruthenium was removed from the feed stream; however, only 30-35 percent of the activity was found in the waste liquors. The remainder of the ruthenium was associated with the cation and anion exchange membranes and could not be removed sufficiently to allow calculations of the percent ruthenium which was cationic, anionic and neutral. Pre-equilibration of the membranes with the feed solution did not alter the results appreciably. Possible explanation for the observed results is sorption of ruthenium on hydrous iron oxide since the feed contains 7 ppm iron. The iron was found concentrated on the surface of the anion exchange membrane, possibly migrating there as negatively charged colloids.

Several thousand gallons of Purex Tank Farm condensate were processed through the engineering-scale stripper to determine the stripper's operating characteristics with actual feed and to obtain stream samples for the evaluation of the stripper performance. The stripper feed was cloudy with a pH of about 7.4 even though samples of the tank truck had been clear with a pH of about 9.5. Bottom samples were cloudy with a pH of about 9.2 while operating at overhead rates up to 9 percent of feed. The feed tank was drained and additional fresh feed received for further testing.

The thin bed ion exchanger was precoated using 100 - 230 mesh and +100 mesh acid-washed clinoptilolite. In both cases the pressure drop across 1/8-inch beds exceeded 20 inches of Hg at a flow rate of 0.6

gpm/ft^2. Apparently, additional pretreatment of the clinoptilolite is required to remove fines. Fifty to 80 mesh Decalso was then used to precoat the thin bed. The pressure drop across a 1/2-inch bed was an acceptable 3 inches of Hg at a flow rate of 1 gpm/ft^2.

A comparative cost analysis for ion exchange decontamination and a one-stage evaporation process for Purex Tank Farm condensate indicated that the ion exchange process would be at least $9.50/1000 gallons less than the evaporation process (HW-SA-2968, "Treatment of Radioactive Condensate Waste," by J.M. Skarpelos).

BIOLOGY AND MEDICINE - 06 PROGRAM

TERRESTRIAL ECOLOGY - EARTH SCIENCES

Hydrology and Geology

The formation of a computer program entitled "Genpath" is two-thirds completed. The program (1) determine the paths of flow from steady potential distributions, and (2) determine the in-place permeability distribution by evaluating appropriate integrals along the stream-lines. The program is designed to permit the permeability distribution to be obtained from the potential observations made in the piezometers. The permeability, in turn, is required for a valid analog.

Resistors and other equipment were ordered for the preliminary (662 nodes) analog. This three-dimensional test model will be used to check assembly methods, operational characteristics, and the closeness which the information obtained from the analog model matches the analytical solution.

Testing of the soil column packer was started. The first tests were designed to check the uniformity of density within a packed soil column, the reproducibility of density from column to column, and the range of bulk density that the packer is capable of producing. Various combinations of feed drive and vibrator motors are being used to meet the last objective. For each combination, two columns will be packed; the columns are then sectioned into one-inch sections, and the bulk density is determined for each section. Tests conducted, using a fine sand, have resulted in the bulk density of each section being within ± 1 percent of the mean bulk density of the column. The mean bulk densities of two columns have varied no more than 0.1 percent; thus, uniformity and reproducibility are good. The packer will be used to assemble columns of "typical" Project soils for unsaturated flow parameter measurements.

Following computer analysis of geophysical seismic field data, and its interpretation by Geophysical Service, Inc., these conclusions resulted:

1. Continuous profiling by reflection methods provides accurate information on the depth to basalt when coupled with advanced computer techniques. Work proceeds rapidly with pre-drilled shot holes. Costs are high because of the need for computer data processing and large amount of drilling. The depth to basalt is difficult to determine when less than 600 feet. No basalt flows beneath the uppermost flow were identifiable.

2. Continuous profiling by refraction seismic methods provides accurate information on the depth to the Ringold Formation and the basalt surface. Computer processing of data is unnecessary. Surface shooting with inexpensive fertilizer-grade ammonium nitrate is completely satisfactory, eliminating much drilling and more expensive explosives. Occasional "tie" holes to basalt are necessary. No basalt flows beneath the uppermost one were identifiable. A low velocity bed directly above basalt, and correlated with what has been called the "Prosser interbed," was identified. Local horizons within the Ringold Formation could not be recognized. Variations in basalt velocities from site to site appear to correlate with different flows where they form the basalt surface.

3. Geological and seismic data from rotary-drilled wells, including that from electric and gamma-ray logs, velocity surveys and samples, was excellent and permitted good correlation. Difficult though fast drilling in many sites makes this an expensive single-method system.

4. No one method of exploration is completely definitive and economical. Combined refraction profiling and rotary drilling, with thorough logging of drilled holes, appears fastest, most definitive and most economical.

RADIOLOGICAL AND HEALTH CHEMISTRY

Radioiodine Studies

During a period of above-normal emission rate of I-131 from a separations plant stack, samples were taken to determine the changes in particulate and gaseous nature of the I-131 containing species. Airplane flight samples were obtained at altitudes of 200-500 feet above the ground, and at 1, 3, 5, 10 and 25 miles downwind from the stack. The flow rate of air through the sampler was only about one-third that required for isokinetic sampling. Data from the September 3 flight showed the material to be about 80 percent gaseous out to the 10-mile distance where it dropped off to 60 percent gaseous. On the September 4 flight, the sample one mile from the stack was 73 percent gaseous while all other samples from the 3, 5, 15 and 25 mile distances showed greater than 90 percent associated with the gaseous fraction. Thus, in the three studies made to date conditions of both increase and decrease in the percentages of I-131 associated with particles have been observed.

During the same period of airplane sampling, a measurement was made of the stack gas using a filter pack containing a membrane filter, a silver mesh, a charcoal filter, and a bed of activated charcoal. Less than

0.1 percent was collected on the membrane filter, while about one-half was collected by the silver mesh, and one-half by the charcoal and charcoal filter. When copper mesh was used instead of silver mesh, only 5 percent of the I-131 was collected at this stage. These results indicate that about one-half of the iodine was being released in relatively non-reactive forms.

Radiation Chemistry

Since the chloride ion concentration may be large (on the order of 0.15 M) in biological systems, the reaction between the hydroxyl radical formed from irradiation and the chloride ion to form a chloride radical may be an important route to structure-damaging reactions. Studies of dye bleaching due to irradiation made in saline solutions show that chloride ion does alter the competition between the reference dye and other compounds present for the reactive radicals present. As an important side observation, it was found that chloride ion has a protection index of about 0.0003. While this is quite small, the large excess of chloride ion over other solutes in a biological system makes its effect important.

ATMOSPHERIC RADIOACTIVITY AND FALLOUT

Particle Sampling Studies

The errors in sampling zinc sulfide particles in an air stream were further defined in support of meteorology research. With a wind speed of 3.2 mph, a sampling rate about 1/14 isokinetic, and particle sizes ranging from 3-18 μ in diameter, the particles collected in the sample were from 1.2 to 2.8 times the number expected from the actual air volume sampled. With a wind speed of 6.9 mph, a sampling rate about 1/30 isokinetic, and for particles 2 to 18 μ, the particles collected were from 2 to 8.2 times the number expected from the actual air volume entering the collector.

The geometry of the filter holder and the backing media have a significant effect on the sampling error. Standard filter holders whose backing media consists of a crepe paper strip rolled onto a hard wood dowel, used in the above study, gave sampling errors considerably higher than for holders with a tapered filter retaining ring and screen backing.

Gravitational deposition of particles in horizontal 1/2-inch diameter tubes was measured and compared with deposition predicted by equations derived for particles in laminar flow. Single size particles were generated with the spinning disc generator and their deposition pattern

measured along the 1/2-inch tube. Fractional deposition as a function of length was in fair agreement with theory, although the maximum distance traversed was somewhat greater than predicted from theory.

The deposition in 90° elbows of a narrow size distribution of particles was measured for three particle diameters and five flow rates. The elbows were formed in standard 1/2-inch aluminum tubing using a bend radius of 1-1/2 inch. The deposition varied from 0.02 percent for 2 μ particles at a flow rate of 0.5 cfm to about 69 percent for 2 μ particles at a flow rate of 2.5 cfm.

I-131 Generator for Field Release Experiments

An apparatus was designed, assembled and tested for insuring a uniform emission rate source for I-131 field releases being scheduled by Atmospherics Physics Operation. Controlled release rates are possible when I-131 solution as KI is fed at a controlled rate into a $NaNO_2 \cdot H_2SO_4$ system. Several experiments were performed demonstrating that closely controlled releases are possible.

ISOTOPES DEVELOPMENT - 08 PROGRAM

Cerium-Rare Earth Separation

Full level hot cell experiments continued during the month on the persulfate oxidation - D2EHPA extraction process which was described in detail last month. The experiments (1) better defined the effect of silver catalyst concentration and acidity on reaction rate, (2) showed that some ruthenium is evolved from aqueous solutions (such as Purex 1WW) in the absence of organic, but not if organic is present, (3) indicated that Ce(IV) is surprisingly stable in the organic phase in the absence of aqueous-phase catalysts or complexants, (4) showed that D2EHPA has a comfortable margin of radiation stability for this use, and (5) further confirmed that permanganate is unsuitable as a cerium oxidant due to instability and solids formation. Current work is aimed at preventing the co-extraction of lead with the rare earths in the initial extraction. Preliminary results (with Pb-210 tracer) indicate that this can be readily accomplished with HEDTA complexing at ca. pH 2 to 3. The work on the cerium-rare earth separation process is summarized in an invention report (HW-78690) and is described in detail in a summary report, HW-78987.

In summary, this simple and compact batch solvent extraction process has survived both rigorous hot-cell tests and a previously-reported highly successful Hot Semiworks test and is therefore established as the method of choice for separation of cerium from other rare earths,

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both for interim production of either cerium or promethium, and for ultimate use in the Hanford Isotopes Production Plant.

Ion Exchange Purification of Promethium

Two very similar, compact-band, chromatographic ion-exchange processes (both based on the Ames "cold" rare earth process) have been utilized, one at Hanford and the other at Oak Ridge, for the relatively small-scale production of very high purity Pm-147, and a comparative evaluation of these two processes is desirable to aid in choosing the best flow-sheet for large-scale Hanford production use. A series of column runs have accordingly been conducted in the laboratory (with a non-radioactive fission product mixture) to compare the two and to determine the effect on each of variables and impurities not previously investigated. The Hanford process utilizes EDTA as eluting agent at a pH of ca. 8.7 and a metal ion (such as Y^{+3}, Al^{+3}, or Zn^{+2}) for band restraint while the Oak Ridge process employs DTPA (diethylenetriaminepentaacetic acid) at ca. pH 5.9 as eluting agent and hydrogen ion as barrier. Both use a similar cascade of columns, a cation resin (such as Dowex-50), elevated temperature operation (to improve kinetics), and similar operating procedures. In the Oak Ridge runs, X-4 (4 percent cross-linked) resin and 80 C operation were used vs. the X-8 resin and 60 C operation at Hanford.

For the comparative runs, the feed was a mixture of Pr^{+3}, Nd^{+3} and Sm^{+3} in equal concentrations and the 110 cm x 0.76 cm^2 columns were filled with Dowex-50W, X-8 (50-100 mesh) resin and operated at 60 C and a flow rate of 2.8 ml/min-cm^2. Either pH 8.71, 0.012 M EDTA or pH 5.94, 0.012 M DTPA were used as elutriant, with zinc(II) as barrier ion with EDTA and hydrogen ion with DTPA. Very precise elution curves were determined by accurate spectrophotometric analysis of the effluent samples. Almost identically high separation efficiency was obtained with the two eluting agents and no choice between them is possible on this basis. It was particularly gratifying that X-8 resin and 60° operation seemed to work as well with DTPA as with EDTA. Pertinent differences were as follows:

1. The rare earth concentration in the DTPA effluent was only about one-half that of the EDTA effluents. Since DTPA is approximately twice as expensive as EDTA, the cost per unit of promethium would be about four times higher. This reagent cost would be partially offset, however, by cost of the metallic barrier ion used with EDTA.

2. In the DTPA system, lead (Pb^{+2}) and yttrium band with the rare earths and will elute with promethium between samarium and neodymium. With EDTA, lead passes through the Zn^{+2} barrier shortly after the start of elution and is completely removed from the system by the time the band has moved half a band length.

On the basis of complexing constants and elution orders, it appears that HEDTA (N-hydroxyethylethylenediaminetriacetic acid) may have most of the advantages of both EDTA and DTPA, and runs are being initiated to investigate this system.

Writing has been completed on a formal report, HW-78651, "Development and Demonstration of an Ion-Exchange Process for Kilogram-Scale Production of High-Purity Promethium."

Cesium Purification with BAMBP

A fresh supply of BAMBP was obtained and used in a highly successful solvent extraction pilot plant demonstration of cesium purification process proposed for the Hanford Isotopes Production Plant (see HW-77770, Fig. 9). The feed for this process contained 0.05 M Cs^+, 2 M Na^+, and 0.4 M OH^-; the solvent was 0.5 M BAMBP in Soltrol-170. A water scrub was used, in a separate scrub column, to remove extracted sodium, and 0.3 M sulfamic acid was used to strip the cesium from the solvent in a third column.

Cesium losses as low as 0.08 percent and 0.14 percent were obtained in the extraction and stripping columns, respectively, at feed/solvent/scrub/strip flow ratios of 1/1.5/0.2/0.18. Approximately 14 percent of the cesium was refluxed by the water scrub as it reduced the sodium concentration in the solvent extract from 0.023 g/l to 0.005 g/l. The final product contained 0.067 g/l sodium, giving a sodium-to-cesium mole ratio of 0.01 and an overall sodium decontamination factor of 4000.

A run in which the solvent flow equaled the feed flow had a comparable overall sodium DF and cesium loss in the stripping column but the cesium reflux in the scrub column was 29 percent and the loss in the extraction column was about 4 percent. Solvent loading by cesium was believed to be the main factor increasing the reflux and loss. For example, a two-phase sample taken near the feed point was found to have a distribution ratio of 1.3 with 0.06 M cesium in the solvent (a distribution ratio of about 50 has been reported by Bray for tracer cesium under similar conditions).

The pulse column used in the above tests contained 12 ft. of 23 percent free area nozzle plates in the extraction column and 10 and 9 ft. of 10 percent free area nozzle plates in the scrub and stripping columns, respectively. The three columns were operated at respective column velocities of 880, 550 and 550 gph/ft^2, and amplitude-frequency products of 65, 74 and 70 in/min, very near the threshold flooding limits. All three columns were run with the organic phase continuous.

W.H. Reas
Manager
Chemical Laboratory

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W.H. Reas:cf

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BIOLOGY LABORATORY

A. ORGANIZATION AND PERSONNEL

Dr. C. E. Breckinridge, a Senior Scientist in the Pharmacology Operation, resigned on August 16, 1963, to accept a position elsewhere.

Dr. J. L. Palotay joined the Biological Analyses Operation as a Senior Scientist on September 3, 1963.

Dr. J. M. Dean was assigned to the Aquatic Biology Operation as a Biological Scientist on September 30, 1963.

B. TECHNICAL ACTIVITIES

FISSIONABLE MATERIALS - 02 PROGRAM

Dowell F-33

Toxicity tests of Dowell F-33 on fish are tentatively terminated. This surfacant is currently being discharged into the Columbia River on occasion to clean and condition the pipes at NPR. Rough estimate of LD_{50} for 72 hours exposure is about 20 ppm. No mortality occurs at 5 ppm. Acute toxicity is often measured by number of mortalities observed; however, for the evaluation of Dowell F-33, the loss of equilibrium is perhaps more meaningful. In the field a young fish with a loss of equilibrium has little probability of survival for obvious reasons. Loss of equilibrium has been quite variable, but it has occurred at concentrations as low as 1 ppm.

Additional tests were made on trisodium phosphate (TSP) alone and a mixture (3:1) of TSP and Dowell F-33. Loss of equilibrium occurred in 400 ppm TSP. At 600 ppm TSP total mortality occurred within a half-hour. No mortality or loss of equilibrium occurred at 200 ppm. Total mortality occurred within 2½ hours in a mixture of 200 ppm TSP and 60 ppm F-33. No mortality was observed at 100 ppm TSP and 30 ppm F-33.

Columnaris

The observations for columnaris on young trout reared in three different temperatures (regular Columbia River water, +4 F warmer and -4 F cooler) continues. After 14 weeks of test the +4 F group clearly shows a higher mortality, but no apparent difference exists between the regular river temperature group and the -4 F group. The trout in the +4 F group are also considerably smaller than the trout in the other groups. The growth, mortality, and columnaris incidence data are summarized below:

Temperature of river water	% Mortality	Columnaris incidence (%)	Avg. Wt. (g) S.D.
Normal	6.8	14	12.7 ± 0.5
4F above normal	50	61	7.3 ± 0.8
4F below normal	9.2	22	13.3 ± 1.9
UV treated	6.9	1	13.3 ± 1.8

Although total mortality and columnaris incidence have increased in most of the troughs during the past four weeks, it can be seen that UV treatment of the water greatly alleviates the condition.

The river water temperature has risen from a low of 67 to 72 F during the past 30 days. The unusually warm water temperatures this month have increased the incidence of columnaris and mortality of the rainbow trout. Approximately 50% of the mortality have had external manifestations of the columnaris disease such as dorsal saddles, ulcerated pectoral and caudal areas.

Refrigeration of the water was also effective in reducing mortality and columnaris incidence, but with the onset of warmer river temperatures, even a reduction of 4 F was not enough to keep the incidence down.

Incidence of columnaris in the water samples obtained from the troughs showed extremely high counts in the heated water. A 100% exposure of the fish seemed evident; however, our total mortalities from all causes during this period have only ranged from 3 to 15 fish per day. Since tests for organisms at trough inlets show that very few of them are entering the troughs, the increased incidence is probably due to cross infection of the fish.

Only two of 69 native river fish obtained from slough areas from Hanford to White Bluffs showed any incidence of columnaris. One was heavily infected and showed body lesions, while the other had no lesions and had a very few organisms on the gills. Water temperatures in these waters ranged from 69 to 71 F.

BIOLOGY AND MEDICINE - 06 PROGRAM

METABOLISM, TOXICITY, AND TRANSFER OF RADIOACTIVE MATERIALS

Strontium

Among the four female miniature swine fed 625 μc Sr^{90}/day starting when nine months old, three succumbed after about nine months of Sr^{90} feeding. The death of these three animals was associated with hematopoietic failure (exhibiting neutropenia, thrombocytopenia and anemia). The fourth animal is still surviving after 16 months of daily Sr^{90} ingestion. There are as yet no significant radiographic lesions. Erythrocyte values are within the normal range, while both thrombocyte and neutrophil numbers are reduced. The relatively long survival time and apparent good health of this animal increases the possibilities of observing a death related to long-term effects (e.g., tumor formation) as compared to the hematological causes of the early deaths observed previously. Although relatively few animals have been studied at the higher levels of Sr^{90} ingestion, the long survival of this animal would indicate that a level of Sr^{90} ingestion slightly less than 625 μc/day would result in the long-term survival of all the animals. Animals on such a level of Sr^{90} ingestion would certainly exhibit chronic changes and a shortened survival time.

Iodine

The I^{131} level in the rations of three cows on daily feeding was increased from 5 μc to 50 μc in preparation for sacrifice and tissue distribution studies. Concentrations of I^{131} reached a plateau in the thyroid after two weeks and in the milk after four to five days and were six times the concentration previously observed when they were fed 5 μc/day. Stable iodine intake in all cows was adjusted to 5 mg/day, the recommended dietary intake.

A study was initiated to determine the uptake of radioiodine vapor through the skin. Young miniature swine will be exposed and their thyroid uptakes will be of primary interest. The exposure chamber and associated equipment is almost ready for use. Monitoring equipment has been set up and geometry factors have been determined.

Plutonium

Five μc Np^{239} and/or 5 μc or 1 μc Pu^{239} was injected in rats. Some of these rats were subsequently treated with DTPA. Percentage deposition of Pu^{239} in liver was somewhat higher in the 5 μc animals than in the 1 μc animals, and deposition in femurs was lower in the 5 μc animals than in the 1 μc animals. Removal of Pu^{239} from the livers by DTPA treatment was somewhat less effective in the 5 μc animals than in the 1 μc animals. These results are in line with previous observations. There was some indication that Pu^{239} retention was increased slightly in animals which also received 5 μc Np^{239}. The more interesting results on Np^{239} distribution as affected by simultaneous Pu^{239} administration, are not yet available, due to difficulties in obtaining a properly functioning calculator.

DTPA administered with zirconium colloid or india ink was no more effective than DTPA alone in removing plutonium deposited in rats 7 days prior to treatment.

Inhalation Studies

Probable toxicity of sodium-calcium salt of DTPA was observed in dogs that were treated following inhalation of $Ce^{144}O_2$. Dogs received 1 g DTPA iv on day 1, followed by 0.5 g DTPA plus 4 cc of 10% calcium gluconate on day 2; and 0.5 g DTPA on days 3 and 4. All dogs were ill following the third treatment, and one dog was dead on day 6. Vomiting occurred before death, but no diarrhea. Autopsy showed lesions of the stomach and intestine. Surviving dogs had temporary low serum alkaline phosphatase and high urinary urea nitrogen levels. Following recovery, treatments with DTPA were continued with no further symptoms. This is the second death of a dog treated with DTPA, the previous having occurred a year ago under conditions where DTPA was suspected but not directly implicated. This may indicate that DTPA is more toxic to dogs than to rats since comparable levels have been given rats without apparent effects.

In earlier experiments the retention, translocation, and excretion of inhaled $Ce^{144}O_2$, as well as the effectiveness of DTPA in removing Ce^{144}, were studied in dogs. In these studies cerium oxide was prepared by oxidizing the nitrate with sodium peroxide. Similar studies are in progress with $Ce^{144}O_2$ prepared by calcination at 375 C for comparison with results obtained in studies with $Pu^{239}O_2$ prepared in a similar manner. Since this product also more clearly resembles the material that would be dispersed in accidents which are generally expected to involve high temperatures, the results of these studies should be more useful than the previous results for hazard evaluations.

Results of tests of aerosol sampling equipment conducted at Los Alamos confirmed the operational dependability of our Walkenhorst type thermal precipitator which was constructed by Technical Shops. This instrument and the point to plane type electrostatic precipitators we are also using deposit aerosol particles directly on electron microscope grids and should provide more accurate estimates of particle size than the samples collected on membrane filters and transferred to the grids.

Gastrointestinal Radiation Injury

An experiment was completed which utilized 60 rats to test the usefulness of I^{131}-labeled PVP as an indicator of gastrointestinal radiation injury. The rats were exposed to 500, 750, and 1000 r X ray or 150, 175, 225, 275, and 310 rads fission neutrons. The PVP was injected intravenously two days after radiation. Fecal PVP excretion was dependent on radiation dose in both the X ray and fission neutron irradiated animals. Cysteine prophylaxis decreased intestinal permeability effects of neutron irradiation but did not decrease mortality. It may be assumed that death was due primarily to hematopoietic injury.

Kidney Studies

In the course of development of a technique for determining the functional capability of the kidneys of sheep and miniature swine using the Hippuran I^{131} renogram, several animals were given mercuric bichloride intravenously to produce kidney changes for study. Mercuric bichloride, at a level of 1.5 mg/kg body weight, resulted in death of both sheep and swine within two hours following administration. A severe acute nephritis was observed in both species and the sheep manifested a hemorrhagic enteritis. A sheep given 1 mg/kg showed functional impairment of the kidneys at 5 hours post-administration. This animal was killed when death appeared imminent eight days after mercuric bichloride administration, showing severe nephritis. A sheep given 0.25 mg $HgCl_2$/kg had functional impairment of the kidneys 30 hours post-injection with return to normal function at 5 days post-administration of the $HgCl_2$. All determinations of kidney function were made using the Hippuran I^{131} renogram. The technique was not wholly satisfactory in the sheep because the kidneys were frequently vertically aligned (one on top of the other), making it impossible to determine the activity associated with each kidney individually.

The neutral approach for ligating a renal artery or ureter in miniature swine was abandoned as impractical in favor of a para-lumbar approach. This latter technique was then used to ligate the right renal artery of one lamb and one adult miniature swine female. The Hippuran I^{131} renogram was then obtained. These two animals were used primarily to develop a surgical technique which will be expanded to accluding the renal artery and ureter in varying degrees. The renograms of these animals will then be compared to animals which have received renotoxic agents and Sr^{90}.

Cellular Proliferation in Fish

A total of 1,011 tissue samples from 72 silver salmon injected intra-peritoneally with C^{14}-thymidine has been assayed for radioactivity. Because of the large sample size the results are being programmed for data processing and analysis. Over 950 tissue samples from 68 fish injected with H^3 thymidine have been blocked in paraffin for sectioning. The subsequent autoradiographs will be processed later at Oregon State University.

Microbiology

Yeast cells grown in D_2O were previously shown to have their growth and division cycles partially dissociated. Now we observed that cells grown in D_2O show decreased RNA, DNA, and protein concentrations. It is probable, but not yet demonstrated, that the decreased protein is a consequence of reduced nucleic acid. When cells are removed from a D_2O medium and placed in H_2O medium, protein and nucleic acid contents return to normal in less than one cell generation. Simultaneously the cell division rate increases.

Plant Nutrition

Iodine-131 gas was released on the Atmospheric Physics' grid and allowed to pass over small plots of rye, potted geranium, soil, and the native plants. Air samplers determined amounts of I^{131} in the air as a vertical as well as horizontal pattern. The rye was randomly sampled over a 16-day period. After correcting for physical decay, the data give a biological half-life of eight days. The I^{131} appeared to be lost throughout the 16 days, not just during the period immediately after contamination.

Great care was taken to avoid washing the I^{131} off the leaves. Some could have been shaken off along with dust adhering. However, it appears more probable that most of the I^{131} was lost by sublimation since a geranium plant was placed in a container through which air was drawn and the discharge air passed through an I^{131} absorber. Although the data were not quantitated, it appeared that the amount of I^{131} on the absorber was adequate to account for a major part of the eight-day biological half-life.

Complete calculations are as yet unavailable, but it is clear that the center of three portions of the rye leaves contained the greatest amount of I^{131}. This is partially due to the bent over state of the leaves, such that the middle portion is actually highest but may also be due to a reduced mass and surface area in the terminal third of the leaves. Total deposition, percent removable, and other data are as yet not summarized.

Plant Ecology

Field sampling of native forage plants and game animal pellets were collected from the Blue Mountain area during the spring and summer months. Radioactivity analyses have been impossible to interpret due to extreme variations, presumably caused by the background variation in the 108 counters. A draft of a manuscript on theoretical considerations in distance sampling was completed and distributed for review.

Moisture content of sagebrush leaves was observed to decline from a spring value of 70% to a low of 50% in July and August. Greasewood leaves during this same period maintained a constant level of 70-80%, indicating that this shrub does not suffer water deprivation. These observations correlate well with those made by D. W. Billings and indicate that greasewood is tapping a ground water source which is about 30 feet underground. Sagebrush, on the other hand, is unable to penetrate to such depths and so depends on the annual rainfall reserves which are gradually depleted during summer drought.

Radioactivity of Alaskans and Their Diet

Whole-body counting of northern Alaskan residents was completed with the examination of 120 people at Point Hope and 157 people at Kotzebue. Recounts of adult natives examined during both 1962 and 1963 showed the following results:

	Number of Persons	Cesium-137 body burden (nc) Average 1962	Average 1963	Maximum 1962	Maximum 1963
Point Hope	59	14	44	44	89
Kotzebue	36	140	150	520	750

The substantial increase in Cs^{137} body burdens among Point Hope residents resulted from greater availability of caribou and greater Cs^{137} concentrations in caribou flesh during 1963 as compared to 1962.

Collection of samples of large mammals utilized as food by the native people of Alaska was begun during the middle of July. Samples of muscle,

bone, and rumen contents from freshly killed caribou, reindeer, and moose were obtained for measurement of fallout radionuclides. In addition, samples of plants important as food of these animals during the season in which they were collected were also obtained for radioanalyses.

Reindeer were sampled at St. Paul Island and Nunivak Island; caribou were collected at Noatak and Cape Thompson, and moose were taken along the Kobuk River and near Fort Yukon.

Arrangements were made for obtaining additional samples of plants and animals during the coming fall and winter.

No data on the levels of fallout radioisotopes in this material are available at this time.

H A Kornberg
Manager
BIOLOGY LABORATORY

HA Kornberg:es

TECHNICAL INTERCHANGE DATA
BIOLOGY LABORATORY

I. Speeches Presented

a. Papers Presented at Society Meetings and Symposiums

None

b. Seminars (Off-Site and Local)

Bair, W. J. Plutonium inhalation studies. Laboratories Du Centre D'Etude de L'Energie Nucleair, Mol, Belgium. September 2, 1963.

c. Seminars (Biology)

Kornberg, H. A. Information meeting on the Biology program. September 10, 1963.

Palmer, R. F. Available services of Biological Analyses. September 10, 1963.

Erdman, H. E. X-rays and flour beetles. September 19, 1963.

Maisin, J. R., Director, Biology Department, Centre D'Etude de l'Energie Nucleaire, Mol-Donk, Belgium. Mechanism of action of radioprotective compounds. September 25, 1963.

Matchett, W. H. Regulation of trypotophane metabolism. September 26, 1963.

d. Miscellaneous

Bustad, L. K. Large animal radiation biology. Hanford Kiwanis Club. September 30, 1963.

II. Articles Published

a. HW Documents

None

b. Open Literature

Casey, H. W., R. O. McClellan, ". J. Clarke, and L. K. Bustad. 1963. Acute toxicity of neptunium-237 and its relationship to liver function in sheep. Health Physics 9: 827-834.

Erdman, H. E. 1963. The differential sensiti-ity of flour beetles, Tribolium confusum and T. castaneum to X-ray alteration of reproductive abilities, induced dominant lethals, biomass and survival. J. Exptl. Zoology, July 1963.

III. Visits and Visitors

a. Visits to Hanford

9/10/63 - Ronald Pine, Washington State Pollution Commission, Yakima, Washington, returned sampling equipment to C. E. Cushing and discuss research.

9/19/63 - 35 members of the USDA County Defense Board toured Biology facilities.

9/19/63 - Columbia Basin Federal Safety Council toured Biology.

9/20/63 - Miss Marie Churney, Institute for Fresh-water Studies, Bellingham, Wash. toured Biology.

9/24-26/63 - Dr. J. R. Maisin, Director, Biology Department, Centre D'Etude de l'Energie Nucleaire, Mol-Donk, Belgium, presented a seminar and discussed research with Drs. W. J. Bair and R. C. Thompson.

9/24/63 - 29 Department of Defense officials from various U. S. Defense installations toured facilities and reviewed the Biology program.

9/27/63 - Dr. S. L. Fawcett, Battelle Memorial Institute, Columbus, Ohio, toured facilities.

b. Visits Off-Site

6/20-9/7/63 - W. C. Hanson conducted research in Alaska.

7/15-9/7/63 - D. G. Watson conducted research in Alaska.

9/4/63 - L. L. Eberhardt and W. H. Rickard collected vegetation on a fallout sampling program at the Wooten Game Range, Dayton, Washington.

9/4/63 - V. G. Horstman inspected feed at the Pendleton Grain Growers, Hermiston, Oregon.

9/2/63 - W. J. Bair presented a seminar at the Centre D'Etude De L'Energie Nucleaire, Mol-Donk, Belgium, and discussed research with Dr. Maisin.

9/4-5 - W. J. Bair discussed research with Drs. Nelson, Sisfsky, and Bjornerstedt at the Division of Radiobiology, Institute of National Defence, Stockholm, Sweden.

9/5 - L. K. Bustad discussed radiation studies with Prof. Ruch, University of Washington, Seattle.

b. Visits Off-Site (continued)

9/9-10/63 - L. K. Bustad and R. O. McClellan attended the annual review of the University of California radiation studies at Davis, California.

9/9-13/63 - J. F. Cline inspected laboratory facilities at the University of California at Berkeley and Los Angeles; and at Lovelace Foundation, Albuquerque.

IV. Achievements - None

V. Honors and Recognitions

Dr. L. K. Bustad was invited to become a member of the Advisory Committee on the American Institute of Biological Sciences monograph series, vice Dr. C. L. Comar who retired from the committee to accept an appointment in Yugoslavia. Chairman of the committee is Dr. A. M. Brues of ANL; other members include Dr. E. C. Pollard of Pennsylvania State University and Dr. C. W. Shilling of George Washington University.

VI. Professional Group or Organization Assignments

None

APPLIED MATHEMATICS OPERATION

MONTHLY REPORT - SEPTEMBER, 1963

ORGANIZATION AND PERSONNEL

D. C. Gray and M. B. Woodroofe terminated September 13 to return to school. D. E. Hudson terminated September 26 to join the Peace Corp.

OPERATIONS RESEARCH ACTIVITIES

Work continues on an improved information and analysis system for outage scheduling of KW and H Reactors.

A meeting was held concerning the application of operations research to certain inspection operation problems. A proposed operations research study is to be presented during October.

A study of HAPO power consumption patterns has been initiated. Preliminary analysis will be limited to FY-1963 data. Upon completion of the preliminary analysis, a decision on proceeding with a full analysis will be made.

The Tri-City-Area Economic Model is being used to test various assumptions about the Area's potential over the next five-year period.

STATISTICAL AND OTHER MATHEMATICAL ACTIVITIES FOR OTHER HAPO COMPONENTS

N-Reactor Department

A design model was formulated and an initial plan submitted for monitoring the precision of the measurement of clad thickness of fuels.

In connection with a proposed first-load fuel swelling study, a set of curves was generated to depict minimum sample sizes as a function of percentage swelling and measurement precision.

The problem of inconsistent results in tests of outer fuel support strength was studied, a procedure was suggested which will assist in identifying important "factors", and should lead to a controlled sequential testing program.

Irradiation Processing Department

An EDPM program was written which calculates the real roots of a cubic polynomial which has parameterized coefficients. The results have been used to assemble a chemical table used in water purity work.

Four calibration curves for the probolog were developed giving a chart reading as a function of known standard tube wall thickness values. In practice the tube wall thicknesses are estimated from the chart value so that the regression line is used in reverse. A program is being developed for the computer to determine 95 percent confidence limits for the estimated wall thickness when the chart reading is known.

Data from eight tests under varying tube wall thickness conditions are being analyzed to see whether factors such as probe speed, water flow in tube, air pressure in bellows affect the probolog readings.

Analysis of a technique to measure the amount of UAL_3 around a transverse cut of a fuel element indicated good measurement reproducibility relative to the variation around a cut and the variation between fuel elements.

Data from a technical journal giving the melting point of an alloy composed wholly of Zn, Sn, and Al are being analyzed with the objective of determining an adequate empirical functional relationship between the variables within a certain region of interest.

Stud pull results were used to compare several methods of deoxidation in the preparation of nickel-plated cores used in the hot-die-sizing canning process. Large sources of variation such as the variation between fuel elements and between replicated conditions made this test insensitive to detecting small differences. It was recommended, for economic reasons, that the test be abandoned without further experimentation.

Further predimensional data are being analyzed to compare the process control characteristics of AlSi and hot-die-sizing canned fuel elements.

The effects of the time, temperature, and pressure variables on the internal diameter stud pull values for fuel elements canned by the hot-die-sizing process are being analyzed.

An analysis indicated that the average pull strengths of rails were significantly higher for fuel elements cleaned by soap as compared to oil, although in general a few values fell below the minimum pull-strength specification. The difference between welder heads was a large and significant source of pull strength variation.

A considerable amount of data has been obtained on eight fuel element bond integrity variables as a function of the furnace temperature (four levels) and pre-heat time (four levels). A response surface is being fitted to each of the eight yield variables. The analysis will show how the process can be optimized with respect to the variables individually and as a group by normalizing each yield measurement once the mean and standard deviation is known and forming a yield variable found as the sum of the normalized yield variables.

Accident data, dating back to 1957, are being analyzed to compare seasonal and yearly frequency rates. An objective is to determine a frequency rate as a function of the year and/or the season so that confidence limits can be placed on the number of accidents expected as a function of the conditions and exposure hours.

A study was done on the probability that spurious scram situations can result as a function of the number of individual tube signals which fail within a temperature monitoring zone. The study is at present tentative, based on a somewhat small-scale simulation of the process. However, a larger, more complete analysis is being planned.

An analysis showed that no simple empirical formula will fit the relationship between the spire canning component and the time to reach various degrees of heat in a bath. For this reason, the average standard deviations and 95 percent confidence limits on the times to reach various temperatures were calculated.

Chemical Processing Department

A meeting of statistical personnel from all sites required to submit quarterly reports certifying compliance of weapon components with chemical purity specifications was attended at Rocky Flats. An informal report of comments of interest to other groups is being prepared.

A review of the current status of alloying constituent (70-58) control indicated the feasibility of decreasing from three to two samples per casting, however, part-by-part acceptance will be retained. The plutonium assay will be changed from part-by-part to a random sample with the retention of all samples from castings not analyzed to permit use of part-by-part acceptance if required.

An informal discussion was held with weapon inspection personnel regarding the feasibility of better defining the data collection and operating systems.

Work on the requirements for a highly simplified "analog" model of the overall "Z" Plant is continuing.

[redacted]

A review is being made of the need for a sampling verification program for CPD.

STATISTICAL AND MATHEMATICAL ACTIVITIES WITHIN HL

2000 Program

Debugging continued on the FORTRAN language program for the solution of the boundary value formulation of the nonlinear system of second order differential equations expressing mass transfer in the experimental pulse column. Test data from a nine compartment linear approximation to the second order nonlinear system are being used to debug the FORTRAN routine. Debug output indicates the presence of excessive round-off error, a common problem in recursive type calculations involving repeated matrix inversions and matrix product operations. In order to pinpoint the numerical difficulties double precision routines are being used for the debug work.

Mathematical assistance in the form of analysis and numerical computations was provided to a study of river bank storage and depletion theory.

Assistance is being given in estimating the total amount of Pu in a crib based on gm-Pu/liter of earth sampled in several holes at various depths below the crib. No real patterns of Pu density gradients emerge from these data so that the uncertainty in the total Pu estimate must needs be large.

3000 Program

Considerable effort is being devoted to debugging and checking out the EDPM program which prepares magnetic tape input for the prototype Sheffield rotary contour gauge. This is in anticipation of impending on-site field tests.

4000 Program

Recent theoretical and experimental developments in the field of sound wave propogation and attenuation in visco-elastic media were discussed with Professor Leon Knopoff at the UCLA Institute of Geophysics. These discussions were motivated by modeling difficulties which arise in studying non-destructive materials testing techniques.

Discussions were held with a representative of Babcock and Wilcox, Fuel Element Research, Lynchburg, Pennsylvania, on the subject of mathematical models and particle packing.

Preliminary experiments to evaluate a blow back filter cleaning system as a function of venturi geometry, and spacial and ambiant variables was run and statistical analysis completed of the experimental data. As a result of this analysis, estimates are now available of the apparatus set up error and the

basic reproducibility of over pressure measurements. Estimates of these errors are necessary to insure that future experiments will be designed in sufficient detail to delineate the properties of the system. It is desired to maximize over pressure for fixed primary air volume. Since primary air volume cannot be regulated directly the relationship between delivery pressure and primary air volume must be determined prior to the design of more experiments. Current efforts are directed toward determining this relationship for several nozzle diameters.

A study, based on a quadratic model in both graphite temperature and water temperature to predict incremental reactivity failed to separate the two temperature effects because of the high correlation between water and graphite temperature. Either water or graphite temperature alone does an excellent job of predicting incremental reactivity but nothing is gained by combining them in a model and indeed computational difficulties are introduced.

Weekly discussions are being held to coordinate Applied Mathematics' effort in quantitative metallography research with the current direction of the swelling study program. Present efforts are directed toward completing the HW formal report which describes the quantitative metallographic techniques derived in the last several years by Applied Mathematics for specific use in evaluating shadowed negative replicate electron microscopy photographs.

Routine analysis of inclusion data for void fraction and void density estimation continues.

Several meetings were held to obtain information for designing a data retrieval system for the REM file.

5000 Program

Work continued on the calculation and interpretation of channel group probabilities used in GEM calculations for the IRA file.

A statistical method was devised for interpreting large chi-squares in GEM program fits in the light of high count rate data. The method takes into account uncertainties in standard probabilities, variable background and instrument drift. The mean square error in individual nuclide estimates can also be calculated as a function of these instrument anomalies.

The final draft of an HW formal report, "Fixed Time Estimation of Counting Rates with Background Corrections" is being typed by Technical Publications.

The main calculational subroutine of the IRA file updating program was reprogrammed and checked out during the month. A program was written and debugged to obtain special IRA reports. The program displays data in a

form which will be useful in evaluation of past data and in guiding future data acquisition.

Work progressed on the program to index crystals for the actinide research project.

6000 Program

Considerable experience has now been gained on the Monte Carlo-based diffusion study. Preliminary results appear to exhibit desirable characteristics not found in other models. Simultaneously, work is progressing on another numerical scheme based on a modificed diffusion equation. Several EDPM programs have been written and are being used to generate sample data.

A computer program was written to record data and calculate certain factors from the data of an experiment investigating cell proliferation in salmon using C^{14} thymidine. The study concerns the origin and migration of cells in several tissues of yearling silver salmon.

An experiment was designed to determine the precision of the trypsin-electronic method of antibody assay. The method is based on the finding that trypsin digests cells injured by the action of antibody and complement but does not affect the uninjured cells. For rapid and accurate counting of cells the Coulter electronic counter is used.

OTHER

A method was outlined to separate the various sources of error in a computational sequence. The computational sequence has been formulated to enable deducing the permeability distribution in a heterogeneous media.

Carl A. Bennett

Manager
Applied Mathematics

CA Bennett:dgl

[redacted]

REACTOR DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Seed-Blanket Studies

Seed-Blanket studies are being continued in water moderated reactors in an effort to find a suitable base case. Variations in seed- and blanket-region sizes and seed loading are being compiled pending receipt of quantitative calculations of seed-blanket reactors.

Effect of Specific Power on Fuel Cost For Some Fueling Schemes

Increasing the specific power of reactor fuel will almost always reduce fuel cost. The major effect is to reduce the interest cost on the fuel. Therefore, the effect is more predominant for fueling schemes which require high enrichments to achieve reasonable fuel exposure (15,000 Mwd/ton). The reduction in fuel cost for a given increase in specific power, say from 10 to 20 megawatts per ton, will cut interest charge by about 50 percent; but a second increase from 20 to 30 megawatts per ton only gains another 16 percent. Consequently, the reward for increase in specific power becomes smaller as the power becomes higher. It should be noted that this analysis only considers fuel cycle cost; whereas, the total power cost includes reactor capital cost which may be significantly reduced by increase in specific power which reduces the core size for a given reactor power.

Figure 1 shows the effect of specific power above a base value of 10 megawatts per ton on minimum fuel cost for six fueling schemes for a simulated water reactor. The individual cost curves show the response to increased specific power. Note, in the cases having thorium as a fertile fuel, the slopes are all steeper than for uranium-238 fuels. This is because thorium has approximately two to three times the thermal absorption cross section of uranium-238; thus, requiring higher enrichment. The slopes are approximately proportional to the initial enrichment cost. In these cases, plutonium was valued at $10 per gram fissile and uranium-233 at $14 per gram (the $10 per gram fissile figure for plutonium may be somewhat low for plutonium because plutonium value calculations show $12 per gram for this reactor). The effect of the $10 per gram price is to lower plutonium burning fuel cycle costs. All other economic conditions were the same. The minimum fuel cost for these fueling schemes at 10 megawatts per ton are:

Fueling Scheme....	U-235-U-238	Pu-U-238	U-233-U-238	U-235-Th-232	Pu-Th-232	U-233 Th-232
Minimum Fuel Cost	1.891	1.72	1.892	2.560	2.039	2.326

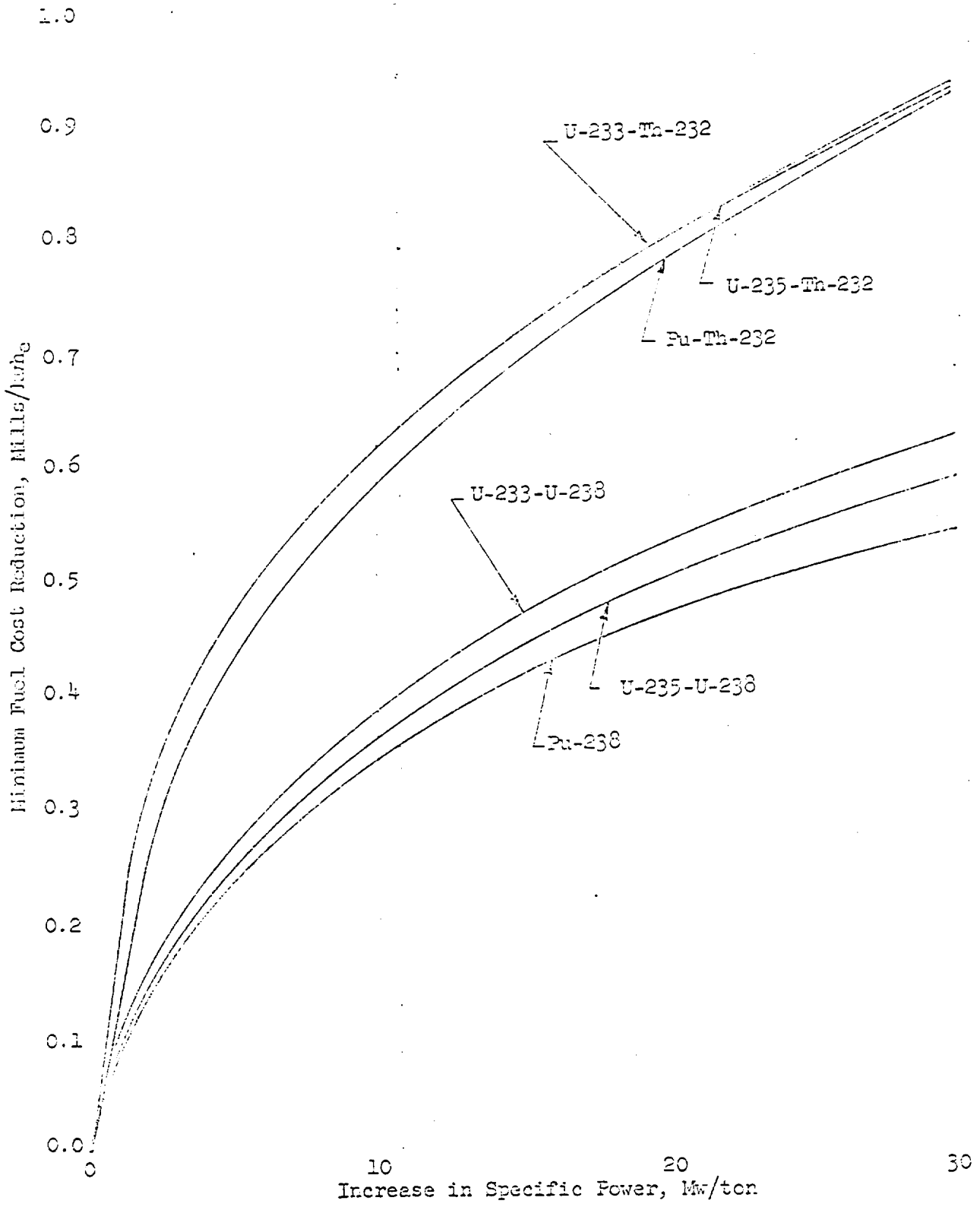

FIGURE 1

FUEL COST REDUCTIONS FOR INCREASING SPECIFIC POWER ABOVE A BASE VALUE OF 10 MEGAWATTS PER TON

1233169

The effect of an increase in the Atomic Energy Commission use charge rate was also investigated for each of the same six fueling schemes.

The results of this study are shown in Figure II. The rise in fuel cost is nearly linear for all the schemes, but each has a different slope. The fuels with steeper slopes will be harder hit by any increases in interest rates. Again, the slopes are proportional to the cost of enrichment to attain a given exposure. The numerical value of the slopes are shown on the curves in parenthesis.

Zone Spectrum Versus Graded Operation

By adjusting the neutron spectrum in a reactor, as is simulated in the zone spectrum operation of MELEAGER, the ratio of fertile and fissile cross sections are controlled so that the minimum use of control rods is required, thus reducing the neutron losses. The adjustment of spectrum usually involves movement of fuel. Consequently, to achieve low fuel cost, a minimum number of adjustments are desired. Fuel movement is avoided by altering the moderator composition such as diluting D_2O with H_2O.

Another method of fueling which achieves high neutron economy is the graded system, where new fuel with excess neutron production is placed near older elements with a deficiency in neutron production. In this case, the excess neutrons are absorbed in the old fuel (containing mostly fertile fuel) instead of control rods. This system operates with a nearly constant neutron spectrum.

For any reactor fuel, there is an optimum single spectrum for graded operation. Zone spectrum, on the other hand, has various spectrums which can be adjusted to optimize the fuel exposure. Thus, it is possible to secure the best performance out of a fuel in a single burn up calculation with zone spectrum compared with a series of single spectrum runs with graded, which may yield quite a saving in computer time. As stated earlier, the neutron economy will increase with the number of adjustments. Figure III shows fuel costs for graded operation as various moderator indices -- the straight lines are for zone spectrum and various maximum allowed excess neutron losses. The fuel used in this case was plutonium in natural uranium. The number of fuel shuffles is indicated and it is noteworthy that a large number is required for the apparently lowest cost zoned spectrum systems.

Fuel Cycle Analysis

Reduced uranium spatial concentration studies for two specific powers (165 and 330 w/cc), three moderator/fuel ratios, three rod sizes (1/8", 1/4", 1/2") and six uranium spatial concentrations have been prepared. Two diluent materials* have been used to replace the uranium-238 removed to reduce the fertile concentration. These cases have been prepared to verify the values of the resonance scattering parameters being used in MELEAGER and to compare previous work with results obtained using the latest cross sections. It is planned to run selected cases through the computer CHAIN sequence using plutonium compositions with less plutonium-240 content than the 40 percent plutonium-240 fuel used in the study to date.

*(ZrO_2 and BeO)

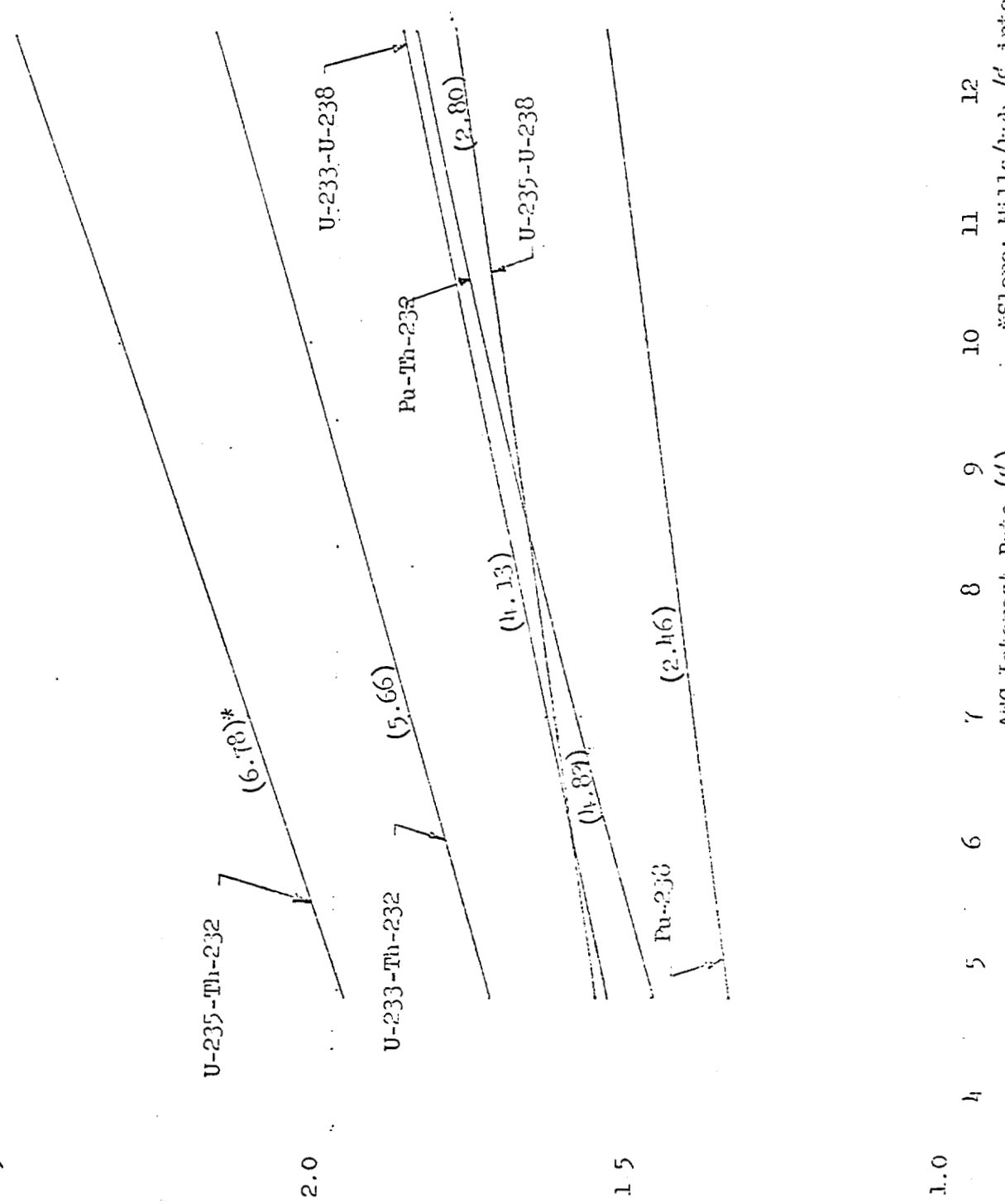

FIGURE 2

MINIMUM FUEL COST VERSUS AEC INTEREST RATE

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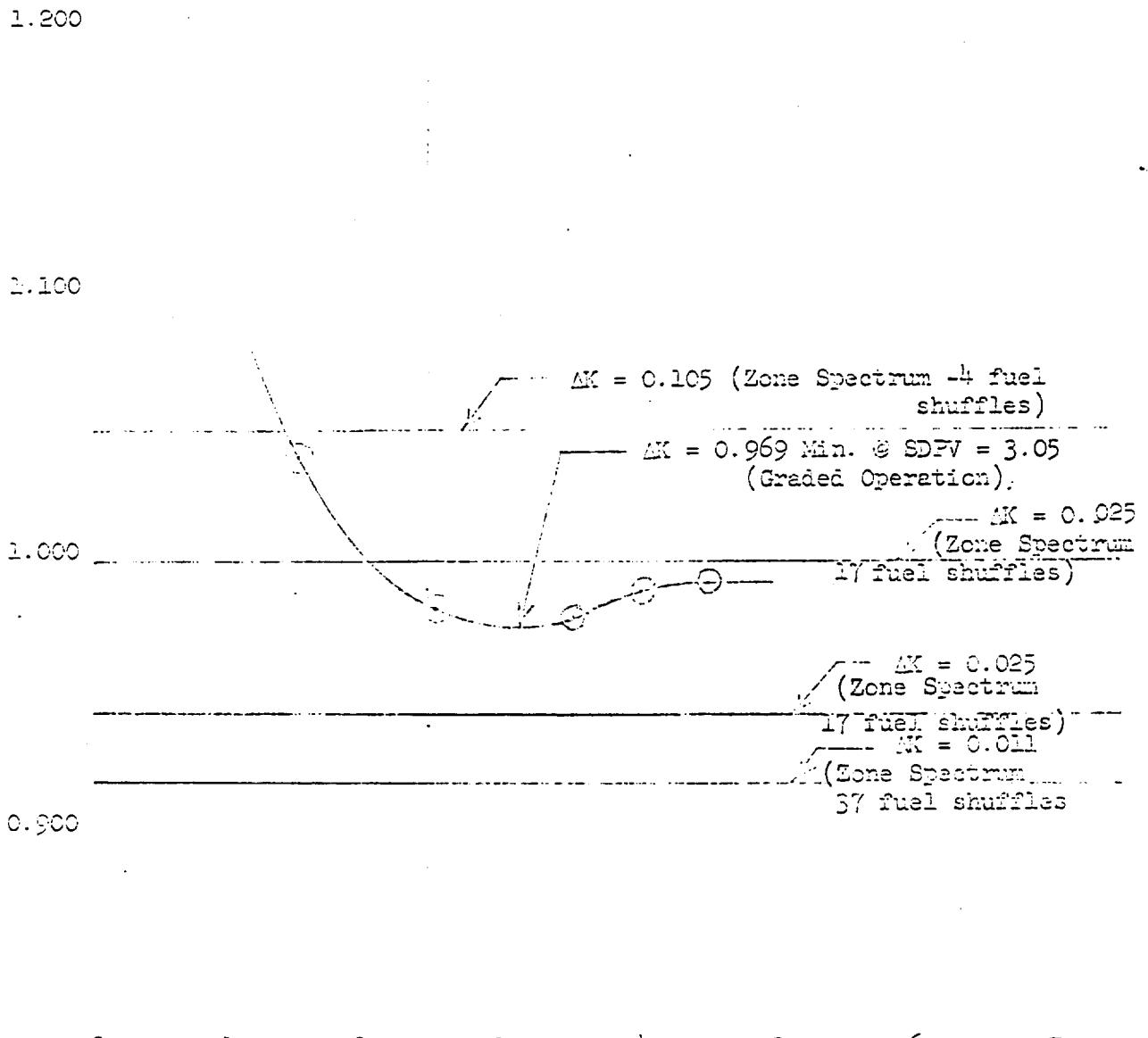

FIGURE 3

COMPUTED MINIMUM TOTAL FUEL COSTS FOR ZONED SPECTRUM AND GRADED FUEL CYCLES

1233172

CODE DEVELOPMENT

Revisions of the JASON CASE GENERATOR and JASON codes have been completed and debugged. The revised codes have been incorporated in the CHAIN system which now includes eleven codes.

It is now possible to vary all of the basic MELEAGER parameters with information put into JASON CASE GENERATOR, a code which prepares cases for the lattice physics parameter code JASON. Formerly, the specific power operating level was entered in MELEAGER and no way was available to vary this parameter if the CHAIN were started in another code (JASON or JASON CASE GENERATOR). The specific power may now be read in either JASON or JASON CASE GENERATOR.

Another new feature is that by setting one control integer in JASON, MELEAGER is automatically set up to operate in the zoned spectrum mode.

Nuclear Safety Activities

A number of presentations were made to the Technological Hazards Council during its meeting at Hanford the week of September 9. The PRTR pressure tube surveillance program was reviewed for the Council along with recent PRTR operating experience, the use of the PRTR automatic controller, and the effect of nonuniform distribution of plutonium in mixed oxides fuels.

OTHER ACTIVITIES

Hanford Isotopes Plant

Although the study on the Hanford Isotopes Plant (HW-77770) was completed, it was considered appropriate to extend the investigation further into the economic area in an effort to estimate the probable selling prices of the products under conditions of private investment and operation for profit. With the assistance of Finance personnel, this phase of the study has been completed with the following results:

Encapsulated Isotope	Annual Production, Megacuries	Selling Price, $/curie
Sr-90	10	0.20
Cs-137	10	0.19
Ce-144	100	0.02
Pm-147	30	0.08

The following bases were used in arriving at these figures:

1. Hanford Isotope Plant manufacturing and overhead costs, exclusive of feed and depreciation charges, as shown in Table I of HW-77770.

2. A 65% depreciation of the $14,300,000 plant investment over a five year operating period; an appropriate allowance for depreciation of service facilities was also included.

3. Approximately 40% of the selling prices shown above, and included in those prices, provides a surcharge to be paid to the AEC in lieu of feed cost or in partial support for R&D and promotional expense expected to be incurred by the AEC in the next few years.

4. The estimates include allowance for a return on investment sufficient to be attractive to investors.

5. The estimates include interest on construction funds and working capital prior to and during the five year operating period.

6. Other expenses such as local, state, and federal taxes, insurance, lease, etc. were estimated and included.

Since only about 20% of the indicated selling prices are involved with direct manufacturing and overhead costs, the economics are thus very closely related to the magnitude of the investment. A substantial change in plant investment will cause a proportional change in those costs other than direct manufacturing and overhead. The large influence of investment costs supports a need for intensified research and development efforts aimed at process simplification and integration of production facilities for this multiproduct plant.

Irradiation Results on Thorium of Varying Th-230 Content

Thorium oxide samples prepared from the four commercial sources which had been obtained earlier were irradiated to about 1,850 and 3,500 grams per ton with the following results:

Th-230 Content, ppm	Contamination, ppm U-232 in U-233 @1,850 g/t	@3,500 g/t
0.17	2.8	7.3
0.37	2.7	7.3
1.27	3.0	7.9
83.00	24.0	55.0

These results show that thorium-230 at the highest level shown above does contribute markedly to the formation of uranium-232 contamination in uranium-233. The results, however, do not account for the high uranium-232 content in uranium-233 made in the past from thorium low in thorium-230. Other factors in the irradiation process must therefore be responsible for these objectionable uranium-232 concentrations experienced earlier.

Milton Lewis

Acting Manager
Programming Operation

M. Lewis:bc

RADIATION PROTECTION OPERATION
REPORT FOR THE MONTH OF SEPTEMBER 1963

A. ORGANIZATION AND PERSONNEL

Alice L. Didier joined the Radiation Protection Operation on September 30, to replace Janice B. Persons, who resigned effective October 4, as Secretary to the Manager of RPO. Betty R. Kent assumed the secretarial duties to the Manager of Internal Dosimetry on September 16 replacing Joy B. Knight who is on a leave of absence effective September 27. Alta M. Morehouse transferred to Environmental Studies and Evaluation on September 3 from CE&UO as a Stenographer. A. F. Van Patten, Journeyman, Environmental Studies and Evaluation, terminated September 13 to accept a position with Reynolds Electric, Las Vegas, Nevada. Four summer employees, B. A. Barron, R. J. Bresina, K. B. Free, and D. L. Heffner, Clerks, in the Composite Dose Studies and Records Operation terminated during September. C. R. Bowers, Jr., E. M. Epperson, G. D. Larson, and J. W. Mathis were hired as temporary replacements. Hollis R. Dawson retired on September 27. June M. Wirth replaced Roberta K. Lattin, Keypunch Operator in External Dosimetry, who was granted a Relocation Leave of Absence. T. L. Ryan terminated as of September 24 to return to school on an AEC Fellowship. J. W. Spoonemore, Engineer, and P. C. Nosler, Engineer, joined the Radiation Monitoring Operation. L. D. Williams transferred from RMO to the Test Reactor and Auxiliaries Operation as of September 3. K. H. Siems transferred to RMO from CPD as a Journeyman Monitor effective September 3.

B. ACTIVITIES

Occupational Exposure Experience

No new plutonium deposition cases were confirmed by Bioassay analysis this month. Re-evaluation of a case previously reported as less than 1% of the maximum permissible body burden (MPBB plutonium with bone as reference is 0.04 μc) revealed that no plutonium deposition had occurred. This resulted in a reduction of one in the number of deposition cases that have occurred at Hanford. The total number of individuals who have received internal plutonium deposition at Hanford is 324 of which 235 are currently employed.

There were eight incidents involving 20 employees that required special bioassay sampling for plutonium analysis this month. The following is a brief description of the more significant incidents:

A CPD operator received an injury at the Weapons Manufacturing Building (234-5) on September 4, 1963, while changing the aluminum tape on an inline monitor. Examination at the plutonium wound counter showed less than 1×10^{-4} μc plutonium present in the wound site. The detection limit for the plutonium wound counter is approximately 1×10^{-4} μc of plutonium.

An operator at the Weapons Manufacturing Building received a plutonium nitrate contaminated injury at 2100 on September 5, 1963. The injury occurred when the employee reached for an object which had fallen into the sump of the ion exchange hood (46-C). A sharp obstruction punctured his hood and surgeons glove and the thumb of his right hand. Examination at the Whole Body Counter showed 2.1×10^{-4} μc plutonium present in the wound site. There was no treatment or excision. The employee is a previous deposition case with a body burden estimated to be less than 1 percent of the maximum permissible body burden (MPBB). The MPBB for plutonium with bone as the organ of reference is 0.04 μc.

A pipefitter at the Weapons Manufacturing Building received a plutonium nitrate contaminated injury at 1340 on September 12, 1963. The injury occurred when the employee reached for a tool while performing maintenance work in Hood 7A of Room 232. Examination at the Whole Body Counter showed 5.9×10^{-3} μc initially present at the wound site. After excision, 1.2×10^{-4} μc remained. The employee is a previous deposition case with a body burden estimated to be less than 10 percent of the MPBB.

A CPD pipefitter received a plutonium nitrate contaminated puncture injury at 1350 on September 12, 1963 at the Weapons Manufacturing Building. The employee was performing maintenance work in Hood 7A at the time the injury occurred. Examination at the Whole Body Counter showed 9.4×10^{-4} μc present in the wound. After excision, the wound count was less than 1×10^{-4} μc. The employee is a previous deposition case with a body burden estimated to be less than 1 percent of the MPBB.

Seven CPD employees were exposed to airborne plutonium contamination at the Weapons Manufacturing Incinerator Building (232-Z) on

September 18, 1963, as a result of a faulty glove. The employees had performed panel changes in three separate green houses in the incinerator building without any great difficulty. Upon completion of the work, minor contamination up to 5,000 d/m was found on 900 square feet of the floor and on the employees' shoe covers. A survey of the employees revealed nasal contamination ranging from 50 d/m to 600 d/m.

The above cases bring the total number of plutonium contaminated injuries for the year to 19 with 13 requiring excision. In 1962, there were a total of 15 contaminated injuries with eight requiring excision.

Also during the month, there were four incidents involving seven employees that required evaluation for possible intake of radioactive materials. These incidents are summarized below:

Examination of a crane operator from the Redox Building (202-S) at the Whole Body Counter revealed the presence of 7 nanocuries of ruthenium-103 and 20 nanocuries of zirconium-niobium-95. The MPBB for ruthenium with kidney as the organ of reference is 20 μc; the MPBB for zirconium-niobium-95 with the total body as the organ of reference is 20 μc. While the employee was working in a crane on September 16, 1963, contaminated air from the canyon seeped into the cab as the result of a failure of the air supply fan. When the constant air monitor high air alarm sounded the employee replaced the filter and proceeded to work. Within approximately 45 minutes the air monitor again alarmed. At that time, a monitor noticing the alarm requested the employee to comply with respiratory protection requirements specified for periods of air contamination. A survey of the employee revealed nasal contamination of approximately 400 c/m.

Evaluation of the beta-gamma film badge dosimeter worn by an IPD operator at the 105-KE reactor for the period of September 6, 1963, through September 11, 1963, showed a dose of 1 rem beta radiation and 0.58 rems gamma radiation. Most of the exposure was received when the employee was performing spline removal operations at the reactor. After the spline machine removed the spline from tube 5585 and dropped it into the elevator chute the operator moved into position to initiate removal of the next spline. Neither the operator, nor the monitor on duty, noticed that the spline had become stuck in the elevator chute and the monitor was not close enough to the chute to notice an increase in the dose rate. The operator's whole body gamma radiation dose for the year, including this occurrence, is 2.3 rems.

A trailer carrying a cask shipped by Phillips Petroleum from Idaho Falls was found contaminated at 1500 on September 9, 1963. A radiation beam measuring 500 mr/hr at 2 inches and 10 mr/hr at six feet was found to be coming from the end of the cask. A survey of the cask and trailer revealed contamination up to 20,000 c/m on an area of approximately 20 sq. ft. where the cask was setting and contamination up to 1,000 c/m smearable on the cask itself. A survey under the truck revealed contamination ranging from 500 c/m to 1,000 c/m apparently where the material had soaked through. No contamination was found where the trailer was setting for several days or on the loading platform at Central Stores; therefore, it was concluded that no contamination was spread during the shipment other than to the bed of the truck.

On September 4, 1963, a radiation monitor received clothing contamination up to 10,000 c/m at the 300-N burial ground while monitoring for a milk pail burial from the Radiometallurgy Building (327). In this case, a paint bucket was used rather than the accepted container that was developed for this work. As the bucket was dropped into the hole, the lid came loose from the bucket permitting contamination to be blown into the air. This resulted in the spread of contamination up to 100 mrads/hr to the surrounding area. In addition, the truck was contaminated up to 100,000 c/m. On September 30, a contamination spread occurred in the 300-Y burial ground during a similar operation. Approximately 400 sq. ft. of ground in the northeast corner of the burial ground was contaminated up to 1,400 mrads/hr. Measurements on the truck revealed contamination up to 180 mrads/hr. The truck had to be decontaminated at the burial ground before it could be released. This makes the third time in several months that contamination was spread in the burial grounds as the result of milk pail burial operations. In addition to these three incidents, there were 10 to 15 cases where minor amounts of contamination were spread during the burial of milk pails from the 327 Building.

Environmental Experience

A total of 62 curies of I-131 was released from the Purex stack over the three-day period from September 2 to 4. A potential release of several hundred curies was averted by suspending the dissolution of metal inadvertently charged before a proper decay period had elapsed. No further processing of this material is planned until late October to provide an appropriate decay period for the material.

About 75 man-hours were spent collecting numerous special milk, vegetation, and stack samples. Two aerial monitoring flights were flown around the 200 Areas and the region south to Benton City. No evidence of contamination was found off project.

A maximum concentration of I-131 in milk was measured in a special sample collected September 12, 1963, from a West Richland farm. Back extrapolation along curves plotted for locations where daily milk samples were collected, indicated a peak concentration for this milk between 300 and 500 pc/l on September 5, 1963. The total radiation dose that could have occurred to the 2 gram thyroid of an infant drinking this milk throughout September was estimated to be only 0.05 - 0.08 rem.

Rinse water containing phosphates used in cleaning some of the 100-N piping were released to the river shoreline. Special samples confirmed prior estimates of the concentrations downstream. The increase in phosphate ion concentration measured at 181-D was 0.03 - 0.05 ppm. The total phosphate concentration in all cases was below 0.10 ppm, the normal seasonal maximum.

Concentrations of fallout materials in the air of the Pacific Northwest averaged 3 pc β/m^3 during September. The average value for the months of July and August was 5 pc β/m^3.

A total of 583 biological, produce, and food samples were obtained for radiochemical analyses. These are listed below:

Milk	316 gallons	190 samples
Pasture grass and native vegetation	262 pounds	262 samples
Fish		90 samples
Waterfowl		21 samples
Beef Thyroids		15 samples
Oysters	4 pounds	2 samples
Peaches	2 pounds	1 sample
Ground Beef	4 pounds	2 samples

Studies and Improvements

An evaluation was made of the data from film ring dosimeters worn by certain Redox and Purex operating and maintenance personnel since the beginning of calendar year 1963. The data showed that only seven out of six hundred ring dosimeters issued during the period exceeded 1 rem, and the highest single dose was 1.8 rems. No employee

exceeded 3 rems during any consecutive three-month period. Based on these results and in light of present criteria for requiring the use of film ring dosimeters, as stated in the RPS, it was decided that the routine issuance program for these groups could be terminated. This was implemented during the month.

The Mobile Whole Body Counter was displayed at the Hanford Visitor's Center from September 17 through September 29. A total of 609 people visited the facility. The Mobile Whole Body Counter and the dual crystal assembly in the Whole Body Counter Laboratory were calibrated with Na^{24}.

The average level of cesium-137 measured in adult males during September was 12.6 nanocuries. The maximum iodine-131 observed from routine examinations was 25 picocuries. Only two examinations resulted in detection of quantities greater than 20 pc, the minimum detectable amount with the thyroid counter.

Design criteria were developed for the renovation of the 242-B facility into a pilot study operation for plutonium dissolution studies. Specific interest areas included building structure and layout, ventilation, waste disposal, stack height, and air sampling.

Energy response curves for the CP, Juno, and ionization chamber finger ring were obtained using the K-fluorescent X-ray machine. Readings from the CP and Juno were taken at each of the K-fluorescent X-ray energy points.

A relative response curve of the ionization chamber ring was constructed comparing the response of this dosimeter when calibrated with radium gamma radiation to its response when exposed to plutonium radiations. The characteristic curve for the unfiltered ring indicates that the maximum response is about a factor of four greater than for radium gamma. When the same rings were filtered with 5 mils of tungsten, the maximum response was obtained at about 60 Kev. At this point, the response is about 65% greater than the response observed for radium gamma.

The He^3 neutron spectrometer system was taken to the 234-5 Building after calibration of the He^3 detector. Several different experimental runs were made on two different plutonium storage hoods. All neutron spectra data were accumulated with a He^3 pressure of five atmospheres. A pressure of five atmosphere yields the best resolution and sensitivity combination.

One of the plutonium storage hoods was nearly empty at the time the neutron spectrum was measured. Data were accumulated both with and without gamma shielding for the neutron detector. The results of the measurements show a pronounced fast neutron peak at about 0.9 Mev. Some interference appeared during the spectrum accumulation with the gamma shielding in place. The interference took the form of a small peak at about 2.0 Mev. The false peak appeared sometime during the first four days of a six-day exposure and did not continue to accumulate during the last two days. Some welding and other maintenance work that might account for the interference was performed nearby during the first two days. For these reasons, the false peak was ignored during the data analysis. Gamma interference was observed for neutron energies up to about 0.7 Mev.

Another plutonium storage hood was nearly full during the neutron spectrum measurements. The results were quite different. No pronounced peak was observed. The gamma interference was much greater than for the first hood, and, in this case, appeared to have covered the fast neutron peak. These spectra will be measured again to see if they can be reproduced.

The computer program "Spec" was modified to include options which allowed two spectrums to be read in and subtracted point for point from each other.

Invention Report, HWIR-1649, "Discriminating Against Undesirable Gamma Radiation When Using a He^3 Spectrometer to Measure A Neutron Spectrum" was filed by G. W. R. Endres and T. L. Ryan on September 10, 1963.

Calibration checks of the thermoluminescent dosimetry reader electronic system were made, and it appears to be working satisfactorily. Two irradiations were completed using the positive ion accelerator. Two sets of neutron and gamma thermoluminescent phosphors were exposed to neutron doses of 0.5 and 1.2 rads. The measurements indicate that 0.5 rads of fast neutrons can be easily detected.

The use of membrane-type filter paper in a routine room air sample location in 234-5 Building was initiated. The air samples are forwarded to RDCO by CPD after they have utilized the filter in their air monitoring program. These filters are being examined initially by exposure to nuclear track film plates in a special holder. Exposure times of up to about three months are needed to detect particles of PuO_2 in the 0.01 to 0.1 micron size range.

One R-meter set was calibrated by the National Bureau of Standards and returned to HAPO. Three additional R-meter sets were matched to this new standard. The north and south calibration wells and the film exposure jig were checked at several distances and found to be within ±3% of the stated dose.

Additional assistance was provided the Nuclear Health and Safety Operation for NPR hazards analysis. This additional work resulted from questions asked of NRD by the AEC Advisory Committee on Reactor Safeguards (ACRS). A comparison was made of the NPR site characteristics with those set forth in 10 CFR 100 (Power and Test Reactor Site Criteria).

Research Studies

Effect of Reactor Effluent on the Quality of Columbia River Water (02)

Temperature traverses and shoreline surveys continued. Analysis of recent dye study data was started and fabrication of portable meteorological station components was completed.

Mechanisms of Environmental Exposure (C2)

Members of the Washington State Game Department were contacted in order to increase return of data from the creel census. Arrangements were made for routine contact between ES&EO and the local Game Protectors.

C. RELATIONS

Five suggestions were submitted by personnel of the Radiation Protection Operation during the month. Two suggestion awards were made. Three suggestions are pending evaluation.

Safety meetings were held throughout the Section during the month. There were no security violations.

Radiation protection orientation lectures were given to new employees in Physical Metallurgy, Fuels Fabrication, Chemical Development, and Chemical Effluents Technology. The first three sessions of the radiation monitoring refresher course were held. Total attendance was 48. Nine CPD employees, and two AEC employees are included in the total. The feedback received from the program was favorable.

A training session was held for about 20 AEC Couriers at the AEC offices at the Richland airport. Subject matter dealt with recognizing radiological

problems under various conditions, the best choice of action, the proper instruments to use, and how to use the instruments correctly. The session included instruction on the use of the High Range (5,000 r/hour) dose rate meter.

D. SIGNIFICANT REPORTS

HW-78894 - "Radioactive Liquid Waste Disposal" by G. E. Backman.

HW-76525-8 - "Radiological Status of the Hanford Environs for August, 1963", by R. F. Foster.

HW-79115 - "Monthly Report - September 1963, Radiation Monitoring Operation" by A. J. Stevens.

PERSONNEL DOSIMETRY AND RADIOLOGICAL RECORDS

External Exposure Above Permissible Limits	September	1963
Whole Body Penetrating	0	1
Whole Body Skin	0	0
Extremity	0	0
Hanford Pocket Dosimeters		
Dosimeters Processed	6,163	57,526
Hanford Beta-Gamma Film Badge Dosimeters		
Film Processed	11,057	87,265
Results - 100-300 mrads	173	1,526
Results - 300-500 mrads	18	139
Results - Over 500 mrads	2	31
Lost Results	50	225
Average Dose Per Film Packet - mrad (ow)	10.5	7.5
- mr (s)	30.3	30.2
Hanford Neutron Film Badge Dosimeter		
Slow Neutron		
Film Processed	1,887	15,341
Results - 50-100 mrem	1	15
- 100-300 mrem	0	2
- Over 300 mrem	0	0
Lost Results	7	97
Fast Neutron		
Film Read	460	4,125
Results - 50-100 mrem	19	260
- 100-300 mrem	31	438
- Over 300 mrem	2	6
Lost Results	7	76
Hand Checks		
Checks Taken - Alpha	37,268	341,403
- Beta-Gamma	54,477	520,692
Skin Contamination		
Plutonium	7	209
Fission Products	43	358
Uranium	0	5
Tritium	0	0
Thorium	0	1

Whole Body Counter	Number of Examinations			
	747-A WBC	1963	Mobile WBC	1963
Subject				
GE Employees				
Regular	51	539	12	42
Incident Cases	11	132		
Terminations	34	122	1	1
New Hires	62	465	1	1
Special Studies	11	432		
Non-Employees				
Children	3	19		
Visitors	1	42		
Environmental Studies	4	19	—	—
	177	1,770	14	44

Bioassay	Current Reporting Limit		Results Above Reporting Limit		Samples Assayed	
			Sept.	1963	Sept.	1963
Plutonium	2.2×10^{-8}	µc/sample	86	811	568	5,351
Fission Prod.	3.1×10^{-5}	µc/sample	7	78	515	4,825
Strontium	3.1×10^{-5}	µc/sample	-	45	-	45
Tritium	5.0	µc/l	123	1,167	205	1,950
Uranium	0.14	ugm/l	-	-	163	1,374
Special Studies			-	-	14	328

Calibrations	Number of Units Calibrated	
	Sept.	1963
Portable Instruments		
CP Meter	1,015	9,552
Juno	227	2,344
GM	599	5,148
Other	231	1,718
Audits	103	957
	2,175	19,719
Personnel Meters		
Badge Film	648	7,196
Pencils	105	990
Other	264	2,726
	1,017	10,912

	Number of Units Calibrated Sept.	1963
Miscellaneous Special Services	52	14,055
Total Number of Calibrations	3,244	44,686

Carl M. Unruh

for the Manager
RADIATION PROTECTION

CM Unruh:ald

TECHNICAL INTERCHANGE DATA
RADIATION PROTECTION OPERATION

I. Speeches Given

"A Comprehensive Study of a Plutonium Contaminated Injury", by F. Swanberg, Jr., to the Seventh Annual Western Industrial Health Conference, held in San Francisco, September 27-28, 1963.

R. F. Foster presented an invited speech on fisheries problems associated with development of atomic power to the Association of Power Biologists meeting at Toketee Falls, Oregon.

"Particle Size Distribution Found in Air at Hanford Plutonium Fabrication Facilities", was presented by B. V. Andersen at the Seventh Annual Western Industrial Health Conference held on September 27 and 28, 1963 in San Francisco, California.

II. Articles Published

An article entitled, "Hanford Report: Dosimetry Investigation of the Recuplex Criticality Accident", C. C. Gamertsfelder, H. V. Larson, J. M. Nielsen, W. C. Roesch, and E. C. Watson was published in Health Physics, July 1963, Vol. 9, No. 7.

III. Visits and Visitors

See attached Visits and Visitors form.

IV. Achievements

None

V. Honors and Recognitions

None

VI. Professional Group or Organization Assignments

None

FINANCE AND ADMINISTRATION

ACCOUNTING

Cost Accounting

Operating funds for Hanford Laboratories contained in the RLOO-AEC Financial Plan #1 were allocated to the sections in September to provide an interim control until receipt of a firm financial plan following passage of the Congressional Appropriation Act.

In September Hanford Laboratories was allocated an additional $150,000 for 02 Program equipment obligations, $2,000 for 03 Program equipment obligations and $14,000 for capital work order costs. FY 1964 capital funds authorized to date for equipment obligations are detailed below by program.

02	$250 000
03	42 000
04	278 600
05	100 000
06	125 000
08	25 000
Total	$820 600
Capital Work Order Costs	$ 54 000

An additional authorization of $57,500 was received for Project Whitney research and development and related scrap recovery work sponsored by Lawrence Radiation Laboratory. Total authorizations for FY 1964 are now $150,000 for research and development and $12,500 for plutonium scrap recovery.

A research and development proposal entitled "Promethium Source Development" was prepared and submitted to RLOO-AEC at the request of the Division of Isotopes Development, Washington-AEC. A study to provide a definitive technological basis for utilization of promethium-147 as a radioisotope heat and/or power source is proposed. The program would employ about six scientific and technical personnel and three supporting people at an annual cost of $415,000.

A current plan for obligating anticipated FY 1964 04 Program equipment funds was transmitted to RLOO-AEC at their request. Summarized by subprogram, planned obligations are:

Plutonium Recycle Program	$405 000
Reactor Fuels & Materials Development	285 000
Radioactive Residue Process Development	52 000
Gas Cooled Reactor - Other	40 000
Plutonium Ceramic Research	20 000
High Temperature Reactor Lattice Physics Studies	10 000
Columbia River Sediment Studies	7 000
Neutron Flux Monitors	6 000
Total	$825 000

Special accounting codes were established for the activities described below:

.8H Consultation with APED by C. L. Brown on problems of nuclear safety. Consultation will be for five days and will be billed at $500 plus travel and subsistence.

.8J Consultation with APED by E. R. Irish to review the overall aspects of environmental hazards of the proposed facility for the reprocessing of spent power reactor fuel. Consultation will be for five days and will be billed at $875 plus travel and subsistence.

.8K Appointment of L. K. Bustad to the Advisory Committee of the American Institute of Biological Sciences - Monograph Series. Billing will be for travel and subsistence only.

.8L Consulting with APED by V. P. Kelly to review the mechanical aspects of handling incoming fuels in the proposed facility for reprocessing spent power reactor fuels. Consultation will be for five days and will be billed at $500 plus travel and subsistence.

.8M Assistance to Washington State University. An individual from Hanford Laboratories will instruct a course in the radiological aspects of sanitary engineering. Billing will be for $3,800 to cover salary plus continuity of service and for travel and subsistence.

A new research and development program code established during the month is:

.71 Exposure Mechanisms (02 Program)

General Accounting

Following is the status of letters requesting AEC concurrence in proposed actions:

AT-310	Service on Washington State Air Pollution Control Board by J. J. Fuquay	Approved 9-5-63
AT-311	Teaching Assistance to Washington State University - Course CE-547	Approved 9-20-63
AT-313	Professional Research and Teaching Leave Assignment	In process

The following OPGs were issued:

OPG No.	New	Revised	Title
1.13 (pp. 3, 4 & 5)		X	Participation in Hazardous Business
1.15	X		Compliance in Antitrust Laws

Hanford Laboratories' net material investment at September 1, 1963 totaled $24.4 million as detailed below:

	(In thousands)
SS Material	$ 22 791
Reactor and Other Special Material	1 304
Spare Parts	340
Yttrium	47
Subtotal	24 482
Reserve: Spare Parts $81	
Yttrium 47	(128)
Net Inventory Investment	$ 24 354

The net Hanford Laboratories' inventory investment, excluding nuclear materials, amounted to $1.6 million at September 1, 1963, or a net increase of $387,529 over the June 1963 balance of $1.2 million. Inventory increases resulted primarily from the following material receipts:

Heavy water from SR00	$350 013
Heavy Water Scrap Generated	14 019
Zirconium	8 741
Spare Parts	12 002
Platinum	2 524
	$387 299

The heavy water inventory at the end of September 1963 showed a loss of 1,654 pounds valued at $22,738 for the PRTR and a loss of 99 pounds valued at $1,361 for the PRCF. Heavy water scrap generated during the month amounted to 3,976 pounds, resulting in a $4,059 charge to operating cost. Heavy water accumulated at September 30 for return to SROO amounted to 17,218 pounds valued at $216,675.

Permission was received from RLOO-AEC to ship 2,624 grams of clean platinum scrap to the New York Operations Office. A reduction of $7,327.41 in the platinum inventory resulted. Efforts to reduce further the dollar value of inventories include submission of a list of other excess materials to the AEC for action. Also, a proposal to charge cost for zirconium procured for specific research and development work at the time of procurement is being considered, although the material would be controlled until withdrawn for consumption, and a $57,038 reduction in the current inventory balance would result.

Results of the annual physical inventory of zirconium holdings conducted during August 1963 indicated a net gain of 31 pounds. The net increase resulted primarily from 45 pounds of plate returned to stock from completed work, and an undocumented issuance from stock of one tube weighing 2.7 pounds. A document, prepared to adjust quantity only, will result in a reduced unit price on future withdrawals from the Laboratory Pool.

Cooperative effort with the Hanford Laboratories' Landlord Operation in the cleanup of the 325 Building basement resulted in materials and equipment valued at $333,557 being transferred to the Pool for storage and/or preparation of documents for disposal. The Landlord estimated total cost for the cleanup to be $528, which does not include overtime or regular time spent by this group or Facilities Engineering Operation. Appearance of the 325 basement has improved significantly. However, it appears that other equipment stored in cages there should also be transferred to the Laboratory Storage Pool.

A report on the annual inventory of reactor and other special materials (excluding zirconium) in the custody of 117 holders on September 24 and 25 should be issued in October.

To satisfy AEC requirements on control, all HL yttrium holdings were transferred to the Laboratory Storage Pool. Withdrawals from the Pool will be considered as consumption. This material, valued at $47,437, is fully reserved.

The cumulative value of nuclear material consumed in research by Hanford Laboratories during FY 1964 (at September 1, 1963) is $108,633 comprised as follows:

02 Program	$ 1 555
03 Program	11 141
04 Program	95 937
	$108 633

Two SS Material forecasts were prepared during the month as follows:

1. SS Material Projects - R & D other than in Production (for all programs except 02 Program). The period covered by this forecast was the 3rd and 4th quarter of FY 1964 and the 1st and 2nd quarter of FY 1965.

2. SS Material Projects - In Production - related R & D (02 Program) for the 2nd, 3rd and 4th quarters, FY 1964.

An audit of Hanford Laboratories' Property Accounting activities was completed with compliments by the traveling auditors.

Custody of remaining equipment, valued at $69,839, procured by HAPO in support of University of California Lawrence Radiation Laboratory research and development programs, was transferred by the Commission to Hanford Laboratories. Total value of equipment acquired through the UCLRL program is $755,856.

Unitization reports were completed and issued during the month on the following projects:

CGH 857 Physical and Mechanical Properties Testing Cell - 327 Building	$387 471
CGH 858 High Level Utility Cell - 327 Building	400 191
CGH 951 A-C Column Facility - 321 Building	47 038
	$834 700

Laboratory Storage Pool activity is summarized below:

	Current Month		FY to Date	
	Quantity	Value	Quantity	Value
Beginning Balance	1 674	$822 310	1 480	$ 811 520
Items Received	145	44 386	581	183 942
Items Reclaimed by Custodians	(13)	(7 498)	(45)	(36 590)
Equipment Transfers	(18)	(5 548)	(103)	(38 681)
Items Disposed of by PDR	(45)	(3 872)	(86)	(4 930)
Items Disposed of by Excess	(31)	(58 715)	(115)	(124 198)
	1 712	$791 063	1 712	$ 791 063 -1)

(1- Includes 147 items valued at $113,416 on loan at 9-30-63.

During the month, 69 items valued at $26,656 were loaned and/or transferred in lieu of purchases. A total of 190 items valued at $75,873 has been redirected to useful purposes this fiscal year. Operating costs for the month of August were $1,465 and operating costs for FY 1964 total $2,663.

Total value of equipment and material in custody of the Laboratory Storage Pool at September 30, 1963 was $1.7 million, including Reactor and Other Special Materials valued at $293,035, SS Materials valued at $163,800 and other materials valued at $411,813.

Activities within Property Accounting are steadily increasing. To illustrate this point, the following statistics reflect the trend of Property Accounting's activities by comparing the first three months of FY 1964 with the same period in FY 1963:

Documents Processed	1st Qtr. FY 1964	1st Qtr. FY 1963
Purchase Requisitions	3 092	2 248
Work Orders	2 312	1 893
Excess and PDR	79	30
Material Transaction Reports	158	103
Off-Site Property Control	60	49

	1st Qtr. FY 1964		1st Qtr. FY 1963	
Laboratory Storage Pool	Quantity	Value	Quantity	Value
Receipts	581	$183 942	245	$182 796
Disposal by PDR and/or Excess	201	129 128	6	434
Placements in Lieu of Purchases	190	75 873	73	36 338
Total Material Holdings at 9-30		868 648		284 318
Total Equipment Holdings at 9-30	1 712	791 063	1 251	703 107

All indications are that the Laboratory Storage Pool activity and the services provided by Property Accounting will continue to grow. The excessing program of the Pool facility has increased considerably, and efforts to achieve even greater excessing results are being applied. The erection of a roof over the dock between the 3718-A and B Buildings, if approved by RLOO-AEC, would provide needed additional storage and floor space from which to work excess materials and equipment continuously.

The following action was taken on projects during the month:

Construction Completion and Cost Closing Statement Issued

CAH-822 Pressurized Gas-Cooled Loop Facility

The following contracts were processed during the month:

CA-406 Hubert J. Pessl
CA-410 Textron Electronics, Inc.
CA-412 Maurice J. Sinnott
CA-413 Lewis W. Seagondollar
SA-300 Kadlec Methodist Hospital
MRO- 65 Phillips Electronics Instrument Division

Personnel Accounting

H. R. Dawson and L. B. Stroup took optional retirement, effective October 1, 1963.

A patent award (HWIR 1077) was made to W. S. Kelly for movable outlets on air supply ducts using metal "zippers."

Personnel statistics follow:

Number of Hanford Laboratories Employees Changes During Month	Total	Exempt	Nonexempt
Employees on payroll at beginning of month	1 792	790	1 002
Additions and transfers in	62	27	35
Removals and transfers out	93	41	52
Employees on payroll at end of month	1 761	776	985

Overtime Payments During Month	September	August
Exempt	$ 5 888	$ 8 069
Nonexempt	33 323	21 894
Total	$ 39 211	$ 29 963

Gross Payroll Paid During Month		
Exempt	$ 769 370	$ 774 553
Nonexempt	670 530	553 416
Total	$1 439 900	$1 327 969

Participation in Employee Benefit Plans at Month End	September Number	September Percent	August Number	August Percent
Pension	1 550	99.4	1 551	99.4
Insurance Plan - Personal	413		423	
- Dependent	1 334	99.9	1 327	99.8
U.S. Savings Bonds				
Stock Bonus Plan	156	39.9	156	41.3
Savings Plan	66	3.8	69	3.8
Savings and Security Plan	1 213	88.7	1 221	86.0
Good Neighbor Fund	1 260	71.7	1 281	71.3

Insurance Claims Employee Benefits	Number	Amount	Number	Amount
Life Insurance	2	$64 160	1	$16 500
Weekly Sickness and Accident	8	6 641	12	879
Comprehensive Medical	45	3 814	43	2 939
Dependent Benefits				
Comprehensive Medical	98	9 832	79	6 843
Total	153	$78 447	135	$27 161

TECHNICAL ADMINISTRATION

Employee Relations

Thirty-two nonexempt employment requisitions were filled; 17 remain to be filled.

Suggestion plan activity included 54 submissions, 30 adoptions, and 30 rejections.

Information and Presentations

Visitors Center activity:

September attendance	2 242
Average attendance per day open	86
Cumulative attendance since 6-13-62	56 625
Conducted groups	3 (totaling 86 people)

Plant tour activity:

	Number	Total People
General Public Relations Tours	6	168
Special Tours	2	91
Cumulative attendance (all tours) since 1-1-63	-	2 376

Documented information flow during the month was comprised of 1,740 titles (15,178 copies) received at Hanford and 67 titles (10,478 copies) sent off-site.

Professional Placement

Advanced Degree - Seven PhD applicants visited HAPO for employment interviews. Three offers were extended; three rejections were received. Four offers are currently open.

BS/MS (Direct Placement) - Two offers were extended. Three acceptances and no rejections were received. One offer is currently open.

BS/MS (Program) - No employment activity in this category this month.

Technical Graduate Program - Ten technical graduates were placed on permanent assignment. Nine new members were added to the roll. Two graduates returned to school and one transferred to APED. Current program members total 75.

FACILITIES ENGINEERING

At month's end Facilities Engineering Operation was responsible for nine active projects having total authorized funds in the amount of $6,739,500. The total estimated cost of these projects is $10,584,000. Expenditures on them through August 31, 1963 were $1,134,000.

The following summarizes project activity in September:

Number of authorized projects at month end ---------- 9

Number of new projects authorized ---------- 0

Number of projects completed ---------- 1
CAH-995, 309 Building Air Conditioning Modifications

New projects submitted to the AEC ---------- 0

Projects awaiting AEC approval ---------- 0

Project proposals being prepared ---------- 8
CAH-114 Critical Mass Laboratory Addition
CAH-116 PRTR Decontamination and D_2O Cleanup
PRTR Storage Basin and Experimental Facilities Modification
Heat Transfer Apparatus for Model Studies
Waste Transport System
141-M Building Addition
Addition to the Fire Alarm System - 100-F Area
Fire Sprinkler System - 300 Area Laboratories Buildings

The current status of projects authorized or awaiting approval is:

CAH-916 - Fuels Recycle Pilot Plant - Construction is 11 percent complete and on schedule. The bulk of construction activity is currently centered around forming and pouring concrete foundation walls and floor slabs. Approximately 1,300 cubic yards of concrete have been placed. One major design change was negotiated to provide additional basement space. Another to make piping changes and eliminate interference in the storage vault is being processed.

CAH-922 - Burst Test Facility for Irradiated Zirconium Tubes - Construction is 60 percent complete compared to a scheduled 68 percent. This lag has occurred primarily within the last month. Failure to stay on schedule is the result of late delivery of engineered equipment. The five containment vessels were not shipped on September 3, 1963 as promised, because of defective fabrication. Failure of the fabricator to establish a delivery date may necessitate removing the work from his shop and completing the work locally using J. A. Jones forces. Delays in placing the instrument panel order resulted in an October 24, 1963 promised delivery date. The Company is trying to expedite the order. The sub-contractor's work is essentially complete. The CPFF construction services contractor is proceeding with electrical and piping work but is being held up by the procurement problems discussed above.

CAH-958 - Plutonium Fuels Testing and Evaluation Laboratories, 308 Building - Construction is 95 percent complete and on schedule. Scheduled work is continuing on installation of the metallograph and painting of walls and ceilings.

CAH-962 - Low Level Radiochemistry Building - Design is 99 percent complete. The Architect-Engineer completed detailed design for Commission and Company review on September 23, 1963. Preliminary review of the mechanical design was made at the A-E's offices on September 13.

CAH-977 - Facilities for Radioactive Inhalation Studies - Detailed design drawings were received from the Commission on September 11, 1963 for review. Comment review meetings with the Commission are in progress.

CAH-982 - Addition to Radionuclide Facilities, 141-C Building - Title I design drawings were reviewed with the Commission. Comments are being compiled by the Commission for transmittal to the Architect-Engineer.

CGH-992 - Additional Fuel Loading Equipment, 308 Building - Construction is 99 percent complete and on schedule. The project will be completed on schedule with exceptions. Installation of wall acoustical tile and expanded metal mesh retainer will extend beyond the scheduled completion date. The expanded metal mesh is a special mill fabrication, and delivery is not expected until October 1, 1963. The directive completion date is October 31, 1963.

CAH-995 - 309 Building Air Conditioning Modifications - Construction is completed. Beneficial use of the refrigeration and ventilation equipment was attained September 10, 1963. Company plant forces balanced the building ventilation system on September 13 and 14, 1963.

CGH-999 - Plutonium Recycle Critical Facility Conversion to Light Water - Construction is 50 percent complete and on schedule. Control and safety rods are being assembled. Lexan plastic sheets received for fabrication of grid plates had numerous surface flaws necessitating repair. Shutdown of the Critical Facility and installation work is scheduled for November 11 to December 31. Schedule setbacks were caused by delays in other parts of the EBWR program.

CAH-100 - High Temperature Lattice Test Reactor - No design has been accomplished since work was stopped for lack of funds on August 23, 1963. Additional interim funds in the amount of $60,000 have been authorized. Equipment development and mock-up work on prototype items, being funded from research and development money, is still progressing. Testing of potential materials of reactor construction at anticipated reactor temperatures and atmospheres is continuing.

CAH-105 - Plutonium Recycle Test Reactor Storage Basin and Experimental Facilities Modifications - At the request of the Company, the Commission returned the project proposal without action. A new preliminary proposal, excluding the underwater fuel handling equipment design, will be submitted as a new project. Project CAH-105 is therefore voided and will no longer be reported.

CAH-114 - Critical Mass Laboratory Addition - A preliminary project proposal is awaiting the General Manager's approval. Informal copies of the design criteria document and project proposal have been submitted to the Commission for approval and review respectively.

CAH-116 - PRTR Decontamination and D_2O Cleanup - The preliminary project proposal is awaiting the General Manager's approval. Informal copies of the design criteria document and project proposal have been submitted to the Commission for approval and review respectively.

Pressure Systems

Installation of the C-1 Loop was completed this month. During subsequent operation, damage to the in-pile section occurred as a result of low coolant flow. Evaluation of the repairs needed is under way.

The audit of code utility piping systems in 325, 326, 327, 328 and 329 buildings is essentially complete. Necessary repair work has been outlined.

Plans for installing hydraulic presses in 231-Z and 308 were reviewed.

Engineering Services

Engineering work provided in support of design and construction on active projects and on project proposals and design criteria for new projects included: (1) field liaison and review of shop drawings on CAH-916, FRPP; (2) review of Architect-Engineer's design on CAH-962 - Low Level Radiochemistry Building, CAH-977 - Radioactive Inhalation Facility (144-F), and CAH-982 - Radionuclide Facilities (141-C); (3) development of design criteria for 329 Building addition; (4) scope and cost for utilization of 3000 Area headquarters building; (5) design criteria for F Area fire protection; (6) scope and design criteria for a fast reactor critical facility; and (7) preliminary study of relocation of biology facilities to 300 Area.

Other engineering and consulting services were provided to customers as requested. Major work items included: (1) study of high background count at 108-F and methods to overcome the problem; (2) engineering development for fabrication of experimental plutonium alloy storage casks; (3) engineering for installation of X-ray equipment in 329 Building; (4) engineering of fixtures for N Reactor startup tests; (5) engineering on operation and development of N Reactor charging machine; (6) engineering development on 325 cask decontamination facility; (7) purchase of meters for laboratory waste flow monitoring; (8) developing indexing mechanism for fuel feed metering device; (9) miscellaneous consulting service for the Chemical Processing Department; and (10) analysis of PRTR thermal shield for increase in power level.

Plant Engineering

Plant engineering work during the month included: (1) estimate of future power requirements; (2) review of administrative control for use of emergency power; (3) investigation of use of neutron sensitive criticality alarms rather than gamma sensitive; (4) review of 306 Building ventilation system; (5) study of 308 second floor rest room modifications; (6) completion of modifications, testing and balancing of 309 sound and evacuation alarm system; (7) study of office addition at 314 Building; and (8) miscellaneous engineering consultation and assistance on plant modification and improvement work.

Facilities Operation

Costs for the month of August were $167,014, which is 121 percent of the forecast for the month. Total costs for the first two months are $291,766,

which is 113 percent of the predicted. During this month improvement maintenance costs were $9,856, as compared to the forecast of $15,000. However, the magnitude of planned improvements will require that additional funds be requested in the midyear budget review.

The monthly criticality alarm tests continue to reveal about two items which require maintenance.

The intensive cleanup program for the 325 basement was completed.

Standard approved HL color sample books have been prepared.

The following table summarizes waste disposal operation:

Item	July	August
Concrete waste barrels disposed of to 300-N burial ground	12	20
Loadluggers of dry waste disposed of to 300-N burial ground from the 325 Building	4	2
Loadluggers of dry waste disposed of to 300-Wye burial ground from the 325 Building	0	0
Loadluggers of dry waste disposed of to 300-N burial ground from 300 Area sites other than the 325 Building	21	22
Crib Waste volume, gal.	415,000	570,000

A revised detailed emergency procedure for disposing contaminated basin water has been prepared and is being distributed.

As of September 16, all dry contaminated waste except high concentration plutonium waste is buried at Wye burial grounds. Plutonium bearing waste is sent to 200-W plutonium burial ground.

On September 27, crib waste disposal was transferred from Redox to TY crib. CPD's Waste Handling and Decontamination Operation assumed the unloading function from Redox Analytical Laboratory Operation.

The following changes in work assignments were made to provide better service in 300 Area Hanford Laboratories' facilities:

1. Maintenance (IPD-F) has assigned a sheetmetal man to inspect, repair, or rebuild all dampers.

2. The instrument maintenance function for the building service equipment in 306 has been transferred from NRD to Hanford Laboratories' Laboratory Maintenance.

3. The air balance crew is being increased to four to meet the increasing demands. During this month, complete air balance was made in 309 and partial ones in 308, 306, 325 and 313.

Drafting

The equivalent of 140 drawings were produced during the month for an average of 31 man-hours per drawing.

Major jobs in progress are: (1) PRTR as-builts; (2) salt cycle experimental for C-cell; (3) preliminary conceptual drawings for fast super-critical reactor; (4) high temperature gas loop; (5) HTLTR mock-up core and safety and control rods; (6) refraction compounds research glove box; (7) glove boxes for 231-Z powder processing line; (8) drawings associated with engineering work reported above; and (9) miscellaneous drawings for Technical Shops purchases.

Drafting work estimated at 150 man-hours was assigned to Vitro Engineering Company. Work performed by Vitro during the month amounted to 380 man-hours.

Construction Supervision

Activity during the month on construction work (J. A. Jones Company) being performed for Hanford Laboratories components is given below:

	Unexpended Balance	
	Regular	Waste Calcination
Orders outstanding beginning of month	$194 250	$40 137
Issued during the month (including suppl. and adj.)	212 287	15 863
J. A. Jones expenditures during month (includes C.O. costs)	133 811	21 462
Balance at month's end	272 726	34 538
Orders closed during month	79 161	

In addition, work on four maintenance work orders issued to plant forces and having a face value of $1,982 was supervised.

Major nonproject jobs in progress are: (1) precooling system, 108-F; (2) feeder stalls, 141-C; (3) modifications and installation of furniture, 141-H; (4) install silo, 141-R; (5) install hay storage, 100-F Area; (6) construct maintenance shop, 231-Z; (7) install glove box, 231-Z; (8) install hood and modify vent system, 242-B; (9) install drain line, 271-CR; (10) construct building addition, 292-T; (11) install electrical bus, 306; (12) replace steam and condensate lines, install flooring in rooms 101, 102 and 113, modify room 125, make startup modifications to fuel fabrication line, install dynapack machine room 112 and relocate dynapack machine room 112, 306; (13) install shielding and modify gas loop, 309; (14) construct building addition and install PRTR tube replacement mock-up, 314; (15) modify cell door, install basement heat and vent system, renovate rooms 400 and 406, construct roof air-sampling room and perform maintenance, 325; (16) install exhaust system, install floor drains, and construct emergency egress, 327; (17) renovate exterior, 3702; and (18) install ceiling, lights and dock roof, 3718.

Five requisitions totaling $8,765 were issued during the month. Total value of equipment being processed is $93,000.

for Manager
Finance and Administration

W Sale:JVM:whm

REACTOR DEVELOPMENT - 04 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Plutonium Recycle Test Reactor

Operation

Reactor output for September was 1359 MWD, for an experimental time efficiency of 79.2% and a plant efficiency of 64.7%. There were four operating periods during the month, of which one was a continuation of an August operating period. Two operating periods were terminated for scheduled refueling and planned maintenance, one was terminated by a scram, and one continued through month-end. One operating period was the longest uninterrupted critical period in the history of the reactor. A summary of the fuel irradiation program as of September 30, 1963, follows:

	Al-Pu		UO_2		PuO_2-UO_2		Other		Program Totals	
	No.	MWD	No.	MWD	No.	MWD	No.	MWD	No.	MWD
In-Core	24	2118.4			61	5840.1			85	7958.5
Maximum		144.9				149.8				
Average		88.3				95.7				
In-Basin	19	1216.8	66	5702.8	16	554.2	1	7.3	102	7481.1
Chem.Proces.	32	2309.3	1	78.0	—	—	—	—	33	2387.3
Prog.Totals	75	5644.5	67	5780.8	77	6394.3	1	7.3	220	17826.9

D_2O and indicated helium losses for September were 1654 pounds and 102,328 scf, respectively.

Approximately 20,000 pounds of D_2O was cleaned up for reuse in the primary system.

Equipment Experience

A total of 70 reactor outage hours were charged to repair work. Main items were:

D_2O and helium leaks	17 hours
Helium compressors	15 hours
Instrument air leaks	10 hours
Injection pumps	8 hours

Preventive maintenance required 321 hours or 6.5% of the total maintenance effort.

Installation of the motorized switches at the PRTR, 13.8 KVA, incoming line was completed during the month. This change permits remote switching from one leg of the 13.8 KVA loop to the other leg, should a local fault occur.

One new Mark II shim rod was installed in the reactor during the month. Two repaired shim rods were also installed.

The control room criticality alarm system was completed and tested during the month. This system permits differentiation between alarm conditions in the process area and the control room. The new building alarm system was also completed during the month and the fire alarm tested.

Improvement Work Status (significant items)

Work Completed

Independent criticality alarm system of the PRTR Control Room
Control Wiring for 13.8 KV Motor Operated Switches
Stiffener on FEEF Air Baffle
H-80 Relocation and Trim Change
Building Alarm System Modifications
Compressed Air Supply Revision

Work Partially Completed

Inline Gas Sampling
Process Tubes Level Indicator
Inlet Gas Seal Replacement
Backup Emergency Power to Primary Pumps
Helium Compressor Unloading Orifice Modification
125-Volt Battery Disconnect Contactor
Filtered Water Pump #3
Shim Rod Shroud to Top Cap Modification
Improved RTD Connector Sealant and Bracing
#2 Exide 125-V Battery Charger
Flash Tank Modification
Instrument Power Transfer System
Light Water Injection System Modifications

Design Work Completed

Thermistor Probe Installation in FEEF

Design Work Partially Completed

Additional Fuel Storage and Examination Facility
Vibration Snubbers for Earthquake Protection
Decontamination Building and D_2O Cleanup Facility
Flux Wire Scanning System
Supplemental Emergency Water Addition
Permanent Installation of Closed Circuit TV
Indication of DC Solenoid Failure
Rupture Monitoring System Modifications
Emergency Personnel Air Lock Door Operators
PRTR Increased Power Level
Battery Power for Galvanometer Light
PRTR Data Handling System
Reactor Automatic Controller
Holdup Tank - High Level Alarm
Containment Valve By-pass for Sump Pumpout Lines

Process Engineering and Reactor Physics

PRTR Test No. 65 (Deaerator Efficiency) was completed during the month. The test results showed that the loss of the deaerator cone resulted in a slight loss in deaerator efficiency and an increased oxygen stratification in the water in the deaerator. This stratification has caused a pitting corrosion attack of the deaerator walls. Recommended methods of arresting the pitting attack are now being evaluated.

A new method of rupture location was successfully used to locate defect fuel element number 5203, a 1% moxtyl, on September 20. The coolant flow through each tube was first throttled, then the activity of the gases at the top of the tube was measured while the nozzle cap was being removed.

Procedures

Operating Procedures issued	3
Revised Operating Procedures issued	6
Revised Operating Standards issued	5
Temporary Deviations to Operating Standards issued	9
Revised Process Specifications accepted for use	1
Equipment Standards issued	2
Equipment Manuals issued	3

Drawing As-Built Status:	Total
Approved for As-Built	1 014
In Drafting	23
In Approval	14
Deleted or Voided	81
	1 132
Scheduled for Review	338
	1 470

1233206

	Manhours
Personnel Training:	
Qualification subjects	257
Specifications, Standards, Procedures	43
Emergency Procedures	9
Maintenance Procedures	15
	324

Status of Qualified Personnel at Month-End:

Qualified reactor engineers	9
Qualified lead technicians	6
Qualified technicians	17

Experimental Reactor Services

The status of the various test elements at the end of September 1963, is shown below. Those elements which had reached their assigned goal exposure or had been permanently discharged for other reasons prior to September 2,1963, have been deleted from this table.

Test No.	Channel Location	F.E. Number	Description	Date Initial Charge	Date Discharged	Approx. Accumulated MWD
14	1956	5097	Moxtyl-Swaged	4/2/62	--	92.8 repad
14	1352	5098	Moxtyl-Vipac	5/8/62	--	149.8 repad
14	1758	5099	Moxtyl-Vipac	5/8/62	--	114.7 repad
37	1649	1097	UO_2 Physics	5/12/62	9/20/63	130.7
37	1552	1098	UO_2 Physics	5/12/62	9/20/63	127.2
37	1584	1099	UO_2 Physics	5/12/62	9/20/63	129.4
37	1651	1100	UO_2 Physics	5/12/62	9/20/63	117.9
48	1253	5150	Moxtyl ($\frac{1}{2}$" x $\frac{1}{2}$" pads)	8/1/62	--	97.6
47	1647	5121	Unautoclaved LX Pu-Al	6/13/63	--	59.2
47	1653	5194	Unautoclaved LX Pu-Al	7/6/63	--	51.0
47	1453	5193	Unautoclaved LX Pu-Al	7/6/63	--	49.9
54	1542	5116	Moxtyl (clip-on pads)	5/8/62	--	108.2 (93.2 w/clip)
54	1554	5118	Moxtyl (clip-on pads)	5/8/62	--	146.3(131.3 w/clip)
61	1443	5185	Moxtyl-Physics	5/28/63	--	64.8
61	1756	5186	Moxtyl-Physics	5/28/63	--	69.7
61	1847	5187	Moxtyl-Physics	5/28/63	--	77.1
61	1455	5192	Moxtyl-Physics	6/13/63	--	63.5

Survey calculations were performed on mixed oxide fuel elements covering the enrichment range from 0.48 w/o to 5 w/o PuO_2 - in UO_2. Parameters of interest were relative power production in constant flux, flux depression within a cluster and unit cell multiplication factor. The results of this study were transmitted to Fuels Testing and Analytical Operation.

Three fuel elements received detailed inspection in the Fuel Element Examination Facility (FEEF) and one was inspected in the basin. Of the three elements inspected in the FEEF, one was accepted and two were rejected due to badly worn wire wraps. The element inspected in the basin was disassembled and four rods were shipped to Radiometallurgy for study.

The MGO fuel element which failed a year ago was buried in the 200-W burial ground.

Visual examination of 15 process tubes showed one tube that had an increase in $>$ .010" deep marks in the tube. This tube, which had previously been scheduled for removal and destructive testing was removed. A section of the tube was shipped to Radiometallurgy for burst test.

Mockup of the Process Tube and Fuel Handling Carriage and the Gamma Scanner have been completed.

Plutonium Recycle Critical Facility

The reactivity measurement series for Pu fuel samples was completed, including reruns with different techniques to obtain confirming data.

The first irradiated fuel measurement was completed on September 13. Two complete cycles of irradiated fuel handling were performed with a full-sized PRTR element (Pu-Al) and with D_2O coolant. Crude worth data was obtained from these preliminary measurements. Biological shielding integrity was again checked and found to be adequate.

Two Process Specifications were accepted for use during the month.

Fuel Element Rupture Test Facility

Operation

Seven hot operating runs were conducted during the month. Most of the runs were of fairly short duration and were terminated under controlled conditions for maintenance work. Only one run was stopped because of conditions which would have caused a reactor scram. This was a high pressure condition caused by failure of the pressure control valve positioner. A more reliable positioner has been installed.

Improvement Work Status

Work Completed

Test Section Emergency Water Injection
Emergency Power to Decontamination Pump, RLP-2
Revised Cleanup System Pressure Relief
Relocation of PSCD Relief Valve

Work Partially Completed

Safety Circuit Bypass Switch
Revised Low Pressure Relief

Procedures

Operating Standards issued	1
Personnel Training:	Manhours
Operating Procedures	225
Maintenance Procedures	132
	357

GAS COOLED POWER REACTOR PROGRAM

Pressurized Gas-Cooled Loop Facility

Operation of the Gas Loop at design temperature of 1500° F was achieved during the month.

TECHNICAL SHOPS OPERATION

Total productive time for the period was 24,068 hours. This includes 13,794 hours performed in Technical Shops, 4,320 hours assigned to J. A. Jones Company, 5,878 hours assigned to offsite vendors, and 76 hours to other project shops. Total shop backlog is 20,632 hours, of which 90% is required in the current month with the remainder distributed over a three-month period. Overtime worked during the month totaled 565 hours or 3% of the total available hours.

Distribution of time was as follows:

	Manhours	% of Total
N Reactor Department	3 212	13.35
Irradiation Processing Department	3 606	14.98
Chemical Processing Department	247	1.02
Hanford Laboratories	17 003	70.65
Hanford Utilities and Purchasing Op.	0	-

LABORATORY MAINTENANCE OPERATION

Total productive time was 17,400 hours of 19,200 hours 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. Manpower utilization for September was as follows:

A.	Shop Work		1 800 hours
B.	Maintenance		6 100 hours
	1. Preventive Maintenance	1 800 hours	
	2. Emergency or Unscheduled Maintenance	1 600 hours	
	3. Normal Scheduled Maintenance	2 700 hours	
	4. Overtime (Included in above figures)	830 hours	
C.	R&D Assistance		9 500 hours

WD Richmond
Manager
Test Reactor and Auxiliaries

WD Richmond:bk

INVENTIONS OR DISCOVERIES

All persons engaged in work that might reasonably be expected to result in inventions or discoveries advise that, to the best of their knowledge and belief, no inventions or discoveries were made in the course of their work during the period covered by this report except as listed below. Such persons further advise that, for the period therein covered by this report, notebook records, if any, kept in the course of their work have been examined for possible inventions or discoveries.

INVENTOR	TITLE OF INVENTION OR DISCOVERY
H. L. Libby and C. R. Wandling	An Eddy Current Tubing Tester with Signal Pattern Display and Graphical Nulling Features

W. H. Reas

for Manager, Hanford Laboratories