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HANFORD LABORATORIES OPERATION
MONTHLY ACTIVITIES REPORT

MAY, 1960

JUNE 15, 1960

HANFORD ATOMIC PRODUCTS OPERATION

RICHLAND, WASHINGTON

GENERAL ELECTRIC

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HANFORD LABORATORIES OPERATION
MONTHLY ACTIVITIES REPORT
MAY, 1960

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Operation Managers

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June 15, 1960

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

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

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TABLE I HLO FORCE REPORT AND PERSONNEL STATUS CHANGES

DATE May 31, 1960

	At close of month			At beginning of month			Additions		Separations	
	Exempt	NonExempt	Total	Exempt	NonExempt	Total	Exempt	NonExempt	Exempt	NonExempt
Chemical Research and Development	129	105	234	130	104	234	0	4	1	3
Reactor & Fuels Research & Development	194	173	367	196	169	365	0	5	2	1
Physics & Instrument Research & Development	70	35	105	68	35	103	2	0	0	0
Biology Operation	37	43	80	37	44	81	0	0	0	1
Operation Res. & Syn.	16	4	20	16	4	20	0	0	0	0
Radiation Protection	35	101	136	35	99	134	0	3	0	1
Laboratory Auxiliaries	53	190	243	53	191	244	1	5	1	6
Financial	14	1[illegible]	29	14	14	28	0	2	0	1
Prof. Placmt. & R. P.	51	19	70	52	18	70	5	1	6	0
Programming	19	4	23	18	4	22	1	0	0	0
General	1	2	3	1	2	3	0	0	0	0
TOTALS	619	691	1310	620	684	1304	9	20	10	13
Totals excluding internal transfers.	619	691	1310	620	684	1304	5	17	6	10

BUDGETS AND COSTS

Costs for May were $1,903,000, an increase of $10,000 from April. Fiscal year to date costs are 84% of the amounts currently authorized to Hanford Laboratories.

Hanford Laboratories research and development programs have the following cost-budget relationship as of May 31.

(Dollars in Thousands)	Cost	Budget	% Spent
HLO Programs			
2000 Program	$ 547	$ 615	89%
4000 Program	6 524	8 208	79
5000 Program	543	609	89
6000 Program	2 004	2 200	91
IPD Sponsored	3 041	3 605	84
CPD Sponsored	1 637	1 909	86
FPD Sponsored	10	10	100

RESEARCH AND DEVELOPMENT

1. Reactor and Fuels Research and Development

The Phase III portion of PRTR construction is about 88% completed versus 95% scheduled based on a contract completion date of June 24, 1960. The contractor has installed the calandria vessel and the top shield and completed acceptance testing on one of the submersible river pumps. The reactor piping is currently being prepared and installed.

The supplement (HW-61236 Sup 1) to the PRTR Final Safeguards Analyses was reviewed by a Subcommittee of the ACRS on May 4. The proposed changes in the limits for exhaust air activity and reactor thermal power were accepted. Steps are being taken to comply with Subcommittee recommendations that a particulate filter be installed in the ventilation exhaust air stream and that flow trip protection be provided for process tube leaks in the range of 65 to 108 gpm.

Swaged UO_2 capsules attained an estimated exposure of approximately 16,000 MWD/T in the MTR and ETR. UO_2 produced by

the salt-cycle electrodeposition process was vibrationally compacted and successfully irradiated to 3500 MWD/T at heat fluxes in excess of 1,250,000 BTU/hr/ft^2 at the Zircaloy-2 surface.

Melting points 50 to 100 C higher than that of unirradiated UO_2 were determined in preliminary studies of irradiated UO_2 in a shielded, high temperature microscopy facility.

A correlation of hardness and density for UO_2-PuO_2 pellets has been established. The data will be used to evaluate in-reactor sintering.

Initial radiometallurgical examinations of one portion of the Zircaloy-2 process tube recently removed from KER Loop No. 1 show: (a) no hydriding, (b) up to 50 per cent recrystallization of the grain structure, and (c) that a suspected "pit" from borescope examinations was actually a spot of crud deposit.

The third graphite irradiation capsule was installed in the GETR in May, scheduled for four GETR cycles at EGCR graphite operating conditions.

Graphite high temperature annealing studies indicate no significant shrinkage due to annealing as a result of the planned increase in K Reactor graphite temperature.

Seven, 12-inch long, 7-rod cluster, coextruded Zr-2/U elements with hot-headed and projection welded closures, were discharged from KER after approximately 2000 MWD/T exposure without rupture. Fuel elements of tube-tube geometry being tested in a KER loop under NPR coolant water conditions have attained an exposure of about 2750 MWD/T without incident.

Radiometallurgical examination of a coextruded Zr-2/U rod which failed in KER Loop 1 in February 1960, has disclosed thinning of the cladding along a line extending from the point of failure which is not associated with an underlying crack.

In ex-reactor tests, irradiated pre-defected coextruded rods disintegrated up to twice as fast in 300 C water as unirradiated control samples.

A Zircaloy-clad, uranium core fuel rod with thermocouple instrumentation is operating successfully in-reactor. Initial operation showed no measurable cladding-to-bulk water film temperature drop due to the build-up of an insulating crud layer.

Candidate methods of fastening inner and outer tubes of the NPR fuel assembly to prevent sliding are being tested by mockups of dummy systems. Developmental work on a brazed NPR fuel element end closure continued during the month. Fuel element supports formed from strips of AISI 1010 and 1020 steels have been wear tested and have performed satisfactorily even when the contact area between the support and autoclaved Zircaloy-2 is reduced to a point or line.

The study of flow rates of steam-water mixtures through orifices under critical flow conditions was continued to gain information valuable in reactor hazards calculations. It was found by experiment that for certain orifices having sharp edged entrances, two distinct critical flows existed for the same upstream conditions. This fact was totally unexpected.

Laboratory heat transfer experiments were continued to determine the boiling burnout conditions of flows and heat generation rates for the NPR tube and tube type fuel element. Thirteen boiling burnout points were obtained that are applicable to the outer cooling annulus of the fuel element.

2. Chemical Research and Development

Fission product release experiments at higher irradiation levels did not show any significant change in uranium oxidation rates or in fission product release.

Thermodynamic calculations showed that it was plausible to explain the uranium fire in the Redox multipurpose dissolver by simple assumptions relating amount of exposed metal, heat generation and dissipation, gas rates, and geometric effects.

Fluidized-bed calcinations were carried out on simulated high acid Purex wastes using a modified ANL feed nozzle. Under proper conditions negligible agglomerate formation and near steady-state particle size were achieved.

Operation of ion exchange equipment in the A cell of the High Level Radiochemistry Facility continued without incident. Product fractions of the rare earths of high purity (> 99 per cent pure) were obtained. A second "cold" run is underway.

The alkaline supernate in the boiling Purex 103-A waste tank contains about 13 curies of cesium-137 per gallon. Both the use of inorganic ion-exchangers and precipitation of zinc ferrocyanide are methods which are technically feasible for the recovery of the cesium.

The alkaline supernate in the boiling Purex 103-A waste tank contains about 90 mg/gal of technetium, thus making kilogram amounts of this element potentially available. Simple recovery schemes are under investigation.

The "C" column test facility to be used in the development of a mathematical model for solvent extraction pulse columns is in shakedown status. Operation to collect data on tape for transmittal to the IBM 709 should begin next month.

Application of controlled potential coulometry to the determination of uranium(VI)/uranium(IV) ratios in uranium oxide samples is a highly precise method. The development of this method has been completed and the method has been transmitted to the Analytical Laboratories Operation for routine use.

The application of controlled potential polarography to fused salt systems promises to be an effective method for gaining information of thermodynamic significance. New evidence for the electrical conductivity of electrolytic UO_2 was obtained.

Voltage scanning coulometry is a powerful tool for trace level chemical analysis. This new analytical method, which still requires more development, is more specific and has a detection limit some 100-fold lower than controlled potential coulometry.

The more rapid dissolution rate of the higher uranium oxides in the Salt Cycle Process was confirmed. The low solubility of UO_2 in the molten salt was again established. Recrystallization of UO_2 from NaCl-KCl eutectic containing UO_2Cl_2 offers intriguing possibilities for controlling particle size and

shape of UO_2 prepared by electrolytic reduction. Evidence was obtained that $UOCl_2$ is not an important intermediate in the Salt Cycle Process. The system, CsCl-RbCl, does not form a eutectic.

Cesium adsorption on clinoptilolite at 25 C is not changed by irradiation to doses up to 1×10^9 R. At 55 C, adsorption is higher at doses up to 2×10^8 R, but not for doses of 5×10^8 or 1×10^9 R.

A slow neutron reaction on Sc^{45} was shown to be the origin of Sc^{46} in reactor effluent water.

Holmium, dysprosium or praesodymium would be better than lanthanum as a precipitation carrier for plutonium when low backgrounds are required. This is because lanthanum usually has radioactive members of the actinium family with it.

Cerium(IV) is adsorbed by Hanford sub-soil much more completely than cerium(III) or promethium.

A highly sensitive flowmeter to detect and measure vertical flows in wells was demonstrated in the laboratory. A sensitivity of two ml/min through an eight-inch well was achieved.

3. Physics and Instrument Research and Development

In the NPR program, the full-scale mechanical mockup of the fuel failure monitor was completed and is now in experimental use. The prototype Linear Remote Area Monitor is essentially completed. Circuit improvements for the final version of the prototype Beta-Gamma Air Monitor were successfully bench-tested. Some questions regarding accuracy of physics parameter determinations have been settled and the graphite for the mockup core measurements in the PCTR has been shipped by the vendor.

In the nuclear safety program, initial occupancy of the Critical Mass Laboratory is expected next month and the first two reactor vessels have arrived on site. A series of experiments to determine critical masses of 2% enriched uranium rods has begun following recent completion of a similar series with 3% fuels. The safe concentration of plutonium in aqueous solutions was revealed to be 10% higher than expected in recent PCTR experiments.

Reactivities of 3% enriched uranyl nitrate solutions were determined to supplement recent data on UO_2 dispersions in hydrogenous moderators.

In the Plutonium Recycle Program, a rather simple theoretical approach gave results in good agreement with recently completed experiments on water-moderated 5% Pu-Al rods. This was somewhat surprising in that a similar approach was unsatisfactory for 3% enriched uranium fuels.

Some final improvements have been made to the Profilometer and Wide Angle Viewer for the PRTR Fuel Examination Facility prior to their installation. A camera system has been designed for detecting and recording displacements of the PRTR calandria. Development of instrumentation for the PRTR tube monitoring program is underway.

Orderly progress continued on the Nondestructive Testing research studies on broadband electromagnetic and infrared techniques.

Automation has been completed of the routine data taking at the Whole Body Monitor. This facility was used during the month for observation of non-background activities in several individuals. It was further determined that shampooing of hair prior to counting was of doubtful value with the current water supply at the facility.

An improved method for analyzing samples taken during atmospheric diffusion experiments for project Green Glow will give relative filter loadings to 8% standard error and absolute values to 12% as indicated by recently completed calibrations of the method.

Work continued on a number of radiation protection instruments. The bench-model personally-carried personnel dose alarming monitor was simplified and satisfactorily tested. Tests of a developmental alpha air monitor indicate the unit will alarm in three minutes when the detector is exposed to an atmosphere containing a uniform, continuous-level concentration equivalent to 100 MPC of airborne Pu^{239}. * There will be no false alarms from

* One MPC is used as equal to a Pu^{239} concentration of 2×10^{-12} µc/cc in air.

radon-thoron concentrations. Experimental fabrication of silicon P-N surface barrier diode nuclear detectors is underway. Investigation of thermoluminescent dosimeters continues.

In the basic data field, numerical values were determined for the rate at which thermal neutrons change their energy distribution as the moderator temperature is changed. These rates appear to depend upon both moderator temperature and initial neutron temperature.

4. Biology

Contamination of terrestrial and aquatic life tended to decrease during the month and was about the same as a year ago.

Findings, incidental to Sr^{90} metabolism work, indicate that chlorosis in plants can be alleviated by strontium. Thus in the synthesis of chlorophyll strontium can partially replace calcium.

In further work on pairs of elements, it appears that fertilization of soil can increase the uptake into plants of Cs^{137} but hardly affects the uptake of potassium. This observation is interesting from the physical point of view as well as from the inappropriateness of using the Cs^{137}/K ratio in hazard predictions.

An outbreak of parasite infestation among members of the beagle colony will cause some revisions of past practices, including the probability that we will have to raise our own pups.

Death caused by PuO_2 in dogs at 50 to 100 days resulted from an average dose of 20,000 rads, assuming uniform distribution of the plutonium in the lung.

5. Programming

A series of experiments was performed, using the Meleager code, to determine the importance of the decay of Pu-241 (13 year half-life) in plutonium fuel cycle analysis. The results show large exposure dependent errors if the decay is ignored; however, simple treatment of the decay effect proved adequate.

The first low exposure plutonium bearing fuel rods to be irradiated in the Savannah River reactors for the production of high exposure plutonium for Plutonium Recycle Program use were charged on May 16.

In conjunction with the Specific Fuel Cycle Analysis Program, senior personnel visited APED for exchange of information on fuel cycle analysis techniques best suited for PWR and BWR reactors.

Considerable effort was expended in attempting to determine the effect on exposure of the individual plutonium isotopes in the Advanced Pressurized Water Reactor plutonium fuel cycle study. The addition of either Pu-239 or Pu-241 results in about the same increase in exposure based on reactivity limitation. Pu-240 appears to have little, if any, effect on the attainable MWD/T in this reactor based on a reactivity limit. Pu-242 additions consistently result in lowered exposure. The shorter exposure effected by a given amount of Pu-242 is on the order of 1/4 to 1/2 of the increase in exposure produced by a like amount of Pu-239 or Pu-241.

TECHNICAL AND OTHER SERVICES

Two appendices were written to be incorporated in a document covering the use of control charts in analyzing rupture data being prepared by Process Technology personnel. One presented the theoretical basis behind the use of such charts, and the other discussed decision rules to be used in analyzing rupture data.

The results of a study made to determine the number of coolant pressure gauges which can be bypassed and tripped simultaneously without invalidating any normal scram signal have been documented.

Results of the spare parts and standby inventory as found by sampling techniques were used to estimate the total HAPO inventory surplus and deficit.

Studies concerned with an evaluation of the FORTRAN-Monitor customer service and the scheduling of routine IBM-709 applications were completed.

There were two cases of plutonium deposition confirmed in May. The total number of deposition cases that have occurred at HAPO is 256 of which 187 are currently employed.

Participation in Operation Alert 1960 held May 3, 4, and 5 was successful. The exercise was conducted at the mobile emergency relocation center. More realism was achieved this year by the fragmentary nature of reports on the simulated attack.

There are 23 currently active projects having combined authorized funds in the amount of $24,779,000. The total estimated cost of these projects is $29,238,000. All but two of those authorized are on or ahead of schedule and none are more than three per cent behind schedule.

Project CG-731, Critical Mass Laboratory is nearing completion. The fixed-price contractor has satisfactorily completed all acceptance tests except the one verifying the gas tightness of the reactor room. He is experiencing great difficulty reducing the leak rate to the prescribed 0.5 per cent drop in pressure in six hours when the room is pressurized to 4.5 psig. The principal obstacles encountered are the difficulty of forming a gas tight seal around and among the myriad of electrical and instrument leads, and ceiling leaks. On June 9 he had succeeded in reducing the pressure drop to approximately 10 inches of water in four hours compared to an allowable 0.9 inches of water in six hours. It currently appears the contractor will be completed with his work about June 20. It still appears the reactor control system will be received about the end of this month. It is currently planned to close the project on the June 30, 1960 directive completion date with an underrun of approximately $20,000.

SUPPORTING FUNCTIONS

Personal Share in G.E. Employee Benefit Plans were delivered on May 13, along with a letter indicating beneficiaries as previously designated by employees. Few errors were reported on the information furnished. Many employees took appropriate action to change their beneficiaries.

Total travel activity in FY 1960 for Hanford Laboratories is not expected to vary significantly from FY 1959. Trips started in FY 1959 totaled 1,385. There are estimated to be 1,400 in FY 1960.

Billing for the neutron dosimeters ordered by the AEC has been received. The bill was for $70,000 as compared to the $61,000 estimate used in our planning earlier this fiscal year.

At month's end the staff of HLO totaled 1310, including 619 exempt and 691 nonexempt employees. There were a total of 528 employees possessing technical degrees, including 313 BS, 114 MS, and 101 Ph. D.

The medical treatment frequency for May was 1.77 as compared with 1.68 for April. There were no serious accidents or unusual incidents. There was 1 security violation during May, bringing the total to 10 for the year to date.

A total of 194 offers were extended for the Technical Graduate Program and resulted in 81 acceptances. There are currently 6 offers open, all to late summer graduates who are outstanding candidates worthy of special consideration.

At month's end there were 38 Technical Graduates and 5 Technician Trainees on Program rolls.

During May there were 6 visits by PhD candidates. Four offers were extended and 1 acceptance was received from a PhD ecologist. For the year to date, 8 PhD acceptances have been received.

H M Parker

Manager
Hanford Laboratories

HM Parker:pmg

[redacted]

REACTOR AND FUELS RESEARCH AND DEVELOPMENT OPERATION

TECHNICAL ACTIVITIES

A. FISSIONABLE MATERIALS - 2000 PROGRAM

1. METALLURGY PROGRAM

Corrosion Studies

Fuel Element Ruptures in Steam. Fuel element rupture studies are being conducted in a steam autoclave over a range of variables from 225 to 500 C and 200 to 2000 psig. The samples are defected pieces of coextruded Zircaloy-2 clad, uranium core rod. Rupture rates are inferred from hydrogen collection data.

Rupture rates of 16 to 19 grams uranium per minute at 400 C and 500 C, 2000 psig, have been observed. The maximum rates are quite pressure sensitive, decreasing with decreasing pressures to 1.5 to five grams per minute at 200 psig over the full temperature range. The rates are not highly sensitive to temperature. However, at 300 C and 225 C, very high apparent rates of up to 50 grams per minute have been observed. It is believed that these very high rates are actually the decomposition of uranium hydride deposits formed during the initial stages of rupture. It is further believed that this decomposition is initiated by the condensation of steam to water. If this interpretation is correct, and the formation and decomposition of large amounts of uranium hydride do occur, then the hydrogen collection rates are not directly proportional to uranium damage and the inferred rupture rates must be considered as qualitative. Further investigation of these phenomena are under way.

Corrosion Testing of Zircaloy-2 Elements with Zr-Be Eutectic Braze Closures. An autoclaving test was run during the past month on coextruded fuel elements containing Zr-Be eutectic brazed and welded, and as-brazed closures. Zr-Be eutectic brazed Zircaloy-2 coupons were included. The purpose of the test was to evaluate the corrosion resistance of the brazed closures and the heat-affected zone of the cladding. The health hazard during etching and autoclaving of materials containing the Zr-Be eutectic braze was also evaluated.

Except for a small ring of grayish oxide on the ends of the fuel elements in the vicinity of the closure, both the brazed-welded and the as-brazed closures showed no adverse effects after autoclaving. There was no detectable difference between the heat affected ends of the elements and the main body of the elements. The brazed Zircaloy-2 coupon showed a grey area on the braze and a very definite grain pattern caused by the heat treatment during the braze cycle. The weight gains on the brazed coupon and the control coupon were normal for 72 hours in 400 C, 1500 psi steam (17 mg/dm^2) and showed no accelerated corrosion.

To evaluate the health hazard associated with processing fuel elements containing Zr-Be braze closures, the extent of beryllium contamination was established at various stages of the etching and autoclaving cycle. The sample results show that there is positive beryllium contamination associated with etching and autoclaving. The concentration of beryllium in the breathing zone of the operator opening the autoclave was 0.15 $\mu g/m^3$ compared to the maximum acceptable concentration of 2 $\mu g/m^3$. Smear samples from the autoclave and the brazed surfaces are not comparable to any available data but show small amounts of loose beryllium-containing solids present on these surfaces. The beryllium concentration in the HNO_3-HF acid etch bath was approximately 5 μg/liter. Although the beryllium contamination in the etch solution was low, processing a considerable number of such fuel elements could raise the beryllium concentration to substantial levels.

Effect of Charging Lubricants on Zircaloy-2. An autoclaving test was initiated to determine the effects of charging oils on Zircaloy-2 and mild steel (ASTM 212B). Half of the test coupons were immersed in "Ucon" charging oil and the other half in a standard soluble oil. The coupons were then rinsed in deionized water and autoclaved statically in 300 C, pH 10, deoxygenated water for two weeks. Neither the Zircaloy-2 nor the carbon steel coupons showed any adverse effects from either of the two oils. The average weight gain for the Zircaloy-2 coupons was 7.3 mg/dm^2, which compares favorably with available data for Zircaloy-2 autoclaved in 300 C, pH 10 water. The descaled weight change for the carbon steel coupons was 121 mg/dm^2 which also compares favorably with available data for carbon steel autoclaved in 300 C, pH 10 water.

Report on NPR Tube Etching Facility. An informal report is being prepared on the results of etching samples of an NFR process tube in a continuous etching facility. Studies were made concerning the scale up of a continuous etching facility to etch a 54-foot-long NPR tube. Indications are that full-scale facilities are feasible.

Corrosion of Aluminum Alloys. Comparisons of aluminum alloy behavior in high velocity, corrosive water environments have been renewed. The test apparatus has been modified to give high flow rates parallel to the sample surface rather than direct impingement obtained with the original sample arrangement. The water is forced to flow in a narrow stream by clamping the sample on a special block which has a thin slot milled between the entry and exhaust holes for the water. 300 Area tap water, deionized water, and reactor process water have been used. The water was heated to 100 C and pumped past the samples at velocities from 116 ft/sec down to 40 ft/sec. Grooves of five mils were corroded into a sample in seven hours with deionized water at 100 C and 116 ft/sec initial velocity. (The flow velocity decreased as the groove depth increased.) Addition of two ppm dichromate to reactor process water and deionized water caused considerable decrease in the corrosion rate.

Samples of 1245 aluminum fuel element jackets were tested at the same conditions as the above samples. The results have not been analyzed

as yet, but visually, they appear similar to X-8001 coupons. The fuel element jacket samples were selected because they had been through the canning process.

Radiometallurgy Laboratory Studies

Examination of Zircaloy-2 capsules burst by internal pressure during irradiation revealed that strain was uniform prior to rupture (RM-551). Four swelling-experiment samples were removed from NaK-filled capsules and examined. No bumping or warping was found, but longitudinal cracks were found in the cladding. In places, the cladding was so thin that thermal expansion of the uranium caused the cladding to part in tensile failure (RM-559). Two irradiated rods were defected and then used for in-reactor decontamination studies. Examination of the ruptured areas showed that the uranium was attacked at the cladding bond layer around the fuel rod, with resultant swelling (RM-327). Cracking was found in samples from coextruded rod type elements, but no other defects were apparent (RM-562). A tube sample from a rod-and-tube element was found to have cracks extending from the uranium through the metallurgical bond into the Zr-2 cladding. These cracks were not found when examined by Battelle.

Results and interpretations of these examinations will be reported in more detail in connection with the development programs served.

Basic Metallurgy Studies

Radiation Effects in Structural Materials. Effects of reactor irradiation at 200-300 C on Zircaloy-2 are being evaluated by use of x-ray diffraction and other techniques. Coupons of annealed and cold worked Zircaloy-2 were irradiated in the KER Loop 3 at an average temperature of 200 C to an integrated exposure of 9×10^{19} nvt. Post-irradiation examination shows that both the annealed and cold worked state, radiation damage has been retained after irradiation at 220 C. The x-ray diffraction lines all show an increase in width. This fact is interesting since in un-irradiated cold worked Zircaloy-2, x-ray line broadening can be partially annealed out after one day at 250 C.

Mechanical and Physical Properties of Materials. The creep properties of Zircaloy-2 are considerably improved by small amounts of residual cold work. The extent to which increasing amounts of cold work influence creep properties and the effects of recovery during testing are being determined on specimens cold worked in the range of 15 to 45 percent. The test conditions, as well as the amount of cold work in the specimens, were selected as limits of conditions that would be encountered in service in reactor process tubing or fuel element cladding. A series of tests have been completed at HAPO and at BMI on an assistance program. Another series of tests were started during the month. An activation energy for creep was calculated and previously reported for the HAPO tests. The value was determined to be 59.7 k cal/gm-mole. The plastic creep strain

of Zircaloy-2 has been analyzed this month using the BMI and HAPO creep tests and plotted as a function Θ, a compensated time parameter of the simple rate reaction, using the relationship: $\Theta = te^{-\frac{H}{RT}}$, where t is time, T is absolute temperature, H is the activation energy, 59.7 k cal/gm-mole, and R is the gas constant. The resulting curves displayed continuity at constant stress and cold work levels over the temperature range 150 C to 480 C. The slope is dependent on time and cold work but independent of stress and temperature. The slopes increase with increasing cold work to around 25 percent cold work. At higher levels they are essentially the same. Studies of the microstructural changes accompanying creep at various values of Θ are being conducted on annealed and 45 percent cold worked Zircaloy-2 specimens. Examination of a 45 percent cold worked specimen by x-ray diffraction and optical metallography indicated partial recrystallization occurred during a 4000-hour creep test at 400 C and at 13,000 psi stress. This recrystallization and accompanying recovery of cold work accounts for the high creep rate of the 45 percent specimen, compared to the 25 percent specimen under the same testing conditions.

Electron and Optical Microscopy. The study of the microstructure of cladding and fuel material after irradiation is a direct way of detecting radiation damage in these materials. Thin films and foils suitable for electron microscopy offer advantages since radioactivity is a minimum. The irradiation of multiple layered films, UO_2 on Pt on C, UO_2 on Ge on C, UO_2 on ZrO_2 on C, and UO_2 on C have been repeated, and positive results have been obtained. All films of the non-fissionable layers had discrete regions in which no UO_2 was present. In the as-irradiated state, these regions show fission fragment tracks in the ZrO_2 multiple film. After shadowing of the films, tracks are visible in these regions in both the carbon and the ZrO_2 films. Stripping the UO_2 film from the underlying substrate and then shadowing discloses tracks in the Pt, Ge, ZrO_2, and C in those regions where UO_2 was present during irradiation.

The observed differences in behavior must be due to differences in chemical stability, thermal conductivity, plastic deformation, and/or vapor pressure of the various constituents in the multiple films. Which of these factors are responsible for the occurrence of fission fragment damage as seen by electron microscopy are being investigated by further irradiations.

Pre-thinned cold worked and annealed foils of high purity aluminum have been irradiated in evacuated capsules to exposures as high as 4.4×10^{19} nvt. Electron microscope studies of dislocations and their motions in these irradiated foils indicate that twinning apparently occurs in specimens having the highest exposure, 4.4×10^{19} nvt. In addition, zig-zag type dislocations which are immobile are now present. The latter type imperfections have been reported to be present in aluminum after quenching from a high temperature. No evidence of the formation of dislocation loops has been found.

Metallic Fuel Development

Cluster Fuel Elements. Production Test IP-288A, which consists of seven 12-inch long, 7-rod cluster elements with hot-headed and projection welded closures, was discharged from KER on May 14 with approximately 2000 MWD/T exposure. The irradiation was entirely successful. Other activities in the KE basin have prevented underwater examination of the elements and selection of an element for Radiomet examination.

Radiometallurgical examination of the ruptured 0.592-inch diameter rod from the 7-rod cluster which failed in KER Loop 1 on February 8, 1960, has continued. A detailed metallurgical examination has been made of a "scratch" or surface striation which extended longitudinally along the fuel rod from one end of the split in the clad. This surface striation corresponds to a thinned area in the clad which, in cross-section, shows extensive local plastic deformation of the Zircaloy-2. In one cross section, removed from the failure area, this local deformation has reduced the clad thickness to six mils from the nominal 20 mils originally present. Of prime importance is the fact that the localized clad thinning has occurred with only a corresponding increase in rod diameter of four mils and without associated cracking in the uranium.

The examination results indicate that localized plastic deformation of the clad may have been responsible for failure of the fuel rod, although radial cracking of the fuel was associated with the clad split at one end of the failed area. The phenomena of localized thinning of the clad, without associated cracking of the fuel, has not been observed before.

Tubular Fuel Elements. Fuel elements of tube-tube geometry are being tested in the KER loops under NPR coolant water conditions. At month end four elements in KER Loop 2 will have achieved an exposure of about 2750 MWD/T. The elements in KER Loop 2 are coextruded tube-tube geometry with enriched cores and Zircaloy-2 clad. Two elements have uranium-zirconium alloy cores, and two have unalloyed uranium cores. Maximum core temperature calculated from present data is 440 C. This temperature is reached in the inner tube of the downstream element.

A tubular element having 2000 MWD/T exposure was examined at BMI. Re-examination of sections of this fuel element at Hanford confirmed the presence of radial cracks in the uranium core near the center of the 36-inch long element. Some of the cracks run from the inner clad to the outer clad. In all cases, the cracks penetrated into the clad no more than one or two mils. In most cases the clad shows ductile metal flow in the region of crack termination.

Evaluation of 1.6 percent enriched two percent Zircaloy, Zircaloy-2 clad KER material is being performed. This material was extruded by NMI. Chief cause for rejection has been deep longitudinal scratches and extrusion defects on the ID of the inner tube. The clad material appears to be low in hydrogen with an excellent zirconium-uranium interface. Clad thickness ranges from 0.018" to 0.025". Uranium quality is poor

with numerous oxide and carbide stringers. Uranium grain size is fairly uniform throughout the cross section, ranging in size from 0.035 mm to 0.065 mm.

Test elements were prepared for a KER loop irradiation to determine the effect of heat treating variables on irradiation behavior of Zircaloy-2 clad tubular fuel. Five heat treatments were employed with the material characterized for grain size and structure and crystallographic texture. The elements were prepared from coextruded tubes, 1.470-inch OD x 0.400-inch ID with nominal 0.020-inch thick inner and outer Zircaloy-2 cladding. Irradiation test PT-IP-317-A was made up of five, six-inch elements and six, nine-inch elements in stainless steel sleeves. One element ruptured in the autoclave, the remainder had a normal black oxide film. One element was sectioned to determine the extent of hydride pickup in the cladding, and two sections of this indicated less than 50 ppm zirconium hydride. The elements were charged on May 14, 1960, in KER-3 with two defect-test assemblies prepared by Fuel Element Design in the downstream position. Above normal activity was observed on the delayed neutron monitor almost immediately after startup. After approximately ten hours the activity exceeded the operating limit and the test was discharged. The elements have not been examined as yet, so at the present time it is not known whether the high activity occurred from surface contamination or from water entry. Two additional nine-inch elements from the group in the autoclave that were rinsed but not cleaned in nitric acid were boiled in eight normal nitric acid. Analysis indicated 490 micrograms total uranium.

Component Fabrication. The heating and quenching rates of sections of NPR inner tube stock, 1.430-inch OD x 0.520-inch ID, were determined for several heat treatments considered for beta heat treatment of this fuel. These treatments and data are given in the following table. The material is being examined for correlation of resulting grain size and structure.

Heat Treatment	Time to Reach Beta Minutes	Time to Reach 730 C Minutes	Quench Rate °C/min
730 C 10 minutes Nusal salt - direct quench to 20 C water	2.7	5.4	5030
730 C 10 minutes Nusal salt - direct quench to 80 C water	2.8	4.7	4770
730 C 10 minutes Nusal salt - direct quench to oil at 25 C	2.7	4.7	3275
730 C 10 minutes Nusal salt - quench to LH980 salt at 590 C 5 min - water quench	2.7	4.6	Approx. 250 C/min in beta 48 seconds to complete transformation; 3 min to reach 590 C.
730 C 10 minutes Nusal salt, air cooled	2.2	4.2	94 C/min in beta 54 seconds to complete transformation.

Dimensional changes recorded indicate no change in outside diameter, 0.004-inch increase in inside diameter, and 0.010-0.016-inch increase in a three-inch length.

The present concept of NPR fuel elements requires that the inner tube be restrained from sliding out of the outer tube during charging, irradiation, or discharging. A number of methods have been proposed to achieve this result. Twelve steel dummy elements four inches long have been built and are being used to mock-up and evaluate candidate methods of fastening inner and outer tubes.

Failure studies require the ability to defect an element at any time during the irradiation cycle. This has been accomplished by shearing a fixture from the side of the element. These fixtures have been attached by electron beam welding. A method of attaching by resistance projection welding has been developed to the point where simulated failure fixtures have been successfully attached to Zircaloy tubing. Advantages for this method of attachment include a much smaller heat affected zone in the region where failure will be initiated and a much faster operation.

Some investigations are being made to determine the flow pattern of a metal as it is being swaged. To do this, a square cross section bar is being fabricated from a number of square cross section copper wires. These wires have been dip tinned with a 50-50 solder and will be heated and pressed into a bar approximately 1.5 inch square. From this bar, that now has a cross section exhibiting a square lattice pattern, will be machined a rod 1.375" in diameter.

Sections of this 1.375-inch diameter rod will be swaged through a series of reductions and at various rates. In each case measurements of and photographic records of the lattice pattern will be made. Such measurements and observations should lead to a better understanding of die design and provide a basis from which to establish a sound theory of metal flow in a swaging die.

Closure and Joining. Equipment for hot heading Zircaloy-2 uranium NPR inner tubes (1.430-inch OD x 0.520-inch ID) was set up in a 400-ton vertical hydraulic press and four tubes were successfully hot headed on both ends. The heading technique is the same used on KER inner tubes for a recent production test.

The headed NPR inner tubes are being used for the development of a projection welded final closure for this size tube. The Zircaloy-2 shoulder on the hot headed tubes appear uniform and of sufficient width to allow the use of multiple projection rings on the closure cap.

The heading operation produced a swell on the tube OD at the junction of the unheated tube grip and the heated heading container of approximately 0.008 to 0.009 inch. This compares favorably to the 0.010 to 0.012-inch swell obtained on the hot headed KER inner tubes and can be readily removed by a subsequent drawing operation. Approximately

5/16-inch is extruded on each end of the tube to bring the Zircaloy-2 clad across the end of the heavier walled tube into the extrusion.

Several more tubes of this size will be hot headed for use in further hot heading and projection welding studies as additional coextruded stock becomes available.

Developmental work on a brazed NPR fuel element end closure has continued during the past month. Emphasis has been on the brazing of different geometries and applying different brazing concepts. Use of a machined disk of braze alloy placed between the cap and the uranium core appears to have considerable promise. Difficulty has been encountered in brazing NPR inner tubes. A sharp bend occurs in the jacket at the braze-uranium interface due to the difference in thermal expansion of the uranium and zirconium. This sharp bend would be a possible point of failure during thermal cycling of the reactor.

Six brazed fuel element test samples were placed in the Elmo 5 loop and were run at 300 C and 1500 psi for one week. At this point a failure occurred. The failed piece was heat treated but had an unwelded braze zone. Failure occurred through a pinhole in the braze which penetrated to the uranium. Failure was quite dramatic. The end caps were popped off with a section of the can wall attached to the cap. The jacket was split open along the heat affected zone for about one-half inch from the end cap. These pieces had not been autoclaved prior to charging. If they had been autoclaved, the defective element would have been detected.

Several sites were visited to determine which brazing alloys, other than the Zry - 5 w/o Be (BeZirc) braze, would be potential alloys for use in NPR fuel elements. Several alloys looked promising from the standpoint of low corrosion rate and low melting temperature. These alloys were Zr-2, 5 w/o Be, 13 w/o Fe and Zr-2, 5 w/o Be 17 w/o Cu. BAPD reports the corrosion resistance of the iron alloy in 360 C water as being slightly better than the BeZirc braze alloy. There are numerous other alloys that have rather poor corrosion resistance but low melting points. These alloys would act as secondary corrosion barriers in the event of weld failure, providing sufficient protection to the uranium until the reactor could be shut down.

Allied Fuel Studies. In-reactor swelling experiments of Zircaloy-2 clad uranium fuel rods with selected uranium temperatures, cladding thicknesses, and exposures are being conducted. Three swelling capsules GEH-14-98, 14-101, and 14-105, are presently being irradiated in the MTR with goal exposures in the range 2000-2500 MWD/T. Exposures and average center uranium temperatures for these capsules are, respectively: 600, 1600, 2000 MWD/T, and 575, 275, 335 C. A fourth capsule in the MTR, GEH-14-97, is to be discharged at the end of the present cycle with an exposure of 3500 MWD/T. A review of the presently available uranium swelling data revealed that more information is needed in the

temperature range at which swelling begins to increase rapidly. Therefore, the irradiation conditions of five more capsules, now awaiting irradiation at the MTR or ETR, have been revised to give uranium temperatures in the range of interest.

Dimensional measurements on four uranium fuel rods irradiated in NaK capsules at D Reactor are complete. These rods, which operated in a temperature range from 380-420 C to an exposure of 1850 MWD/T, have increased in volume up to one percent. Ductile failure of the Zircaloy-2 cladding on one of these rods occurred during irradiation. Non-uniform straining of the cladding, without associated fuel cracking, occurred at several places on the rod.

Internal macrocracking was observed in the center of the rod. The behavior of this test specimen is remarkably similar to that of the ruptured fuel rod from the 7-rod cluster which failed in KER Loop 1, February 8, 1960.

It has been demonstrated in the past that coextruded fuel material in the beta treated water quenched condition behaves poorly in defect tests. Aging or annealing of water quenched material at temperature below 590 C, however, improves its behavior to the point where it is equivalent to that obtainable by other heat treating methods. It has been determined that autoclaving for 48 hours at 400 C ages the bond of water quenched material sufficiently to produce adequate bond quality. Water quenching thus should be acceptable in a fuel element heat treating process insofar as bond quality is concerned.

Laboratory work on the in-reactor burst testing of 15 Zircaloy-2 tubes simulating fuel element jackets is complete. Previously reported indications of an in-reactor loss in uniform circumferential strain at fracture were in error. More accurate measurements on metallographic cross sections through the capsules showed no significant difference in uniform elongation at fracture between specimens burst in-reactor and those burst ex-reactor. The average uniform elongation was 16 percent. The hydrogen content after 1300 hours in the reactor at 350 C was, on a basis of metallographic estimates, 100 ppm in both the annealed and cold-worked specimens.

Ex-reactor tests show that Zircaloy-2 supports on full size NPR fuel elements severely scratch the autoclaved Zircaloy-2 process tube as the fuel element is charged and discharged. Fuel element supports formed from strips of AISI 1010 and 1020 steels have been wear tested and have performed satisfactorily even when the contact area between the support and autoclaved Zircaloy-2 is reduced to a point or line. The oxide film on the steel support resulting from autoclaving at 400 C and 1500 psi for 72 hours has no adverse effect on the performance. Several steel supports with 5/8-inch long bearing surface have been formed from 1010 and 1020 steels to evaluate the wear performance of this new support design. A method for attaching these supports to a Zircaloy-2 surface is being evaluated. Short pieces of Zircaloy-2

wire are inserted through holes in the end of the steel support and spot welded to a Zircaloy-2 surface. The heat and pressure from the spot-weld upsets the Zircaloy-2 wire and effectively rivets the support to the Zircaloy surface. Spot-welded supports along with other samples of the steels in contact with Zircaloy-2 are being tested in pH 10 water at 300 C and 1500 psi to check their gross corrosion behavior and any galvanic effects with Zircaloy-2. An order has been placed for an experimental lot of Zircaloy-2 roll clad with a low carbon steel. Wear, formability, and corrosion evaluation of this steel clad Zircaloy is planned.

In order for the development of self supports for NPR fuel elements to progress on a firm basis, it is desirable to know the flexural and crushing properties of various experimental supports. Load deflection tests were made on variations of the 30-mil Zircaloy-2 support in current use. The maximum load these supports will hold before buckling was found to be 950 lbs/inch and the maximum room temperature elastic deflection was 10 mils.

Of the many possible types of fixtures for attaching inner NPR fuel tubes to the outer tubes, ten were selected for evaluation. Efforts are being concentrated on two types of fixtures: (1) those which are independent of end closure design, and (2) those which may involve end closure design but will require no welding after the fuel is autoclaved.

During cyclic temperature operation, microstresses are developed in polycrystalline uranium due to the anisotropic thermal expansions of the uranium grains. As previously reported, these microstresses increase the macroscopic creep rates for 500 psi and 2000 psi loads. During testing at 750 psi the thermocouple failed. A new specimen was placed in the capsule and testing at 750 psi load has been resumed.

The Dynapak was instrumented to measure extrusion punch force as a function of time. These impulses were measured on a series of steel extrusions at 10/1 reduction ratio with fire pressure and billet temperature as extrusion variables. Typically, the force on the punch reached 200,000 psi, and the duration of the extrusion impulse was five milliseconds. These types of data are required for effective adjustment of extrusion parameters.

2. REACTOR PROGRAM

Coolant Systems Development

In-Reactor Single-Pass Testing. The six KE single-pass tubes were recharged. Two tubes are now testing the corrosion of standard aluminum-jacketed fuel in pH 7.0 process water with one ppm dichromate inhibitor; two in pH 6.5, two ppm dichromate; and the other two tubes contain regular unweighed production elements.

Single-Pass Decontamination of Old Reactors. Four tests were completed in the 242-B Single-Pass Flow Facility. A cyclic process alternating 2.5% Turco-4518 and 2.5% sulfamic acid gave a DF of 650 on specimens cut from stainless steel reactor pigtails. A mixture of H_3PO_4 and $Na_2Cr_2O_7$ gave a DF of 14. A cyclic process using 2.5% Turco-4518 and 2.5% Wyandotte-112 gave a DF of 33 on the pigtail and 6-10 on sections of an aluminum process tube. A mixture of 0.9M H_2SO_4 and 0.3 M oxalic acid (inhibited with two grams/gallon of phenyl thiourea) gave a DF of 98 on the pigtail samples and reduced the process tube contamination to background, while corroding carbon steel washers only 0.001 mil. All four tests were for 24 minutes.

Zircaloy Corrosion. Two lots of Zr-4, classed by WAPD as "poor" and "good" material, respectively, were exposed 4500 and 3000 hours in pH 10 290 C water. No difference was found.

Six discharges have been completed to date of the coupons of Zr-2 exposed to velocities of 18.6, 42.4, and 86 ft/sec in pH 10, 290 C water. Accumulated exposure is 2481 hours. The samples at the highest velocities have continued to lose weight; however, this is suspected to be due to fretting.

Brazed Zr End Closures. Tubular coextruded U-Zr-2 elements with end closures brazed with 95% Zr - 5% Be were exposed one week in Elmo-7 at pH 10, 300 C. One element ruptured, apparently because of a pinhole at the braze. The braze appeared to have good corrosion resistance.

Slug Rupture Tests. Three more runs were made in the Heated Slug Rupture Prototype with isothermal heat treated coextruded U-Zr-2 tubes. These were predefected with a 0.025-inch pinhole and run without internal heat generation at 300 C, 1650 psi, and 16 fps until the rupture was detected by a hydrogen detector. After detection, the NPR cool down schedule was followed. An outer tube defected on the outside surface lost 13 grams of uranium, and the ruptured area consisted of two broken mounds, each about 3/8 inch in diameter and 0.10 inch high. An outer tube defected on the inside surface lost five grams of uranium. There were two ruptured areas located on opposite sides of the tube, possibly indicating the tube had been defected in two places. One area had two broken mounds, each about 3/8 inch in diameter, and the other area had a single 3/8 inch diameter broken mound. An inner tube defected on the outside surface lost five grams, and the ruptured area exhibited a broken mound about 3/8 inch and two other unbroken mounds about 1/8 inch in diameter.

The second rupture test was made in IRP Loop using a single rod from an irradiated 7-rod cluster. After rupturing 40 minutes at 300 C, the ruptured area extended completely around the rod and about one and one-half inches along the length. It was characterized by both blistering and splitting. This rod had received about twice the in-reactor exposure as the one employed in the first test, and it appeared to have ruptured more severely in only half the time. The loop was decontaminated using peroxide-carbonate alkaline permanganate and Wyandotte 112. DF's of 16 to 240 were measured, and corrosion of the carbon steel coupons was 0.1 mil.

Hydrogen Detector. Modification of the recorder to permit an on-time of two seconds every minute appears to give satisfactory readings from the palladium-platinum resistance detector. The present detector has been used about two years and shows no sign of deterioration or leakage. Two more hydrogen detectors are being built for installation in the IRP and Elmo-4 Loops. The IRP detector will be employed to determine whether the hydrogen detector can sense a rupture before or as fast as the radiation monitors, as well as to follow the amount of rupturing.

KER Thermocouple Fuel Element. A one-inch diameter by 12-inch long thermocouple slug of uranium coextruded with a 20-mil Zr-2 cladding was charged in KER Loop 1 during the month. It contains one thermocouple in the center core and two just under the cladding; two others measure the adjacent water temperature. This joint test with Fuels Development is intended to measure any significant increase in the temperature drop between the cladding and the water due to the build-up of insulating crud on the surface. No such increase was detected during the first eight days of operation. The thermocouple slug is positioned at the center of the reactor and upstream of other elements in the charge, the location where crud deposition is expected to be the greatest. The water is 260 C, pH 10; and the loop is of carbon steel. The crud content of the water is being measured with a recently installed hot crud probe.

High Flow Deionization. The high flow deionization studies were completed. These tests indicate that high flow rate operation is feasible in both the make-up and clean-up systems if slight capacity losses can be tolerated. The useful capacity of the clean-up resin was five to 15% lower than that for the make-up system mixed bed resin.

Corrosion of Stellite During Decontamination. Testing of Stellite alloys is continuing in an inhibited version of Turco 4502 (240 gms/liter) for two hours at 105-110 C, followed by 15 minutes in Wyandotte-1112 (90 gms/liter) at 60 C. Penetrations after three cycles were 0.05, 0.19, and 0.15 mils for Stellites 6, 6-B, and 12, respectively.

Colmonoy. Samples of Colmonoy-5 (a Cr-Ni alloy considered for NPR valve seats in place of Stellite) have been cycled six times (with two hours per exposure) in alkaline permanganate solutions. There was very little corrosion as compared to Stellite on specimens exposed to 18% caustic, 3% $KMnO_4$; to 2 lb/gal Turco-4502; or to 2 lb/gal Wyandotte-1113.

Structural Materials Development

NPR Process Tubes. A visit was made to the corrosion testing laboratories of each of the three NPR process tubes vendors. All are using etching and autoclaving methods and equipment which should be acceptable according to Hanford practice.

However, Allegheny Ludlum Steel Corporation has been routinely machining at least 0.020-inch from the surface of test coupons prior to etching. This practice defeats the purpose of the corrosion test for detecting

the effects of possible surface contamination. It is also possible that the surface texture produced by this method of machining contributes to Allegheny Ludlum's difficulty in consistently obtaining a satisfactory black film in the corrosion test. A request has been made to discontinue machining the samples, and instead to test them with a surface as prepared for the next step in the fabrication process.

Harvey Aluminum Company has experienced difficulty with white stringers on their corrosion test samples. Of nine samples tested only one was free of stringers. Samples from these tubes were incorporated into a reciprocal testing program between the corrosion laboratories at Harvey and Hanford. This series of tests compared both etching and autoclaving processes at both laboratories. All samples were entirely acceptable on the basis of weight gain, but differences were observed in surface appearance. No bias was introduced by differences in etching techniques, but Harvey's autoclaving produced an inferior surface appearance. Stringers were more numerous and more pronounced. All tubes were judged acceptable on the basis of samples autoclaved at Hanford, in spite of the fact that those tubes represented by the worst of the samples autoclaved at Harvey would be rejected. This test shows a need for Harvey to modify their autoclave technique. A series of standards was selected from this test by which to judge future test samples. One coupon has a perfect glossy black surface with a limited population of small gray or white flecks and stringers. This sample represents the minimum surface condition that can be accepted. A third coupon is included for purposes of comparison representing a definitely rejectable surface. It has a population of flecks and stringers considered to be excessive. It must be emphasized that this group of standards can be applied only to tubes produced by this one vendor using his particular method of fabrication.

The inability of the other two NPR tube vendors consistently to produce entirely black autoclave films indicates the need for similar reciprocal testing programs with assistance from Hanford in identifying and correcting non-standard Zircaloy surface treatment procedures.

"C" Reactor Zircaloy Tubing. Fabrication of 200 smooth-bore Zircaloy-2 tubes for C Reactor is nearly on schedule; 170 tubes are expected to be ready for shipment on the new delivery date of July 1. The remaining should be completed by July 15. Included in this group will be four to six tubes made an extra five feet long for corrosion tests in K Reactor.

Three new fabrication techniques for smooth bore tubes which should provide lower tubing costs in the future are being developed. The trials are being made under purchase orders whereby Hanford will buy a limited number of the tubes if they meet all Hanford specifications.

Van Stone flanging tests performed by IPD on the first ribless Zircaloy-2 tubes received have shown no difficulty with the smooth, 30 percent cold-worked tubes made by Harvey Aluminum but have resulted in failures by cracking in some of the rough-surface, 65 percent cold-worked

Bridgeport Brass tubes. To consistently obtain crack-free flanges and to obtain a more desirable flange microstructure for the Bridgeport tubes on site, the following recommendations have been made:

1. Polish the inner surface of the tube where the flange will be turned.
2. Anneal the sections of the tube to be flanged.

Future tubes from Bridgeport will be annealed by the vendor at the flange locations and, as specified, a crack-free flange must be turned on a section from each tube.

The tubes fabricated by Harvey Aluminum Company have a residual cold work of about 30 percent, a very fine grain size, and smooth, pickled surfaces. No difficulty is anticipated in continuing to obtain crack-free flanges without annealing this tubing.

Nonmetallic Materials Development

Annealing of High Temperature Irradiation Damage. A series of anneals at 700, 800, and 1000 C were made on two samples of TSGBF graphite irradiated to 2400 MWD/AT in the 2C test hole in KE Reactor at ambient moderator temperatures. The primary purpose was to determine the effect of thermal annealing on contraction when the maximum permissible graphite temperatures are raised at the K Reactors. For these samples, which had contracted approximately 0.01 percent during reactor operation, twenty-nine hours at 700 C produced no effect. Nineteen hours at 800 C produced a growth of approximately 0.006 percent, and three hours at 1000 C produced a shrinkage of approximately 0.006 percent. Thus, at the completion of these annealing treatments the samples were at their starting, i.e., as-irradiated, lengths. Although the exposure on these samples was low, their behavior indicates that thermal annealing from the proposed increase in moderator temperature will not cause significant dimensional changes.

Reactor Flux Measurements. On February 14, 1960, one boat of small graphite samples was discharged from 1960-C. The boat was centered 99 inches downstream from the center line of the graphite stack and contained five nickel and cobalt-aluminum flux monitors located four inches apart. The integrated fast thermal flux values are tabulated below. The gross thermal to fast flux ratios are twice those obtained in two previous experiments, in which the monitors were positioned near the reactor core. The discrepancy is likely due to the fact that these recent monitors were located on the very edge of the metal loading pattern.

Distance Downstream of Centerline, Inches	Integrated Fast Flux (nvt/MWD/AT) E>1 Mev*	Integrated Gross Thermal Flux (nvt/MWD/AT)	Thermal to Fast Flux Ratio
91	7.4×10^{15}	8.2×10^{16}	11
95	8.1×10^{15}	8.0×10^{16}	9.9
99	7.5×10^{15}	7.9×10^{16}	11
103	6.8×10^{15}	7.7×10^{16}	11
107	6.6×10	7.3×10^{16}	11

*Assumed watt spectrum.

Graphite Oxidation Studies. Graphite monitoring samples were discharged from 1880-KW on April 29, after twelve months in the reactor. No oxidation rate above two percent per 1000 operating days was noted.

Thermal Hydraulic Studies

Heat Transfer Experiments Pertaining to Present Production Reactors. The recent simultaneous occurrence on some reactor coolant channels of high rear header pressure (up to about 75 psig) and low Panellit pressures (120 psig or sometimes less) has necessitated a careful review of reactor "trip-after-instability" temperature limits. Since the validity of the limit calculation techniques rely heavily on laboratory verification, additional experiments were performed with particular emphasis placed on data at low Panellit pressures and high rear header pressures. In addition, changes in fuel element geometry and significant improvements in techniques and equipment were incorporated in these data. The data include steady state hydraulic demand requirements and transient demand characteristics following simulated plugging incidents and are applicable to BDF-type reactors.

The steady state demand data were taken for tube powers of 500, 700, 1000, 1250, and 1600 KW. These data (utilizing standard BDF fittings and a simulated I & E fuel charge) show that the usual empirically calculated "boiling demand curve" will predict conservative (higher than actual) demand pressures and hence conservatism would be retained in the unstable flow point predicted by using the empirical "boiling demand curve". Preliminary analysis of the data also indicated that there would be no unstable flow point with a slow plugging occurrence at tube powers less than about 800 KW. The data also indicate that high Panellit trip back-up protection would be available for tube powers greater than about 600 KW. Both of the above tube power values are based on a front header pressure of 580 psig and an initial Panellit pressure of 250 psig with 125 C initial outlet temperature. For all tube powers except 1600 KW, the demand curves were carried to flow rates sufficiently low to allow the detection of film boiling at some point on the simulated fuel charge.

Transient data were recorded for tube powers of 700, 1000, 1100, 1250, and 1400 KW with various conditions of flow meter geometry, initial outlet temperature, severity of plugging occurrence and rear header pressure. Preliminary analysis of these data indicates the following:

1. There is very little deviation between the observed minimum Panellit pressure (as seen by an electro-mechanical pressure transducer) and the predicted minimum Panellit pressure based on the non-boiling isothermal demand curve (using flow to the 1.8 power in predicting pressure drop demand across the fuel charge). The deviation was generally less than ± 5 psi and was only infrequently greater than ± 10 psi. The accuracy of data reduction from the high speed recording equipment is regarded to be in this same range, ± 5 to 10 psi.

2. The technique of "normalizing" tube inlet data to selected initial Panellit pressures as outlined in HW-42469 C was verified as being applicable for different venturi sizes and for a double orifice combination.

3. Variations in rear header pressure had no apparent effect on minimum Panellit pressure during flow reductions or the normalizing technique.

4. For tube powers of 700, 1100, and 1400 KW, "sudden plug" simulation was carried out with plug flow rates as low as two to three gpm with rear header pressure of 75 psig and initial outlet temperature equalling 130 C. Tube power was reduced according to a programmed simulated 1100 in scram as soon as severe film boiling conditions were detected by heater rod temperature increase. In no case was the scram initiated less than four seconds after plugging and obtaining minimum Panellit pressure. And, in no case did heater rod damage occur due to excess temperatures after the scram was initiated. A check run at 1400 KW with 125 psig rear header pressure indicates that the higher rear header pressure allows a very small increase in the allowable time lapse between plugging and power reduction.

Hydraulic Studies. Experiments were conducted to determine the relative pressure drop for two different types of fuel element supports using 1.501" (avg) OD solid fuel elements in a 1.681" ID ribless zirconium alloy tube. One type support consisted of a plate (approximately 3/4" wide by one inch long by 0.030" thick) welded with its plane tangent to the fuel element periphery. The other type was the familiar "suitcase handle" shape (approximately 3/16" wide by 2-1.8" long by 0.075" raised portion) made from ~0.030" plate.

The data show a ΔP for the flat plates which is about 1.08 times the ΔP for the "suitcase handles". This ratio varies slightly with the rate and the temperature because of the conditions mentioned below. The 1.08 value is somewhat of an average value for a flow of 30 to 40 gpm and a temperature between 15 and 50 C.

The data obtained show two suggestive characteristics: (1) the general slope of the flow versus ΔP data is greater for the "suitcase handles" than for the flat plates, and (2) the variation in ΔP with fluid temperature is greater for the flat plates than for the "suitcase handles". These two characteristics would lead one to believe that the flat plate exhibits a greater proportion of wall shear stress than the "suitcase handle" or conversely that the "suitcase handle" exhibits a greater proportion of contraction-expansion type turbulence losses than the flat plate. This compares well with the dimensional characteristics of the supports in that the flat plate has about seven times as much surface area as the "suitcase handle" and only 1.5 times as much cross-sectional projected area as the "suitcase handle".

Critical Flow Experiments. Experimentation was carried out on critical flow existing in the flashing of initially subcooled water through short, sharp-entrance nozzles with diameters of approximately one-half inch and lengths of one-fourth, one-half, one, and three inches. Holding the nozzle inlet conditions constant at 100 psig and either 140 C or 160 C, the back pressure was changed in small increments and the effect of these changes upon the discharge rate was noted. The results obtained were unexpected in that two distinct critical flows existed for the same upstream conditions.

At a sufficiently low pressure differential across the nozzle the usual dependence of pressure drop on the flow squared was noted. After a certain critical downstream pressure was reached, the discharge rate was found to become independent of ΔP, and this condition normally could be expected to persist for all downstream pressures less than this value. This was, however, not found to be the case. By decreasing the downstream pressure further to such a value that the downstream pressure corresponded to the saturation pressure at the upstream temperature, a distinct departure from critical flow was in evidence. A further decrease in the downstream pressure resulted in a re-establishment of the flow squared-pressure drop dependence. When the downstream pressure was decreased even further, a second critical pressure differential was noted after which a further decrease in downstream pressure would not cause a corresponding increase of flow. Subsequent measured pressure profiles indicated that the lower valued critical pressure value corresponded to a choking condition which was occurring in a zone near the entrance (vena contracta) of the nozzle at the axial position where the pressure was such that the water was saturated. This critical zone ceased to exist at the above mentioned conditions. The second or high pressure differential critical was observed to apparently occur at the nozzle exit as was expected. This "double-critical" condition was not in evidence when inlet flow was saturated or at low quality, nor was it observed in nozzles where L/D ratio exceeded approximately the value of six.

Boiling Burnout Conditions for NPR Fuel Elements. Laboratory heat transfer experiments were continued to determine the boiling burnout conditions of flows and heat generation rates for the NPR tube and tube type fuel element. Thirteen boiling burnout points were obtained that are applicable to the outer cooling annulus of the fuel element.

Two different test sections were used in the experiments. The first consisted of an annular coolant passage formed by a 2.390-inch OD heated surface within a 2.70-inch ID process tube. The second test section was a single heated tube with water flowing through the inside in a passage possessing approximately the same hydraulic diameter as the annulus in the first test section. Both test sections had heated lengths of 24 inches.

The boiling burnout points were obtained for the following ranges of conditions: flow, 1,000,000 to 5,000,000 lb/hr-sq ft; outlet conditions, 14 F subcooled to 10% by weight steam; heat flux at burnout, 595,000 to 1,695,000 Btu/hr-sq ft. An initial analysis of the data showed that the burnout conditions for the two test sections were almost identical.

Boiling burnout for these test sections was detected by noting a sharp increase in temperature of the heated surface. In all cases the power was then decreased before the test section melted. Experiments were terminated with the annulus test section due to failure of thermocouples, while the single tube test section failed when a longitudinal crack opened, apparently due to thermal stresses.

Test Section for NPR Heat Transfer Experiments. Bids were received and orders placed for materials to build a full-scale experimental heat transfer test section simulating the downstream half of an NPR charge of tube and tube fuel elements. Efforts to develop welding techniques suitable for joining the dissimilar materials used to achieve the cosine heat generation along the length of the test section appeared to be successful.

Shielding Studies

Attenuation Measurements. The following table summarizes the data obtained by baking two types of iron-serpentine concretes at various temperatures.

Loss of Water in Iron-Serpentine Concrete

Bake Temp., °C	Type I Density (lb/ft^3)	Type I Water Content* (lb/ft^3)	Type II Density (lb/ft^3)	Type II Water Content* (lb/ft^3)
As-Cured (about 25°)	268	15	223	19.2
As-Cured (about 60°)	267	13.3	221	17.2
100	261	8.0	-	-
320	260	6.4	214	10.7

*Includes water in serpentine.

The gamma dose rate (through 48 inches of concrete in the 320 C test) was 8 x 10^{-3} mr/hr/MW for type I and 2 x 10^{-2} mr/hr/MW for type II or a factor of 2.3 greater. To obtain the total dose rate, the dose rate from the neutrons would be added to the gamma dose rate. Because of the higher water content of type II, the neutron dose rate is expected to be smaller than that of type I. This information is not available at this time; type II is being irradiated for the first time after being baked at 320 C, and the foils from the 320 C test on type I are being counted.

Shielding Instrumentation. After four months of operation including an instrument move, the multichannel analyzer developed a marginal failure in the adder circuit as well as several tube failures and a power supply failure. Repairs have been affected, and a major chassis realignment has been completed.

Initial checkout of the new Argonne neutron chamber shows that the calibration source has been spread inside the chamber to such an extent that the chamber is not usable in its present condition. Initial checkout procedure is under way on the original Argonne chamber which is now vacuum tight, and results to date indicate that the chamber is usable.

Design and Component Testing

NPR Charge Machine. The order for a prototype magazine has been placed. Work orders were issued for fabrication of one transfer arm assembly, one idler roll assembly and the power roll assembly. Design of the magazine positioning assembly is 65% complete.

B. WEAPONS - 3000 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 - 4000 PROGRAM

1. PLUTONIUM RECYCLE PROGRAM

Plutonium Fuels Development

PRTR Fuel Fabrication. The first 30 elements for critical testing of the PRTR are currently being etched and autoclaved. The etch facility was activated, and rods were etched before acid leaks developed in the system which necessitated a shutdown for repairs. Twelve of these rods were autoclaved at 400 C and 1000 psi for 48 to 92 hours, but three of these were rejected due to acid staining. The acid staining appears to be caused by high surface temperatures attained in the semi-static etch tank. By increasing the agitation rate and decreasing the etch rate, the problem seems to be minimized.

Preparations are well advanced for refabrication of these elements for PRTR power operation. This design (Mark I-H) utilizes the 0.035 inch wall Zircaloy-4 tubing currently on order and scheduled for delivery in July. Refabrication is required due to the seriously cracked condition of the Zircaloy-2 tubing available for the original fabrication. In addition, the refabrication allows the incorporation of the latest development results: increased tube wall thickness to reduce collapse under reactor coolant pressure which causes damage on thermal cycling and possible change of core alloy to improve separations problems.

Fabrication Development. The pneumatic injection casting equipment being developed for fabricating PRTR fuel elements will not consistently produce castings over 90% density. The porosity that exists in the castings is not evenly distributed throughout the fuel rods so that the in-pile heat generation would not be uniform along the length of one-half inch diameter fuel elements. Various methods of heating and "hot topping" have been tried in an effort to feed shrinkage porosity in one-half inch diameter fuel rod castings, but no satisfactory solution has been found.

Aluminum was injection cast into 89-inch long, 3/4 inch diameter, Zircaloy tubing that was flattened on a rolling mill to 1/4 inch by one inch cross section. Porosity was significantly reduced on the two castings that were made in the flattened tubing; however, the thickness of these elements was not uniform because the injection pressure expanded the 1/4 inch dimension of the cladding so that the inlet end was 1/8 inch thicker than the opposite end.

In another design that was tried the tube was not flattened all in the same plane, but the direction of flattening was rotated 90 degrees every five inches. This alleviated the swelling problem and could have

a beneficial effect on the thermal ratcheting difficulty experienced with round rods, since the tube shortened 5/8 inch after the aluminum solidified indicating that differential longitudinal expansion and contraction could be restrained when such a fuel element operated in a reactor. The radiographs of this casting revealed only two defects and no porosity at the junctures of the alternately flattened sections where it could be expected to be porous because of the larger cross section.

Thirty billets were cast for fuel fabrication; eleven were cast in steel molds to compare the amount on blistering in extruded rods between graphite and steel molds. Twelve other extrusion billets were cast with lower silicon contents to determine the minimum silicon concentration required to impart corrosion resistance to an Al - 1.8 w/o Pu alloy with the nickel level at 1.3 w/o. One alloy was cast with zirconium substituted for silicon, and two alloys were cast at a higher plutonium concentration. The corrosion resistance of these alloys will be evaluated after the rods are extruded.

Final fabrication of the Mark I-G end brackets for the PRTR loading is near completion. Distortion was held to a minimum by restraining the parts and sequence welding, the atmosphere was changed from helium to argon because it is much easier to weld manually in an argon atmosphere than in helium. Due to time consumed assembling the brackets, it is only possible to fabricate six brackets in an eight-hour period. The holding fixtures are used on each assembly.

Fuel Evaluation. The eleven-inch long Zircaloy clad, 3-rod cluster containing 1/2 inch diameter graphite lubricated Al-Pu rods which has been irradiated 17.5 days in the GEH-4 loop has been returned to Hanford for examination. Dimensionally, the element appears to be unaffected as a result of its irradiation, and no "crud" has formed on its surface. The heat transfer portions of the rods, however, have a mottled effect of light and dark areas. Perhaps this was caused by intermittent heat transfer contact between the core and cladding. Fission gas analysis will be conducted before the rods are sectioned.

The Zircaloy clad 3-rod Al-Pu cluster which has as much as nine mils gap between the core and cladding has been reinserted into the loop for an additional cycle of operation and the 42-inch long Zircaloy clad UO_2-PuO_2 element has been sent to the ETR for irradiation. An in-pile thermal cycling experiment of a 42-inch long 7-rod Zircaloy clad Al-Pu element is being proposed.

Radiometallurgical examination is continuing on the sixteen irradiated Al-Pu and Al - 12 w/o Si-Pu alloy capsules (GEH-14-5 through 12 and GEH-14-42 through 49). During decladding operations on the Al-Si-Pu alloy specimens, it was observed that mechanical and/or metallurgical bonding between the fuel core and the Zircaloy-2 end cap had occurred on an AlSi - 20 w/o Pu alloy capsule (GEH-14-49). The sample operated in the reactor with a maximum core temperature (calculated) of 897 F (481 C).

Facilities. The 30-ton mechanical compacting press has been checked out with the new dies. Some machine work will be necessary before the electric clutch and brake can be repaired in the hood.

The gas generating equipment for the hydrogen sintering furnaces has been started up and found to work satisfactorily. There is still a considerable amount of testing and modification necessary before the furnaces can be started up.

Work has been started on the loading hoods for the vibratory compactor. It is hoped that delivery of the vibration equipment will be made soon after the first of the fiscal year.

The modification of the gamma absorptometer to determine the density of full length oxide fuel rods is continuing. A feeding device has been built, and the lead cask holding the sensing unit is being modified to mount the uranium colliminator.

UO_2 Fuel Development

Fabrication Development. The "Magnetic Force" Resistance Butt Welder has been installed and trial operated. Various welding parameters are being investigated to find the optimum weld joint design and machine settings. Closures on 0.563 OD Zircaloy-2 clad fuel rods can be made by this process in air, vacuum, helium, or other atmospheres. The time of welding current flow is 1/60 of a second. Normal sequence of the machine theoretically would permit making approximately 250 closures per hour in an air atmosphere and 60 welds per hour in a vacuum or an inert atmosphere. The heat required for welding is generated by the electrical resistance of the material being welded. Zircaloy and stainless steels are amenable to the process because of their relatively high electrical resistance.

Zircaloy-2 clad, PRTR size fuel rods were swaged with lead as a core material to provide dummy fuel elements for in-reactor physics tests. These rods will be assembled into standard PRTR 19-rod fuel element clusters.

A density of 97.5 percent of the theoretical was obtained by compacting PWR type UO_2 in a Dynapak machine under conditions which resulted in a density of 99.4 percent with micronized UO_2. Compaction of the micronized UO_2 at the same pressures, but at room temperature, resulted in densities approximately 83 percent of the theoretical. Equipment is being assembled for resistance heating of stainless steel capsules for compaction experiments at higher temperatures.

Hot swaging of -100 mesh UO_2 in Inconel-X tubing at 1200 C resulted in a density increase of 11 percent of theoretical over that obtained by swaging at room temperature. The cladding was resistance heated through graphite contacts.

Twelve fuel elements were fabricated by vibrational compaction for measurements in the PCTR by Nuclear Physics Research. The UO_2 cores (Norton fused oxide) have a particle size composition of 60 w/o (-3 +20) mesh, 15 w/o (-35 +100) mesh, and 25 w/o (-200) mesh. The aluminum clad elements are 2.00" OD with a 0.035" wall thickness. Ten of the elements are 36" long, and two are 8' long. Similar elements clad in stainless steel will be fabricated.

Fuel elements consisting of a central column of undersized pellets, embedded in vibrationally compacted powder also are being investigated. Zircaloy-2 tubes, 0.505" ID, were loaded with sintered pellets, approximately 0.465" diameter. The pellets had a density of 94 percent T.D., and were badly chipped and cracked. Fused UO_2, consisting of 70 w/o (-35 +65) mesh and 30 w/o (-200) mesh, was added to the top of the column, and the assembly was vibrated on the Genisco-Savage moving coil vibrator at frequencies between 300 and 5000 cps. The bulk density of the UO_2 core was 93 percent of theoretical UO_2 density, and radiographs showed nearly perfect alignment of the pellets in the center of the rod, with the powder uniformly distributed and tightly packed around them. Capsules are being prepared for irradiation. One of the potential applications of this method is the fabrication of fuel elements containing mixed uranium and plutonium oxides in any predetermined geometric distribution.

The Genisco-Savage 750-pound force vibration system was transferred to the Radiometallurgy Building for fabrication studies of recycled, electrolytically reduced UO_2.

Corrosion Studies

Zircaloy Fretting Corrosion Tests. The first fretting test on Zircaloy-2 has been completed in CEP-2 at 316 C and pH 10. The system simulates a single PRTR rod with a Zr-2 circular spider suspended in a Zr-2 tube. The variables being studied are velocity, clearance between the spider and tube, vibration frequency of the system, and contact area. Several significant observations have been made:

1. With a 5-mil clearance, fretting has occurred on the spider and tube even without applied vibration.
2. Fretting is the same at 15 and 30 ft/sec flow velocity.
3. The oxide film does not prevent this fretting.
4. Fretting increases when the natural vibrations of the loop (from flow, pump vibration, etc.) are supplemented by additional sample vibration.
5. Penetrations after three weeks are estimated to be approximately one mil with no external vibration and one to two mils with an additional one cps vibration.

The test is being continued studying clearances of 20 mils and 50 mils and supplemental vibrations of three cps. Preliminary data indicate that clearances as large as 50 mils do not result in as severe fretting as smaller clearances and that fretting is more rapid at higher frequencies. It was observed that much more extensive penetration took place where a Zr-2 member was contacting the sharp threads of a set-screw than where larger contact areas were involved. In another test an eight-foot single-rod PRTR fuel element with the wire wrap cut at one end to simulate a broken wire was exposed for one week in pH 10, 300 C water. There were no signs of fretting on the fuel rod or wire.

Corrosion of PRTR Shroud Tubes. Plain and Stressed Coupons of 6061-T6 aluminum alloy have been exposed for a month to a flowing mixture of water vapor and helium at 305 C and atmospheric pressure. The water vapor is in equilibrium with water at 70 C. No highly localized corrosion has been observed, and no measurable weight gains have been obtained.

Cleaning of Aluminum Corrosion Specimens. An efficient cleaning method has been developed for aluminum corrosion specimens. Specimens exposed at temperatures from 130 to 300 C (including heat transfer surfaces) have been completely cleaned without significant loss of base metal. The method (described in HW-64483) involves heating of the specimens to 300-500 C, and subsequent cleaning in a solution of phosphoric acid, sodium dichromate, and acetic acid.

Structural Materials Development

PRTR Process Tube Monitoring. The Mark I prototype process tube monitoring equipment is being developed and assembled to inspect the process tubes in place in the reactor prior to power operation. Development testing of lens and lighting systems is proceeding with the aid of a rented TV camera. Delivery of an improved camera is promised for August 1. An ID measuring device employing differential transformers is being developed by PIRDO, and assembly of a test model has begun.

A mechanical device for accurately positioning the sensing head in the process tubes is essentially designed and procurement of this and other needed auxiliary equipment is in progress.

Mark II Process Tube Monitoring Development. In contrast to the Mark I monitor, the Mark II monitor must perform in a high intensity gamma radiation environment. In addition to TV viewing and ID measurement, devices will be developed to measure the wall thickness and gas gap and to detect flaws and hydrogen pickup.

Irradiation tests have been started to determine acceptable components for a television camera to operate in the high gamma field to be encountered in the PRTR. Little change in characteristics of vacuum tubes, other than browning of the glass envelope, was noted after

10^6 roentgens gamma radiation. Little change was noted after the same irradiation on a p-n-p and one n-p-n type transitor while another n-p-n type showed a 35% change in base conductance and resistance. The peak current on a tunnel diode decreased slightly after the same irradiation. Corning Glass Company purified fused silica appears to be the most suitable material for optical and lighting systems and vidicon face plates. Current information indicates that little darkening is encountered to at least 10^9 R total gamma. Samples have been ordered for comparative testing with ordinary and "non-darkening" "Crown" and "Flint" glass and ordinary fused silica.

Little change in characteristics have been noted after 10^8 R total gamma on barium titanate, lithium sulphate and quartz ultrasound transducer crystals for a Vidigage wall thickness tester. A special barium titanate crystal probe curved to fit the PRTR tube ID has been received from Branson Instrument Company for evaluation of wall thickness measurement from the inside using only water for ultrasound coupling.

Instrument Research and Development Operation is investigating the use of eddy current methods for measuring the insulating gas gap between the Zr-2 pressure tube and the Al shroud tube. Using a magnaflux circuit, it was demonstrated in a mockup of the Zr-2 pressure and shroud tube that the gap and changes in the gap could be detected. The signal output increases as the gap decreases, indicating the present experimental setup is more sensitive when the gap thickness is small.

KER Loop 1 Tube Examination. Two 15-inch tube samples were cut from the Zircaloy-2 tube irradiated in KER Loop 1 and delivered to the Radiometallurgy Laboratory. Thorough examination of the inner surface of sample #11 failed to show the pit defect reported in the in-pile borescope examination of the tube. Several spots which, prior to splitting of the tube sample, appeared to be pits were actually spots of crud deposit. The bottom half of the tube was generally covered with a reddish film while the film in the upper half was more spotty and localized. A full cross section of the tube is being examined by metallography. To facilitate handling, polishing, etc., the cross section has been cut into six segments. One segment from the upper half of the tube has now been examined metallographically. It was found that recrystallization to the extent of more than 50% had occurred. At the extreme outer surface, very substantial grain growth had occurred. From examination of this one specimen, it is anticipated that recrystallization will be found in the entire cross section of this sample as further metallographic examination is carried out. In this one sample there was no metallographic evidence of hydriding. Examination for hydriding will be continued.

Zircaloy Sheath Tubing Evaluation. The first fifty-five 0.505-inch ID Zircaloy-2 sheath tubes from Order No. HOK-42400 for 200 tubes were inspected by Radiographic Testing Operation and the results reported. The vendor specifications for this order require outside surface Zyglo examination for acceptance and inside surface Zyglo examination for record only. Routine inspection at Hanford includes ultrasonic and

eddy current tests on a 100 percent basis and spot checking with Zyglo. During routine inspection at Hanford, all 55 tubes passed the eddy current test, 18 randomly-selected tubes passed inside surface Zyglo examination, 25 failed to pass the ultrasonic test, and five of the 25 also failed to pass the outside surface Zyglo examination. These five tubes will be returned to the vendor for credit since they should have been rejected by the vendor.

Failure of the Zyglo test to correlate with the ultrasonic test was traced to the presence of a surface film of oil or grease which prevented the fluorescent dye from entering the surface defects. This information has been fed back to the vendor for remedial action on further shipments.

Radiometallurgy Laboratory Studies

Services, equipment, and additional shielding are being installed in the decontamination cell for fabrication of fuel rods from partially decontaminated, electrodeposited UO_2 (RM-328). Examination of Zircaloy clad Pu-Al rods showed aluminum diffusion into the cladding and hydriding of the Zircaloy (RM-658). Internal pressure distorted but did not rupture the end cap of a swaged UO_2 capsule. A large quantity of fission gas was withdrawn from the capsule (RM-607). A purposely defected, swaged UO_2 capsule was examined to determine hydriding of the Zr-2 cladding. Hydride concentration appears to 50 ppm two inches from the hole but only 10 ppm at the hole (RM-605). The cause of failure of a UO_2 rod-and-tube element was found to be reaction between Zr-2 and UO_2 at the site of localized heating (RM-601). Complete sintering and some relocation of the fuel was revealed by examination of a UO_2-PuO_2 capsule (RM-653).

Results and interpretations of these examinations will be reported in more detail in connection with the respective development programs of Fuels Development and Plutonium Metallurgy Operations.

Thermal Hydraulic Studies

Problems of a Small Leak Downstream of the Orifice in a PRTR Process Tube. A small leak downstream of the orifice of a PRTR process tube would significantly reduce the flow past the fuel element without causing a significant increase in the flow through the flow monitor. Protection against flows which might cause boiling burnout by means of a high flow trip would be questionable under conditions of original design. The decision has been made to revise the supply characteristics to make a high flow trip feasible. Elimination of the conservatism of the original analysis of this problem reveals that if the ring header to ring header pressure drop were decreased by 20 pounds and the tube inlet orifice revised to provide about a 28 psi frictional pressure drop, a high flow trip of 110% would provide adequate protection. The decrease in the ring header to ring header pressure will be accomplished by trimming the primary pump impellers. However, since the conservatism of the original analysis has

been eliminated, namely in the discharge piping two-phase pressure drop calculations, experiments will be made to confirm the degree of protection obtained.

PRTR Project Management and Design

Phase III PRTR Contract. The Phase III contractor is estimated to be about 88% completed as of June 1, 1960, versus a scheduled 95% based on a contract completion date of June 24, 1960. Over-all PRTR Project is estimated to be about 91% completed versus a scheduled 93% based on the revised project estimate.

Installation of the reflector vent line on the calandria was successfully completed, and the calandria was installed on May 6. The top primary shield was installed on May 13, and steel shot poured into the core region of the shield. No work was accomplished on fabrication of the reactor core from May 13 through May 23, as a result of the contractor not having the tools necessary to check the alignment of the top and bottom shields and the calandria.

Assembly of the fuel handler in the reactor building is about completed. Rail stops and limit switch brackets are being installed for the floor rails. It has been necessary to raise the cask to permit travel across the reactor hall floor, which is out of tolerance in a number of locations.

The acceptance tests on bow measurement, hydrostatic and leak testing of process tubes were completed during the month. Bow measurements and assembly of tubes and nozzles were completed.

The first river pump was tested and run-in for the six-hour period called for in the acceptance test. The power cable to the second pump was defective and failed during starting. A new cable is scheduled to be installed about May 25, at which time the pump will be run-in. The river pump-condenser facility should be turned over to GE shortly thereafter, at which time a 70-day run-in of these pumps will be started.

The Phase III contractor has installed the periscope support plate, the vertical shield, and the cover blocks in the Fuel Examination Facility. This completes the installation of the shielding obtained from Mosler Safe.

The contractor continued installation and fitup of piping in the various flow systems. It appears that his prefabrication methods are causing some difficulties in matching the as-built locations of the vessel nozzles. This is particularly true in the primary system between the pumps, HX-1, and pressurizer.

The rotating and stationary secondary shields have been prime coated and moved inside the containment vessel preparatory to closing the large construction opening in the containment vessel.

Assembly of inlet jumpers and of outlet ring header and jumper piping began. The outlet face mockup from 314 Building was loaned to the contractor to assist in set up of the outlet piping. Some bends having poor appearance are being checked for wall thickness ultrasonically.

Instrumentation and Control. Attempts are being made by the panel vendor to obtain replacement DC to AC inverters for power supplies to the Keithley amplifiers used in the containment system. The inverters originally supplied require 24 volts DC input; panel wiring provides 125-volt DC input.

To provide back-up in case the panel vendor fails in his attempt to obtain inverters operable on 125 volts DC, design has started on a 24-volt DC power supply with battery back-up. In the meantime, a temporary line will be provided supplying 115 volts AC to the amplifiers. This will permit operation of the amplifiers during ATR's and will

Load-Out Cask. The vendor resubmitted the cask drawings with the requested changes incorporated. The drawings were approved and returned to the vendor. Fabrication has been started but is proceeding slowly. Expediting has been asked to take the steps necessary to insure meeting the mid-June delivery date. An estimate of $2,150 was received from Minor Construction for decking the load-out cask trailer and mounting the heat exchanger and cask saddles on the trailer.

PRP Critical Facility (Project CAH-842). The bid package for the building was completed and forwarded to the AEC for inclusion in the Maintenance and Mockup bid package.

The development work required on the adjustable weir, the control and safety rods, the thimble tubes, and the source positioner has been started.

An addendum clarifying the lock specifications has been prepared and is being circulated for approval. Design of the thimble tube recirculating coolant loop is under way.

Fuel Element Rupture Test Facility (Project CAH-867). The revised project proposal, HW-64309, which requests total funds, has received approval at HAPO and has been forwarded to Washington for Atomic Energy Commission action.

The test of the design criteria is being routed for approval. Preliminary procurement specifications for various special items of equipment, such as circulating pumps, regenerative heat exchanger, and cooling heat exchangers, are being prepared to facilitate rapid action when funds are authorized for the project.

Work on transient analyses has continued. The objectives of these studies are to determine the behavior of the system during various disturbances and the effectiveness of convective circulation of coolant after total power failure.

Several methods for cooling a stuck and ruptured fuel element are being investigated. These methods provide for cooling the fuel element indefinitely and provide a backup for the normal transfer cooling time of one-half hour. The methods under consideration all modify the juggernaught to feed water into the top of the test section.

Design and Component Testing

Design Test PR-1 - Discharge Operation Mockup. The design of the revised shroud assembly for the PRTR fueling vehicle was completed.

PR-10 - Primary Loop Mockup. PRTR primary process pump No. 352471, which required 52 oz-in balance correction on the flywheel on April 23, required only three oz-in correction on April 27, when it was reassembled after inspection of the mechanical seals. The change in imbalance was probably due to looseness in bearing fits or flywheel core.

A hot test of 68 hours on pump No. 352471 was completed on May 2. Vibration of the pump shaft and pump case during this test was two mils and 0.2 mil, respectively. Inspection of the seals following this test indicated some overheating of the seal faces.

All four primary process pumps are now at the Byron-Jackson factory undergoing the following modifications:

1. Double the moment of inertia of the flywheels.
2. Trim the impellers to reduce the head 20 psi at 4200 gpm and a specific gravity of 0.873.
3. Improve the fit between the shaft and the flywheel core, impeller core and bearing races.
4. Change the radial bearing to a thrust bearing with a 10^{o} contact angle. The thrust bearing will be preloaded downward with 1000 pounds spring pressure.
5. Rebalance each pump assembly.

The prototype process pump was disassembled for inspection on April 27, after completing 3685 hours of operation including 66 starts. The high pressure seal was in excellent condition with 86 mils of raised face height remaining on the carbon face. The leak rate prior to disassembly of this seal was 0.1 gph at equilibrium operation.

The pump was reassembled on May 12, using a new self-adjusting seal assembly which breaks the pressure down across two sets of faces. A 100-hour hot test on this assembly was completed on May 16. Leakage during this test was 3 to 3.5 gph. The pump seal was disassembled for inspection following the hot test and was found to be in excellent condition. The pump was reassembled with no relapping of seals and has since operated 162 hours. Leak rate has now decreased to 1.3 gph.

The R/M Vee-Flex packing rings, Style # R/M 1204, installed on the small capacity Aldrich pump, have operated 360 hours with a very small leak rate.

Process tube #6063 was re-installed in the single tube prototype loop and was operated for 255 hours and six thermal cycles during the month. Total operation for tube #6063 at simulated reactor conditions is now 2255 hours.

The nozzle-to-process tube (NTPT) seal of the single tube prototype operated for 255 hours during the month with an average leakage of 2.2 ml/hr. This seal was made without shimming, and no apparent reason has been found for the high leak rate. A new gasket has been installed in this location.

The special NTPT test piece was operated for 350 hours at 500 F and 33 temperature cycles. Two gaskets were tested with shimming and two without shimming. Leak rate for the unshimmed gaskets averaged less than 0.2 ml/hr. Leak rate for the shimmed gaskets continued to be excessive, ranging from one to ten ml/hr and became progressively worse with increase in operating time and temperature cycles. Bolt loading of the gasket did not change during these tests. Evaluation of the shimmed gasket seal will continue.

Nozzle cap seal experience improved during the month; however, this seal is not yet considered reliable. The cap plugs of the single tube prototype and the flexure loop test nozzle were modified by relieving the gasket inner retaining ledge. Two gasket seals were evaluated on each nozzle. The first seal on the single tube prototype leaked at a rate of 20 ml/hr. This seal was again modified which resulted in a leak rate of 1.5 ml/hr for 200 hours of operation. The first gasket seal on the flexure loop test nozzle operated for 350 hours and 35 temperature cycles with a leak rate of 0.2 ml/hr. The second gasket seal operated for 210 hours and 20 temperature cycles with a leak rate of 0.4 ml/hr. A redesigned cap plug incorporating a wider gasket has been fabricated for use in the single tube prototype nozzle.

PR-40 - Shim Control Mockup. Operation of the corrosion test mockup continued during the month.

A new motor, replacing the one which failed last month, was received from the vendor. This motor was placed on test and failed electrically after about three hours of operation. An order has been placed with Western Gear for four motors for test and evaluation. Delivery is scheduled for June 25.

The four assemblies received from APED have been tested, and one had a short from the common limit switch terminal to ground. This defect is being repaired. The other assemblies operated satisfactorily.

APED has thirteen additional drives in various stages of final assembly and testing. These thirteen drives are scheduled for shipment by June 6. Completion of the last seven drives is contingent on replacement motors. Delivery of these motors is being expedited. One motor, which was here for testing, has been shipped to APED.

PR-70 - Helium Compressor Test. Testing of the oil make-up pump continued during the month.

PR-80 - Air Cooling Duct Test. Final testing of the air ducts was completed, and operation of both ducts was satisfactory.

Special Tools. Fabrication of the load-out cask pin and hanger remover has been completed. Initial tests indicate that the design is feasible. Fabrication of a mockup to facilitate further testing was started.

Modification of the push rods for the fuel element extractor was started.

Procurement of components and material for development of the shroud tube removal tools was started.

Drawings for the nozzle elbow cut-off saw were issued for comment.

Electrical Structural Opening Sealers. The final report, HW-64972, was issued.

PRTR Process Instruments. Orders were placed for the precision servo-manometer for accurate measurement of the height of the PRTR moderator and for the fuel element temperature detectors for the Fuel Examination Facility.

Design Analysis

PRTR Safeguards Analyses. Analyses presented in HW-61236 SUP1, which was written to describe actions taken and provide information with respect to the ACRS comments on PRTR, were discussed with the PRTR Sub-Committee of the ACRS and personnel of the Hazards Evaluation Branch, AEC, on May 4, in Washington. No objections were raised to the actions indicated or the information presented in regard to the ACRS comments. The proposed changes in the limits for exhaust air activity and reactor thermal power were accepted.

The PRTR Sub-Committee, ACRS, recommended that further consideration be given to the installation of a particulate filter in the ventilation exhaust air stream. Further, they recommended that the process tube flow monitor system be revised to provide safety circuit trip protection for process tube leaks in the range of 65 to 108 gpm. It had been proposed that safety circuit trips to protect against the consequences of 65 to 108 gpm process tube leaks be initiated by pressure switches in the reactor dry gas system and the lower access space when the pressure increased in these locations as a result of process tube leaks. As indicated in HW-61236 SUP1, the present tube orifice design restricts the flow increase resulting from a process tube leak sufficiently to prevent a high flow trip unless the process tube leak is greater than 108 gpm. It is now planned to reduce the excess dynamic head of the primary coolant upstream of the venturis so that a process tube leak of 65 gpm or greater will result in a safety circuit trip. Process tube leaks less than 65 gpm may result in bulk boiling but not in film boiling.

PRTR Startup Preparations. The Hazards and Restrictions Summary section for the PRTR Critical Test document was discussed with the Startup Council. Comments of the Council were incorporated, and the section prepared for final publication.

Writing of PRTR Process Specifications continued. Fifty percent of the Process Specifications have been written in rough draft form. Thirty percent have been rewritten in final form, incorporating comments of the PRTR Startup Council, and six specifications have been approved by the Council.

Individual test descriptions are being written for the power test phase of PRTR startup. A preliminary description of xenon poisoning measurements has been completed.

PRTR Process Tube Ruptures. Calculations were made to determine the flow transients following various size ruptures in a PRTR process tube. In each instance the rupture was assumed to occur at the base of the fuel element and the reactor was scrammed within about one second following the rupture.

In making the calculation, the following sequence of events was assumed. After a rupture occurs, a steam-water mixture will discharge from the break. Dependent on the size of the rupture, flow will originate either from both ring headers or from only the bottom ring header. It was assumed that the primary pumps would operate normally until the pressurizer was voided. After the pressurizer was drained, the pumps were assumed to be vapor locked and no longer operable. The reactor coolant at this point was assumed to be stagnant. At this time flow to the break will be from both the headers for all rupture sizes with liquid or steam-water mixtures passing from both legs. The liquid in the heat exchanger, outlet 14" pipe, and top ring header is discharged through the process tube leg. Simultaneously, the inlet 14" line is being drained through the inlet jumper leg. When the entire outlet piping, heat exchanger, and one-half the top ring header had been drained, it was assumed that the affected process tube was "blown down". At this time pure steam will pass through the affected process tube. The system pressure begins to decay approximately when the pumps lock. The initial decay is primarily due to the expanding gas volume thus decreasing the helium partial pressure. The pressurizer pressure will drop from 1040 to about 800 psia during the time required to blow down the affected process tube. After the process tube is blown down, the pressure decay rate increases since the D_2O vapor pressure is also being reduced to create the necessary steam flow rate at the existing system pressure. After the process tube is blown down, the affected fuel element is cooled only by superheated steam until the system pressure decays to 100 psia and emergency light water injection begins.

Rupture sizes with equivalent diameters of 0.75", 1.12", and 1.98" were examined. Following a rupture the critical period occurs after the process tube is blown down. The critical process tube is dependent upon the size of the rupture. Large ruptures will allow large steam flow rates in the affected tube and thus prevent excessive fuel element temperature rises. The large steam flow may, however, cause the intact process tube fuel elements to become uncovered (due to loss of liquid coolant) and thus to experience excessive temperatures. A small rupture, on the other hand, will limit the steam flow in the affected tube and possibly cause high temperatures. The small leak rate will reduce the possibility of uncovering fuel elements in intact tubes.

The 1.98" hole size was examined to determine how long a time an intact process tube fuel element would remain uncovered. Assuming that only the steam flow discharging from the process tube leg is removed from

the reactor core inventory of D_2O, these calculations indicate that fuel elements in the intact tubes will not become uncovered before the system pressure decays to 100 psia. The steam flow rate in the affected process tube decreases to about 2.0 lb/sec. Since about a 0.2 lb/sec flow is adequate to maintain Pu-Al fuel element temperatures below 1200 F, the affected tube is more than adequately cooled.

Thus, it appears that large process tube ruptures do not lead to excessive fuel element temperatures. The 0.75" diameter case was calculated to determine the time available before steam flow over the affected fuel element becomes inadequate. For a rupture of this size, however, the total discharge rate decays to less than the makeup feed rate of 32 gpm, and hence before the steam flow rate becomes inadequate, the reactor core is filled and D_2O spills over into the affected process tube. In other words, a steam flow rate of less than 0.2 lb/sec in the affected process tube apparently will not occur.

Critical Facility Analyses. Analysis of the worth of control and safety rods in the PRPCF has been initiated. The variation of rod worth as a function of radius predicted by the IBM-709 Code RECON has been compared to the variation expected from the statistical weight distributions determined in multigroup calculations. This comparison reveals that the representation of statistical weight by $[J_0(\mu R)]^2$ as in RECON approximates very closely the exact weight $\phi\phi^*$. (μ is the major radial buckling, R is the radius, ϕ is the radial flux, and ϕ^* is the radial importance function).

Kinetics studies of the PRCF have been initiated in support of the hazards evaluation of the system. Data to be used in an analog study are being compiled.

Calculations of radiation dose rates for the final shield design of the Critical Facility are under way.

PRP Shielding Analysis. A review of the PRTRO list of potential sources of radiation was completed. This review resulted in a recommendation for shielding around the air filter on the PRTR fueling vehicle when handling ruptured fuel elements.

The radiation dose rate at a point immediately outside the 26" and 12" steam line penetrations of the PRTR containment vessel was calculated to be in the range of 175 to 200 mr/hr during reactor operation. It was recommended that seven inches of steel shielding be provided for these penetrations.

PRP Physics Analyses. The S-4 One Group Transport Cylindrical Cell Code has been prepared for use, and a document concerning the code has been published as HW-65031.

Reactivity and moderator level change versus reactor period have been recalculated using revised delayed neutron fraction values. The results

Moderator at	Step Level Increase of		
Half Level (55")	1/2"	1"	1.5"
Period (sec)	16.6	3.8	2
Reactivity (mk)	1.72	3.44	5.16
Three-Quarter Level (83")			
Period (sec)	78.0	28.0	13.2
Reactivity (mk)	0.65	1.3	1.95
Full Level (106")			
Period (sec)	> 200	104	61
Reactivity (mk)	-	0.525	0.788

Work on two dimensional analysis of the PRTR core is continuing. This work is to be performed with the 709 ANGIE Code.

Consideration was given to the reactivity effect of increasing the Ni and decreasing the Si content alloying aluminum in Pu-Al fuel because of chemical processing problems with Si in the present alloy. Based on a previous analysis, the effect of doubling the present Ni content (from about 1.3 to 2.4 percent) was estimated to result in an additional reactivity loss of about five milli-k. This can be compensated by the addition of one spike element.

Heat generation and reactivity studies of two 7-rod cluster fuel element configurations were completed at the request of Plutonium Metallurgy Operation. In one case each fuel rod contained a center region of depleted UO_2 surrounded by a mixture of PuO_2 and natural UO_2 (0.35 w/o PuO_2). For the second case each rod contained a center region of MgO surrounded by a similar PuO_2-UO_2 mixture. Heat generation calculations were also made for several cases of solid PuO_2 cores of varying rod diameters and densities, surrounded by MgO. This work was performed utilizing the IDIOT and S-4 computer codes.

Plutonium Fabrication Pilot Plant

The project is estimated to be 96% complete.

Construction work on the oxide fuel line is complete. The sintering furnace gas system was placed in full operation with the aid of vendor representatives. Startup work on the sintering furnaces is under way.

Mr. Gunther Von Elbe of Combustion and Explosives Research, Inc., visited the plant as an operations safety consultant. He inspected the furnaces and the furnace gas system and discussed the testing, startup, and operation of the furnaces with operations and project personnel. He will present a report within a few weeks, probably before introduction of hydrogen into the furnaces.

Construction work on the second floor, with the exception of painting the corridor floor, was completed. The plaster partitions have been left unpainted due to lack of project funds.

The 20-inch rolling mill was received May 9. It was set and leveled, the base was grouted, and work on the electrical connections was under way at month's end.

Installation of the cryolite reduction furnace and hood was completed. All of the concrete block partitions and building wall panels were completed and plastered. Painting of these plaster panels will depend on the availability of project funds.

PRTR Operations Planning

Pre-Startup Activities. Seven operating procedures were issued during the month. Seven additional procedures will be issued in June. The remaining eight procedures will be written when sufficient BPF or design information is available.

The first shipment of heavy water, 85,000 pounds, was received at month-end.

In response to a request of PRTRO, Operations Research and Synthesis personnel reviewed the statistical accuracy of the heavy water liquid level instrumentstion. The analysis revealed that there is little statistical value in performing two volume determinations on each of the three heavy water systems. Accordingly, a recommendation was made to the PRTR Startup Council to eliminate Design Tests 41, 42, and 43 from the Design Test Schedule. These tests pertain to light water volume determinations of the three heavy water systems.

Approximately 50% of the PRTRO analytical equipment was received during the month. It will be used for training purposes until needed for process analysis.

The PRTR Electrical Manual was issued to interested PRP personnel. The manual will be used in the electrical system training program being conducted by PRTRO engineers for the engineering assistants and technicians.

Stock Adjustment Requests have been prepared for all spare parts considered to be of a high-priority nature. A number of bids have been reviewed and orders placed. Purchasing has been asked to expedite the parts order for the Hofer High Pressure Helium Compressors.

Liaison is in progress with Facilities Engineering Operation who will coordinate "Third Party" inspection and pressure vessel review for PRTRO.

Startup Tests. All design tests, except the light water injection system test, have been submitted for final operational and design review. The light water injection test is being withheld pending final design of the system. Design of the auxiliary heating system for hot tests of the moderator, reflector, top and bottom shield coolant systems is complete. Procurement of the electrical heaters and other components has been initiated.

Rough drafts of six of the anticipated 33 power tests were reviewed, including Xenon Poison, Fuel Element Rupture, Pilot Tube, Heavy Water Quantity and Quality, Reactor Heat-Up and Cool-Down, and Equipment Malfunctions.

PRTR Training Program. The general written qualification examination on the reactor and its systems was taken by thirty-one members of PRTRO. In addition, four persons took the written examination on the automatic controller, reactor safety systems and other operational features of the reactor. To date, all persons who have taken the examinations have demonstrated they have excellent comprehension of the reactor and its systems.

Training efforts continue with extensive review of piping systems, operating procedures, control room panel discussions and study of shut-down and alarm annunciators.

2. PLUTONIUM CERAMICS RESEARCH

Experiments during the past month on plutonium carbides have been directed toward obtaining data on the kinetics of the reaction

$$PuO_2 + C \longrightarrow PuC + CO$$

Indications are that the reaction begins with a slight evolution of gas at about 850 C. With increased temperatures, the rate of gas release increases parabolically and at 1500 C the reaction is extremely rapid. X-ray diffraction analyses have shown the reduction of PuO_2 and conversion to the carbide to be dependent on carbon content and temperature. The following phases were present after 1.5 hours at 1575 C in vacuo. The quantities of carbon represent that in the starting materials and are, respectively, 50%, 75%, and 100% of the carbon needed for stoichiometric PuC formation.

Pure PuO_2	PuO_2 + 50 a/o C	PuO_2 + 75 a/o C	PuO_2 + 100 a/o C
85% PuO_2	65% PuO_2	15% PuO_2	50% α Pu_2O_3
15% α Pu_2O_3	35% α Pu_2O_3	15% α Pu_2O_3	50% Pu_2C_3
		70% β Pu_2O_3	

From this experiment the reduction route appears to be
$PuO_2 \longrightarrow \alpha\text{-}Pu_2O_3 \longrightarrow \beta\ Pu_2O_3 \longrightarrow$ Pu carbide.
It is thought that the 50% Pu_2C_3 may have formed from β-Pu_2O_3.

This mechanism of oxide reduction and carbide formation has also been observed by heating, at constant time, to progressively higher temperatures. β-Pu_2O_3 is a close packed hexagonal structure with a_o = 3.827 Å and C_o = 6.027 Å. Very little PuC has been formed from PuO_2 and the major carbide phase is always Pu_2C_3. This is probably the result of poor temperature control with the large induction coil, since the Pu_2C_3 formation at these carbon concentrations is the result of a peritectic decomposition. Single phase PuC has been formed, however, by the decomposition of PuH_3 at 1450 C in vacuum. The resulting cubic structure had a lattice parameter of 4.968 Å.

One conceivable method of determination of in-pile sintering and irradiated densities in ceramic materials might be structural hardness. A correlation between pre- and post-irradiated hardness of UO_2-PuO_2 pellets is thus being attempted. The following data were obtained on pre-irradiated sintered pieces with a Tukon (10 kg load) microhardness tester.

% Theoretical Density	UO_2	UO_2-60 PuO_2
67	140	90
71	180	--
73	--	245
76	230	--
77	--	125
81	--	325
85	355	--
91	700	--

When hardness is plotted versus density for each composition, a fairly uniform curve results with the exception of one point. For the case of pure UO_2, a very sharp hardness increase is seen between 85 and 91 percent of theoretical density. High density ($>$ 94% TD) pure PuO_2 pieces cracked under the 10 kg load, and it may be necessary to use a smaller load or different type of hardness test for these extremely brittle pieces. It is intended to obtain hardness data on capsules discharged from the MTR.

Examination of the 24 irradiated UO_2-PuO_2 high and low density capsules is in progress. A brief summary of the fission gas measurements obtained to date is as follows:

GEH-14 No.	19	21	90	83	87	88
UO_2-PuO_2,(a/o PuO_2)	0.0259	0.0259	0.0259	1.02	4.13	5.67
Pellet Type	MCO(1)	MCO	MM(2)	MM	MM	MM
% Theoretical Density	90	65	91	93	91	91
Fission Gas Analysis:						
K_r, (%)	2.8	1.23	< 0.1	< 0.1	0.19	< 0.01
X_e (%)	14.5	11.4	< 0.1	< 0.1	0.89	4.3
Fission Gas Release,%	23					
Burnout of Total Atoms, (a/o)	0.18	0.13	0.15	0.15	0.16	0.10
Calculated Initial Core Center Temp. (°F)	3400	1600	2300	3800	2500	3100
Central Void Formation	No	Yes				No

(1) MCO = Mixed crystal oxide (UO_2:PuO_2::5:1) diluted with natural UO_2.
(2) MM = Mechanical mixture of PuO_2 and natural UO_2.

Facilities. The thermal conductivity device and controls were moved and installed in the 308 Building during this period. An initial testing of the device showed that the recirculating pump contributed a significant amount of heat to the cooling system. Calculations showed that approximately 208.6 k-cal were added to the system at equilibrium conditions. This additional heat may necessitate some changes in the cooling system. Under the present conditions, the coolant temperature at equilibrium is approximately 53 C.

A BET surface area apparatus for measuring fine particle surface areas of plutonium-containing powders has been designed. The glassware components of the apparatus are 85% complete, and assembly awaits the completion of an open face hood and equipment rack. Other essential components such as vacuum pumps, furnaces, and a cathetometer have been received or are on requisition.

The Perkin-Elmer-Shell Model 212 sorptometer is being investigated. Perkin-Elmer literature maintains that this apparatus greatly simplifies apparatus requirements and significantly speeds analytic procedure. Although BET data are now the most widely accepted, the sorptometer may be a useful complement. Pricing and availability information has been requested.

3. URANIUM DIOXIDE FUELS RESEARCH

Fuel Evaluation. Swaged UO_2 capsules attained an estimated exposure of approximately 16,000 MWD/T in the MTR and ETR. Electrolytically reduced, vibrationally compacted UO_2 was successfully irradiated tc 3500 MWD/T at heat fluxes in excess of 1,250,000 BTU/hr/ft^2 at the Zircaloy-2 surface. No failures of swaged UO_2 fuel elements have occurred during irradiation.

The third in a series of tests of deliberately defected, swaged UO_2 fuel elements was completed at the MTR. A much higher concentration of fission products was observed in the coolant during this irradiation than during previous defect tests. The increased fission gas release is attributed to the use of more finely divided UO_2. The Zircaloy-4 clad element is being sectioned to determine the extent of hydriding.

To study higher operating temperatures for swaged UO_2 fuel, two 7-rod clusters have been fabricated with rod diameters of 0.906". Depleted UO_2 was swaged to 86 percent of theoretical density in the 0.032" wall 304 stainless steel cladding. The three-foot long clusters have a central rod with six rods positioned around it on a 2.062" diameter bolt circle. The clusters have been flow tested and are ready for irradiation in the ETR 6x9 loop.

A three-foot long, 7-rod cluster of UO_2 swaged in 0.030" wall Zircaloy-2 and Zircaloy-4 cladding has been fabricated for a defect test in the ETR. Two rods clad in Zircaloy-2 and two clad in Zircaloy-4 have been purposely defected with 0.005" diameter holes to study hydriding in the cladding and to gain more information on fission gas release under in-reactor rupture conditions. All rods complied with PRTR fuel standards before being defected.

A vibrationally compacted, Zircaloy-2 clad fuel assembly was discharged after 24 days of irradiation in an ETR loop at a coolant temperature of 524 F. The three-foot long, 7-rod cluster contained fused UO_2. The assembly will be returned for post-irradiation examination.

Basic Studies. The Newsletter No. 18, covering fundamental studies of uranium dioxide, was received from Harwell, duplicated, and distributed.

Detailed evaluation of electron microscope features, performance, and applicability to ceramic fuels research was completed. Performance and design characteristics lead to the conclusion that the JEM instrument can best fill our needs. Bids have been received.

The contract with BMI for continuation of thermal conductivity measurements of both irradiated and unirradiated UO_2 was reactivated. New specimens for unirradiated UO_2 measurements are being developed. Another in a series of UO_2 thermal conductivity specimens was removed from a Hanford reactor after approximately two years of irradiation; it will be sent to BMI.

Melting points 50 to 100 C higher than that of unirradiated UO_2 were determined in preliminary studies of irradiated UO_2 in a shielded, high temperature microscopy facility. Additional melting point determinations and other studies are continuing.

Samples of irradiated uranium dioxide have been shipped to Harwell, England, for fundamental studies. Similar samples have been used by Ceramic Fuels Development for thermal conductivity and fractography experiments.

4. BASIC SWELLING STUDIES

Irradiation Program

Construction and testing of two types of capsules have continued: one containing carefully precharacterized metallographic swelling specimens and the other containing general swelling specimens.

General swelling capsule #5 was assembled, successfully bench tested and shipped, along with control equipment, to the reactor in April but still awaits authority for charging. Capsule #4 is continuing to perform according to design expectation at a control temperature of 550 C. The internal spacers in these capsules have been redesigned to handle hollow, split, cylindrical specimens that will be irradiated in subsequent capsules of this type and components are being fabricated.

The split cylinders are about one-half inch in diameter, one-half inch long, and have a 0.030-inch wall thickness. Calculations indicate that the temperature gradient across the specimens would be less than 10 C in a flux of 10^{14} cm^{-2} sec^{-1}. Preliminary tests indicate that these specimens can be readily handled in the Radiometallurgy "Hot Lab" facilities with respect to density, metallography, hardness, etc. Due to the small size and the large surface area to volume ratio of these cylinders, there was some question as to whether high precision density determinations could be made. Accordingly, four specimens having weights greater than 2.1 grams and less than 5.5 grams, and having different geometries were subjected to critical density measurement to establish reliability limits. Three immersion liquids, H_2O, Hg, and tetrabromoethane were utilized for density measurements. Determinations in Hg give poor precision and accuracy; the precisions for tetrabromoethane are better than those for water as the immersion medium. For the 2.1-gram uranium hollow cylinder employed, the organic medium yielded a density value of 19.020 $\pm$ 0.060 g/cc with a 95 percent confidence limit. Tetrabromoethane will, therefore, be employed in density determinations for attainment of high precision and accuracy.

The three metallographic specimen swelling capsules that were assembled for the irradiation test all failed during bench tests conducted prior to shipment to the reactor. The failures were due to the internal heater connection shorting to the capsule wall as the capsules were heated. The capsule that was built to establish the validity of the heat transfer

calculations, operational characteristics, temperature and power limits, and cooling water requirements performed satisfactorily during bench testing as more clearance existed between the heater and capsule wall. New parts have been fabricated, and assembly is in progress on three more capsules.

Pore Size and Distribution. Optical and electron microscopy are being used as a direct means for determining the size and distribution of pores in irradiated uranium. Various applications of microscopy to irradiated and unirradiated uranium are being investigated.

A precharacterized metallographic specimen, one of a series of six irradiated in the MTR to burnups as high as 0.25 a/o at low temperatures, is being processed. This specimen, GEH-14-33, irradiated to a calculated burnup of 0.03 a/o at a maximum temperature of 200 C increased less than one percent in volume. The diameter of the cylindrical, 15-gram specimen increased from 0.5017 to 0.5030 inch, and its length remained the same. Optical microscopy on replicas of the specimen clearly shows evidence of extensive grain distortion and twinning on the free surface; original microhardness indents have been sheared and partially displaced within a grain, and Bierbaum microhardness scribe lines show nonlinearity at grain boundaries. Electron microscopy reveals no swelling pores with diameters greater than 500 Å. The next specimen to be examined will be GEH-14-37, irradiated to 0.07 a/o at a maximum temperature less than 200 C. Feasibility of bonding uranium to uranium by butt welding and by contacting a droplet of molten uranium with a cold clean surface of uranium is being studied. If a sharp narrow diffusion bond as revealed by differences in the uranium microstructure on either side of the bond can be achieved, then non-irradiated uranium will be bonded to irradiated uranium and the sandwich will be subjected to annealing studies. The purpose of this study is to establish the mobility of fission gases present in the irradiated portion of the couple into the non-irradiated portion. Six experimental couples are being sectioned and polished for metallographic analysis.

Specimens with a burnup of 0.29 and 0.41 a/o burnup, respectively, are being processed for short-term post-irradiation annealing studies to parallel previous longer term annealing studies. Statistical analysis of pore diameter frequency distributions in the annealed specimens is continuing.

5. IN-REACTOR MEASUREMENTS OF MECHANICAL PROPERTIES

This program has been initiated to determine the mechanical properties of structural materials during irradiation. Currently, the study of in-reactor creep properties of Zircaloy-2 is in progress. The specimen is annealed Zircaloy-2, and a duplicate specimen is being tested in the laboratory to provide a direct comparison with the in-reactor test. The test temperatures for both specimens have been raised since the last reported creep data from 500 F to 550 F (260 to 287 C), while holding the stress at 30,000 psi. An increase in rate in the creep of the

ex-reactor specimen was observed; the rate has increased from 1.5×10^{-7} to 1.5×10^{-6} in/in/hr. However, technical difficulties with the in-reactor instrumentation have not permitted any significant readings this month. The carrier current generator in the creep monitor for the in-reactor creep sensors slowly lost its output causing the readings to become erratic. The transducers are still satisfactory as determined by use of a second monitor. The condition in the monitor was caused by a resistor changing value and overloading the local oscillator. This condition was reported to the vendor, and corrective measures have been made on the instrumentation on the multi-ranged transducer monitors for the second generation capsules now on order.

A plant visit was made to the vendor's plant to observe the construction of the capsules and to check on the methods and calculations of the heat transfer within the capsule. The construction is proceeding on schedule, and delivery should be made during the month of June. These capsules are expected to be more reliable than the prototype now in use.

The design is being prepared for a capsule capable of operating in a vertical position in the ETR at Arco, Idaho. The major difference in the capsules is the smaller size required for an ETR instrumented irradiation.

6. GAS-GRAPHITE STUDIES

EGCR Graphite Irradiation Tests

The irradiation capsule for the third GETR experiment has been completed and was installed during the Cycle 13 shutdown about May 20. This capsule contains graphite similar to the type to be used in the EGCR.

EGCR Combustion Hazard

At the request of the AEC, the basis for predicting ignition temperatures in the event of air leakage into the EGCR was reviewed. The Hanford analysis indicates that combustion temperatures will be lower than those previously predicted by Allis-Chalmers. The ignition temperatures under EGCR transient conditions have not yet been computed, but the A-C computer procedure is being modified to run calculations based on predicted oxidation rates.

Small-scale laboratory experiments on the combustion of graphite in oxygen are currently being used to check critical assumptions in the oxidation rate calculation. The full scale EGCR burning prototype is scheduled to be completed in about three weeks and will be immediately utilized to test the equations for predicting ignition temperatures.

Graphite Oxidation by Oxygen

Oxidation studies on CSF graphite at temperatures of 550 C to 700 C indicate a zero order reaction with respect to oxygen in that range. Rates

in air are within experimental error of those observed in pure oxygen. An activation energy of 48 kcal/mole was noted. The order of the reaction of graphite with oxygen is subject to some controversy and enters into the calculation of ignition temperatures.

Gas-Graphite Capsule Irradiations

Four capsules filled with pure CO_2 to pressures of 246, 276, 489, and 626 psig were discharged from a Hanford reactor, and examination of these samples has been started. Mass spectrometric analysis of the gas in one capsule shows 90 percent CO_2 and seven percent mass number 28 (CO or N_2). The graphite sample and the walls of the capsule were deposited with a dark-black, sooty material.

Microwave Studies

A microwave glow discharge was established in CO_2 at pressures of 175, 300, and 500 microns of mercury. At each pressure, input power levels of: 63, 94, and 125 watts r.f. were used. The glow discharge cell was positioned in front of a 50-micron input slit on a Jarrel-Ash, diffraction-grating emission spectrograph and ion spectra were photographed. Identification of characteristic lines is being made.

Fourier Analysis of X-Ray Diffraction Lines

During the annealing of high temperature irradiated graphite, it appears that the x-ray diffraction line shape is affected more significantly than the line position. It is worthwhile to attempt a more careful analysis of the changes in line shape during annealing since further insight into the state of the damaged graphite might be gained. One technique, which can be used, is the Fourier analysis of the diffraction lines. A 709 computer program designed to yield the values of the complex Fourier component, corrected for instrumental broadening in the manner of Stokes/Proc. Phys. Soc. (London) 61, 382, (1942)/ has been completed by Data Processing. Since a general formulation was made, the program is not restricted to the analysis of any particular material.

Pyrolytic Graphite

A number of pyrolytic graphite samples, obtained from GERL as part of HAPO Contract ATH-HL0-3-60, have been characterized by x-ray measurements and are being prepared for irradiation. A range of C_c lattice spacings was found from 6.704 Å, a value characteristic of natural flake graphite, to 6.89 Å, which would be characteristic of highly damaged graphite. Apparent crystallite sizes ranged from 40 Å to greater than 2000 Å. These extremes were exhibited on materials from a single deposit; one having been heat treated to 3000 C. Since the two materials are identically made except for heat treatment, the analysis of the behavior of the materials under high temperature irradiation should be simplified.

Graphite Coatings

Coated samples of graphite and coating-base graphite samples have been discharged after several thousand MWD/AT at high temperature. The coated samples which include representative materials from three different manufacturers were visually inspected. The SiC coatings appear to be in very good condition with no change in general appearance and no large cracks or blisters. These samples will next be exposed to flowing air at 1000 C. Prior to irradiation, the same test was run to check for coating integrity.

Thermal cycling of unirradiated SiC coated graphites has been started at a rate of approximately six cycles/hour over the range of 200 C to 1000 C. Two samples have been run to date, and there appears to be no damage to the SiC coatings.

Gas Loop Project Management and Design (Project CAH-822).

The Phase "C" portion of the pressurized gas cooled loop (loop services and interconnections) was awarded to J. A. Jones in the amount of $85,905. Specifications for Phase "D" bid assembly (installation of the loop equipment) were completed during the month.

Fabrication of the first in-reactor test section is approximately 75% complete. All component parts have been machined, and assembly welding is in progress. Pressure tube for this section is Inconel. The second test section is scheduled for completion by June 30, and will have a Hastelloy-X pressure tube.

Fabrication of the Phase "A" package by Struthers-Wells is approximately 95% complete. The one-half inch Hastelloy-X tubes for the electrical pre-heater have been partially rejected due to weld cracks, consequently delaying completion of this item. It is anticipated that one blower will be dispatched from Bristol-Siddeley to arrive at least three days ahead of loop testing, which is anticipated to commence about June 10. The first blower may subsequently be returned to England if additional performance testing of this blower is necessary.

Discharge cask drawings, revised as a result of comments on the first issue, have been reissued for comment.

Gas Loop Component Testing

Design of the assemblies for mounting the in-reactor section for testing was completed. Requisitions for mockup components were issued. Fabrication of the assemblies was started.

The gimbal bellows expansion joint failed in testing after 410 hours of operation which included 314 pressure, temperature, and flexure cycles. Failure occurred as two cracks, one in the root and one at the top of a convolution. A new bellows type gimbal joint has been installed in the furnace and testing has started.

The dome seal was extensively modified to improve the leak rate. The last assembly operated for 100 hours at 1500 F and 500 psig with a leak rate of 0.005 cu ft/day.

The nozzle closure test assembly for use with various types of gaskets continued to cause trouble. The cap was modified to use six hold-down bolts instead of three. Improved seal performance resulted but is still not adequate. A variety of spiral wound gaskets have been ordered for testing.

Gas Loop Design Analysis

The feasibility of using bottled helium gas as emergency back-up coolant in the gas-cooled loop was examined.

The total weight of helium required to maintain the shroud tube temperature below 600 F following the simultaneous loss of both the helium shroud coolant and the CO_2 primary coolant was determined. The proposed backup helium will enter at the top of the reactor into the process channel, make a single pass, and then exit at the bottom.

The largest helium supply will be required when the incident occurs during reactor shutdown while the loop coolant is maintained at a maximum 1500 F temperature and the maximum shroud tube temperature is 529 F. With these conditions at the time of the incident, about 130 pounds of backup helium will be required to maintain the shroud tube temperature below 600 F for the first hour. In these calculations the backup helium flow rate was assumed to be constant at 1000 lb/hr for the first 10 seconds. The flow rate then decayed exponentially to 100 lb/hr in five minutes. After five minutes, the flow rate was assumed constant at 100 lb/hr.

Further calculations indicate that if the incident occurred during full power reactor operation and with a 500 KW fuel element in the gas loop, the backup helium requirements are reduced to about 100 pounds for the first hour following the incident. Further calculations are in progress to determine the backup helium requirements if the helium is injected simultaneously into both the shroud annulus and the process channel.

A series of anticipated transient conditions are currently being set up on the Berkeley analogue computer. Results are not yet available.

Irradiation Effects on Nickel-Base Alloys for Gas-Cooled Loop Facility

Nickel-base alloys are being considered for use as in-reactor structural materials for the gas-cooled loop in the PRTR. Tensile specimens of Inconel, Inconel-702, Hastelloy-X, and Hastelloy R-235 have accumulated approximately two months of exposure of their respective three and six months of irradiations. Thin washer samples of several candidate alloys exposed for 30 days to reactor atmosphere and neutrons are being measured for weight gain and hardness change. Four additional alloys, Ferral

modified (an iron base-aluminum-chromium alloy), AISI 406 stainless, AISI 304L stainless, and AISI 316L stainless, will be irradiated for evaluation of changes in mechanical properties. Tensile specimens of these four alloys are being prepared for irradiation as the next phase of the program.

D. RADIATION EFFECTS OF METALS - 5000 PROGRAM

Radiation damage recovery is being studied for a number of metals, namely, copper, nickel, titanium, zirconium, iron, molybdenum, and type 347 stainless steel. Tensile properties, microhardness, electrical resistance, and x-ray diffraction spectra are being studied to determine the characteristics of recovery mechanisms. One hour isochronal annealing treatments at 25 C increments were extended from 575 to 675 C for molybdenum, from 225 to 300 C for iron and copper, and from 275 to 375 C for titanium. No significant changes have occurred since the last report. Isochronal annealing of zirconium and nickel specimens was terminated after annealing at 625 and 600 C, respectively. Other specimens of zirconium and nickel are now being prepared for isothermal annealing. Molybdenum specimens containing 0.066 w/o carbon were solution treated at 1700 C and artificially aged at 300 C for periods up to 24 hours. The lattice expansion produced upon solution treating corresponded to a solution of 0.008 w/o carbon at interstitial sites in the molybdenum lattice. After aging, increases were observed in lattice parameter, hardness, and (400) line width. This suggests that the hardening mechanism is much more complex than precipitation of carbon from solution. The material appeared to over-age after 16 hours at 300 C.

E. CUSTOMER WORK

Radiometallurgical Examinations

1.47% Enriched I & E Fuel Elements (RM-404). Two additional self-supported elements that had been exposed to some of the highest specific power levels were received for examination. Although these two pieces had been irradiated under very severe conditions, they appear to be in much better condition than the other elements examined previously in this test. There appears to be very little deterioration of the aluminum cladding on the outside. Examination of the core and bonding quality is progressing.

Examination of cracked Process Tubes from 105-H (RM-406). Examination of samples from the second transversely cracked process tube failure from 105-H was begun. A longitudinal section exposing the tube metal from interior to exterior was removed. The sample contained one crack which penetrated the tube wall and two cracks which began at the internal surface but did not extend completely through the wall thickness. Metallographic examination showed that the cracks had occurred along stress risers present in the tube. It was noted that other stress risers were present with no evidence of cracking.

Concrete Testing (RM-332). Concrete core samples from the dome of storage tank 241-A-103, 200 E Area have been received and prepared for compression testing.

Metallography Laboratories

Annealing of samples is in progress for the study of time and temperature effects on the grain structure of AlSi braze material. Tests just completed have shown the furnaces being used have less than ± 2 C variation between the indicating thermocouples and a sample in any position within the central working zones of the furnaces. These furnaces will be used to anneal samples at six different temperatures for times of from one to 100 days. Additional samples will be prepared in another facility for exposures of less than one day.

A chemical etch for removing Zircaloy-2 cladding from uranium is an acid mixture of about 20 volume percent hydrofluoric (48%) strength and 80 volume percent nitric acids. Zircaloy-2 cladding has been successfully removed from uranium samples with this acid mixture with very little attack of the uranium. The reaction starts easily at room temperature.

The results and interpretations of these and other metallographic examinations and electron microscopy work will be reported in connection with the respective research and development programs served.

Samples Processed During the Month:

Total Samples	464
Carbon Replicas	54
	518

Photographs:

Micrographs	332
Macrographs	46
Electron Micrographs	200
	578

Special Fabrications

To date, 288 fuel rods have been shipped to the Savannah River Laboratory. The coextruded rods contain Al - 7.35 w/o Pu alloy and are clad with aluminum (X-8001 alloy). At the present time there are 369 pieces in the process stream, and they are distributed as follows:

93	cast fuel cores
4	extruded and straightened rods
193	rods ready for final etching and inspection
79	rods ready for shipment
369	rods total.

[redacted]

Of 515 rods subjected to the ultrasonic bond test, 453 (88%) were satisfactory. The specification calls for rejection of a rod if a non-bond area greater than 0.125 square inch is detected.

Contamination of fuel rod cladding with mercury has been noted on six to nine rods. Laboratory experiments have shown that four ppm Hg in the HNO_3-HF etching solution will produce rather uniform discoloration of the fuel rod cladding. To date, it has not been possible to duplicate the condition observed on the actual fuel rods. The contaminated rods each exhibit one spot only, and it is usually 1/32-1/16 inch in diameter and located fairly near the mid-section of the rod.

In the acid etching treatment of the finished rods, a preliminary 10% HNO_3 rinse followed by a running water rinse, has been included. This preliminary rinse has the purpose of dissolving any salts or mercury droplets which may have been the source of the mercury contamination in the past. The effectiveness of this pre-etch treatment is not truly known, but in the etching of the 102 rods this month, there were only four cases of suspected mercury contamination of the etched rods. Even in these four suspected cases, the etch baths were not mercury contaminated, as had previously occurred before the pre-etch rinse was started.

Two hundred forty-one Al - 7.4 w/o Pu billets were cast for coextrusion cladding in high exposure plutonium fuel fabrication process; twenty-six billets which were remelted were rejected for gas pockets. All billets were cast with both end configurations eliminating machining and scrap generation. The cut-off operation was eliminated by closer control of the tolerances on the mold and redesign of the cap.

The casting process is as follows: aluminum and plutonium are alloyed at 900 C for 20 minutes. The billets are cast at 760 C. The fire clay pouring cup is broken and the hot-top is clipped off with bolt cutters. Sharp edges and high spots are removed by filing. The billets are then ready for etching and assembly.

Two dummy billets of 1100 Al, representing the five-foot I & E element, were extruded using a tapered, floating mandrel and a streamline die with 90° entrance angle. The first billet was stopped halfway through the extrusion step and part of the extruded length and butt was sectioned and etched to reveal flow lines. The second billet was extruded to ~six feet in length. Measurements taken from radiographs of this element show the walls and annulus to be uniform along the full length. The extrusion is to be roller straightened and returned to radiography to determine any dimensional changes caused by straightening. Both of the extrusions exhibited smooth inner and outer surface finishes.

The design of a component billet, having a 8001 Al can and a C823 Al contoured core, was completed and is currently being fabricated, and the billet design for a 10-foot I & E extrusion has been prepared. Calculations for a three-shell pre-stressed container for this size billet are proceeding.

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PHYSICS AND INSTRUMENT RESEARCH AND DEVELOPMENT OPERATION

MONTHLY REPORT

MAY 1960

FISSIONABLE MATERIALS - 2000 PROGRAM

FUELS

Nuclear Safety in FPD

Nuclear safety calculations for 1.1% enriched NPR tube-in-tube fuel elements in water have been completed. Based on these calculations, the nuclear safety of the proposed autoclave facility in the 333 Building was evaluated and found to be acceptable; the results were submitted to Design and Projects.(1) FPD plans to install two rows of ten autoclaves at a spacing of six feet between rows and alternating four and six feet between autoclaves within each row.

Each autoclave is to be 14" I.D. by about 80" high and will have capacity for a total of 42 tube-in-tube fuel elements (three tiers, 14 fuel elements per tier). The nuclear safety calculations show that, a) the autoclave diameter is safe by 40%, b) the maximum autoclave loading (mass of uranium) is safe by 50%, and c) the spacing between autoclaves is safe by about 10% (based on solid angle-interaction formulations).

STUDIES RELATED TO PRESENT PRODUCTION REACTORS

Neutron Rethermalization Experiments

The analysis of traverses of the thermal activity of copper across a temperature discontinuity in graphite has continued. The objectives of this analysis have been to find the rethermalization cross sections of graphite which yield the best fits to the experimental traverses and to determine the sensitivity of the cross sections to the uncertainties in the assumed diffusion parameters. The rethermalization cross sections have been determined and the sensitivity tests have been started.

The experiment with no temperature discontinuity (293°K) was analyzed to yield the "best" diffusion parameters for use in the analysis of experiments with temperature discontinuities. A number of interesting results were found in this analysis. The fast flux could not be fit with single values for the slowing down cross section and diffusion coefficient in the experimental region. However, the objective in fitting the fast flux was simply to obtain the correct shape of the thermal neutron source, if necessary, by modification of any parameters which were not involved in the coupling between the fast and thermal fluxes. This was accomplished by introducing a negative absorption cross section for fast neutrons in the outer region and keeping the slowing down cross sections and fast diffusion coefficients equal in both regions.

The fit to the thermal flux was obtained by adjusting the thermal absorption cross section of the fuel region. The cadmium ratio was satisfied by changing the magni-

(1) Personal Communication, C. L. Brown to W. L. Hampson, May 11, 1960.

tude of the thermal flux only through adjustment of the slowing down cross sections. When the slowing down cross sections were changed, the inverse relaxation lengths established by the fit to the fast flux were held constant by adjustment of the fast diffusion coefficients. The fact that only the magnitude of the thermal flux changes with a change in the slowing down cross section is difficult to show for this problem using the normal boundary conditions of diffusion theory. However, an extension of some earlier work has shown this to be the case.

All of the diffusion parameters determined in the analysis of the room temperature experiment were employed in analysis of the remaining four experiments which had temperature discontinuities. Initial results were found by assuming the rethermalization cross sections were equal on both sides of the temperature discontinuity. These results are tabulated in Table I. These results do not yield the best fit to the experimental curves. In view of the latter, the restriction of equal rethermalization cross section was discarded and the vivariate iteration on unequal cross sections was carried out. The results are tabulated in Table II. These results are still to be considered preliminary. Only the low temperature set of data is expected to change appreciably.

This expected change is due to the temperature dependence of the diffusion coefficient for thermal neutrons. An approximate calculation indicates changes as large as 20% in going from 300°K down to 100°K. A single test analysis with an increased diffusion coefficient indicates a very large change in the rethermalization cross sections. Further investigation of this problem is underway.

TABLE I

RETHERMALIZATION CROSS SECTIONS EQUAL

Temperatures		Macroscopic Cross Sections Inner and Outer Regions
T_1	T_2	
°K	°K	10^{+3} cm^{-1}
144	283	2.75
523	299	22.0
690	308	30.0
803	323	35.0

TABLE II

RETHERMALIZATION CROSS SECTIONS NOT EQUAL

Temperatures		Macroscopic Cross Sections
Neutron Group °K	Graphite °K	10^{+3} cm^{-1}
144	283	16.5
283	144	2.13
523	299	20.7
299	523	26.0
690	308	33.0
308	690	22.8
803	323	33.3
323	803	46.5

Multimaxwellian Group Analysis

The computer code FIT-1 was operated without programmer assistance during much of May. In this period, it received heavy use in analyzing data from the rethermalization experiments. In the process, several minor bugs in the program were detected. These are being traced and the program is being "cleaned up" generally, in anticipation of the publication of a descriptive document.

Neutron Energy Spectrum Studies

Slowing Down Spectrum Program

Several test cases have been run successfully on the scattering kernel and spectrum codes from General Atomics which were described last month. The two codes are being combined for greater convenience and to facilitate the addition of a slowing down calculation, to be added soon.

3X Control Ball Reactivity Measurements

A study of different control ball materials has been started. The reactivity of several materials is being measured in the PCTR to establish the relative control strength of the materials in a 7-1/2" lattice. Some of these will be irradiated and then retested to determine how long it takes to burn out the poison.

Instrumentation and Systems Studies

A program to study transients due to loss of lithium has been prepared and will be placed on the EASE computer in early June.

An analog computer problem related to the present reactors was completed for IPD Reactor Physics Operation. It consisted of determining the amount of excess reactivity addition necessary to hold the reactor power level at some predetermined low level, differing from the normal operating level by factors of 1/1,000 and 1/10,000, following a scram.

A basic layout was made for a thousand-channel slow neutron time-of-flight analyzer. This is to be used in the neutron cross section program. It is expected that a magnetic drum for storage and plug-in transistor logic will be used.

The microvolt meter to be used as a null detector on the period measurement equipment for the critical mass lab arrived and was tested for noise and drift. It is much better than specifications. Actual construction has started, although a ten-turn exponential pot for interpolation has not yet arrived. This development is also being evaluated for reactor application.

STUDIES RELATED TO FUTURE PRODUCTION REACTORS

Exponential Pile Measurements of Large Diameter Fuel Elements

Final buckling values have been determined for a 6 foot by 8 foot exponential pile with a wet 2.5 x 2.0 and 1.66 x 1.1 inch fuel assembly at a lattice spacing of 8 3/8 inches. The results are shown in Table I.

TABLE I

Buckling $10^{-6}cm^{-2}$	λ^*(side-side) (inches)	λ^*(front-rear) (inches)	Source Position
-72	1.1	1.0	Split
-68	1.6	1.9	Clustered

*λ is the extrapolation length.

The uncertainty in the bucklings due to the uncertainty in the "least squares" fit is 4 microbucks for both measurements. The sources are placed at ($\pm$ a/4, 0) and (0, $\pm$ b/4) for the split source case, and $\pm$ 1 1/16 inches for the clustered source cases. The aluminum, water, and carbon to uranium volume ratios are, respectively: 0.493, 1.102 and 21.12. These bucklings agree reasonably well with the value $-64 \times 10^{-6}cm^{-2}$ determined in the 4' pile.

Preliminary buckling values are available for the same tube-in-tube assembly with H_2O coolant using an 8 foot by 8 foot exponential pile at a lattice spacing of 8 3/8 inches. An assumed extrapolation length of 1.0 inches both side-to-side and front-to-rear was used in the buckling calculations shown in Table II. Because of the limited number of tube-in-tube fuel elements a buffer region of 2.5 x 1.6 I and

E fuel elements was used to fill out the graphite lattice. The exponential pile was 10 lattice units high. The first one and the last two lattice units were buffer regions.

Vertical traverse data were taken first with the buffer fuel elements dry and then wet in order to achieve a better match to the neutron flux spectrum of the tube-in-tube fuel element and check the effect of a slight mismatch. With buffers wet, the buffers match the values of cadmium ratio, buckling and C/U ratio in the lattice.

TABLE II

Buffer Region	Buckling (10^{-6} cm^{-2})	Type of End Correction
Dry	-90 ± 2	2 region
Wet	-90 ± 3	2 region
Dry	-89 ± 2	1 region

Table III shows the constants characterizing the buffer and measurement regions.

TABLE III

Fuel Element	C/U Ratio	Cadmium Ratio	Buckling (10^{-6} cm^{-2})
2.5 x 1.6 dry buffer	21.47	17	-65
2.5 x 1.6 wet buffer	21.47	30	-70
2.5 x 2.0 wet with 1.66 x 1.1	21.12	29	-68*

*Clustered source case 6 ft. by 8 ft. pile.

As shown in Table II it appears to make no difference in the buckling measured whether the buffer region is wet or dry, or whether one or two region end corrections are used in the analysis of the data.

Horizontal traverses have been taken at several cell positions in the 8 x 8 foot pile. The results are given in Table IV.

All traverses were taken with the neutron sources split as defined above.

No reason has been found for the discrepancy of about 20 x 10^{-6} in bucklings measured in the 6 x 8 foot pile compared to the 8 x 8 foot pile listed in Table I and II.

TABLE IV

λ Inches	Cell Position
0.82 ± .14	Cell edge, fill layer, with fine structure correction.
0.84 ± .31	Cell edge, fill layer, under process tubes.
0.81 ±.18	Cell corner, fill layer.
0.64 ± .07	Cell edge, tube row.
0.79 ± .10	Radius of equivalent cylindrical cell (approximate)
1.16 ± .12	Front-to-rear.

PCTR Measurements of Lattice Parameters of Large Diameter Fuel Elements

The flux perturbations in cell components due to copper poison inserted for a k_∞ measurement has been calculated for the 2.5-inch diameter solid fuel element in a 10 1/2 inch lattice. The thermal flux distributions with and without absorber wrapped around the process tube were obtained from the P_3 part of the Idiot Code, for both the air and water-cooled cases. The perturbation has been studied to evaluate the effect of copper near the fuel, where the flux in the fuel and process tube might be depressed, since usually the copper is at the cell edge, depressing only the flux in the graphite. The following table lists the perturbation of the average flux in various components of the cell. The fluxes in all cases are normalized such that the average flux in the fuel is 1.0. The amount of copper in the cell corresponds to the estimated k_∞ of the lattice. The net effect of these perturbations on the inferred value of k_∞ is also given.

	Air Coolant	Water Coolant
k_{ex}	+0.049	+0.025
$(\Delta\phi\phi)_{\text{process tube}}$	-0.036	-0.006
$(\Delta\phi\phi)_{\text{coolant}}$	--	-0.003
$(\Delta\phi\phi)_{\text{graphite}}$	+0.066	+0.014
Effect in k_{ex}	-0.0035	-0.0006

Despite the magnitude of the flux perturbations, it is concluded that because of their small effect on k_∞, the most accurate procedure is to determine the changes with the P_3 program. However, the perturbation of the flux in the moderator will be checked by irradiating foils in the case with no coolant.

The program which was written to process lutetium foil data has been altered and presently uses saturated activities in determining the spectral index. A value

for the normalization factor which is dependent upon the counting system used has been determined, based on data collected from bare lutetium foils irradiated in the thermal column of the TTR.

The copper flux traverses taken in the 2.5" tube-and-tube elements are being analyzed using the P_3 code. The effective neutron temperature is being varied to determine cross sections to use in the code, attempting to fit the flux traverse. First, the spectral hardening in the fuel is calculated from blackness weighting the fuel cross section. Then the moderator neutron temperature required to fit the flux traverse is determined by iteration. For the three cases tested, the required neutron temperature ranges from 50 to 100°C above the physical temperature.

A first attempt to determine the neutron temperature distribution in the cell was made using the F_3 code with two thermal groups, one at 900°C and one at room temperature. Transfer between groups was defined by the rethermalization cross section for gaseous graphite. Although a reasonable weighted average temperature distribution was obtained, the diffusion treatment should not be expected to reproduce the flux depression in the fuel.

Rod Replacement Analysis

A version of the digital computer code for small source theory analysis has been completed for a specialized case. Work on the two group theory code for more general geometry has begun. Contact has been made with C. N. Klahr, of Technical Research Group, Inc., who is also investigating the use of small source theory. His group has prepared a digital computer code for a one-group version of small source theory in finite lattices. He reports the code is working but a minimum of six months will be needed before it will be in a form suitable for distribution.

A Program for Analyzing PCTR Data

The two elusive program errors in APDAC-I have been found and corrected. Since there are no known remaining errors in the program, it has been given full production status. A letter describing the production set up in detail is being prepared.

COMPUTATIONAL PROGRAMS AND SERVICES

AIM-5, a multigroup, one dimensional diffusion theory code from Atomics International, has been converted to the HAPO monitor system. AIM-5 allows up to 12 groups, 20 regions, and 239 space points, with downscattering from any group to any lower energy group. It calculates fluxes, adjoint fluxes, and multiplication factors. Criticality searches may be performed on any one of the following parameters: Critical radius, homogeneous poison, transverse buckling, location of a poison boundary, or location of a fuel boundary. The code has been run successfully on two sample cases.

PCTR Measurement for N-Reactor

Graphite for the mockup core has been shipped. Graphite for the condensed lattice core will be fabricated here. Delivery of the cladding is expected momentarily. Fuel delivery is not expected until July 1.

Instrumentation and Systems Studies

The basic fabrication of the mechanical portion of the NPR prototype fast-slow scan Fuel Element Rupture Detection System is completed and installed on the 329 Building experimental platform. The gear motors have been installed and the slip-ring brush assembly is completed and ready for installation. Test radioactive sources have been ordered and will be inserted after arrival. Development work continues on the necessary circuitry for the system, and the circuits will be assembled in prototype demonstration form when all tests are completed. The packaged three crystal detector probe for the fast-scan system was assembled and satisfactorily tested.

Completion of the tests on the prototype NPR Logarithmic (5 mr/hr to 5 r/hr) Scintillation Remote Area Monitor will be accomplished as soon as the necessary Corona regulator tubes are received. All other components are installed and the system was satisfactorily tested using a different power supply. The Corona regulator tubes will be used with a new less-expensive power supply modification.

The NPR prototype Linear Scintillation Remote Area Monitor is essentially completed including circuitry temperature tests which were satisfactory from 0°F to 130°F. The low-range (the system includes two separate ranges including separate probes and meters) cyclic alarming circuit was modified to incorporate a transistorized alarm-pulsing circuit. The low-level alarm, when activated, will energize a 1.0 kc oscillator with timing of one-second-on, one-second-off continually until the radiation field strength drops below the alarm set point. The low-level system automatically resets and no manual operation is required. The high-level alarm system requires manual reset for proper safety purposes.

All transistorized circuitry for the NPR prototype Scintillation Beta-Gamma Air Monitor was completed in design and satisfactorily bench-tested including temperature tests to +140°F. The circuits will now be fabricated in final form and the instrument assembled. The lead-shielded scintillation head is completed and is being sealed and assembled for use. The beta-gamma air monitor is completely transistorized with a logarithmic indication from 100 c/m to 10^6 c/m with a recorded output.

At the request of IPD Reactor Physics Operation, a study was made on the presently proposed systems for NPR coolant flow monitoring.

Studies were continued on the solutions of the reactor kinetic equations with sinusoidal excitation functions. The solutions obtained with the analog computer to date are not in good agreement with theory. It is expected that the discrepancies are partially due to computer parameter drifts in critical circuits but this needs to be investigated further. An attempt will be made to reduce the drift problem by improved scaling techniques. In addition, a similar set of equations whose exact solutions are known will be programmed on the computer as a check on the method of solution.

In preparing for 709 solutions, it has been found that very short time intervals are required for the step-by-step integration. It is thought that the presence of high order harmonics of appreciable amplitude might account for this.

Mechanism of Graphite Damage

The installation of the beam sweep equipment and the necessary alterations to the electron Van de Graaff were completed. The control circuitry was installed. The high voltage supply for the apparatus is still missing, but delivery is promised for early in June.

The new energy loss calorimeter was wired and vacuum tested. It is being installed in the water bath.

STUDIES RELATED TO SEPARATIONS PLANTS

Plutonium Critical Mass Facility

Completion of the work of the fixed price contractor on the Plutonium Critical Mass Facility has been scheduled for June 1. It appears that in general this schedule will be nearly met. All construction is complete and equipment installed. With two exceptions, all acceptance tests have been met. All service equipment has been tested and is operable. All fixtures are installed and operating.

Trouble has been encountered in placing the instrumentation and control system into service. To some extent this has been the result of minor fabrication errors as might be expected in a system of this size. There has, however, been an unusual number of errors made by the vendor in construction (wires omitted or crossed, etc.). This is particularly true of the electrical interlock system. The instrumentation has not been checked out as yet, but should be less prone to such difficulties.

The acceptance test for pressure containment of the reactor room has not been made. No known delays are anticipated in performing this test; however, if leaks exist there may be considerable difficulty and time involved in locating them.

Installation of the in-hood equipment for the startup experiments will be delayed until the latter part of June because of late delivery of the critical assembly components.

The control building proper may be accepted in the first week of June and operating personnel will be able to move in soon thereafter. Work will be limited primarily to familiarization with the equipment; little can be done directly relating to the initial experiments until the in-hood reactor equipment is installed.

Two of the four reactor vessels which were ordered have been received. The two vessels received were the 11 and 13 inch diameter cylinders which are to be used in the initial series of critical experiments with unreflected cylinders.

Measurement of k_∞ in the PCTR for Aqueous Pu Solution

For aqueous solutions or other homogeneous hydrogeneous mixtures, a quantity of special interest is the limiting concentration for which k_∞ becomes unity. Providing the H/X ratio can be maintained at values for which $k_\infty <$ unity no other restrictions will be required to insure nuclear safety. Experiments were conducted in the PCTR for determining the concentration at which k_∞ = unity for a plutonium nitrate solution.

Calculations had indicated the limiting Pu concentration to be between 8.5 and 9.5 gms Pu/liter. Initially the buffer tanks were filled with a solution containing 6.5 gms Pu/liter and the core tanks were filled with solutions containing 6.5, 7.5 and 8.5 gms Pu/liter. These mixtures were prepared, and the tanks filled and emptied, by Finished Product Operation, CPD. Previous experiments with 3% enriched UO_3 systems indicated that an accurate extrapolation of the limiting concentration could be obtained with the buffer tank this far from actual limiting concentration. The extrapolated value of the limiting concentration from the initial data was 10.8 gms Pu/liter. Since rather large quantities of stainless steel and polyethylene were used for containment of the solutions, and very little was known about the effect these materials might have on the measurements, more emphasis was placed on the theoretical calculations than on the experimental results and the concentration in the buffer tanks was raised only to 8.5 gms Pu/liter. The core tanks were then filled with solutions having 7.5, 8.5, 9.0 and 12.0 gms Pu/liter. The extrapolated value of the limiting concentration obtained from these solutions was 10.6 gms Pu/liter. A thorough investigation of the effects of the stainless steel and the polyethylene was then undertaken. The preliminary results of this investigation indicated there was essentially no effect on the measurements from the stainless steel and that there was only a slight effect from the polyethylene. The effect from the polyethylene is probably caused by a slight change in the neutron energy spectrum incident on the solution which results in a correction to the measured value of the limiting concentration of approximately 0.2 gm Pu/liter.

At this point a contamination incident occurred and it became necessary to halt the experiment.

The preliminary value of the limiting Pu concentration for which $k_\infty = 1$ for these plutonium nitrate solutions was therefore 10.4 gms Pu/liter. A preliminary chemical analysis indicated the solutions to be approximately 0.5 molar nitric acid solutions; the plutonium contained approximately 5% Pu-240.

The contamination incident, which potentially could have resulted in a very serious contamination problem, was minimized by careful monitoring procedures.

Exponential Pile Measurements with Natural Uranium Fuel Rods in Light Water

The series of exponential pile measurements with natural uranium fuel rods in light water was completed with the measurement of the 1.40-inch lattice spacing. The fuel rods, which were 0.925 inch in diameter and 44 inches in length, were encased in thin walled (1/32") Lucite tubes for insertion in the lattice assembly which contained 85 tubes in a hexagonal pattern. A buckling of zero was measured (k_∞ = unity) for the 1.40-inch lattice, which has an H_2O/U volume ratio of 1.37. From the plot of B^2 vs the H_2O/U volume ratio, the maximum buckling was estimated to be about $30 \times 10^{-6} cm^{-2}$ for an H_2O/U ratio of 1.6.

These measurements were undertaken in order to better evaluate the safe mass limits for natural uranium in light water, and also to obtain buckling values in connection with planned experiments involving a three percent enriched lattice reflected with a natural uranium tamper.

Criticality Studies in Support of Processing Power Reactor Fuels

Critical mass studies were continued in support of processing power reactor fuels with experimental work proceeding on both heterogeneous and homogeneous systems. The first critical approach experiments were made with the 0.925 inch diameter rods of 2 percent enrichment; measurements were made in water moderated lattices at five different H_2O/U volume ratios. The first measurements were made in the PCTR for determining k_∞ of 3 percent enriched uranyl nitrate mixtures; the H/U ratio of the initial mixture was, $\simeq 6$. Irradiations were made for determining the fast effect (ϵ), and the resonance escape probability (p) of this mixture.

a. Experiments with Heterogeneous Systems

The critical approach and exponential experiments which are planned with the 2 percent enriched uranium invclve fuel rods of two different diameters, 0.925 and 0.600 inch, and of two different lengths, 16 and 32 inches.

The critical approach measurements were completed for the 0.925 inch diameter rods of 16 inch length and measurements were begun with the 32-inch fuel rod length. The fuel rods were encased in thin walled (1/32") Lucite tubes for insertion in the lattice assemblies which were fully water reflected; a hexagonal pattern was used for the lattices. The results of these critical approach measurements are given in the following table.

CRITICAL MASS AND BUCKLING FOR 2.00 PERCENT U-235
0.925-INCH DIAMETER RODS

Lattice Spacing (Inches)	H_2O/U (volume ratio)	Critical No. of 16-inch Rods (cyl. geometry)	Critical Mass (cyl. Geometry)	Calculated Critical Mass (spherical geometry)	Critical, or Material Buckling (10^{-6} cm^{-2})
1.50	1.89	117.6	865 lbs. U	818 lbs. U	10,806
1.60	2.29	103.7	763 lbs. U	720 lbs. U	10,897
1.70	2.72	99.9	734 lbs. U	692 lbs. U	10,511
1.80	3.17	102.2	751 lbs. U	703 lbs. U	9,876
1.95	3.89	119.0	875 lbs. U	795 lbs. U	8,535

The critical number of rods was determined by a least square fit to the neutron multiplication data between 85 and 96 percent of the estimated critical number of rods. The above buckling values were calculated by assuming the extrapolation lengths (λ) to have the same values as those used for 3 percent enriched uranium of the same fuel rod diameter and H_2O/U ratio.

The minimum critical mass for the 0.925 inch fuel rods of 2 percent enrichment is ~ 690 lbs. of U which occurs at an H_2O/U volume ratio of ~ 2.8. This may be compared with the 3.06 percent enriched uranium rods of the same diameter which had a minimum mass of ~ 387 lbs. of U at an H_2O/U volume ratio of ~ 3.2.

b. Experiments with Homogeneous Systems

From the PCTR measurements, a preliminary value of k_∞ for a 3% enriched uranyl nitrate mixture with a nominal hydrogen-to-uranium atomic ratio of 6 is, 1.12. The effect of the nitrogen in these systems is clearly seen by the fact that for the same H/U atomic ratio, the value of k_∞ for a 3% enriched UO_3 mixture was, 1.34.

Critical Hazards Specifications

Nuclear Safety in HLO

a. The nuclear safety specifications for Hanford Laboratories, which are being prepared in accordance with HLO Nuclear Safety Bulletin No. 1, are about 72% complete.

b. The nuclear safety of the PRTR operation was reviewed and comments submitted to the Reactor and Fuels Research and Development Operation. This review was based on a study completed this month, in which more accurate nuclear safety parameters were established for the Al - 1.8 w/o Pu 19-rod cluster fuel elements in H_2O and D_2O. The previous study, made in March, 1959, was based primarily on calculations in which the fuel element clusters were treated as a homogeneous system of plutonium, alumimum and water; this approach was conservative and simplified calculations. The current study is not only supported by the critical mass experimental data obtained on Al-5 w/o Pu alloy rods in H_2O, but the calculations were made treating the 19-rod cluster as a multiregion system by use of the IBM-709 IDIOT computer code. The PRTR nuclear safety review included the storage and transfer basins, the primary coolant system, and the fuel transfer casks.

Data Correlation - Development of Nuclear Codes for Criticality Calculations

a. Calculation of Lattice Parameters for Uranium Rods in Water

An investigation of slightly enriched (1% to 3%) uranium, water moderated lattices is presently being carried out. The purpose of this study is to develop analytical techniques for predicting the critical size of similar lattices. Especially attracting attention is the inability to reproduce the critical size for 3% enriched uranium, water lattices. Errors on the order of 5000 μB exist in the calculations of the bucklings for the 3% metal by the usual simplified age-diffusion approximations. The major difficulty appears to be the nonescape probability for water moderated lattices, especially systems in which $\sim$40% of the fast neutrons are lost due to leakage. The usual age theory for evaluating the fast nonescape probability, $e^{-B^2\tau}$, while being quite good for over moderated graphite lattices, is especially inadequate in hydrogen moderated systems where the slowing down cannot be adequately accounted for by a continuous slowing down model.

A very complete experimental investigation of slightly enriched, water moderated lattices has been carried out at BNL by H. Kouts. The main emphasis in our study to date has been to reproduce the k_∞ values, as determined by Kouts in his analysis of the 0.600 inch rod experiments. When we are capable of reproduc-

ing the values of k_∞, then the major effort will be directed toward calculating the fast neutron leakage.

The 0.600 inch diameter rod, water moderated lattices have been run on the IDIOT Code. From these calculations, the experimental and calculated thermal utilizations are in good agreement, along with fair agreement for the fast effects. The inferred values of resonance escape probabilities are in rather poor agreement with the calculated values. This poor agreement is logical in that the IDIOT Code does not account for any mutual shielding of the resonance flux by neighboring rods in a tightly packed lattice. The major emphasis is now on developing a technique which accounts for this mutual shielding by the rods of the resonance flux.

b. Monte Carlo Code

Work on the one hundred group cross sections is continuing. The Pu-239 cross sections have been completed along with the cross sections for H_2. The cross sections for Pu-240, oxygen and nitrogen are partially completed.

A random number generator has been received from Atomics International that is approximately six times faster than any number generator presently available at Hanford. The arrival of this number generator, along with the completion of the Pu-239 and H_2 cross sections, will permit debugging to start immediately.

c. 9-Zoom Code

The first application of the 9-Zoom Code, a one-dimensional multigroup diffusion theory reactor code for the IBM-709, was made to cylindrical (reflected) plutonium critical assemblies of the Hanford P-11 experiments. The comparison between theory and experiment appears to be good for the range of H/Pu between 300-600. The calculations were made using 18 group cross sections developed by personnel of Critical Mass Physics.

A series of calculations were also made for fully reflected spheres of the P-11 experiments with H/Pu ratios in the range of 300-900. For these cases the effective value of k was calculated too high. A few more test cases will be run to try and determine why the cylinder calculations are satisfactory while the sphere calculations are not.

d. Comparison of Theory and Experiment for Al-5 w/o Pu Alloy Rods in Water

Buckling and critical mass calculations were made for Al-5 w/o Pu alloy rods of 0.506" diameter (0.03" Zr-2 clad) in a water lattice; the calculated values were compared with the critical mass data obtained from experiments. The results of this comparison are given in the following table:

COMPARISON OF EXPERIMENTAL AND CALCULATED VALUES FOR Pu-Al ALLOY RODS IN WATER

H/ Pu*	V Water / V Alloy	Extrapolation Length (cm)	Buckling (10^{-6} cm^{-2}) From Exp.	Buckling (10^{-6} cm^{-2}) Calc.	Critical Mass for Spherical Geometry (Kg Pu) From Exp.	Critical Mass for Spherical Geometry (Kg Pu) Calc.
218	1.17	8.1	9605	11100	3.31	2.60
355	1.86	7.9	10838	11500	2.07	1.70
427	2.24	7.9	11261	11400	1.70	1.64
583	3.06	7.7	10853	10900	1.53	1.50
755	3.96	7.3	10107	9900	1.53	1.57
944	4.95	7.0	8840	8600	1.73	1.88
1149	6.03	6.0	7681	7200	2.12	2.42

*Pu-240 isotope $\sim$ 5.3 percent.

The calculations were based on standard critical equations; the reactivity parameters were obtained using the IBM-709 IDIOT computer code. Values for the reflector savings were obtained from the experimental data, which appears reasonably accurate up to an H/Pu ratio of about 1000; beyond 1000, the values of λ are less certain.

The calculated critical mass values are conservative except for high H/Pu ratios where the calculated values are larger than those measured; however, there is good agreement between the calculated minimum critical mass and that predicted from measurements.

e. Kinetics with Time Dependent Reactivity

Program HAIREK, the Hanford modification of the Atomics International reactor kinetics code AIREK, has been tested satisfactorily on several cases of interest. The code may now be considered operational for the following time variations of reactivity: 1) step function, 2) ramp function, 3) that accompanying a changing geometrical buckling produced by a linear time variation of one spatial dimension, and 4) tabulated reactivity vs. time. Other functional forms, e.g., sinusoidal variation can be readily included.

Instrumentation for Determination of Reactor Kinetics Parameters

A pile noise analyzer was completed and is currently being tested. This device will be used for measuring the zero power transfer function of a reactor, for determining neutron lifetimes. It is planned to use this instrument in connection with the plutonium critical assemblies in the new plutonium critical mass facility.

In order to correct the spectra obtained from the Pile Noise Analyzer, measurements were made of the frequency response of the instrument.

The measurements were made using a large ("slug" type) BF_3 tube filled with enriched BF_3 to nearly atmospheric pressure. The chamber was exposed to white noise in the form of a 1.3 curie Co^{60} source.

The system has a response range of 2.30 to 560 cycles per second and with this tube appears to be most sensitive at lower frequencies, peaking at 3.98 cycles/second.

Mass Spectrometry

The high voltage breakdowns in this mass spectrometer continued to be a problem. Voltage breakdowns were isolated in three separate components. The electron multiplier power supply was found to be defective and was replaced. Temporary measures were taken to increase the insulation of the cabling to the spectrometer source and cable with higher breakdown rating was ordered. Voltage breakdowns continued to occur in the source region and a new insulating seal was designed and ordered to attempt to remedy this problem. As a temporary expedient the mass spectrometer has been operated at a reduced ion accelerating voltage of 7,000 volts. At this voltage no breakdown occurred.

Two uranium samples were analyzed for Critical Mass Physics.

NEUTRON CROSS SECTION PROGRAM

Slow Neutron Scattering Cross Sections

One of the aluminum large single crystals was sawn to give three half inch thick disk crystals. Each of these crystals showed similar properties under neutron diffraction giving reflectivities of 20 to 35 percent and rocking curves of the order of 3 minutes of arc. Since the large ingot exhibited similar properties it is believed that extinction effects are of importance in this type of crystal. Further, this shows considerable promise for obtaining desired reflectivities by stacking thin crystals or changing properties of large crystals by deformation.

Subthreshold Fission

Measurements were made on the fission in the 6.7 ev and 10.2 ev resonances in U^{238}. No fission was detected in either resonance. The results have not been analyzed as yet to obtain meaningful upper limits to the fission widths of these resonances. The 10.2 ev resonance is a small one which has been attributed to p wave neutrons from total cross section measurements. A positive fission width for this resonance could have been interpreted as evidence that the observed fast neutron fission threshold is also for p wave neutrons. The observed negative result probably casts little light on this possibility.

The spectrometer resolution was worsened to obtain a higher neutron intensity for measurements of the fission in resonances of Pa^{231}. The first two resonances in Pa^{231} at about 0.4 ev and 0.5 ev were found in fission. The measured fission widths are about two orders of magnitude less than expected from the simple exponential barrier. Preliminary data taken at the resonances at about 0.75 ev and 1.24 ev indicate that the fission widths of these resonances are not appreciably greater than the widths of the first two although no fission was seen in these measurements.

A preliminary analysis indicates that the observed fission widths of Np^{237}, Pu^{240}, U^{234}, and Pa^{231} are all consistent with an exponential barrier with a characteristic energy of 0.3 to 0.35 Mev. It is probable that when good upper limits are established for U^{236} and U^{238} that these nuclei will also be consistent with this value.

The barrier model for Am^{241}, however, is consistent with the characteristic energy of 0.83 Mev obtained from the shape of the fast neutron fission cross section curve.

Fast Neutron Cross Sections

Construction of the components of the Van de Graaff beam tube has proceeded with some items completed.

A conceptual design of an experiment to measure total cross sections using a pulsed white spectrum neutron source and time-of-flight has been completed. A thick target $Li(d,n)Be^8$ source and a flight path of six meters will be used. The measurements are expected to cover the energy region of about 3 to 15 Mev with an energy resolution of the order of three percent. Design and fabrication have been started of the apparatus required for these measurements.

REACTOR DEVELOPMENT - 4000 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Low Exposure Plutonium Lattices

Analysis of the 10 1/2 and 8 3/8 inch graphite lattice experiments using 0.5 inch dia. rods of 1.8 w/o Pu-Al in 19 rod clusters is essentially complete. Some modifications to the stand k_∞ calculation were necessary, arising from the change in effective neutron temperature upon removal of the absorber from the lattice.

$$k = \frac{(\eta f)'}{(\eta f)} - 1 = \left(\frac{\eta'}{\eta}\right)\left(\frac{f}{f'}\right) - 1$$

The change in η has been estimated from Westcott's tabulations using the measured value of $\left(\sigma_f^{239}/\sigma_f^{235}\right)$ to infer a neutron temperature. The change does not exceed 2% in either case.

The absorption rates for computing f and f' were obtained from the ratio of total reaction rates per atom of a plutonium foil and a copper foil at the center of the fuel cluster. The results are as follows:

8 3/8 inch lattice --- $k_\infty = 1.568$, $f = 0.868$

10 1/2 inch lattice --- $k_\infty = 1.512$, $f = 0.840$

High Exposure Plutonium Lattices

The first two MTR Pu-Al elements will reach goal exposure and be discharged from the ETR sometime during June. The remainder will continue to be irradiated toward the 40% Pu-240 goal.

Instrumentation and Systems Studies

The analysis of the experimental gas loop and control system is continuing with the study on the EASE analog computer.

Laboratory tests have been started to determine the dynamic range requirements for instrumentation to be used for PRTR mean neutron lifetime measurements. Computation of power density spectra and correlation functions requires the use of multiplying and squaring devices and associated scale factor equipment. The effects of the inherent inaccuracy of this type of equipment, for near-zero inputs, on the overall problem accuracy will be determined.

The transducers were received for an experimental process tube inside diameter measurement instrument.

Preparations are being made to evaluate the period controller and to analyze the critical facility.

Two compensating lenses (half lenses) for the Fuel Examination Facility Profilometer have been reground and polished to correct their focal length to that required for bringing the main and comparison images into simultaneous focus. Mirrors flat to within 20 micro inches have been installed throughout the Wide Angle Viewer with resultant improvement of image quality.

Assistance has been given in designing a camera for detecting and recording displacements of the PRTR calandria and in specifying equipment needed for independent, absolute calandria shift measurements.

Circuitry modifications for the fuel rupture monitor at the MTR-GEH-4 fuel testing loop have proved satisfactory in use.

NONDESTRUCTIVE TESTING RESEARCH

The behavior of the output signals of the broadband electromagnetic testing system being developed for measuring jacket thickness and jacket-to-core gap variations in an unbonded fuel element was observed in detail. New sample cores for the mock-up fuel elements being used were fabricated in the shop for use in determining the instrument behavior in the jacket thickness region of 15 to 28 mils.

Two phantastron type adjustable time delay circuits were built to replace two General Radio pulse generators used as the source of timed sampling pulses used in the time domain sampling section of the system. The vacuum tube gate circuits of the sampler were replaced with two semiconductor gate or sampling circuits. These changes have served to simplify the circuitry. Noise and drift are the lowest yet achieved with this test.

Preliminary tests of a prototype infrared radiometer for making fuel surface temperature measurements during development of heating and scanning methods have been made. These tests showed that noise presently causes variations of about 3°C in the temperature indicated by the instrument when looking at a 60°C autoclaved X-8001 surface during an interval of 0.003 second. This would be the duration of signal from a 1/4-inch diameter hot spot on the surface of a 1-1/2-inch diameter cylinder rotating at 1000 RPM.

A Radiation Electronics Corporation model TA-2 ultra low noise pre-amplifier has been ordered. According to the manufacturer's literature, this unit should have a slightly lower noise figure than the cascode vacuum tube amplifier now being used in the radiometer. A more adequate mechanical scanning system is also being designed.

GAS COOLED REACTOR PROGRAM

Lattice Parameter Measurements

The analysis of the data taken during the EGCR stainless steel loop experiment has been completed except for an error analysis. Preliminary results for a 3 x 3 supercell consisting of a central stainless steel tube surrounded by eight fuel elements of 1.8 w/o UO_2 are as follows:

1) stainless steel tube empty $k_\infty = 1.036$

2) 2.6 w/o fuel element SS tube $k_\infty = 1.073$

The principal source of error is in the estimated flux and adjoint mismatches.

Analysis of the data obtained in the measurement of k_∞ and f for the 2.6 w/o UO_2 fuel is continuing.

A report on the (r, θ) power distribution and the flux effects of stainless steel spacers in UO_2 fuel of 2.6 w/o enrichment has been prepared (HW-65074) and distributed to the customer. The results were generally similar to those obtained from the experiment on the 1.8 w/o fuel.

Variation of Doppler Coefficient with S/M Ratio

Preliminary values for the resonance escape probability, p, and the fast fission factor, ϵ, are listed for solid, 1.923 inch diameter, natural uranium fuel elements in an 8 3/8 inch graphite lattice with air and water coolant. The revised values of k_∞ and f and the inferred values of η are also included.

Parameter	H_2O	Air
k	1.0189 ± 0.001	1.0116 ± 0.001
f	0.910 ± 0.004	0.945 ± 0.004
p	0.826	0.792
ϵ	1.035	1.038
η	1.310	1.302

The p and ϵ analysis follows the method outlined in HW-63768 by P. F. Nichols, et al.

The dry values of p and ϵ are not in agreement with the comparable values of 0.762 and 1.058 given by W. E. Niemuth and R. Nilson. This discrepancy has not been explained.

Preliminary analysis of the 1.92" dia. slug fuel temperature coefficient data has resulted in values of (1/RI)dRI/dt ranging from + 1.24 x 10^{-4}/C at 175°C to +1.11 x 10^{-4}/C at ~450°C. These results tend to confirm the change in (1/RI)dRI/dt with increasing temperature. Much additional analysis is necessary before any final results can be presented, because of the rather large moderator heating corrections which need careful examination. It may become necessary to revise the experimental

method to reduce the size of these corrections.

BIOLOGY AND MEDICINE - 6000 PROGRAM

ENVIRONMENTAL SCIENCES

Atmospheric Physics

Development work progressed on the phosphorescence technique for assaying the amount of zinc sulfide on membrane filters. Although statistical evaluation of the calibration data is not yet complete, certain limitations of the system have been established. The detection limit for positive samples was found to be approximately 3×10^{-8} grams with a standard counting error of 15 percent. The standard error decreases as the mass loading increases so that, in the range from the detection limit to 2×10^{-6} grams, the best estimate of the standard error in counting is 5 percent. When the weighing, dilution, and counting errors are combined, the standard error in the absolute mass determination on a single filter was calculated to be 12 percent, whereas the relative mass determination was 8 percent. Some small reduction these percentages is expected from fitting an appropriate mathematical function to the calibration points. At month end, calibration of the system for mass loadings up to 10^{-3} grams was in progress. Beneficial use of the system for analysis of Green Glow samples is expected early next month.

Plans for the AEC Meteorology Program Leaders Meeting at Hanford, on June 20, 21, and 22, 1960, were formulated and coordinated with the Fallout Branch, Division of Biology and Medicine. Preparation of material for the Hanford sessions of the program was started.

DOSIMETRY

The first IBM run of data collected routinely at the whole body counter was completed. This operation will be on schedule with completion of the June processing of data. A paper tape punch was received to be operated from the multichannel analyzer. When in operation, it will permit machine punching of the cards used by the IBM and thus eliminate all hand work on the counter data.

A series of experiments is in progress to determine how much radioactivity accumulates in the hair and thus how important it is that a shampoo be taken before the whole body count. One female subject was counted both before and after shampooing on eight separate occasions during the past two months. In every case shampooing caused a 100 to 200% increase in the radioactivity in the hair. The increase was found to be due to the radioactivity in the water used. Distilled water does not show the radioactivity that is present in the regular water at the whole body counter. When distilled water was used by the above subject for shampoos, the radioactivity in her hair was decreased below that before the shampoo. Other experiments are being made with a wig of natural human hair. After three days outside in rather stormy weather, the decay products of radium could easily be identified in the wig. When the wig was placed at the position of the head in the standard whole body counter, it increased the K-40 values about 4%, the Cs-137 values about 8%, and would produce very significant errors in the Zn-65 values when these are low. An exposure of the wig during milder weather produced even more significant differences but other exposures showed smaller effects.

Two occasions arose that permitted comparisons of the background of the Hanford whole body counter with those of other very similar counters. During a trip to Los Alamos a tape of their background spectrum was obtained. Their counter is two inches (50%) thicker than ours; this is the only significant difference. Their background is slightly higher due to the larger counter and to their higher elevation with its consequent greater cosmic ray effects. There is also some evidence for slightly higher background from the daughters of radium. The new counter for the animal counting facility of the Biology Operation was also compared with the Hanford whole body counter. This counter is slightly smaller in diameter than ours, and it has only four photomultipliers compared with our seven. Its background is smaller by 53% under the K-40 photopeak and 29 and 27% under the Zn-65 and Ca-137 photopeaks. Tests by Radiological Chemistry with the Biology counter showed that the background in our iron room is not significantly different from that obtained in a good lead shield. It is of considerable interest that the new Biology counter shows a peak shift phenomenon that is similar to ours: If a source is placed on the photomultiplier side of the counter, its photopeak will appear a couple of channels lower than if it is counted on the other side. Private communications have indicated that this is observed in other large counters also.

An attempt was made to detect uranium in a subject having a high and constant bioassay count; nothing could be detected. An attempt was made to detect Pu-239 in a subject suspected of having a high body burden; nothing was detected other than that in the wound (before its excision) that had presumably led to the burden.

A subject who had inhaled radioactivity while working on the rear face of a reactor was found to contain 92 muc of Zn-65, 11 muc of Sc-46, and 230 muc of Cr-51. Twenty-four days later he contained 64, 5.3, and 112 muc of the same isotopes. During the latter examination a scan of his body showed that there was a concentration of activity in the upper lung area.

Na-24 was detected in four subjects who had been working on the removal of a ruptured slug. The amounts were between 1 and 4 muc. In another recent case a radiation monitor was found to contain 2.5 muc of Na-24 after working on a rear face during a shutdown. These cases were discovered through the routine counting program.

Zn-65 data obtained in recent months seem to show that the average body burden of employees working in a reactor area increases with the number of reactors upstream from that area.

Further tests with the shadow shield counter indicate that the radiation scattered from a person into the counter can be almost completely eliminated by surrounding the subject and counter with sheets of lead 1/4 inch thick.

The ion source of the positive ion Van de Graaff wore out and had to be replaced. Otherwise, the machine was in good working condition. During replacement of the source, the heaters of the palladium leaks were altered to permit better source control. The warning light system was also revised slightly. A check of the alignment of the system showed it had shifted only about 0.01° during this maintenance work; the shift in the energy calibration of the proton-moment detector was only about 0.015%.

New experimental data were obtained on a fairly large PoBe source, a small PuBe source and an intermediate PuBe source. Any neutron energy degradation in the latter source was below the limit of detectability. A search was made for 7.65 Mev gamma radiation from these sources. Theory indicated that one of the possible alpha-neutron reactions in the sources would lead to a state from which such radiation might be emitted but that it should not be found; the search showed no such radiation. The information acquired recently concerning the energy spectra and the energy degradation in neutron sources was incorporated in a paper to be presented at a meeting of the American Physical Society. Replacement of the brass parts of the three precision long counters with aluminum parts is proceeding.

Preliminary tests of normal and enriched LiI scintillation crystals were carried out to indicate their suitability for neutron spectrometry.

A technique was developed for making tritium-titanium targets for the Van de Graaff on tantalum backing material. Tantalum is harder and cheaper than platinum and does not require inventory.

INSTRUMENTATION

One bench-model personally-carried personnel dose alarming monitor was simplified and satisfactorily tested with both Ra^{226} and a Co^{60} source. A sensitive miniature relay, for the alarm circuits, was ordered after satisfactory tests were completed with an equivalent relay. The Clairex CL-403 photocell was found to produce the best signal-to-noise ratio of the many photocells and phototransistors tested. The CL-403 will be used in the device. A transparent screen was assembled and tested. This will permit a user to read the accumulated dose at any time he desires. The present model alarming dosimeter, with selectable alarm levels from 10 mr to 200 mr, consists of a 10 cc ion chamber, a light and light flashing mechanism, the miniature sensitive relay, the alarm, and two batteries. Estimated final size will be 10 to 15 cubic inches with a weight of seven ounces.

The keyboard for manual entry of data into the RCL multichannel analyzer for the radiological body monitor was fabricated and is being wired.

Two double diode-pump transistor circuits were added to the developmental transistorized coincident-counting technique alpha air monitor. The tests, thus far, indicate an alarm sensitivity--with no radon-thoron false alarms possible--of 100 MPC of airborne Pu^{239} in three minutes or less. Continuous-run testing is expected to commence in June.

Experimental prototype fabrication is one-third complete on the transistorized beta-gamma scintillation dose-rate meter. All development work is completed.

Development work was proposed and some initial investigations performed concerning a portable, transistorized scintillation multichannel gamma energy analyzer including scalers and count-rate meters. The completed package is to be battery operated. A direct application to the Biology Operation experimental work is foreseen for the instrument with several other applications possible.

Investigations are being carried out, using transistors, tubes, and tunnel diodes, concerning gamma irradiation damage to circuitry components. A tunnel diode tester was designed and fabricated for use in the tests. Thus far, total doses of 10^8 r

have been applied with no apparent damage effects except a discoloration of the glass of the vacuum tubes. All electrical qualities of all items tested to date have been unchanged.

Experiments are continuing concerning a logarithmic pulse amplifier modification of circuitry for use with multichannel analyzers. This work is to be directly applied, if successful, at the Total Body Monitor. A pseudolog display has been obtained, to date, over a gamma energy range of 60 Kev to 1.3 Mev. The obtained data do not, as yet, indicate a truly logarithmic character. Modifications are being undertaken to improve the response quality.

Investigations were made at 100-H concerning the gamma energy spectrum in several locations in the 105 Building. The 200 channel analyzer was used for the tests in the work area, storage area, water-sample room, gas-sample room, X-1 level, tool decontamination room while the reactor was up. Subsequent scans were later made in the rear face area when the reactor was down. Only parts of the data have been reduced to date.

Work progresses satisfactorily concerning the P-N surface barrier diodes to be used as alpha, beta, and neutron detectors for alpha energy analysis, fission fragment, and general detection work. We are now cutting silicon wafers from a 400-ohm cm silicon ingot supplied by CPD. Finished diodes will be available in June. A transistorized amplifier and counter circuit was designed and applied to a three-fourth-inch diameter surface-barrier diode obtained from the Savannah River Laboratory and it worked quite satisfactorily for Pu^{239} alpha particle detection with a geometry exceeding 20 percent with a six-volt bias applied to the diode. The diode output pulse rise time is apparently in the order of one nanosecond. The diode noise level appea. to be equivalent to the signal from a 0.5 to 1.0 Mev alpha particle.

Plastic investigations and experiments continued during the month. Several experimental probe housings were fabricated for use with the non-gamma sensitive alpha scintillation detector. Attempts are being made to cast the complete alpha probe from plastic. This will materially reduce the cost of the probe.

A prototype six-watt transistorized amplifier, both battery and 110 VAC operated, was completed and satisfactorily tested for use with the standard "Scintran" scintillation transistorized alpha monitors. The six-watt amplifier is to be used where ambient noise levels preclude satisfactory use of the one-half watt speaker incorporated in the Scintrans.

All electromechanical drafting work was completed by the Drafting Operation on the combined alpha-beta-gamma transistorized scintillation hand and shoe monitor, and the unit will now be returned to demonstration service. Previous to removal from service, the instrument operated nine continuous months with only several hours downtime caused by a defective component.

Continued investigation was made into the use, theory of operation, handling techniques, readout methods, and storage effects on the thermoluminescent dosimeters of the type developed by the U. S. Naval Research Laboratory. The units linearly cover a dose range from less than three mr to 10^4 r and can be easily read out to obtain the accumulated dose information. Loss of information from the time-aging standpoint is slight, and it can be correctly predicted to eliminate readout errors. The energy response of the units appears to be flat to ±10% from 10 Kev to better than 1.0 Mev

by using proper shielding techniques. The dosimeters can be made quite small and have direct application in the finger-ring and wrist badge dosimetry problems.

WASHINGTON DESIGNATED PROGRAM

Isotopic Analysis Research and Development

A study was started of the ion optical properties of a possible potential barrier energy selector that could be used to improve the abundance sensitivity of the mass spectrometer. The ion optics are being investigated by an analog field plot and ray tracing technique.

The mass spectrometer for this program operated routinely throughout the month with a negligible loss of time from any operational difficulty.

TEST REACTOR OPERATIONS

Operation of the PCTR continued routinely during the month. There were two unscheduled shutdowns. One was caused by electronic failure and the second by faulty by-passing technique.

The 3% $UO_2(NO_3)_2$-Max. k_∞ and Aqueous Pu-k_∞ = 1 Experiments were nearly completed during the month. The Aqueous Pu Experiment was terminated because of a leak in the outer containment vessel. The Pu spill was cleaned up with a loss of only four graphite shim bars.

The experiment, to support IPD effort to find a 3 X ball for present reactors which will burn out faster than present materials, was started during the month.

A 3 5/16 inch diameter by 25 inch deep hole was drilled in the fixed face of the reactor in preparation for a scheduled Neutron Rethermalization in Water Experiment. The necessary graphite bars for this experiment and zirconium tube and piping were also prepared.

The TTR facilities were used for critical mass approach experiments for most of the month.

The reactor was operated three days to calibrate and normalize foils for experiments in the PCTR.

There were no unscheduled shutdowns during the month.

CUSTOMER WORK

Weather Forecasting and Meteorology Service

Type of Forecast	Number Made	% Reliability
8-Hour Production	93	83.7
24-Hour General	62	82.2
Special	134	90.3

Consultation was rendered on meteorological and climatological aspects of 1) cooling tower design (Project CAC-881), 2) calculation of heat exchange with the environment of reserve reactor water stored in overhead tanks, 3) release of chlorine from a roof vent in the 321 Building, and 4) release of oxides of nitrogen from 306A Building.

The last in the series of three scheduled reports on prospective crests of the Columbia River flow at Hanford Works was issued on May 13. Because of a slightly higher snow-water inventory in the Columbia River watershed, the expected peak flow at Trinidad was revised upward from earlier forecasts by approximately 5 percent. This revision represents only a one-half to one-foot increase in peak stage at the 100 Areas.

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

The past month was the cloudiest May in 14 years of record. Sky cover from sunrise to sunet (scale 0-10) averaged 7.7. This compared with a May average of 5.7 for the first 13 years of record and with a previous May high of 7.4 in 1948. The precipitation total of 0.71 inch was more than twice the normal amount for May. The temperature average of 58.5 was 4.2 degrees below normal. The period from the 12th to 28th was notably cool with daily departures ranging from 4 to as much as 17 degrees below normal.

Instrumentation

All field and evaluation tests were satisfactorily completed on the Mask Monitor instrument designed for the Laundry Operation. Operation instructions were written, and the unit is now scheduled for routine service. The unit detects, in one step, beta-gamma contamination on the mask surfaces; the use of the unit eliminates the previous laborious handchecking methods used.

The final two Scintillation Transistorized Alpha Hand Counters were received, tested, and are ready for use. The units will be used in the 308 Building and were fabricated to our specifications by a Seattle firm.

The battery-operated selectable-level alarming scintillation dose-rate meter (ranges of 0-1 r/hr and 0-10 r/hr) designed for IPD for use as a reactor elevator "stand-in" monitor operated quite satisfactorily during the month. Three more units are now scheduled to be fabricated in the 328 Building Electronics Shop. Ranges of 0-300 mr/hr and 0-5 r/hr will be used in the new units. The same 3-1/2 pound instrument can be adjusted to give any range desired, with any-point selectable alarming, from 0-20 mr/hr to 0-20 r/hr.

Two Model II, gated-oscillator loudspeaker output, scintillation transistorized alpha advanced Scintrans were completed in fabrication, tested, and are now ready for demonstration use. These have a much louder speaker output than the original Scintrans; and when used with the new alpha probe, the instruments have no gamma response in fields up to 10 r/hr. By merely changing probes to the type necessary, the same instrument can be directly used for beta-gamma or neutron monitoring.

Fabrication continued on: (a) An in-cell beta-gamma monitoring system and a special cell air filter monitor for the Chemical Research Operation, (b) Ten linear dose-rate monitors for 614 Building, and (c) A GM tube instrument for monitoring coolant activity in test loops operated by the Coolant Testing Operation.

Evaluation tests were completed on an IPD-developed integrating dose-totalizer, seven 614 building scintillation monitors, a commercial pocket dose-rate indicator, and sixteen HAPO Model I Scintrans. Comparison tests between RCA and Dumont Type 6655A photomultiplier tubes indicated the RCA tubes to be much superior for HAPO applications. Temperature tests were completed on several 1B85 GM tubes and three HAPO C-P instruments. Evaluation of several Ni-Cd small rechargeable instrument batteries was started.

The computer study of the FPD autoclave temperature control problem has been completed. The instrumentation portion of the 333 Building Autoclave Installation Design Criteria was prepared, based on the results of the computer study. A report describing these results is in preparation.

A new model ion count control for the experimental nuclear physics mass spectrographs was designed and several critical circuits breadboarded. All parts are available, and construction may start next month.

A reference system for calibrating the Schaevitz DRS-100 Micro-Displacement System for in-reactor creep measurements has been selected and the required components have been ordered or are under fabrication on site. The system is expected to become operational during the latter part of June. The system will incorporate three simultaneous, and relatively independent, modes of indication which include: A Templin calibrator, a Tuckerman autocollimator, and a Gaertner traveling microscope. Fused quartz linkages will be employed in transmitting motion from the LVDT, inside the furnace, to the measuring devices, outside the furnace. Linearity and long term drift will be examined at temperatures ranging from 20° to 400°C. In order to minimize vibration during the calibration, a special setup bench has been designed which is capable of supporting at least a ton of lead, should it become necessary, in order to attain the required degree of stability.

Further investigations to confirm the feasibility of making the process-to-shroud tube gap measurement in the PRTR by eddy current methods were conducted using the Magnaflux FW-400 located at White Bluffs. The results were essentially favorable. A preliminary investigation to determine possible probe materials and components which will meet the temperature and radiation requirements has been initiated, and conductivity stability is expected to present the major difficulties. The tests using the FW-400 were performed with a frequency of five kilocycles and the instrument produced detectable indications throughout the full range of gap variation. A prototype laboratory probe is expected to become operational during June, and a considerable amount of data concerning the other parameters encountered in the measurement will be obtained using the new probe.

Optics

Pyrometer Telescopes - Three small telescopes have been designed and fabricated for use as radiometers in controlling and indicating brightness temperatures. Two of these are in use by Ceramic Fuels Development Operation. The third is being fabricated for R. G. Wheeler. The sensing element is a Hoffman Photovoltaic Detector Capsule which has been provided by Ceramic Fuels.

PRCF Periscope - Design sketches have been prepared describing the lenses, spacings and essential features of a periscope to be installed in the PRTR Critical Facility.

Underwater Lighting for 105-C FEF - A mirror and lamp assembly has been designed for use with the Variable Power Underwater Viewer at 105-C Fuel Examination Facilities.

Quartz Fixtures - Design of quartz fixtures to be used in calibrating the Linear Displacement Motion Transducer was completed. Fabrication has been started.

Radiation Ratio Pyrometer - A new sensing head has been designed which can be mounted directly on the stage of a metallograph. This head and the associated electronic readout eliminates the drift and position sensitivity experienced with the first model.

FPD - Materials Engineering authorized development of a radiation ratio pyrometer for measuring the temperature of copper clad coextrusion billets. This instrument is to have an accuracy of at least ± 10°C at 730°C. If feasible, further development will be done towards a second instrument with an accuracy of ± 2°C.

A total of 449 manhours shop work was performed during the four-week period (May 1 to May 29). Of this, 9% was for IPD, 23% for CPD, 62% for HLO, and 6% for CEO. The work included:

Repair of borescope components for Irradiation Testing Operation.

Modification of an eyepiece of the Underwater Microscope for 105-C Fuel Examination Facilities.

Fabrication of a lamp and mirror mount for 105-C FEF.

Fabrication of a set of 10 glass bearings for CPD.

Fabrication of two pyrometer telescopes.

Fabrication of 8 quartz windows for a photometer cell.

Reconditioning of a lead glass window in 327 Building.

Repair of a stereomicroscope for Plutonium Metallurgy 234-5 Building.

Modification of focus compensation lenses for the PRTR Profilometer.

Analog Computer Facility Operations

The new EASE computer has now been placed in full service. The acceptance tests have been completed and formal acceptance of the equipment may be made at any time. The Chief Field Engineer for Beckman/Berkeley Division spent May 3, 4, and 5 here and was successful in clearing up most of our difficulties. The digital voltmeter trouble was isolated and determined to be due to excessive temperatures within the component cabinet. This, in turn, was due to the use of an undersized cooling fan by the manufacturer. He promised to contact the manufacturer in an attempt to provide the necessary modification. In the meantime, the troubles can be temporarily overcome merely by having the voltmeter chassis partially out of the computer rack.

This will provide the necessary additional cooling for stable operation.

The computer lab was used to conduct four three-hour classes in Reactor Physics for the University of Washington.

The PRTR gas loop problem has been on the EASE for the entire month. The GEDA was out of service for almost the entire month for routine servicing, for installation of trunk lines to the EASE, and for planning changes to improve reliability.

There was no unscheduled down time due to equipment malfunctions this month.

R S Paul for

Manager
PHYSICS AND INSTRUMENT RESEARCH
AND DEVELOPMENT
HANFORD LABORATORIES OPERATION

PF Gast:mcs

Chemical Research & Development

RESEARCH AND ENGINEERING

FISSIONABLE MATERIALS - 2000 PROGRAM

IRRADIATION PROCESSES

Uranium Oxidation and Fission Product Volatilization Studies

Three fission product release experiments were performed in the high level facility at 292-T Building. The first used a 11.5 gram uranium specimen irradiated to 2×10^{14} nvt, the same level used previously; this completed the base line experiments. Tests at higher irradiation levels were started to determine the effect of burnup on release of fission products from uranium heated in air. Two tests at about 3×10^{16} nvt were performed under similar conditions as used in the base line experiments, 11.5 gram uranium cylinders heated in air for 24 minutes at 1215 C. The oxidation rates were the same for the higher irradiated specimens; preliminary indications were that the release of fission products was not appreciably affected by the approximately 150 times greater irradiation. Preparations were completed for an experiment at 2×10^{17} nvt.

An investigation of the Xe^{133} counting technique showed that direct counting of the charcoal traps from tests at high irradiation levels may introduce serious coincidence losses; collimation techniques should minimize the errors.

NPR Effluents

Further laboratory experiments confirmed the effect of ammonium citrate in proposed NPR decontaminating agents for preventing the scavenging of radiocobalt by precipitates formed in the mixed solutions. Systems containing an ammonium citrate and EDTA mixture resulted in scavenging decontamination factors of 3 to 5, while similar systems containing ammonium citrate but without EDTA resulted in scavenging decontamination factors of 7 to 9. Systems containing EDTA only, omitting the ammonium citrate, resulted in decontamination factors of 50 to 100. These may be compared with scavenging decontaminating factors of 2000 to 6000 for mixtures containing neither EDTA nor ammonium citrate.

Reactor Effluents Treatment

It became necessary to change the site for the pilot scale facility to be constructed for determining reactor effluent decontamination bed variables. The advantages leading to an earlier decision to locate in the 100-KW Area were offset by the potential for flooding the facility during a period when a reactor effluent basin was draining. An alternate site at 100-D permits nearly the same design with a lower cost for installation. An order was placed for the five tons of aluminum which will be machined locally into bed material.

Determination of 0.01 to 0.001 Percent Silicon in Aluminum

Silicon was determined in high purity aluminum by the alternating current arc spectrographic method. Comparisons were finally obtained by direct current arcing; its insufficient sensitivity was overcome by adding copper fluoride to vaporize the silicon as the tetrafluoride. Getting comparisons by wet chemistry was futile; reagents introduced more silicon than was present in the aluminum samples.

SEPARATIONS PROCESSES

Feed Preparation

Thermodynamic Calculations for Redox Dissolver Incident - Calculations have been made in an effort to determine the thermodynamics conditions which led to the Redox Multipurpose Dissolver incident. Since uranium oxidation rates observed by various investigators and reported in the literature vary considerably, and since the heat dissipating conditions existing in the dissolver are difficult to define and predict, the calculations are, at best, approximations. However, with the assumptions used in the calculations, the plausibility of such an incident was demonstrated. The calculations indicated that a self-propagating chain-type chemical reaction could take place in the air-steam exposed slug bed in approximately 12 hours. This compares with the 30 to 36 hours actually required during the dissolver incident. The calculations also indicated that heating of the exposed slug bed would proceed slowly until the bed temperature reached 120 to 130 C; then the bed temperatures would increase very quickly (greater than 200 C per hour). Calculations were also made to determine the possibility of such an incident occurring in a "conventional" Redox crib dissolver. These calculations indicated that the crib dissolver is "safe" for a similar quantity of air-exposed metal because of the better heat dissipating characteristics of the slug bed and dissolver system. However, these calculations indicated that significant changes in the conventional dissolver system (e.g., doubling the air-steam exposed metal heel; halving the air in-leakage rate) could produce reactive conditions with prolonged exposure of a metal heel.

Processing Nickel-Coated Aluminum-Clad Elements - Further studies on the dissolution of full size nickel-coated aluminum-clad I and E fuel elements were made. These elements had nickel coating on both sides of the aluminum cladding. They had been heated at 590 C for 45 seconds in one step during fabrication. The outer nickel coating was not attacked by boiling $NaNO_3$-NaOH decladding solution. Underlying aluminum was attacked through imperfections in the nickel coating. Boiling 1 M HNO_3 attacked the outer nickel coating slowly (three hours were required to remove the coating). Boiling 1.5 M UNH-1.5 M HNO_3 removed the coating in 25 minutes and 7 M HNO_3-0.002 M $Hg(NO_3)_2$ removed the coating before the solution reached boiling.

Aluminum cladding, both alloy C-64 and X8001F was removed readily by boiling NaOH-$NaNO_3$. Both alloys were present in the fuel pieces used in these studies. It is of interest that the dissolution of alloy X8001F was very slow in either 7 or 3 M HNO_3 containing 0.002 M $Hg(NO_3)_2$. Alloy C-64 dissolves rapidly in these reagents. The inner nickel coating was essentially unattacked by NaOH-$NaNO_3$ decladding solution. Underlying Al-Si bonding layer was attacked through imperfections in the coating. Spectrographic analysis of the inner coating indicated aluminum, iron and silicon as major components in addition to the expected nickel and phosphorus. Samples of the inner nickel coating and the Al-Si bonding layer were found readily soluble in 2 M HNO_3-0.002 M $Hg(NO_3)_2$ but not in 2 M HNO_3 alone. Both dissolved readily in 12 M HNO_3-0.002 M $Hg(NO_3)_2$ leaving considerable silica as a residue from the Al-Si. Five declad cores, with more or less intact inner nickel coating and Al-Si bond, were dissolved in nitric acid (initially 13 M). In all cases, coating and bond material were undercut and attack on the underlying metal was rapid. Penetration rates were not measured since exposed area was not measurable. End grain attack was very marked.

NPR Decladding - Front end and rear end defects plus sections from the center of extruded NPR annular fuel elements were declad in three runs with 5.5 M NH_4F - 0.5 M NH_4NO_3 dissolvent at a F/Zr mole charge ratio of seven. A batch tubular dissolver was used for the dissolutions. An average boilup rate of 0.25 lb-mol/hr-sq.ft. based on initial Zircaloy surface area was maintained with the condensate diverted to a separate vessel and replaced by water addition. A dissolution time of three hours was not sufficient to dissolve all of the massive Zircaloy, but was long enough to expose approximately 90 percent of the uranium metal core. Data from the runs indicate that losses to the Zirflex decladding waste are less than 0.5 percent for this type of operation. It will be necessary to charge about 10 percent excess of fluoride and to operate approximately four hours in order to completely declad the uranium. Final dilution of up to 200 percent of the charge solution is necessary to avoid zirconium precipitation.

Processing of U-Zr Alloy Cores in Redox - It has been proposed that uranium-low percent zirconium alloys be used as fuel in the NPR reactor. A survey to determine the problems associated with processing such fuels in the Redox plant is in progress. Studies to date have been made with U - 2 weight percent Zr alloy. First concern is the loss of core material to the Zirflex decladding solution proposed for removing Zircaloy cladding. Experiments to determine this loss with proposed fuels are being held up pending solution of the problem of measuring and controlling pH in Zirflex solutions.

Also of concern is the possible formation of explosion sensitive surfaces on uranium-zirconium alloy when dissolved with nitric acid only. Such surfaces are readily formed on alloys containing from five to twenty-five percent zirconium. The lower limit of zirconium content for sensitive surface formation is not well defined. Attempts to form such surfaces on U - 2 weight percent Zr alloy have been successful only when the alloy was given a prolonged (3 weeks) heat treatment at 575 C before dissolving it in nitric acid. Reproducibility was poor even with this treatment.

Dissolution rates for the U - 2 weight percent Zr alloy in nitric acid only were very low compared to rates for uranium metal under similar circumstances. Penetration rates decreased from about one mil/hr. in boiling 10 M HNO_3 to 0.1 mil/hr. in 2 M HNO_3-1.75 M UNH.

The only procedure currently available for preventing sensitive surfaces on U-Zr alloys during dissolution in nitric acid is to add fluoride ion. Several studies have shown that the concentration of fluoride must be at least four times that of the dissolved zirconium. However, to use this procedure in the Redox 300 series stainless steel dissolvers, it would be necessary to protect the dissolvers against severe corrosion by the nitric acid-hydrofluoric acid mixture. Aluminum ion in a mole ratio Al/F of one or more is effective. Previous studies have shown that, when aluminum ion is present, the fluoride to dissolved zirconium mole ratio must be greater than four. Based on these requirements, a test flowsheet having terminal dissolver solution composition 1 M UNH-1 M $Al(NO_3)_3$-0.8 M fluoride-0.05 M zirconium was proposed. Although synthetic solutions with this composition and with free nitric acid from zero to 0.8 M were stable towards solids formation, solid-free solutions could not be obtained in attempts to dissolve U - 2 weight percent Zr alloy to terminal solutions of this composition. Dissolution rates for U - 2 weight percent Zr in these solutions, while higher than in nitric acid only, were still low compared to the dissolution of uranium metal in nitric acid.

Solvent Extraction

Purex C Column Studies - Demonstration Unit 1C column tests using 1CX prepared from Purex water treated with the new cation resin (Nalcite HCR-W) indicated satisfactory plant performance would be obtained with this water. At the standard test conditions (1270 gph/sq.ft., one inch pulse amplitude, 60 C), the instability threshold frequency with this water was 47±3 cyc/min, compared with 57±4 with distilled water.

A sample of A-6 crib (steam condensate) was also tested as 1CX. The instability threshold was not significantly higher than that obtained with the new demineralized water.

Several additives such as might occur in demineralized water were added to distilled water 1CX to test their effect on the instability threshold. These included finely ground samples of the former cation resin, Anthrafilt, and sodium p-toluenesulfonate (the cation resin "building block"). At moderate concentrations (10 ppm or less), the cation resin had an adverse effect on the instability threshold; the others showed no effect.

Mistron and Bentonite were individually tested as stabilizing additives to demineralized water 1CX. Both at 20 ppm completely stabilized the nine-foot tall column within ten minutes at 51 cycles per minute and permitted stable operation up to 60 cycles per minute.

Purex 3B Column Studies - Development studies are almost complete on the cartridge design for the proposed 3B column. The most satisfactory cartridge tested so far contains four-inch spaced stainless steel nozzle plates with the free area and hole diameter graded from 23 percent and 3/16-inch, respectively, in the top third of the column to ten percent and 1/8-inch in the bottom two-thirds, and with 23 percent free area linear polyethylene plates containing 3/16-inch holes inserted at one-foot intervals in the upper three-fourths of the column. The plastic plates tend to stabilize the column by continually coalescing the tight emulsion and preventing the growth of large globules of organic which tend to form at the top of the column at high rates. The plastic plates also permit efficient-appearing operation under local flooding conditions. In fact the most efficient-appearing operation occurred at frequencies just below the complete flooding thresholds.

The following table indicates the range of operability of the cartridge at about 0.6-inch amplitude:

Volume Velocity, Gal/Hr-Sq.Ft.	Frequency, Cycles/Min. 680	1020	1350	1690
Tight emulsion buildup began at:	75	70	65	-
Mild local flooding began at:	90	75	67	60
Complete flooding at:	105	98	93	-

The effect of pulse frequency and aqueous-to-organic flow ratio (L/V) on the dispersion profile was observed in one series of runs using a 23 percent free area nozzle-plate cartridge. At volume velocities ranging from 1100 to 1500 gal/hr-sq. ft., the onset of instability was characterized by a tight emulsion at the bottom at L/V = 0.1, at the top at L/V = 0.3, and in the middle at L/V = 0.5. This unusual behavior is believed to be related to the acid profile in the column; particularly to the great amount of aqueous phase backmixing that occurs at very low aqueous flow rates.

Cavitation Calculations - Purex 3A Column - Calculations show that the minimum pressure developed at the piston of the Purex 3A column will be approximately 5 psia. Since the vapor pressure of water at 140 F is approximately 3 psia, there does not appear to be a cavitation problem. The leakage rate for a piston pulser is calculated to be approximately 0.03 gal/min at typical operating conditions.

WASTE TREATMENT

Observation Wells

A well-drilling contract was awarded by the AEC to the Hatch Drilling Company of Half Moon Bay, California. The contract is for the construction of 19 monitoring, test, and research wells at a cost of $77,430. In preparation for this construction tests were performed to evaluate the ability of Kai-Well casing to withstand the pressure generated during jet perforation with shaped charges of high explosives. Examination of test perforations with the closed-circuit TV camera indicated some tendency for the casing to split under this treatment. During one of the tests the casing apparently collapsed on a section of the perforating gun, lodging it in the well. As a result of these studies the drilling contractor was notified by the AEC that the light weight casing should not be used in constructing the new wells.

There were no significant changes in ground water contamination patterns in the vicinity of the 200 Areas over the past month.

A special sample of ground water obtained recently from well 299W-22-5, located 200 feet east of the abandoned 216-S-1 & 2 cribs, contained Sr^{90} at a concentration of 1.5×10^{-8} uc/cc. The appearance of Sr^{90} at this location is not unexpected since it is consistently present in samples from well 299-W-22-2 at the cribsite. Also, it was detected in soil samples obtained from near the ground water table when the W22-15 well was drilled in 1955. Special processing of three-liter samples from nearby wells has been requested to further define the extent of any Sr^{90} spread in the ground water at this location.

Approval to sink six two-inch well points at selected locations near the inactivated 106 tank in the 241-TY Tank Farm was obtained. Probing of these 70-foot shafts is expected to yield useful data relative to the spread of waste in soils for it is suspected that some waste had leaked from this tank about six to eight months ago. Such data may be of significant value in appraising tank leak detection systems.

Disposal to Ground

Proposed methods of disposing of wastes from the T-Plant decontamination facility were studied. The used cleaning solutions and cell drainage waste are to be routed to the 216-TY-3 crib. The low volumes and expected low activity of these wastes should make ground disposal acceptable, even though they contain decontaminating chemicals that inhibit adsorption processes in some cases. The existing route to the crib is by way of the 111-T and 112-T tanks. These tanks currently contain sludge and supernatant solution representing second-cycle waste from the bismuth phosphate process. This material contains relatively high concentrations of Cs^{137} (1.8×10^{-2} uc/cc) and Sr^{90} (3.0×10^{-5} uc/cc). The possible effect of chemicals in the decontaminating solutions on the radioisotopes in this residual waste is being studied.

Semiworks Waste Calciner Prototype

Seven runs were completed during the month employing a modified ANL feed nozzle and a feed of simulated high acid Purex waste.

Performance of the modified ANL feed nozzle (liquid tip extended 3/16-inch beyond air tip) was characterized by negligible agglomerate formation and near steady-state particle size conditions. Atomizing air flow requirements for this nozzle are only 75 percent of that required in the "standard" nozzle. Atomizing gas to feed flow ratios as low as 270 resulted in satisfactory particle size control and an acceptable agglomerate formation rate. At gas-feed ratios of 360, no agglomeration occurred; however, the average particle size decreased during the run, indicating an optimum ratio for this nozzle at 300-325.

Under the above conditions, the total off-gas solids entrainment amounted to 1 to 4 weight percent of the product. Of this amount, approximately one-half exited at the scalping cyclone, and the remainder with the condensate and scrub streams. Analysis of the condensate and scrub indicates approximately one weight percent of the sulfate in the product is carried past the cyclone presumably as calcined fines.

Two runs were made to determine the effect of preheated (100 - 200 C) atomizing air on nozzle performance. Although the runs were of short duration, no problems were encountered nor was there any significant difference from runs employing comparable conditions using ambient atomizing air.

Batch Waste Calcination

Two laboratory scale studies on the fixation of Purex waste in an unagitated pot were made during the month. In one study, sodium sulfate crystals were placed between two layers of powder from the fluid bed waste calciner (the simulated Purex waste feed to the fluid bed unit had a sulfate to salt nitrate ratio of 0.48). The quantity of sodium sulfate added simulated a feed with a sulfate to salt nitrate ratio of 1.0. Under such conditions, a melt formed at 900 C as expected. However, the melt formed only in the lower portion of the pot, the upper layer of calcined powder remained unchanged. As a result, a large void developed within the pot. Pot corrosion was severe in the region of the sodium sulfate layer.

In the second study, a liquid feed high in sulfate and phosphate was calcined at 850 C. The sulfate plus phosphate to salt nitrate ratio was 1.4 and the sulfate molarity was 1.5 times that of the phosphate. Pure sodium sulfate and sodium pyrophosphate form a eutectic (MP 748 C) at the above sulfate to phosphate ratio. In the calcination study, a melt did form but was very viscuous (more viscuous than previously observed at sulfate to salt nitrate ratios of 1.4), suggesting the formation of polyphosphates. Pot corrosion was negligible.

Corrosion of 304-L Stainless Steel by Alkaline Purex 1WW

Coupons of 304-L stainless steel have now been exposed to liquid and vapor phases of boiling synthetic Purex 1WW at pH 10.5 for a total of 1100 hours. General corrosion rates are less than 0.01 mil/mo. However, some very small pits which appear to be developing at about 0.1 mil/mo have been observed. Exposure of the samples is continuing.

TRANSURANIC ELEMENT AND FISSION PRODUCT RECOVERY

Promethium Purification

The first cold run in the A-Cell equipment, reported last month, was completed and all solutions analyzed. Separation of the rare earths into individual bands was excellent with the "heart cut" of each band assaying >99 percent pure. The very early separation of yttrium into a band at the leading edge of the rare earth band will permit elution of this high-wattage element to waste early in the elution cycle. The only slight difficulty experienced during the run was precipitation of some of the lanthanum in columns 3 and 4 (however, this did not plug the columns or prevent elution). This precipitation was due to the fact that the lanthanum-EDTA complex is less soluble than the rare earth-EDTA complexes, to reduction of flow rate on transit from column 3 (two-inch diameter) to column 4 (one-inch diameter), and to shutdown over two weekends. Lanthanum precipitation would not be expected in a normal run, where the lanthanum, praeseodymium, and most of the neodymium would be eluted to waste after column 3. Following the run, resin was displaced from the column remotely using the same technique that will be employed after "hot" runs.

A second cold run was begun May 23. Conditions are identical to those of the first run except for substitution of Dowex 50W, X-12 resin for Dowex 50, X-8. Use of the higher cross-linked resin is desirable because of expected greater resistance to radiation damage. Early indication from this run is that the X-12 resin is as satisfactory as the X-8.

Following the current run, it is planned to make one more "cold" run before introducing Purex concentrate. Feed for the third run will contain a "spike" of promethium, and also possibly americium tracer. Flow rate will be increased from 3.6 ml/min,cm^2 to about 6 ml/min,cm^2 in the first three columns. The flow would then be reduced to about 4 ml/min,cm^2 in the smaller columns. If all goes well and feed is available, it is planned to go hot early in July.

An informal report, The Separation of Cerium from the Trivalent Rare Earths Using Hydrogen Peroxide and Sodium Acetate, by E.J. Wheelwright, HW-52505, May 18, 1960, was issued during the month.

Cesium Recovery from 103-A Tank Supernate

The alkaline supernate in the boiling Purex 103-A waste tank was recently shown to contain some 13 curies of well-aged cesium-137 per gallon, and there is interest in shipping a concentrate of this material to Oak Ridge for isolation, packaging, and sale. Two lines of research have been pursued in behalf of this goal. One involves an extension of previous work with zinc ferrocyanide and the other the use of inorganic ion-exchangers, the latter to be contained in an existing ORNL shipping cask to both concentrate the cesium and minimize in-transit hazards. Both approaches were found technically feasible.

Two absorbers, the mineral clinoptilolite and the synthetic inorganic ion-exchanger Decalso, were treated batch-wise with successive volumes of full-strength 103-A supernate, with the solution allowed to sit in contact with the exchanger for a period of time after each loading. On completion of the loading cycle, the bed was washed exhaustively with water, eluted with successive volumes of 10 M NH_4NO_3, and all eluates analyzed. The loading and elution behavior of the two absorbents was essentially identical. The Decalso loaded to over 80 curies

of cesium per gallon, and over 95 percent was removed with only four bed volumes of 10 M NH_4NO_3. Very little cesium was removed by water washing (aimed at removing entrapped impurities and demonstrating hazard reduction in event of cask rupture). Cesium content of the last water wash was only 0.08 μc/ml in the case of Decalso and 1.6 μc/ml with clinoptilolite. The respective strontium-90 values were 0.0006 and 0.006 μc/ml. Although equivalent chemically, the physical characteristics of Decalso are superior to clinoptilolite, and it also has the advantage of ready commercial availability.

Experiments with zinc ferrocyanide were directed toward precipitation of cesium from alkaline solutions containing the concentrations of carbonate and nitrite found in the 103-A supernate. Cesium recoveries ranged from 91 to 98 percent, and it was found that neither carbonate nor nitrite interfered with cesium recovery as cesium zinc ferrocyanide. Previous experiments which indicated that carbonates interfered with the process were apparently in error. Experiments, based on these findings, with a synthetic 103-A supernate demonstrated that cesium can be recovered from the tank supernates in good yield and purity by precipitation of cesium zinc ferrocyanide.

Strontium Recovery

The new 75 ton Dake press was received, set up, and has been used for pressing a number of one-inch diameter strontium titanate pellets, using as starting material a mixed strontium-titanium oxalate prepared from commercially available titanous sulfate. Pressing characteristics were superior to and densities somewhat higher than with the commercial strontium titanate powder used in most previous pressings. A larger quantity of mixed oxalate is now being prepared for trial pressing of 2-1/2 inch pellets. X-ray diffraction studies are also being made to elucidate the chemistry involved and identify the intermediate.

Strontium Isotopic Analysis

Although the strontium in the Purex 103-A tank is not of interest from a recovery standpoint (since most of the strontium is in the inaccessible sludge layer rather than in the easily removed supernate), the isotopic composition has been determined as a test of newly developed analytical methods and since the extent to which this material is contaminated with natural strontium may be a measure of the quality of Purex strontium. For heat source application, very little non-fission strontium can be tolerated. A strontium-90 content of only 17 percent was found, versus 61 percent expected. Source of this large dilution with natural strontium is unknown. Analytical methods are accordingly being developed for the determination of strontium in uranium metal and for the isotopic analysis of strontium in Purex 1WW. Even a few ppm of strontium in the uranium slugs charged to the reactors would constitute a serious dilution.

Technetium Recovery

Development of analytical methods for the determination of technetium-99 in a variety of plant process and waste streams continues. The 103-A supernate was analyzed by three different methods based on (1) solvent extraction, (2) ion exchange, and (3) polarography. The results were in good agreement at about 90 mg/gal and showed that this supernate is a rich potential source of technetium. If the supernate is pumped from the tank for cesium recovery, it should be

relatively easy to recover kilogram quantities of technetium. Methods for doing this are being explored. Both an ORNL-type magnetite precipitation and anion-exchange treatment of the alkaline supernate show promise. Dowex 1 readily absorbs over 99 percent of the technetium; however, subsequent elution with dilute nitric acid is somewhat slow and is being investigated in more detail.

A sampling program has been set up at the UO_3 and Purex plants which should allow establishment of a technetium material balance over a fairly extended period of plant operation. These results should also indicate the best point for continuous plant recovery.

Shielded Solution Transfer Cask Calibration

A series of experimental heat transfer measurements were run on the first (of two) 200 gallon shielded solution transfer casks to determine the number of watts of radioactive decay heat which can be accommodated without forced cooling and without exceeding a safe solution temperature (200 F). The critical heat input rate was found to be 4.6 KW for 80 F ambient temperature conditions and 5.4 KW at 60 F. Both of these are greater than the design value of 3.5 KW.

Fission Product Packaging Prototype

Tests were continued on the drying of water soluble salt brines in the induction heated rotary kiln. These tests included the use of intermittent feed, a long scraper knife, and steel ball loadings to keep the scraper free of caked salt. The intermittent feed and agitation derived from the balls kept the scraper free from salt cake. However, the scraper assembly deflected about 1/8 inch and cake buildup persisted on the walls of the kiln. Because of this salt accumulation, a recovery factor of only 43 percent was achieved during a seven-hour run. Further tests are planned to modify the scraper assembly and to investigate the feasibility of using volatile salt additives to alter the caking characteristics.

Cerium "Rough Cut" Filter Studies

The proposed cask to be used for the transfer of the "rough cut" cerium filter to Oak Ridge contains a low melting alloy (Asarcolo 158) to dissipate the heat generated by the fission product cake. Since limited information is available on the heat transfer characteristics of the metal, and since excellent heat transfer is required to minimize shipping hazards and to prevent overheating of the filter cake, laboratory experiments simulating the actual cask heat transfer system were performed. In summary, the experiments demonstrated that the resistance to heat transfer across the alloy-stainless steel film was acceptably low. Details of the studies have been submitted to CPD Facilities Engineering.

ANALYTICAL AND INSTRUMENTAL CHEMISTRY

Solid State Electronic Power Pulse Generator

A report (HW-65455, "A Solid-State Power Pulse Generator," June 1, 1960) describing this device is in publication. This unit has been in use (on 24-hour per day service) in the Non-Metallic Materials Development Operation for three months and has now been shut down only because of failure in a solenoid pump which is powered by the power unit.

Voltage Scanning Coulometry

A paper with the title "Voltage Scanning Coulometry: Its Application to the Determination of Traces of Iron" (Report HW-SA-1848) has been prepared for presentation at the Summer Analytical Symposium at the University of Houston in June and for subsequent publication.

This new analytical method, which is more specific and has a detection limit some 100-fold lower than controlled potential coulometry, should have wide applicability for trace level chemical analysis. The improved sensitivity is obtained by scanning the potential between the working (titrating) electrode and a reference electrode at a constant rate and over a range embracing the reduction potential of the couple being titrated. The current which flows in the absence of a sample (i.e., the blank current) is relatively insensitive to potential and plots as a fairly flat curve against potential. In the presence of a titratable species, however, the total charge necessary to convert this species from one oxidation state to another must be provided at a potential near the thermodynamic reduction potential. The titrated species thus contributes a sharp current peak superposed on the flat blank current. Thus, correction for the blank current can be made quite precisely and enables much greater sensitivity. The potential at which the current peak occurs defines the species being titrated, and its amount can be deduced from the total integrated current over the peak. In actual fact the peaks are quite symmetrical and concentrations can be related directly to the peak heights.

This analytical method has been shown to be applicable also to the determination of lead, cadmium, mercury, silver, copper, gold, plutonium, and neptunium. A detection limit for iron of 5×10^{-4} microequivalents (0.025 micrograms) or, assuming a 5 ml sample, of 10^{-7} molar and a standard deviation of ± 0.02 micrograms have been obtained.

Determination of Sr^{89} and Sr^{90} in Milk

Strontium-89 and strontium-90 were separated from milk by ion exchange. Dowex 50W, x 8, 50-100 mesh was used in the sodium form. Milk spiked with Sr^{85} and milk obtained from cows dosed with Sr^{85} were used to confirm the method. Preliminary work resulted in overall recoveries of 80 percent. Use of the resin is expected to eliminate the need for dehydrating, ashing, and solubilizing the ash.

Determination of Technetium in Uranium Product

Beta counting was used to determine the Tc^{99} concentrations in product uranium. Preliminary extraction of technetium was necessary. Hexone saturated with tetraphenylarsonium chloride extracted 95 percent of the isotope.

Determination of Zinc in Plutonium Metal by Polarography

Impurity zinc was determined in plutonium metal with a precision of ± 3.5 percent. The metal was dissolved in 9 M hydrochloric acid. Polarography was applied to sample diluted with 0.1 M KCl to an acidity below 0.01 M thus avoiding interference from a hydrogen wave.

EQUIPMENT AND MATERIALS

Z Plant Centrifuge Testing

Preparations are underway for 300 Area testing of a 6-inch continuous centrifuge for Z Plant. Process testing in the 321 Building will include operation with simulated NPF dissolver slurries as well as a simulated Z Plant process slurry. After operational testing the machine will be dismantled and reassembled in a mock-up glove box for development of Z Plant box maintenance techniques.

Dynamic Balancing Machine

A dynamic balancing machine capable of handling rotating components from 1/2 inch to 44 inches in diameter, with lengths between 4-1/2 inch and 55 inches and weights from 1/2 to 1000 pounds has been received and is currently being installed in the Technical Shops. The balancer is sensitive to 0.01 inch-ounce unbalance and is available to service HAPO requirements.

Pump Testing

HW-65024, "Development and Testing of a Magnaflow Pump," is currently being issued.

Magnetic Pulser

Calculations indicate that a 125 pound force-solenoid type-magnetic pulser can be used to pulse a 4-inch Recuplex A column at a frequency of 80 cycles per minute and an amplitude of 1 inch. For calculation purposes a 50 foot-U tube column containing 130 plates with 13 percent free area was assumed. Specifications for a test pulser of this type are being prepared for submission to magnet manufacturers for bids.

Comparison of 309 SCb and 309-L Stainless Steels

Following heat treatment at temperatures ranging from 1300 to 2150 F, samples of 309 SCb welded with 309 SCb and 309-L welded with 309-L were exposed for 400 hours to boiling synthetic Purex 1WW (6 M HNO_3). No significant differences in corrosion rates as a function of heat treatment temperature were observed among the 309 SCb samples. Coupons of 309-L in the as-welded condition and when heat treated at 1300 and 1500 F showed sensitization with corrosion rates ranging as high as nine mils/mo. There has been no evidence developed to date that 309-L is more satisfactory than 309 SCb for service in nitric acid systems.

PROCESS CONTROL DEVELOPMENT

"C" Column Test Facility

Instrument calibrations continued during the month. The 1CX and the 1CF flow recorder controller calibrations were completed, and a preliminary calibration of the 1CF photometer obtained. Final calibration of the 1CF photometer and of the column density instrument will be made after the desired ranges of these instruments have been established. The 1CF flow indication was correlated with the 1CF uranium concentration, and the data reduced by least squares techniques for use with the data reduction code.

Shakedown runs of the facility have resulted in satisfactory operation of the control systems for the 1CX and 1CF flows, interface position, pulse frequency, 1CX pH, and 1CF uranium concentration. The 1CX and 1CF temperature control systems, while acceptable, are sluggish and required prolonged operation to reach temperature equilibrium. Minor modifications to the steam and condensate piping to the heat exchangers are expected to improve this condition.

A blown diaphragm on the 1CF temperature control, air-operated, steam valve and a similar occurrence with an identical valve on another installation, indicate that better diaphragm material will have to be provided for these valves.

During the shakedown runs a glass section of the column was broken while inserting the mid-column photometer into a sample port. Redesign of the photometer support and counter balance system has been initiated and a possible redesign of the sample ports is being contemplated to minimize this problem.

Control Model Development

Theoretical operating lines for a C-type column has been developed in differential form. With the multipoint data to be collected from the C column test facility the equations can be rigorously tested and the coefficients evaluated.

The final results are expected to be an expression of uranium concentration in either phase as a function of input variables and column height. The final model will be used as a basis for a control system for a column of fixed geometry at steady state conditions.

Instrumentation for Bubble Counter

Development of a time to pulse amplitude converter for use with a bubble counter transducer has been completed. The converter operates with bubble durations from 0.05 to at least 1.0 second and may be calibrated from about 0.1 second to 1.0 second using the present calibration circuit. Read out for the system is a 20 channel analyzer which sorts pulses according to amplitude and also totalizes the pulses. This information is analagous, respectively, to individual bubble diameter and total number of bubbles per unit time in the solution being analyzed.

UO_3 Calciner Furnace Control System

An equation describing the calciner furnace transfer function, based on a theoretical model, has been derived. Plans are to simulate the calciner control system on an analog computer to determine the validity of the model and the requirements for a stable control system.

NON-PRODUCTION FUELS REPROCESSING

Mechanical Processing

Shear System Studies - Recent studies on the 40-ton development shear system which contains the basic operational components of the mechanical cell shear system (shear, water recirculation and clarification devices) have demonstrated the basic feasibility of the complete shear system. The hydroclone and water recirculation system

operates effectively to route greater than 99.8 percent of the sheared UO_2 into the shear catch bucket. The shear-to-bucket "rough" seal maintained water leakage well below the hydroclone capacity. During the studies approximately 100 pounds of UO_2 were sheared.

Initial results of the shear blade studies show (1) shear blade hardness in excess of about Rockwell C55 is not desirable, and (2) sharp, fragile points on Vee blades are not desirable (i.e., "points" should be generously rounded or flattened).

Coldsaw and Hacksaw Studies - HW-62843, entitled "Interim Report - Hacksaw Studies for Power Reactor Fuels Reprocessing," is currently being issued. This document summarizes Process Equipment Development "cold" saw and hacksaw studies and recommends hacksaw feed mechanisms and blades for cutting Hanford's proposed reprocessing load.

Fuel Element Disassembly - HW-65380, entitled "Yankee Band Cutting," is currently being issued. The document discusses the various methods studied for removing the tie straps and bands which hold the Yankee subassemblies together. Fuel element shimming, abrasive sawing and slitting knife studies are discussed.

Dissolution of Arnel Filter Material - Synthetic Redox process feed solution was prepared by co-dissolution of uranium dioxide and Arnel filter material (amounts corresponding to six pounds of Arnel per ton of uranium). Dispersion and disengaging tests indicate no emulsion forming tendency due to the dissolved Arnel. In similar tests made previously with Orlon filter material, emulsion formation occurred. The test was made in connection with a proposal to recover solids from the shear basin filter by dissolving filter and occluded fines while dissolving uranium dioxide cores.

Feed Preparation

Zirflex Process - Two runs were made to demonstrate the Zirflex decladding of oxidized FRTR fuel elements (Zircaloy-2 clad UO_2) in a recirculating dissolver. Dissolvent charge concentrations for the runs were 5.5 M NH_4F plus 0.5 M NH_4NO_3 with a F/Zr mole charge ratio of seven. A steam sparge was used for motivation of the dissolvent in the first run, and an air sparge was used in the second so that uranium core losses to the decladding wastes could be compared for the two methods. The fuel element cladding including end plugs and hangers was completely dissolved in less than six hours in both cases. The waste solutions were cooled overnight, centrifuged to remove UO_2 fines and UF_4 precipitate and sampled to determine soluble uranium losses. For the steam sparged run, uranium losses were approximately 0.7 g/l or 0.33 percent of the charge. Losses for the air sparged run were increased by approximately a factor of three to 2.0 g/l or 0.85 percent of the uranium charge. These losses were higher by a factor of 10 and 28 than the losses from the steam sparged dissolution of unoxidized elements reported last month, possibly because of the typical uneven penetration always secured with oxidized elements.

Laboratory-scale decladding of Zircaloy-clad UO_2 by the Zirflex process was done in an attempt to explain the unusually high uranium losses sustained in the above pilot plant runs. The Zircaloy cladding was oxide coated. Ammonia removal was by steam sparge. Uranium content in the decladding solution was followed as a

function of decladding time. As expected, the soluble uranium content rose rapidly to a maximum of about 3.5 g/l at about one hour. Thereafter it steadily declined to about 1.7 g/l at the end of decladding (four hours). After 5.5 hours steam sparging was stopped. Soluble uranium in the cooled solution was 0.65 g/l which decreased to 0.45 g/l at 22 hours. A uranium content of 1.3 g/l represents 0.5 percent loss in this run. These data are consistent with the recirculating dissolver experience described above.

No completely satisfactory solution to the problem of measuring pH in Zirflex solutions has been found. By careful buffering and by remaining in the pH range 6.2 to 7.7, reproducible results were obtained using new general purpose Beckman glass electrodes. The same dependence of Zircaloy dissolution rate on hydrogen ion concentration as previously reported was found -- dissolution rate is proportional to $(H^+)^{0.68}$. Preliminary data on the dependence of Zircaloy dissolution rate on free fluoride concentration indicate dissolution rate proportional to $(F^-)^{1.6}$ at pH 7.

Sulfex Process - Small scale studies of nitrate destruction by formalin in typical Sulfex decladding solutions have clearly indicated that the nitrate removal is a function of total acidity. At initial nitric acid concentrations of about 0.5 M, nitrate destructions varied from 3 to 99 percent of the initial as total acidities increased from 0.5 to 2.3 M.

One Sulfex dissolution of simulated fuel elements has been performed in the Niflex-Zirflex-Sulfex pilot scale dissolver facility. About 200 pounds of uranium dioxide pellets, clad in 0.016-inch wall thickness, 1/2-inch diameter, type 304L stainless steel tubing were successfully declad with sulfuric acid. The initial acid concentration was four molar, and this was increased to about six molar by slow acid addition. The hydrogen evolution rate indicated that the attack rate was markedly reduced from that obtained in glassware runs on small pieces of the same tubing. The rate was very slow at first, built up slowly to a maximum with acid addition and then fell off very gradually with consumption of stainless steel. The hydrogen evolution profile is strongly reminiscent of a probability curve. The fall off in reaction rate was demonstrated to not be solely due to depletion of the acid by the observation that addition of acid in the latter stages occasioned no increase in hydrogen evolution. These phenomena are currently postulated to be due to a random variation of activity of stainless steel and a random partial occlusion of portions of the stainless surface by the UO_2 pellets and other stainless steel pieces.

Hydraulic Studies - Recirculating Dissolver - In studies of air-lift induced recirculation through UO_2 packed beds, the improbability of obtaining adequate liquid flows when air is introduced below the bed was demonstrated. The air displaces the liquid from the bed with the result that all liquid flow ceases whereas the air flow encounters almost no resistance. Further studies are planned on a system employing a simulated fuel element cannister with the air being introduced above the cannister bottom seal and into annular space (1/4-inch) between the cannister and the dissolver wall. In this manner the air can be introduced into the dissolver above the bed, but it may be possible to promote circulation.

Materials of Construction

Samples of the second twelve heats of experimental alloys were received from BMI. Experiments to determine their corrosion behavior in Huey tests and in Zirflex and

Sulfex process solutions are underway. Preliminary data on corrosion of these alloys in Sulfex and Niflex solutions have been received from BMI. Not enough corrosion data have been obtained to warrant detailed discussion of the effects of composition changes in these alloys. Some of them appear to be somewhat superior to the best of the first twelve heats in Niflex solutions.

"In-Tank" Boron Monitors

Tests on the Boron Monitors proposed for five locations in the Redox plant have been completed in the 321 Semiworks. Calibration data for the three aqueous make-up tanks (2EX, 1BX and 2DA) arecomplete. Calculations are being made to determine what effect different U-235 enrichments will have on the monitors' sensitivity for the two evaporator (F-2 and F-5) applications.

Preparation of Feed Materials for Criticality Studies

The feed materials for the first experiment to determine k_∞ versus H/U atomic ratio for the three percent U^{235} enriched homogeneous uranyl nitrate-water system have been prepared and delivered. The shipment consisted of approximately 300 pounds of boron-poisoned uranyl nitrate trihydrate (H/U = 6).

The preparation procedure consisted of (1) dissolution of UO_3 in nitric acid, (2) concentration to $UO_2(NO_3)_2 \cdot 3H_2O$, (3) solidification, (4) pre-crushing, (5) pulverizing, (6) blending of boron carbide impregnated polyethylene and uranyl nitrate, and (7) loading into plastic lined aluminum tanks. The first six operations were successively performed in four separate batches of the total uranyl nitrate to meet critically-safe specifications. The average composition of the soluble material was 53.1 weight percent uranium, 28.2 weight percent nitrate, and 11.6 weight percent water.

REACTOR DEVELOPMENT - 4000 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Processing PRTR Fuels in the Redox Plant

Aluminum alloy 6061 is being considered for fabrication of baskets to transport PRTR fuel elements to the Redox plant. The dissolution behavior of this alloy (which contains three to four percent of non-aluminum constituents) in HNO_3-$Hg(NO_3)_2$ was found to be very similar to that of Pu-Al-Ni-Si-Fe alloys proposed for spike fuels - rapid in low and slow in high acid concentrations. Dissolution of the basket material in HNO_3-$Hg(NO_3)_2$ instead of $NaNO_3$-NaOH is proposed for those cases where ruptured spike fuels are present to avoid rapid attack on exposed core material. The similar dissolution behavior of core material and alloy 6061 in HNO_3-$Hg(NO_3)_2$ indicates significant selective dissolution of 6061 in this reagent is not possible. The use of 2S aluminum baskets would permit selective dissolution of the baskets since 2S aluminum dissolves rapidly in strong HNO_3-$Hg(NO_3)_2$ solutions.

A series of dissolutions of Al-Pu-Si-Ni-Fe alloy was made to determine if the rapid dissolution of this alloy in HNO_3-$Hg(NO_3)_2$ solutions at low acid (ca. 3 M) could be moderated by the presence of uranyl nitrate. Moderation of the dissolution

rate is desired because of hydrogen production. These runs demonstrated that good control of dissolution rate is feasible. Dissolution times for one-half inch diameter rods were increased from one to 24 hours as uranyl nitrate concentration was increased from zero to 0.75 molar.

Simulated Redox feeds were prepared from the dissolver solutions prepared in these runs. In all cases, stable emulsions were formed when these were contacted with neutral hexone. Emulsion formation could, in general, be prevented by addition of Mistron-25 (65 - 250 ppm) prior to contacting with hexone provided the solutions contained sodium dichromate and had been heated (plutonium oxidation step). Addition of Mistron-25 to solutions not containing dichromate had a varying and non-reproducible effect on emulsion formation.

Dissolver solutions prepared by dissolving Al - 2 w/o Pu - 2 w/o Ni alloy in HNO_3-$Hg(NO_3)_2$-UNH solutions were visibly clear and free of solids. Dissolution rates were comparable to those for the Al-Pu-Ni-Si-Fe alloy used in previous studies. Dispersion-disengaging time tests were made with these solutions (and neutral hexone) following adjustment to Redox feed composition and simulating plutonium oxidation. In all cases, disengaging times were comparable to those obtained with control solutions prepared from laboratory reagents. It was noted, in these studies, that disengaging times were markedly influenced by the acidity of the feed solution when dichromate was present. Increasing the feed acidity from -0.2 to 0.1 M increased disengaging times from one to three minutes. The Redox plant is currently operating without emulsion problems using acidic dichromate-containing feeds.

Continuous Ion Exchange Contactor Development

MABIE Contactor - Hydraulic studies of the MABIE contactor were continued in a two-stage column. Various cartridge geometries were investigated using 20 to 50 mesh resin to optimize the stage separator and resin downcomer design and delineate operating characteristics. The significant results of the studies to date are summarized below:

1. A stage separator composed of sieve plates with 0.08-inch diameter holes and 23 percent free area provided good performance.
2. A one-inch diameter downcomer pipe, extending approximately two inches below the stage separator and nearly to the center of the column provided adequate resin transport.
3. Good operation was demonstrated with the aqueous flowing either upward or downward in the column.
4. The resin flow rate is independent of both agitation and aqueous flow rate.
5. A resin hold up of approximately 67 percent of the contactor volume resulted in good operation with a minimum agitator power.
6. [redacted]

Jiggler Contactor - Hydraulic tests with Permutit SKB resin (10-20 mesh) indicate that the resin recycle capacity of the one-half inch recycle line is about 100 ml/min. The resin flow has been shown in recent tests to be unrelated to the amplitude-frequency product. Factors affecting the rangeability of the resin flow to meet different flowsheet conditions are now being studied. These include the height of introduction of the air jet to the resin recycle line, the total aqueous flow in the "A" column, and the diameter of the resin recycle line. Other variables that will be measured or calculated are the resin and liquid pressures at various points in the systems.

Salt Cycle Process

Determination of O/U Ratio in Uranium Oxides - Development work on the determination of uranium(VI)/uranium(IV) ratio in uranium oxide samples by controlled potential coulometry has been completed and the method transmitted to the Analytical Laboratories Operation for routine use. The precision attainable by this method is indicated by analyses of a standard U_3O_8 sample yielding for the O/U ratio a value of 2.6677 ± 0.0009. A paper describing the method is in preparation for publication.

Polarography in Molten Salts - Many experimental problems have required solution to enable satisfactory polarograms to be obtained under the rather extreme conditions required to work in molten NaCl-KCl mixtures. One of the major problems has been obtaining a suitable sheath around the Ag/AgCl reference electrode which would protect this half-cell and still maintain a suitable electrical contact with the salt solution. A sheath of "Supremax" glass suffices in all respects except that it imposes a high resistance which limits the current which can be drawn from this electrode and distorts the polarographic wave. This problem has been solved by employing the controlled potential polarographic technique. An operational amplifier controls the potential between the micro electrode and the reference electrode at the applied scan potential throughout the scan. The current required to maintain the necessary condition of concentration polarization at the micro electrode is drawn largely from a third electrode so that very little current flows through the reference electrode.

With this set up well-formed polarograms are obtained from which information of thermodynamic significance can be deduced. For example, interpretation of the polarogram for the Cu(I)/Cu(C) couple yielded a measured value of 1.08 for the electron change.

Insufficient work has been done with the uranyl ion as yet to permit conclusions as to the mechanism of reduction of UO_2^{++} to UO_2. However, it was observed that the half-wave potential for the UO_2^{++}/UO_2 reduction changed when the scanning rate was changed, implying a kinetically-limited process. Also, the indication is that deposition of UO_2 on the micro electrode enlarged the area of this electrode sufficiently that a limiting current was not obtained. Among other things, this implies that UO_2 deposits so formed have a rather substantial electrical conductivity.

Dissolution Rates for Uranium Oxides in Molten NaCl-KCl - Comparative dissolution rates were measured for various uranium oxides into NaCl-KCl eutectic at 700 C with a uniform chlorine sparge rate. Using one gram samples of -100, +325 mesh powder, the amounts of uranium dissolved in 5 and 30 minute periods were measured with the following results:

	g U Dissolved	
	5 minutes	30 minutes
Pot type UO_3	0.79	-
U_3O_8 prepared by ignition of Pot type UO_3	0.51	-
Spencer Arc-fused UO_2 (O/U = 2.01)	0.038	0.125
Horton Arc-fused (O/U = 2.01)	0.062	0.155
Electrolytic UO_2 (O/U = 2.01)	-	0.125

It is apparent that substantial improvements in dissolving rate can be obtained by converting UO_2 to a higher oxide prior to initiating chlorine dissolution. In the Salt Cycle Process as presently scoped, UO_2 will be converted to U_3O_8 in the course of the decladding operation.

Apparently, within the range of readily attained particle sizes, dissolution rates of the above near-stoichiometric electrolytic UO_2 were relatively insensitive to particle size. In 30-minute exposures of one gram samples of various sieve screen samples the following results were obtained.

Mesh Size	g U Dissolved
-150, +325	0.125
- 60, +100	0.121
- 20, + 60	0.113
- 9, + 20	0.091

Solubilities of Uranium Oxides in Molten NaCl-KCl - Apparent solubilities of uranium oxides in NaCl-KCl eutectic have been measured at 700 C. Measured uranium(VI) concentration in the salt after five-hour exposures were as follows:

Solid	O/U Ratio	g U(VI)/kg salt
Pot type UO_3	3	66
U_3O_8 prepared by ignition of Pot type UO_3	2.66	13
Electrolytic UO_2	2.17	0.05
	-	0.01
	2.01	0.004

These results confirm earlier results in showing a much greater solubility for the higher oxides. Likewise, in no case could any species other than uranium(VI) be detected in the melt.

Thus, there still remains a possibility that the slight solubility measured for UO_2 stems from oxidation by traces of oxygen or moisture in the system or slight excess oxygen in the UO_2.

Recrystallization of UO_2 - Recrystallization experiments with UO_2 from three sources confirmed earlier observations. When electrolytic UO_2, which forms as aggregates of cubes, is "steeped" in NaCl-KCl-12 w/o UO_2Cl_2 at 800 C certain faces of the cubes dissolve more rapidly than others so that the original cubes grow continually thinner in one dimension and enlarge in the plane normal to that direction. After four hours about half of the UO_2 is still in the form of aggregates, but the original cubes have changed into flat plates oriented at random angles with each other. After eight hours few aggregates remain and the flat plates have become so thin and fragile that they are easily broken into fragments. Starting with -20, +60 mesh material the +60 mesh fraction had been reduced to 18 percent after four hours and to only one percent after eight hours in one case and 28 percent and five percent, respectively, in another case. Norton arc-fused UO_2 (near-stoichiometric) recrystallized in much the same fashion.

When the same process was attempted with massive chunks of UO_2 the overall size of the lumps was not greatly altered in four hours, but two parallel flat faces had developed and various irregularities had been removed from the remaining edges.

These recrystallization processes offer intriguing possibilities for controlling the particle size distribution and shape of UO_2 powder prepared by electrolytic reduction. However, beneficial application will require considerably greater insight into the process than now exists. The effects of recrystallization on chemical purity and O/U ratio are scheduled for early study.

Stability of UO_2Cl_2 in Molten NaCl-KCl - The uranium oxide produced by thermal decomposition under vacuum of uranyl chloride in molten NaCl-KCl at 800 C was found to have an O/U ratio of 2.58 and the X-ray diffraction pattern corresponded to a mixture of UO_2 and U_3O_8. Collection of the off-gas from a run at 700 C indicated the presence of chlorine. The following conclusions have been drawn from this brief study of UO_2Cl_2 in molten NaCl-KCl:

1. At 700 to 800 C, UO_2Cl_2 decomposes by a simple decomposition reaction to produce UO_2 and chlorine.
2. Some uranium(IV) was always found but in runs of any length the quantity was small compared to the UO_2.
3. The mechanism of formation of U_3O_8 is unknown. U_3O_8 formation is greater at 800 C than at 700 C.

$UOCl_2$ Studies - When partially depleted salt cycle electrolytes are dissolved in acidified aqueous solution, a small amount of uranium(IV) is almost invariably found. It has been conjectured that this may arise from uranium(V) by disproportionation or by the aqueous reaction of uranous oxychloride, $UOCl_2$. A sample of $UOCl_2$ was therefore prepared and some of its chemical properties were examined.

Preparation was by the method of C.A. Kraus (CC-1717) which uses the direct reaction of UO_2 with an excess UCl_4 at 600 C, followed by vacuum removal of the excess chloride at 450 C. The greenish yellow solid product analyzed 21.2 percent chlorine and 74.3 percent uranium; theoretical for $UOCl_2$ is 21.8 percent chlorine and 73.3 percent uranium. The X-ray diffraction pattern was well defined, but did not correspond to the patterns for UCl_3, UCl_4, UO_2Cl_2, UO_2, U_3O_8,

or UO_3. The product was very hygroscopic and insoluble in nitromethane, pyridine, ether, acetone, and phosphoryl chloride. Attempted dissolution in water resulted in formation of UO_2 and a green colored (UCl_4?) solution. Dissolution in concentrated hydrochloric acid resulted in a solution whose absorption spectrum was that only of UCl_4; the spectrum of uranyl chloride was not observed.

Absorption spectra were obtained of the salt mulled in petrolatum over the range of 400 to 1600 millimicrons. A broad absorption band was observed between 930 and 1225 millimicrons that showed fine structure reminiscent of the fine structure of the uranyl peak at 420 millimicrons.

In addition, there were two smaller absorption peaks at 580 and 1285 millimicrons. For comparison, solid UCl_4 was examined under the same conditions. An absorption peak in the same 930 to 1225 millimicrons range was observed, but it contained none of the fine structure associated with the $UOCl_2$. Also, the two peaks at 580 and 1285 millimicrons were absent. From the above data it is quite evident that the sample was $UOCl_2$ of rather high purity.

When $UOCl_2$ was added to molten NaCl-KCl eutectic, a green color formed and upon standing, UO_2 precipitated. The green salt so produced was powdered and an absorption spectrum of it as a mull was measured. This spectrum compared very closely with that of UCl_4-NaCl-KCl. The peaks at 580 and 1285 millimicrons associated with the $UOCl_2$ spectrum were absent. It was inferred from this evidence that $UOCl_2$ is unstable in molten NaCl-KCl and reacts by double decomposition to yield UO_2 and UCl_4. It is believed that $UOCl_2$ is not an important intermediate in the Salt Cycle Process having, if at all, only transitory existence.

Preparation of Pilot Plant Quantities of Electrolytic UO_2 - Construction of a unit to produce 5 to 10 pound batches of electrolytic UO_2 daily is nearly complete. The equipment consists of a 13 KW Trent furnace, an off-gas system with a caustic scrubber, and a 50 KW rectifier. The 50 mol percent NaCl-KCl mixture has been melted in 20 liter batches in a fused silica crucible. All the molten salt in the crucible has been transferred successfully at 700 C from the furnace through a three-foot uninsulated quartz line by vacuum transfer into an identical silica crucible. The salt was cooled and removed from the second crucible in one chunk with no damage to the crucible. The graphite electrodes can be moved into and out of salt bath by means of counter weighed electrical leads. Testing of the efficiency of the off-gas system for chlorine absorption is underway.

Non-Metallic Materials - Four different ceramic compounds were tested in a sodium-potassium chloride melt (equal mol percentages) containing 10 weight percent uranyl chloride. The melt was maintained at 800 C and sufficient chlorine gas was bubbled through the melt to keep the uranium in solution. Results of the test are summarized below:

Material Tested	Duration of Test	Remarks
Alumina Crucible A-402 (Norton Company)	12 days	No change; excellent resistance.
Magnesium Oxide Crucible Magnifrax 0340 (Carborundum Company)	13 days	10 mil attack above the melt. Crucible weight decreased 2 grams.
90% MgO, 10% TiO_2 Slip Cast Crucible (234-5 Ceramics Shop)	6 days	Salt percolated thru crucible. Crucible weight decreased 2 grams.
CaF_2 Crucible (Local Fabrication)	--	Crucible cracked and broke when cooled in air. Subject to local attack.

Other Pyrochemical Systems

Despite the ease of reduction of ruthenium(III), it was found that the distribution of ruthenium-106 tracer between molten aluminum and $AlCl_3$-KCl did not exceed 1.5. This rather surprising result confirms earlier experiments with fission product ruthenium from long cooled irradiated UO_2.

Continued experiments have shcwn that a number of halide mixtures form immiscible liquid phases in contact with molten $AlCl_3$.KCl. Some of these immiscible systems are 50 m/o LiCl-35 m/o KCl-15 m/o NaCl, 60 m/o LiCl-40 m/o NaCl, and 40 m/o $CaCl_2$-40 m/o LiCl-20 m/o NaCl. In these systems the two phases retain their identities quite well with only a slight amount of cross contamination.

Distribution behavior in these systems is very interesting. Uranium(IV) distributes in favor of the aluminum chloride phase; whereas, trivalent uranium prefers the alkali chlorides. Since plutonium(III) behaves like uranium(III), this system, in principle, can effect separation of uranium(IV) and plutonium(III). Ruthenium-106 tracer favored the alkali chloride phase in distribution studies between NaCl-LiCl and $AlCl_3$-KCl. The distribution coefficients ranged from 7.4 to 10.

Visible and Ultraviolet Spectra of Uranium Chloride-Alkali Chloride Systems

Because the determination of species in molten salt systems cannot be satisfactorily made by analysis of derived aqueous solutions, the development of spectrophotometric methods for fused salts in the visible and ultraviolet regions has been intensified.

Using ultra-thin (0.025 mm) quartz spectrophotometer cells, it has been possible to obtain absorption spectra of both alkali chloride-uranium(III) chloride molten and frozen salts over the range 300 to 1300 millimicrons.

In molten NaCl, KCl, or CsCl, UCl_3 exhibits similar absorption spectra with indication of at least two complexed species, one of which is predominate in the CsCl system.

The same systems were cooled in the spectrophotometer; the transitions being readily observed by abrupt changes in the transmission. At temperatures below the second transition (believed to be the eutectic), the absorption spectra of UCl_3 in NaCl, KCl, and CsCl were entirely different. The NaCl-UCl_3 system gave a spectrum similar to that of UCl_3 in petrolatum indicating segregation of the salt. The other two systems were different from the NaCl system in that the UCl_3 spectrum was not observed. It has been assumed that complexing occurs in the KCl and CsCl systems, and in fact, indications of this appear in the phase diagram for the system RbCl-UCl_3. Microscopic examination of the alkali halide-uranium halide samples revealed that segregation occurred in the slow cooled KCl and CsCl salts but no UCl_3 spectrum appeared. On the other hand, even very rapid quenching from 890 C of the NaCl-UCl_3 system failed to prevent the UCl_3 spectrum.

Pressed pellets of UCl_4 in the alkali chloride salts gave spectra at room temperature that were all different. These systems, like those containing UCl_3, showed similar spectra in the molten state. Also, as in the case of UCl_3, evidence for complex ionic species were obtained in the molten state.

Infrared and X-ray diffraction spectra data were also obtained but did not provide much help in the elucidation of the species present.

CsCl-RbCl System

The liquidus of the CsCl-RbCl system was determined to see if this system contained a sufficiently low melting eutectic for use in pyrochemical studies. Unfortunately, no eutectic was found, the temperature monotonically dropping from the melting point of RbCl, 718 C to that of CsCl, 646 C. The modified Beckman DU spectrophotometer turns out to be very useful in determining when phase transitions occur. The reproducibility of temperature is about ± 1 C.

RADIOACTIVE RESIDUE PROCESSING DEVELOPMENT

Radiant-Heat Spray Calcination

Ten runs were made during the month to determine the capacity limitations of the spray calciner for operation with simulated formaldehyde-killed, high-sulfate Purex waste. The degree of calcination, as measured by weight loss and chemical analysis, was only slightly affected by feed rates up to 11.3 gal/hr,ft^2, the limit set by the spray nozzle and Calrod heaters. The tap density of the powder product increased with flow rate and also with the addition of 50 g/l of sugar. Thus, the product densities ranged from about 0.9 to 1.4 g/cc with sugar and from 0.85 to 1.0 g/cc without. Since glass-forming additives were not used, all of these densities are gratifyingly high, compared to those obtained in earlier runs. Reason for the increase in density with flow rate is not apparent but may well be related to the feed/steam ratio, a point which will be explored further.

Post-calcination heating of spray-calciner powders to 950 C continued to show that there is a large (30 to 40 percent) weight loss and evolution of large amounts of SO_2 and SO_3 in the case of high-sulfate Purex waste. This weight loss was found to be substantially reduced by addition of calcium and even more, by a factor of ten, when 250 g/l of sugar was added to the waste prior to calcination. The calcium presumably forms thermally stable calcium sulfate whereas sugar promotes decomposition of most of the sulfate in the spray-calciner itself. Heating tests were also made this month on spray-calciner powders produced some time ago with low-sulfate Purex waste. There was no weight loss, in fact a slight gain, on heating these. Sulfate concentration of the high-sulfate waste was 1.6 M as compared to 1.25 M in the low-sulfate material. The sulfate/sodium mole ratio in these two feed compositions is probably more significant in explaining the difference than is the actual sulfate concentration. Values of these ratios were 1.69 and 0.5, respectively, in the high and low sulfate wastes, i.e., the low-sulfate waste contained sufficient sodium to form sodium sulfate.

A series of new corrosion coupons were exposed during the month's runs and indicated corrosion rates far lower than reported earlier. Type 446 stainless steel and Inconel showed rates of < 0.01 and 0.4 mils/month, respectively.

Thermal Conductivity Studies

A sample of calcined simulated 1WW in a 60 percent Pb-40 percent Sn matrix was prepared by drawing the molten alloy into the voids in a cylindrical bed of the calcined 1WW. The resulting composite had a density of 4.4 grams/cc and a thermal conductivity of 2.6 Btu/(hr.-sq.ft. °F/ft.) at 150 C.

Mineral Reactions

Laboratory tests indicated that mine-run clinoptilolite is somewhat more friable than is Decalso, a commercial aluminosilicate ion exchanger. Screened samples of these materials were agitated under water for 48 hours. Clinoptilolite containing weathered surface material produced 4.9 percent fines (< 0.25 mm), unweathered clinoptilolite produced 1.3 percent fines, and Decalso produced <0.4 percent fines. Vigorous washing of the clinoptilolite as the commercial material was washed might have reduced the apparent degradation.

Breakthrough curves obtained for cesium adsorption on 50 g, 23 cm beds of 0.84 - 1.0 mm and 1.2 - 1.4 mm grain size clinoptilolite were relatively flat for flow rates of 5 gal/ft^2/min. It was found that the same effect was obtained when the residence time was increased by either reducing the flow rate or increasing the size of the bed.

Experiments were repeated to study the influence of irradiation on the adsorption of cesium by clinoptilolite. Again, a significant difference was found between those mineral specimens receiving dosages of up to 2 x 10^8 R and those receiving 5 x 10^8 to 1 x 10^9 R. The adsorption was studied in temperature-controlled equilibrium systems. At 25 C no differences in the distribution coefficients for any of the specimens were evident. Those samples that received gamma doses of 2 x 10^8 R or less gave coefficients nearly 20 percent higher at 55 C than at 25 C. Those samples receiving 5 x 10^8 and 1 x 10^9 R did not give higher coefficients at 55 C than at 25 C. Thus, at 55 C the distribution coefficients for the most highly irradiated specimens were lower than for those receiving lower dosages. These results tend to indicate that the temperature effect is in some way associated with the solid phase. It is possible that the higher temperature accentuates an effect that is not large enough to be discernible at the lower temperature.

An experiment was completed in which Purex high-level waste was passed through a clinoptilolite column and the cesium later eluted. Cesium analyses are not yet complete but preliminary study of the breakthrough results indicated by monitoring instruments gave a capacity of about 600 column volumes of 20:1 diluted waste (30 column volumes of actual waste). When the column was eluted with 10 M NH_4NO_3 nearly all of the cesium was removed from the mineral by the first two column volumes.

The combined treatment by activated carbon and clinoptilolite removed cesium with a decontamination factor of about 25 at the low flow rate and about 190 at the high flow rate. Strontium was removed with a decontamination factor of about 30 at the low flow rate and about 12 at the high flow rate. The Zr^{95}-Nb^{95} isotopes were removed with a decontamination factor of about 3 at all flow rates. The cesium results are the reverse of what normally would be expected. Further tests must be made to evaluate the accuracy and significance of these results.

Further experiments were performed to study the removal of radioruthenium by beds of metal powders. If the mechanism of removal is ion exchange on the oxide film of the metal the presence of large concentrations of competing cations should suppress ruthenium uptake. To demonstrate this, 1 M $NaNO_3$ solutions containing radioruthenium were equilibrated with 1000 ppm powdered lead, iron, manganese, zinc, copper, magnesium, and aluminum. A small decrease in ruthenium adsorption

over that observed in the case of low-salt systems was evident from the powdered lead experiment. In reaction with the other metals tested the results were quite dependent on the initial pH of the solution. In the case of pH 11 solutions iron, manganese, and copper showed increased ruthenium removal in the high salt systems. Accelerated oxidation of iron was evident in the strong electrolyte systems which may explain the increased ruthenium removal. The results of these experiments in high salt systems are not conclusive but do not appear typical of conventional ion exchange reactions.

Condensate Streams

Studies on the decontamination of Purex Tank Farm condensate in the 271-CR Building Micro Pilot Plant were continued. During Run 4 the waste was passed downflow through a bed of activated carbon having a particle size of 0.6 to 2.4 mm, a bed height of about 36 inches and bed diameter of 1 inch followed by a bed of clinoptilolite having a particle size of 1.1 to 1.3 mm, a bed height of about 36 inches and bed diameter of 1 inch. Temperature of the system remained at 25 C and pH varied from 8.3 to 10.5. The TBP concentration in the feed fluctuated from 28 to 55 mg/liter, and was removed by the activated carbon to less than 1 mg/liter.

The only isotopes removed significantly by the activated carbon were those of strontium. At about 0.5 gpm/cu.ft. the decontamination factor for strontium was about 4.2. As the flow rate was increased to about 2.3 gpm/cu.ft. the decontamination factor was reduced to about 1.2.

BIOLOGY AND MEDICINE - 6000 PROGRAM

Origin of Sc^{46} in Reactor Effluent Water

Sc^{46} can be produced in the reactors by a fast neutron reaction on Ti^{46} or a slow neutron reaction on Sc^{45}. In order to determine which mechanism was responsible for the Sc^{46} observed in the aluminum process tubes, a series of samples of a tube were taken along its length so that a wide range of ratios of fast to slow neutron flux would be represented. These samples were analyzed for Sc^{46}, Mn^{54} (which is formed by fast neutron reaction only) and Fe^{59} (which is formed by a slow neutron reaction). Sc^{46} to Fe^{59} ratios are relatively constant while Sc^{46} and Mn^{54} ratios vary markedly along the tube indicating that a slow neutron reaction on Sc^{45} is the source of the Sc^{46}.

Removal of Arsenic by Alum Floc

In laboratory tests of the effectiveness of alum flocs in removing arsenic from river water it was observed that 98 percent of ionic arsenic is incorporated into the floc at pH values from 6.0 to 7.2 and alum concentrations of 40 ppm. At pH values above and below this range the efficiency drops significantly. At 10 ppm alum only about 60 percent of the arsenic is removed. Since 10 ppm is about the concentration now used in the process water treatment plants, an improvement in arsenic removal and a consequent decrease in As^{76} in reactor effluent water may be possible. Further small scale studies will be undertaken upon completion of a small prototype water treatment plant now under construction.

Sample Concentration by Electrodialysis

Initial tests of electrodialysis as a means of concentrating large volume water samples showed that about 80 percent of Sr^{85} from a 50 liter sample could be transferred through an ion exchange membrane into a cathode chamber of 1-2 liter capacity in 24 hours. Further studies will be undertaken to evaluate and improve this technique for application to environmental samples.

Low Background Carrier for Plutonium Precipitation

In a study of the effect of choice of carrier for the precipitation of plutonium in the bioassay procedure it was observed that use of lanthanum resulted in a background of 17 tracks per week on the nuclear track film. Substitution of Yttrium, holmium, samarium, dysprosium, or praesodymium resulted in 9, 1, 91, 2, and 1 tracks, respectively. For low background work holmium, dysprosium or praesodymium would be better than lanthanum.

Ground Waste Investigations

The small 6" x 6" crib experiment was completed and the soil beneath the site is draining in preparation for an additional field experiment. It is planned to repeat the 2' x 2' crib experiment with special measurements of the lateral spread of water. The wells in the vicinity of the crib were again probed with the neutron moisture detector. Integration of the probe data indicated a total moisture content in the unsaturated soil above the water table of 887 gal. This may be compared with 965 gal. determined in a similar fashion earlier in the experiment. These results are considered to agree with the nitrate ion breakthrough which occurred after 800 gallons of solution had been discharged to the crib.

Soil Chemistry and Geochemistry

Equilibrium experiments were performed to study the effects of pH and accompanying ion on strontium adsorption by soil. The soil was pre-treated with acid to remove calcium carbonate, but care was taken to avoid destruction of clay minerals which occurs at higher acid concentrations. Experiments were performed at pH 1, 3, 5, 7, 9, and 11 and with accompanying barium ion in concentrations of 0, 1, 10, 100, and 1000 ppm. It was found that the equilibrium distribution coefficient for strontium was affected by the presence of 1 ppm barium at pH 3 while, at pH 5 and above, 100 ppm or more barium was required to give a measurable effect. No appreciable adsorption of strontium was obtained in any experiments conducted at pH 1.

Earlier experimental attempts to compare the adsorption of Ce(IV), Ce(III), and Pm by Hanford sub-soil indicated that all three species had about the same affinity for the soil. It is assumed that the conditions of the experiments resulted in the reduction of Ce(IV) to Ce(III) to give the same equilibrium adsorption in both experiments.

Experiments were performed in which oxidation conditions were maintained by the addition of $NaBiO_3$. In these systems the adsorption of cerium was significantly greater than that of promethium, indicating that Ce(IV) is the species concerned in these experiments. Under the conditions of these experiments 99 percent of the cerium was adsorbed compared with only 58 percent of the promethium. It was earlier found that Ce(III) and Pm reacted in an essentially identical manner in soil systems.

A calcite-Zn^{+2} replacement reaction was investigated for two reasons: To test the theoretical conclusion that replacement reactions are solubility controlled, and to test the practical value of a statistical method of data treatment originated by Yates. The reaction effectively removes zinc from solutions containing as little as 10^{-3} M Zn^{+2}. Up to 0.3 M $NaNO_3$ did not affect the rate of this reaction. Other variables included column flow rates of 500 and 5000 gal/ft^2/day, calcite surface areas of 0.014 to 0.164 m^2/g, influent pH of 6.0 and 8.0, temperatures of 25 C and 60 C, and the addition of 1 mg/l $ZnCl_2$. None of the variations of the system significantly affected the average Zn^{65} decontamination factor of 100. X-ray diffraction was used to identify the final product of the reaction as $ZnCO_3$. Yates' method was an effective means of ascertaining the relative significance of system variables.

Geology and Hydrology

A suggestion previously made about movement of ground water at Hanford was again presented independently by Dr. Stevenson Buchan, geohydrologist of the U.K. Geological Survey during his recent visit. He suggested that ground waters might be flowing beneath and parallel to the Columbia River for appreciable distances before entering the river. This effect elsewhere is important where old river channels filled with permeable gravels lie below present channels, but it also occurs where permeable beds or geologic formations lie beneath the river bed. No old river channels in the top of the Ringold formation beneath Hanford are now known to bottom lower than the bed of the present Columbia River. Limited information indicates that the Columbia River is actively downcutting its channel into the Ringold formation below the channels earlier formed. Underflow in old river courses therefore is not likely; however, the complete picture of the old channels is not established.

Greater in potential is the underflow through permeable beds of the Ringold formation. Some beds of that part of the formation lying below the Columbia River have an extent and permeability great enough to permit some underflow up to Wallula Gap, where the Ringold formation ends against basalt. Some of these same Ringold beds also may be transmitting waste waters to depths in the Separations areas vicinity. Some waste waters thus may be escaping detection in this complex flow path but the relatively low permeability and high exchange capacity of the concerned beds probably prevents the creation of undesirable situations. Transmittal of ground and waste waters through permeable horizons in the basalt series ultimately into the Columbia River is also a potential not yet resolved. Wells to be drilled on Project CAH-885, now beginning, will better determine the structure in the Ringold formation, the continuity of the concerned beds, their permeability and regional patterns of variations that will better define this problem.

Geologic samples obtained during the construction of a well by a drive-barrel technique were examined in the laboratory. Physical and chemical characteristics of the samples were compared with those of samples obtained by conventional churn drilling in adjacent wells. In this evaluation the effect of churn drilling was evident from the larger fraction of fine material present in these samples. There was no significant difference in the cation exchange capacity of the samples, however. The two sets of samples were very similar with regard to calcium carbonate content and pH, even though drilling water was used during construction of the wells by churn drilling and was omitted in the drive barrel process. This study indicates that alteration of geologic specimens by drilling would be most evident in the determination of permeability or other physical properties.

A computer program for evaluating transient unsaturated flow in a heterogeneous medium was successfully completed and tested. Tests indicated rapid convergence of the iteration process. The mathematical model is for drainage of a column of

embraced a particle size range from 0.8 to 30 u, a particle density range from 2.7 to 7.8 g/cm^3, a conduit diameter range from 0.54 to 2.64 cm, and Reynolds' Numbers from 3,000 to 30,000.

A relation was derived relating the length of a horizontal circular duct in which all particles will settle by gravity and the length within which 50% will settle. The equation from which the relation was derived takes into account the velocity gradient across the circular duct.

L P Bupp

Manager
Chemical Research & Development

LP Bupp:cf

BIOLOGY OPERATION

A. ORGANIZATION AND PERSONNEL

No significant changes in organization or personnel occurred during May.

B. TECHNICAL ACTIVITIES

FISSIONABLE MATERIALS - 2000 PROGRAM

BIOLOGICAL MONITORING

Radioiodine Contamination

Concentrations of I^{131} in the thyroid glands of jack rabbits were slightly lower than those observed one year ago. Values follow:

Location	μc/g Wet Thyroid Average	μc/g Wet Thyroid Maximum	Trend Factor
4 mi SW Redox	3×10^{-4}	1×10^{-3}	-
Wahluke Slope	2×10^{-4}	4×10^{-4}	-2
Prosser Barricade	2×10^{-4}	3×10^{-4}	-

Columbia River Contamination

Concentrations of gross beta emitters in Columbia River organisms collected at Hanford were about the same as those observed one year ago. Values follow:

Location	Organisms	μc/g Wet Weight Average	μc/g Wet Weight Maximum	Trend Factor
Hanford	Minnows (entire)	2×10^{-3}	3×10^{-3}	-
Hanford	Juvenile Chinook Salmon (entire)	2×10^{-3}	3×10^{-3}	-

Fallout Contamination

Fission products occurred in rabbits from the Hanford Reservation in the following amounts:

Sample Type	Total Beta Avg. μc/g Wet Material	Trend Factor
Feces	3×10^{-5}	+3
Bone	9×10^{-6}	-2
Liver	7×10^{-6}	-
Muscle	5×10^{-6}	-

Effect of Reactor Effluent on Aquatic Organisms

Young chinook salmon were held in effluent from the 100-KE reactor at concentrations approximating those which currently exist in the Columbia River, and at higher concentrations predicted for the future. At the end of seven weeks exposure, no adverse effect was detected in any of the concentrations tested.

BIOLOGY AND MEDICINE - 6000 PROGRAM

METABOLISM, TOXICITY, AND TRANSFER OF RADIOACTIVE MATERIALS

Phosphorus

Exposure of cichlids to aquaria water containing P^{32} was discontinued after approximately eight months. Cursory observations did not reveal radiation damage in the fish, some of which contained more than 0.1 μc P^{32}/g.

Strontium

None of the yearling trout which have received Sr^{90}-Y^{90} five days a week via force feeding have yet shown gross signs of radiation damage. The high level group has now received 0.5 μc/g of fish five days a week for thirteen weeks. The fish in all lots have approximately doubled their weight during the course of the experiment.

A surgical technique for providing agastric fistula in trout is being perfected for future studies of the assimilation of orally administered isotopes.

Data were being collected on first generation Ephestia (moths) from parents that were cultured on cornmeal spiked with 1 μc and 3 μc of Sr^{89} per gram of cornmeal. Upon the bases of this preliminary experiment, an experiment was initiated to compare the productivity of populations of Ephestia cultured on five different concentrations of Sr^{89}.

The blood picture of the adult miniature swine fed 1.5 or 25 μc of Sr^{90} daily for over one year continues to be generally indistinguishable from the control animals. There is, however, a suggestion of a lowered neutrophil count in the adult animals fed 25 μc per day and in their four-month-old offspring. (An X-ray reading protocol for assessment of damage was established. All X-rays taken to date of the Sr^{90} toxicity and comparative toxicity animals involving about 750 X-ray plates were re-read and evaluated according to the new coding system. This new method should allow us to evaluate damage by the use of the IBM process.)

A previous observation that strontium alleviated chlorosis in bean plants was confirmed. Chlorotic symptoms were less pronounced in the present experiment than previously observed and in this case occurred only when calcium in the nutrient solution was extremely low (0.05 mM). Thus, in the synthesis of chlorophyll, strontium can partially replace calcium.

Iodine

Preliminary observations on the first group of lambs given in vivo or in vitro I^{131} labeled milk indicated that the thyroid uptake was approximately the same in each sub-group. (The second group of lambs will be initiated in June.)

Cesium

Bean plants grown with varying concentrations of Cs and K and the sum of the two ions held constant showed only a very slight change in discrimination factor even though the ratio of the two ions varied widely. The shift in discrimination factor was in opposite directions in roots as compared with other plant parts, suggesting that roots are withholding one or the other ions from transport to the rest of the plant.

The effect of soil moisture on uptake of Cs^{137} and K by bean plants was studied under conditions of heavy fertilization (including K and Cs) and with soil to which no nutrients were added. With heavy fertilization Cs^{137} uptake was clearly increased when available water was at a minimum compared to more moist soils. There was little change in uptake of K with different soil moisture under both conditions of fertilization. The discrimination factor for Cs was clearly higher with minimal soil moisture, higher both in leaves and stems.

Plutonium

Adult Habrobracon, parasitic wasps, were fed upon a saturated sugar solution spiked with different concentrations of Pu^{239} supplied as citrate. Longevity was not affected except among those which fed upon the highest concentrations, containing 0.1 μc of Pu^{239} per ml of medium. Plutonium was found in eggs of females which had fed upon the spiked food. Egg production and viability was reduced.

Tattooing, injection procedures, and monitoring techniques are undergoing final checking prior to initiating the main study on the effects of intradermal plutonium in pig skin.

Radioactive Particles

Examination of the beagle colony revealed a major problem in parasite infestation. The problem can be partially solved by raising our own pups. Only the new dog runs provide adequate isolation facilities to control parasite re-infestation. The older runs will have to be either substantially modified or replaced.

A study of the acute toxicity of plutonium inhalation was completed. A major clinical manifestation was reduced lymphocyte count beginning two weeks after exposure and continuing until death. Death occurred 50 to 100 days after exposure and followed a period of extreme respiratory involvement. In twelve dogs the lung burden at death varied from about 7 to 50 μc. The mean radiation dose to lung tissue, assuming uniform distribution of plutonium, was about 20,000 rads.

Gastrointestinal Radiation Injury

Investigations into the mechanisms of serum protein leakage into the X-irradiated intestine have shown that in the rat about 1/4 of the I^{131} labeled polyvinyl-pyrrolidone (PVP) given intravenously and excreted via the gastrointestinal tract is excreted into the intestine by the way of the bile duct. This amount does not appear to be increased by exposure of the gastrointestinal tract to radiation and results are not yet completed which should show if bile flow indirectly affects PVP excretion. Additional results suggest that some PVP is absorbed from the gut and excreted in the urine.

Screening of the histopathologic changes of about 100 rats surviving acute irradiation of the intestine by plutonium, yttrium and X-irradiation showed that 5 rats exposed to X-ray developed neoplasms of the small intestine but none were found in the lower intestine (colon). No obvious changes were found in the intestine or the kidney which indicated that acute exposure of the intestine to alpha, beta or X-irradiation accelerated the aging process. The data are too few to be anything more than suggestive.

Microbiological Studies

Yeast cells deficient in catalase were observed to be more sensitive to H_2O_2 following irradiation as compared to non-irradiated cells.

Experiments are continuing on the problem of permeability of yeast cells to K^{42} and P^{32} but as yet no generalized results are available. Additional data are being obtained on the effect of mercury and the degree of binding of mercury (using Hg^{203} as a tracer) to the cells. There is, apparently, a different affect of mercury binding on the permeability of P^{32} as compared to K^{42}.

H A Kornberg

BIOLOGY OPERATION

HA Kornberg:es

C. Lectures

a. Papers Presented at Meetings

H. E. Erdman, "X-rays and the Weakest Link in Habrobracon Ontogeny," Radiation Research Society Meeting, May 11, 1960, San Francisco, Calif.

R. A. Hennacy, "Preliminary observations on the pharmacodynamics and biological effects of inhaled plutonium oxide in dogs," Radiation Research Society Meeting, May 11, 1960, San Francisco, Calif.

F. P. Hungate, "Radiation sensitivity studies on respiration deficient yeast," (by R. T. O'Brien), Radiation Research Society Meeting, May 11, 1960, San Francisco, Calif.

M. F. Sullivan, "Plasma protein loss after X-irradiation or nitrogen administration," Radiation Research Society Meeting, May 11, 1960, San Francisco, California.

J. E. Ballou, "Effect of combined plutonium and X-irradiation in the rat," Radiation Research Society Meeting, May 11, 1960, San Francisco, Calif.

L. A. George, "Distribution pattern and effects of intradermally injected plutonium," Radiation Research Society Meeting, May 11, 1960, San Francisco.

b. Off-Site Seminars

H. A. Kornberg, "The Biology Program at Hanford Atomic Products Operation," Seminar on Implications of the Life Sciences to General Electric, May 4, 1960, Santa Barbara, California.

W. C. Hanson, "Project Chariot Ecological Studies," May 12, 1960, Civil Engineering Society group, Kennewick, Wash.

c. Seminars (Biology)

W. C. Hanson, "Environmental Studies at Project Chariot," May 4, 1960.

J. E. Ballou, "Combined Effects of Plutonium and X-irradiation," May 4, 1960.

R. L. Uhler, "Free Space and Ion Uptake," May 18, 1960.

R. H. Schiffman, "A profusion study of the movement of strontium across the gills of rainbow trout," May 18, 1960.

d. Seminars (local)

None

D. Publications

a. HW Publications

None

b. Open Literature

Foster, R.F., "Radioactive Tracing of the Movement of an Essential Element through an Aquatic Community with Specific Reference to Radiophosphorus," Pubblicazioni della Stazione Zoologica di Napoli, Volume 31, Suppl. pp. 34-69. Pubblicato il 15-XII-1959.

OPERATIONS RESEARCH AND SYNTHESIS OPERATION
MONTHLY REPORT - MAY, 1960

ORGANIZATION AND PERSONNEL

There were no changes in personnel during the month of May.

OPERATIONS ANALYSIS STUDIES

Quality Certification Program

There was no activity in this area during May other than consultation in connection with IBM processing of test data.

Fuel Element Failures

Two appendices were written to be incorporated in a document covering the use of control charts in analyzing rupture data being prepared by Process Technology personnel. One presented the theoretical basis behind the use of such charts, and the other discussed decision rules to be used in analyzing rupture data.

Comments were submitted to Process Technology personnel relative to the disposition of the remaining fuel elements canned in C-64 aluminum components.

Two reports were written presenting sequential plans for comparing rupture performance of two types of fuel elements. The first report covered the situation in which reactor conditions were identical for the two metal types, and the throughput ratio was constant. Operating characteristic and average sample number curves were computed for several cases of interest. In the other approach, provisions were made for adjusting observed rupture experience based on a variable throughput ratio and possibly different reactor conditions. The statistic used in this case is the ratio of times between rupture adjusted for operating conditions.

Optimization of Reactor Operations

Preliminary work was done in connection with evaluating the feasibility of purposely shutting down a given reactor when all others are operating such that charge-discharge and maintenance work can be accomplished without competing for manpower from other reactors.

Z-Plant Information Study

Work is still being held in abeyance until official bid approval is received from the AEC. This is expected during the first part of June.

Radiation Protection

Statistical consultation was provided in connection with the intersite health film badge calibration study. Preliminary data were analyzed and tentative inferences drawn. An analysis was made on data from a recent film fading study to compare the characteristics of Eastman and DuPont film with respect to fading as a function of time. The results of the analysis were interpreted for interested persons.

[redacted]

Reliability Studies

Consultation was held with a member of the Physics and Instrument Research and Development Operation for the purpose of giving mathematical and probabilistic expressions for reliability of a control system.

Work began on the evaluation and comparison of the reliabilities of existing and proposed panellit systems for the NPR.

Work continued on the statistical evaluation of a proposed NPR GM tube type fuel rupture monitor and on the reliability and equipment failure study of the KW reactor.

The results of a study made to determine the number of coolant pressure gauges which can be bypassed and tripped simultaneously without invalidating any normal scram signal have been documented in HW-65435. A similar investigation is now in progress to answer the same questions for a proposed modification of the safety circuits.

Operating characteristics were determined for several plans proposed to test the reliability of the functioning of the boron ball hoppers.

Inventory Studies

The method of sampling used in the spare parts and standby inventories on May 27 was reviewed. Results of the inventory were used to estimate the total inventory surplus or deficit. This represented the first application of sampling techniques to estimate inventories at HAPO.

Redox Dissolver Study

Study of the literature to obtain background information on the reduction of nitric acid in metal systems continued. This has resulted in the formulation of a mechanism for the dissolution of uranium in nitric acid which appears quite realistic. Based on this mechanism, a mathematical model can be formulated. However, there appears to be little hope of testing the model with the GCL computer program since operating data are not available for certain critical variables.

An alternative model based upon semi-empirical considerations is near completion. This model will be tested by the GCL computer program with currently available redox operating data. However, in light of the information now available as a result of the above mentioned literature study, there is little hope of obtaining a good fit to the operating data with this model.

STATISTICAL AND MATHEMATICAL ACTIVITIES FOR OTHER HAPO COMPONENTS

Fuels Preparation Department

Analyses of two sets of stud pulling data were completed. Stud pulling is a test used to measure the bond strength of a fuel element. One set of these data pertained to regular production fuel elements. The fuel elements in the other set were canned in the pilot plant under varying duplex bath conditions. The fact that the stud pulling test detected known effects of these duplex variables on bond strength gave promise of its usability as a routine measurement tool.

A test was designed with the primary purpose of examining the effects on bond strength of duplex bath cycle times. Other variables of interest will also be considered in this test.

[redacted]

Assistance was provided in the design of a test to evaluate the effects on component wettability of vibrator frequency.

An analysis was made of data from an experiment conducted in the pilot plant designed to evaluate the pulse spire agitation technique with respect to its effect on the quality of the spire wall bond.

An evaluation was made of the effects of varying quench conditions on changes in dimensions after heat treating co-extruded tubes. Since growth indices, computed from X-ray diffraction data, were found for the test samples, it was also possible to investigate the correlation between such indices and the actual dimensional changes.

Assistance was given in connection with the design of a production test to evaluate the UT-2 attenuation tester with respect to its ability to predict post-irradiation dimensional distortion.

Irradiation Processing Department

Several discussions were held with personnel interested in the results of the production test concerned with sort measurements (sonic orientation resonance tester). The data from this test are currently being processed.

An evaluation was made of coal sampling procedures, including the choice of cars to be sampled, the system of sampling from the conveyer belts, and the compositing of the samples.

Corrosion data from the enriched I and E run to rupture test conducted to evaluate the self-support concept are being used to further develop a corrosion model for I and E fuel elements.

Mathematical assistance is being given on a problem of fuel design. Specifically, the problem involves determining the optimum positioning of fuel element supports so as to allow maximum warp within a process tube without interference. Based on limited knowledge of the warp characteristics of fuel elements, several mathematical models have been proposed and are presently under investigation.

Chemical Processing Department

Further work was done in connection with establishing part by part acceptance criteria for the final product. Two-sided tests are currently being developed.

Consideration was given the problem of determining the size of an in-line storage facility required for a proposed continuous slag and crucible dissolver. If the required size is not too large, such a facility would eliminate the necessity of removing material from line to vault storage except in unusual cases.

Analytical expressions which can be used to compute the flux resulting from specific irregularly-shaped geometric sources are being developed. Except for special cases which are characterized by their symmetry of location, general answers must await the tabulation of several new transcendents.

Contract and Accounting Operation

Two reports were written in connection with the Electronic Data Processing Operation study. One dealt with the FORTRAN-Monitor customer service evaluation, and the other was concerned with scheduling routine 709 applications, specifically, how much cushion should be associated with given applications or series of applications such that work could be completed on schedule with reasonable probability.

Construction Engineering & Utilities

Current data on fair cost estimates for HAPO projects were reviewed. Comparisons are being made of actual median and low bids with fair cost estimates and predicted low bids.

STATISTICAL AND MATHEMATICAL ACTIVITIES WITHIN HLO

2000 Program

Reactor Kinetics

Solutions to the reactor kinetic differential equation under various assumptions on three parameters involved were obtained by analog methods. In particular cases they exhibited characteristics incompatible with that predicted by theory for differential equations which possess periodic coefficients. As a check, it was decided to obtain the same solutions by numerical methods on digital equipment. Several trial solutions were hand computed to gain insight on methodology, convergence rates, and error control. An IBM-709 computer program has been ordered from SHARE which should be easily modified to the study of the present problem.

Separations Development

A rough draft summary of results from the analysis of an experiment to determine the reduction of sensitivity arising from installing a radiation seal between the pan and beam of a beam balance was issued. The final draft of the report awaits the completion of an exhaustive calibration program for the beam balance and the analysis of resulting data.

Fuel Element Measurement Program

Discussions have been held with interested personnel concerning analysis of strip chart data from a continuous fuel element measuring device to be used to explicitly describe the exterior geometry of NPR prototype fuel elements prior to their irradiation. Harmonic analysis techniques have been suggested for summarizing the strip chart data. Statistical analysis should provide detailed description of the exterior geometry of the fuel element including diameter as a function of axial position measured from one end of the element; ovalidity, a measure of the noncircularity of a cross section as a function of axial position; the distortion in the central axis; and the smoothness of the exterior surface. These statistical techniques are being reduced to computer operations.

Several statistical analyses were performed on pre-irradiation and post-irradiation diameter and length measurements of clustered fuel elements. These analyses investigated the variation of diameter measurements at different positions and orientations on the fuel element surface and calculated precision statements for the estimates of the change in volume due to irradiation.

Pulse Column Test Facilities Study

The evaluation of the precision and accuracy of a device for electrically sizing the organic phase without interruption of the column operation is currently being considered. Appropriate mathematical formulas for estimating the surface to volume ratio of the organic phase have been developed, and their precisions using sample data are being estimated.

4000 Program

Plutonium Recycle

Statistical evaluation was completed of the estimated precision of the proposed heavy water volume calibration program prior to PRTR start-up. Recommendations were made concerning improvement in the precision as a function of the instrumentation and the number of repeat calibrations.

Discussions were continued in connection with the use of statistical methods for determining the maximum of a function defined over a multi-dimensional space. The program will be used with HLO's Meleager physics code to optimize plutonium reactor fuel as a function of initial plutonium isotopic composition.

Swelling Studies

Analysis was completed on the precision of uranium density determinations for different media and sample sizes.

Application of the generalized theoretical model to the study of micrographs of plastic balls in a "scotchcast" medium is being continued.

Waste Disposal

Work was begun on a problem involving the numerical solution of a partial differential equation associated with fluid flow through porous media.

5000 Program

Atmospheric Diffusion Studies

Statistical consultation continued in connection with the calibration of zinc sulfide particle detectors to be used to analyze the sample filters used in last summer's diffusion and deposition study.

Biology and Medicine

Work continued on statistical analysis of data from an experiment involving a challenge dose of radiation applied to pre-irradiated, and nonpre-irradiated mice.

[redacted]

General

Work continued on a statistical method for constructing joint confidence region estimates for the peak heights of multiple peak gamma energy spectra. Data from several spectra of two monoenergetic isotopes are being used to check the estimation method. The technique will be of immediate value to those responsible for the initiation of the study. A generalization of this method should be of value to gamma analyser users throughout the laboratory.

J. L. Jaech

for Carl A. Bennett, Manager
OPERATIONS RESEARCH & SYNTHESIS

JLJaech:kss

[redacted]

PROGRAMMING OPERATION
MAY 1960

A. REACTOR DEVELOPMENT - 4000 PROGRAM

1. PLUTONIUM RECYCLE REACTOR

Cycle Analysis

Computer Code Development. The method of handling the decay of Pu-241 in fuel cycle codes was the subject of a number of computational experiments. Three methods of increasing complexity were tried.

a. No decay: This method assumes that the decay of Pu-241 is a negligible quantity.
b. Radioactive decay with no further treatment: This method assumes that the loss of the high cross section Pu-241 is by far the main factor.
c. Radioactive decay coupled with a full treatment of the resultant isotopes.

Results of experiments show that the difference between methods b. and c. is slight, about 4 milli K, and is constant for all exposures. The non-decay cases (method a.) differ significantly from the others by a factor which is proportional to exposure with a mismatch of about 40 milli K at an exposure of 20,000 MWD/T.

The Meleager A2 code was further improved; it will now provide an assigned initial reactivity by:

a. Change in the concentration of a single isotope,

b. Change in the concentration of two or more isotopes at fixed concentration ratios to each other, or

c. Change in the concentration of a poison added to decrease initial reactivity.

The rough draft report describing the Meleager code was completed and is undergoing final revisions.

A portion of the new LOLA optimization code has been successfully programmed. A set of sixteen data points as input gave answers (Yates, first-order analysis) which checked hand calculations.

The entire RBU input code has been coded and checked except for a few short service routines, and is ready for debugging. Several minor revisions were made in the Monte Carlo and running time and rate of convergence were studied for the problem now being used for testing

purposes. Running time appears to be about the same as the GMC Monte Carlo code, although a direct comparison has not been made.

A completed PUCK code deck is being used to examine the significance of important economic factors on plutonium value. These analyses need be made on only three reactor types to span the significant range. In the meantime another version of the PUCK code is being prepared to update the physics logic and cross section library. The PUCK physics section (GPR) and Meleager burn-up codes will then have similar logic but the GPR code is still limited to U-235 enriched once-through or self-sustaining plutonium recycle operation.

PRTR Startup

A plan was developed for combining ATP's (Acceptance Test Procedures), Design Tests, and Critical Tests to achieve PRTR criticality at the earliest practical date. Requirements for testing the primary system with light water prior to charging D_2O were examined in detail. Other startup action included review of Process Specifications and analysis of individual tests in the Power Test phase of startup.

Other Activities

Assistance was rendered in planning and scheduling for PRCF startup and experimentation. Plutonium Metallurgy and Ceramic Fuels Development were informed of the number and kinds of fuel elements needed for PRCF startup. No problems are foreseen in obtaining the required fuel elements.

The possibility of obtaining reactivity data from MTR irradiations of selected HAPO fuel specimens using the MTR - Reactivity Measuring Facility was studied and appears to be promising.

Several properties of matter which exhibit isotope effects were studied with intent to identify any isotope separation methods which might be especially applicable to plutonium isotopes; a low cost method to eliminate Pu-242 from mixtures of plutonium isotopes would be of great potential value. Absorption of neutrons, a phenomenon highly specific for individual isotopes, was considered as a means of generating either an excited species capable of undergoing high activation energy chemical reactions, or (e.g., by n, β reaction) a different chemical species capable of easy separation from the remaining unaffected isotopes. While this approach is possibly technically feasible, the high cost of neutrons and the difficulty of obtaining ample fluxes of monoenergetic neutrons indicate that the method is probably impractical. Electromigration under unusual conditions was given some consideration and will be further examined. Photo- and other radiative excitation methods to promote chemical reaction in specific isotopes were examined briefly without success.

The first low exposure plutonium bearing fuel rods to be irradiated in the Savannah River reactors for the production of high exposure plutonium for Plutonium Recycle Program use were charged on May 16. The availability of a few kilograms of desirable Canadian material for our use has been confirmed. The early recovery of such materials would be very beneficial to physics studies. Uncertainties relating to the actual site for chemical processing of any of the high exposure materials does not permit firm resolution of scheduling problems.

A special study was undertaken to determine the degree to which PRP chemical reprocessing expense could be reduced via shortened dissolver cycle times using less concentrated nitric acid if the nickel content of Pu-Al spikes were increased and the silicon content decreased. Such a new alloy may show adequate corrosion resistance and yet reduce foaming tendencies of nitric acid solutions of Pu-Al alloys containing substantial silicon.

2. SPECIFIC FUEL CYCLE ANALYSIS

Additional computational experiments covering plutonium enriched fuel cycles in the Advanced Pressurized Water Reactor study were completed. Plutonium discharged from a 3 per cent enriched uranium cycle was combined with depleted uranium to form the fuel charge (at enrichments of 2.5, 3.0, and 4.0 per cent fissile) for the next cycle. The following cycle used discharged plutonium from these three cases combined with depleted uranium to form nine new cases at enrichments of 2.5, 3.0, and 4.0 per cent fissile. Finally, the discharged plutonium from the nine cases was combined with depleted uranium to form the fuel charge for twenty-seven new cases.

Considerable effort was expended in attempting to determine the effect on exposure of the individual plutonium isotopes in the Advanced Pressurized Water Reactor plutonium fuel cycle study. Although the study is not yet completed, the following trends appear consistent for the conditions studied.

a. The addition of either Pu-239 or Pu-241 results in about the same increase in exposure based on a reactivity limitation. The addition of either appears to have slightly greater effect at lower total enrichment.

b. Pu-240 appears to have little, if any, effect on the attainable MWD/T in this reactor based on a reactivity limit. It should be noted that this conclusion may change if one couples in such effects as changes in reactivity or heat generations over the course of the cycle.

c. Pu-242 additions consistently result in lowered exposure. The shorter exposure effected by a given amount of Pu-242 is on the order of 1/4 to 1/2 of the increase in exposure produced by a like amount of Pu-239 or Pu-241.

Successful development of this data will greatly simplify obtaining convergence of the associated economic analysis.

Programming of the Fuel Value Economics Code continued during the month and, except for small, graded discharge portions, it is close to the final debug stage. Preliminary debugging of the Fabricating and Jacketing sub-code has already been made.

The month's activities included (1) presentation to J. M. Vallance, Washington, AEC-DRD, on the code's general composition and purpose, (2) fuel cycle economics discussions with APED personnel at San Jose, and (3) fairly extensive revisions to the code's working capital cost logic resulting from Use Charge and Nuclear Material Depletion payment information obtained in discussions with Commission personnel.

Barring unforeseen difficulties, the code should be ready for simple batch discharge applications in June and for more sophisticated and varied applications in July. However, for rapid use, a communications routine and other refinements will be necessary.

Four of the eight major sections of the LOLA code were written and are being debugged at this time. These sections are:

(1) The first order surface fit preparation. This, the first link of the monitorized Fortran code, has been partially debugged and is being used. The link is completely general and is not tied to any particular experimental medium.

(2) The Meleager A compatibility packages. These two sub-routines link Meleager to the LOLA code, one at the front of the Meleager and one to extract and transmit information to the next link of LOLA.

(3) The Yate's Analysis. This section makes the analysis of information obtained from the second Meleager compatibility package. The first-order surface fit is herein constructed.

(4) The Path of Steepest Ascent. The information of the Yates Analysis is used to calculate the current "Best Path to an Optimum". It also contains several error subroutines.

The second order fit and analysis plus error sub-routines are not yet coded.

The preliminary report on LOLA is 60 per cent complete in rough draft form.

B. BIOLOGY AND MEDICINE - 6000 PROGRAM

1. RADIOLOGICAL CONSULTATION

A presentation was prepared and delivered at the hearings by the Subcommittee on Radiation of the Joint Committee on Atomic Energy.

Consultation was rendered concerning the Washington State Advisory Council on Atomic Energy, the metabolism of internal emitters, medical services in nuclear plants, environmental monitoring, and site selection. Proposed material for inclusion in a revision of "The Effects of Nuclear Weapons" was prepared and submitted to the Commission.

C. OTHER ACTIVITIES

Professor C. P. Costello from the University of Washington delivered a seminar on the effects of artificial gravitational fields on heat transfer coefficients in boiling systems.

Final arrangements were made for a University of Washington graduate student to perform his thesis research at the Hanford Laboratories.

Assistance was rendered in arranging 14 tours (involving 493 people) through HLO and HAPO facilities.

Manager
PROGRAMMING

LH McEwen:dl

RADIATION PROTECTION OPERATION MONTHLY REPORT -- MAY 1960

A. ORGANIZATION AND PERSONNEL

Three exempt employees were reassigned within Radiation Protection Operation to provide broadened experience. These reassignments, effective May 1, 1960, were R. W. Meisinger from Manager, Calibrations to Specialist, Radiological Defense; V. M. Milligan from Specialist, Radiation Monitoring to Manager, Calibrations; and B. G. Lindberg from Specialist, Radiological Defense to Specialist, Radiation Monitoring.

J. D. Forsythe transferred from Exposure Evaluation and Records to CPD on May 2, 1960. Emily H. Szymanski was reactivated and D. L. Silver was added to the rolls of the EE & RO on May 2, 1960. T. E. Ludlow was reactivated from military leave on May 31, 1960. D. W. Constable, Technical Graduate, ended his three-month rotation in RPO on May 31, 1960.

B. ACTIVITIES

There were two cases of plutonium deposition confirmed during May. The total number of deposition cases that have occurred at HAPO is 256 of which 187 are currently employed. One of the confirmed deposition cases was discovered by the routine sampling program; the other was detected following a known exposure incident resulting from a fire and the spread of plutonium air contamination. Both deposition cases appear to involve less than 10 per cent of the maximum permissible body burden. There were 44 radiation incidents reported to EE & RO during May. None of these resulted in exposures exceeding operational controls. Nine requests for exposure summaries on former HAPO employees were received and completed.

A total of 103 persons were counted at the Whole Body Counter. During 1960, 513 persons have been counted at the WBC. Studies to determine accumulation of radioactivity in the hair are now in progress. Preliminary results indicate that shampooing before a whole body count may actually increase the radioactivity in the hair. This is largely attributed to the radioactivity found in the water.

Attempts to detect uranium in a person having a high and constant bioassay count were not successful. Four cases of Na^{24} occurrence in the body were discovered through the routine counting program. Investigations reveal that these employees had been working in the reactor rear face areas shortly after shutdown.

A maximum dose rate of 20 rads/hr and a hand dose rate of 4 rads/hr were observed during the spiking of feed capsules with Sr^{90} for trout experiments. Leakage from a tank containing 150 liters of 8 gms/liter plutonium-nitrate solution caused equipment contamination to 80,000 d/m and hand contamination to 30,000 d/m on one employee at the Physical Constants Test Reactor. Air samples collected at the work location and nasal smears from the employee involved were below detection limits. Prompt decontamination action was successful. Floor contamination to 100,000 d/m in Rooms 208 and 210 of the 308 Building originated from an

unmarked box containing several rolls of masking tape and miscellaneous equipment which had been received from the 231-Z Building. Prompt discovery and decontamination prevented any personnel contamination.

A bucket of perfs was lifted from the 105-KW basin and after an estimated 15-20 seconds, it was discovered that an irradiated slug was in the bucket. The radiation alarm system was not working at the time. Film badge results for the employee directly involved indicated doses between 200-300 mr.

Personnel from RPO components participated in the 1960 Operational Alert Exercise held on May 3, 4, and 5. The exercise for Hanford was conducted at the Mobile Emergency Relocation Center. A more realistic practice was conducted this year through the use of fragmentary information obtained intermittently throughout the exercise period from the normal communication channels. The events directly affecting the Hanford operations were: a two megaton burst 10 miles NNW of Richland causing fallout levels in the separations and reactor areas that prevented personnel entry for several days, a flood from the destruction of Grand Coulee Dam rendered reactor water supply systems inoperable and destroyed electrical service and telephone lines; and a bomb burst at Spokane destroyed telephone and teletype trunk lines, thereby isolating HAPO from communication with other parts of the nation.

A set of working limits was established for the discharge of the liquid radioactive waste to the river from the PRTR installation. Mandatory shutdown of the reactor was recommended at 5×10^{-4} μc β/cc of water at the point of measurement. Further recommendations include improvement of steam monitoring equipment bypassing the shielded coolant water and a review of the analytical program.

A number of ionization-type finger ring dosimeters were readied for limited field test. Energy dependency studies showed that for energies below 300 Kev correction factors will have to be applied to attain good dose estimates. The gamma ray spectrum from plutonium has been arbitrarily divided into four energy groups and the finger ring response has been determined for each of these energy groups. These calculations have been corrected for the energy spectrum distortion resulting from the shielding properties of hood gloves composed of neoprene and with zinc or lead coatings. Studies of the shielding properties of these materials at the gamma ray energies of interest have been completed and the necessary information has been incorporated into the calibration curves that are required to interpret ionization-type finger ring results.

Hanford Drawing SK-3-9484 entitled, "Personnel Dosimeter Model III" was completed by Drafting. The basic characteristics of this badge dosimeter were mentioned in the April report. The actual selection of the absorbers or shields to be used in this new dosimeter was investigated both theoretically and experimentally. No ideal combination of absorbers has yet been found which will exhibit characteristics required for precise discrimination of low-energy gamma radiation and beta radiation. Experiments are continuing in this phase of the dosimeter development program and although a solution to this discrimination problem has not been found, encouraging results have been observed.

Final billing for the Oak Ridge Criticality Dosimeters (Hurst Dosimeters) was $70,402.50. The initial quoted cost for the 90 devices purchased for Hanford use was $39,150. The use of a more economically practical system similar to the Savannah River criticality neutron detection devices is being studied and evaluated.

The Columbia River Monitoring Station has operated throughout the month on a test basis. The alarm system has been redesigned and in its present form will essentially duplicate fail-safe fire alarm systems.

The Specialist, Radiation Protection, attended the two weeks of public hearings on Radiation Protection Standards - Their Basis and Use, held in Washington, D. C. by the Joint Committee on Atomic Energy. Some of the material for the HAPO participation at the hearings was prepared. Consulting service was provided Hanford participants.

C. EMPLOYEE RELATIONS

Three suggestions were received this month. A total of six suggestions were evaluated during the month. There were no outstanding suggestions at the end of the month. No awards were received by RPO personnel.

There were two medical treatment injuries during the month for a frequency of 0.92. No security violations occurred during May.

Radiation protection training included: one information meeting on contamination control and Controlled Injury Zone procedures to 308 Building craftsmen, one indoctrination lecture to new employees, one lecture on PRTR operation to RPO personnel; and a report to the RPO exempt force on the events of Operational Alert 1960.

L. G. Faust and L. C. Rouse attended the Emergency Radiation Monitoring Team Training Exercise at the Nevada Test Site for one week.

D. SIGNIFICANT REPORTS

HW-54154 "Analysis of Radiological Data for the Month of April, 1960" by R. L. Junkins.

HW-65441 "Monthly Report - May 1960, Radiation Monitoring Operation" by A. J. Stevens.

HW-64375 "Radioactive Contamination in Liquid Waste Discharged to Ground at the Separations Facilities Through December, 1959" by M. W. McConiga.

HW-65343 "Backscatter Effects Influencing Calibration of BF_3 Tubes" by F. H. Sanders.

ENVIRONMENTAL MONITORING - RESULTS - (Mid-April 1960 - Mid-May 1960)

Sample Type and Location	Activity Type	Monthly Average	Units
Drinking Water			
100-F Area	Isotopic	0.5	% MPC_{GI}*
Separations Areas	Gross Beta	1.1×10^{-7}	µc/cc
Pasco	Isotopic	< 4.8	% MPC_{GI}**
Kennewick	Isotopic	< 0.8	% MPC_{GI}**
Richland	Gross Beta	$< 3.0 \times 10^{-8}$	µc/cc
Columbia River Water			
Above 100-B Area	Gross Beta	7.0×10^{-9}***	µc/cc
100-F Area	Isotopic	2.2	% MPC_{GI}*
Hanford	Isotopic	3.9	% MPC_{GI}*
Pasco	Isotopic	16	% MPC_{GI}**
McNary Dam	Gross Beta	1.8×10^{-6}	µc/cc
Vancouver, Washington	Isotopic	0.5	% MPC_{GI}**
Atmosphere			
I^{131} Separations Areas	I^{131}	1.3×10^{-13}	µc/cc
I^{131} Separations Stacks	I^{131}	0.6	Combined curies,
Active Particles - Project	--	0.4	ptle/100 m^3
Active Particles - Environs	--	0.1	ptle/100 m^3
Vegetation (Control limit for vegetation is 10^{-5} µc I^{131}/g)			
Separations Areas	I^{131}	1.5×10^{-6}	µc/gm
Residential	I^{131}	$< 1.5 \times 10^{-6}$	µc/gm
Eastern Washington and Oregon	I^{131}	$< 1.5 \times 10^{-6}$	µc/gm
Fission Products less I^{131} - Wash. and Ore.	Gamma Emitters	$< 1.0 \times 10^{-5}$	µc/gm

*The % MPC_{GI} is the percent of the maximum permissible limit for occupational exposure to the gastrointestinal tract calculated from drinking water limits contained in NBS Handbook 69.

**The % MPC_{GI} is the percent of the maximum permissible concentrations for persons in the neighborhood of controlled areas for continuous exposure to the gastrointestinal tract calculated from drinking water limits contained in NBS Handbook 69.

***This location is now sampled quarterly. The most recent result is tabled.

EXPOSURE EVALUATION AND RECORDS

Exposure Incidents above Permissible Limits

	Whole Body	Localized
May	0	0
1960 to Date	1	3

Gamma Pencils

	Pencils Processed	Paired Readings 100-280 mr	Paired Readings Over 280 mr	Lost Readings
May	15,248	152	1	0
1960 to Date	89,288	1,120	17	7

Beta-Gamma Film Badges

	Badges Processed	Readings 100-300 mrads	Readings 300-500 mrads	Readings Over 500 mrads	Lost Readings	Average Dose Per Film Packet mrad(ow)	mr(s)
May	11,086	752	56	29	82	7.57	13.59
1960 to Date	58,613	4,607	885	220	212	10.61	18.76

Neutron Film Badges

	Film Processed	Readings 50-100 mrem	Readings 100-300 mrem	Readings Over 300 mrem	Lost Readings
Slow Neutron					
May	1,287	0	0	0	9
1960 to Date	5,561	1	0	0	25
Fast Neutron					
May	104	14	0	0	9
1960 to Date	945	71	25	0	20

Bioassay

	May	1960 to Date
Plutonium: Samples Assayed	732	3,610
Results above 2.2×10^{-8} µc/sample	21	198
Fission Products: Samples Assayed	728	3,504
Results above 3.1×10^{-5} µc FP/sample	0	3
Uranium: Samples Assayed	344	1,569
Confirmed Plutonium Deposition Cases	2	12*

Whole Body Counter

	Male	Female	May	1960 to Date
GE Employees				
Routine	96	4	100	479
Special	1	0	1	13
Terminal	0	0	0	1
Nonemployees	2	0	2	16
Pre-employment	0	0	0	4
Total	99	4	103	513

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Uranium Analyses

Sample Description	Following Exposure Units of 10^{-9} µc U/cc Maximum	Average	Number Samples	Following Period of No Exposure Units of 10^{-9} µc U/cc Maximum	Average	Number Samples
Fuels Preparation	771	17	65	54	5.4	48
Fuels Preparation*	15	15	.2	0	0	0
Hanford Laboratories	618	30	30	22	4.9	32
Hanford Laboratories*	116	41	3	0	0	0
Chemical Processing	82	7.8	77	49	4.3	69
Chemical Processing*	37	11	9	2.9	1.8	4
Special Incidents	0	0	0	0.	0	0
Random	1.6	0.9	5	0	0	0

* Samples taken prior to and after a specific job during work week.

Thyroid Checks	May	1960 to Date
Checks Taken	19	151*
Checks above Detection Limit	3	3

* Includes a total of 132 counts made prior to May 1960 which were not reported previously.

Hand Checks		
Checks Taken - Alpha	30,717	159,063
- Beta-gamma	43,522	226,340

Skin Contamination		
Plutonium	25	115
Fission Products	46	212
Uranium	4	24

CALIBRATIONS

	Number of Units Calibrated May	1960 to Date
Portable Instruments		
CP Meter	904	4,313
Juno	321	1,513
GM	767	3,870
Other	182	919
Total	2,174	10,815
Personnel Meters		
Badge Film	1,252	6,602
Pencils	-	1,912
Other	448	2,049
Total	1,700	10,563
Miscellaneous Special Services	317	1,987
Total Number of Calibrations	4,191	23,365

E. M. Unmack
for the
Manager
Radiation Protection

AR Keene:CMU:kc

LABORATORY AUXILIARIES OPERATION
MONTHLY REPORT - MAY, 1960

GENERAL

Security performance for the Operation was satisfactory with no violations during the month.

Safety performance of the Operation was considered satisfactory. There were no major injuries; the minor injury frequency rate was 3.72 which is considered about average experience.

TECHNICAL SHOPS OPERATION

Total productive time for the period was 21,954 hours. This includes 14,461 hours performed in the Technical Shops, 2,644 hours assigned to Minor Construction, 562 hours assigned to other project shops, and 4,287 hours assigned to off-site vendors. Total shop backlog is 23,149 hours of which 75% is required in the current month with the remainder distributed over a 3-month period. Overtime hours worked during the month was 7.9% (1,415 hours) of the total available hours.

Distribution of time was as follows:

	Man-hours	% of Total
Fuels Preparation Department	2,109	9.6
Irradiation Processing Department	731	3.3
Chemical Processing Department	1,075	4.9
Hanford Laboratories Operation	17,662	80.5
Construction Engineering & Utilities	12	.1
Miscellaneous	365	1.6

Requests for emergency service increased to a level which required an overtime rate of 7.9%. Total backlog increased approximately 3%, but the short-range nature of the work required the subcontracting of 7,493 man-hours to other project and off-site shops.

One additional machinist has been requested to report for work on June 20. Screening of candidates for two additional Journeyman Machinist positions has been completed and two men from Pueblo, Colorado have been requested to report by July 15, 1960. A Stock and Tool Attendant position is still open with on-site candidates being considered.

Purchase orders were placed for several major pieces of new shop equipment with delivery of all but one piece expected by July 1, 1960.

RADIOGRAPHIC TESTING OPERATION

A total of 3,337 tests were made of which 1,044 were radiographic (including x-ray and gamma-ray) and 2,293 were supplementary tests. Out of a total of 2,553 man-hours, 783 (30.6%) were in connection with radiographic tests, and 1,770 (69.4%) were used on supplementary tests. The supplementary test work included: autoclave; borescope; eddy current; leak testing; penetrant (fluorescent O.D. and I.D.); surface treatment (alkaline cleaning, pickling, and vapor blasting); and ultrasonic (flaw detection, core integrity, bond testing, and thickness measurement).

The number of pieces handled this month totaled 2,983 items. The feet of material represented by these items amounted to 42,493 feet. Work on tubular components continued to account for the large percentage of the footage of material tested.

Work was done for 20 different organizational components representing most of the operating departments and service organizations. A total of 35 reports were issued detailing test findings with conclusions and recommended action. Radiographic Testing Operation was consulted on 35 different occasions for advice and information on general testing theory and applications for other than the jobs tabulated in Part II - Testing Statistics.

Considerable progress is being made in the equipment and building modifications at C-25 Building, White Bluffs, but the construction schedules are not being maintained. The building siding has been completely installed. Also completed is the sprinkling system in the process and office areas. Installation of the autoclaves is still progressing; the facility is still not at a point where it can be tested. Modification of the pickling facility has been started. The deionized cold water rinse and storage tank has been enlarged and is approximately 80% complete. Pipe and pump modifications are in the design stage. The material handling facilities are progressing rapidly; the unloading and loading stations have been completed, both at the railroad siding and at the receiving end of the building, and at the shipping end; the monorail installation in the north end of the building has been started.

Productive testing has been sharply curtailed because of the lack of tubes to be tested and because of the construction activity which has required shut down of certain equipment items. In the interim, use is being made of the available time for testing equipment alignment and for training of testing personnel.

Field work is proceeding routinely. The pressure vessel survey involving ultrasonic thickness measurements in the 100-F Area has been completed. Work is being carried on, on a continuing basis, for the Biology Operation at the 100-F Area animal farm involving swine and strontium Sr-90 pick-up. Field operation activity will be augmented by the construction of an x-ray exposure room in the southeast corner of the C-25 Building. Concrete walls will be poured to provide adequate shielding for protection of personnel and permit x-ray work to be carried on during the day shift.

300 Area work continues at a high level. The number of finished TPU rods tested was increased by 32%. The current TPU order has been extended through September 1960 and will involve additional testing. Fabrication of a new ultrasonic tank for TPU rods will be completed June 1, 1960, and installed in the 308 Building. Modifications to the fluorescent penetrant station in the 314 Building is in progress with installation of a new wash tank and tube drain rack. The sheath tube borescope stand has been moved from White Bluffs and placed in 314 Building. Complete fluorescent penetrant work can now be done in this facility. Installation of equipment in the 306-A Building is about 50% complete. Availability of the x-ray exposure room would be of considerable benefit in meeting present commitments.

Testing Statistics

Component	No.of Tests	Ft. of Weld or Material	No. of Pieces	Description
CE&U	260	127	179	Film interpretation of radiographs PRTR site; Radiograph weld on qualification coupon; Radiograph cast section of four pressure control valves.
CPD	60	67	39	Radiograph welds on vapor line tower; Radiograph welds on H-4 vessel.
HLO	2272	34,148	2236	Aluminum pot with T.C.; .505" I.D., s.s tubes; Zr-2 clad UO_2 fuel rods; s.s sheathed thermocouples; NaK capsules; .680" I.D., zr-4 tubes; Unmachined TPU fuel rods; Pu test samples; Radiograph Palm fabrication; Hastaloy and Inconel tubing; .582" I.D. s.s. tubes; Fluorescent penetrant test - Hastaloy 90° ells; TPU fuel rods; Perform ultrasonic thickness measurements of pressure vessels and hi-tanks in 100-F; PRTR tubes.
IPD	745	8,151	528	Radiograph weld qualification coupons; Cleaning; Perform helium leak tests in 110 receiving station and in 105 Building; Immerscope of 57' zirc tubes.
Total	3337	42,493	2982	

CONSTRUCTION OPERATION

There were 49 existing J. A. Jones Company orders at the beginning of the month with a total unexpended balance of $153,431. Forty-three new orders, 4 supplements and adjustments for underruns amounted to $123,039. Expenditures during the month on HLO work were $126,310. Total J. A. Jones backlog at month's end was $150,160.

Summary

	HL		CE&U	
	No.	Unexpended Balance	No.	Unexpended Balance
Orders outstanding beginning of month	45	$ 141,277	4	$ 12,154
Issued during the month (Inc.Sup. & Adj.)	43	120,039	0	3,000
J. A. Jones Expenditures during month (Inc. C.O. Costs)		122,219		4,091
Balance at month's end	50	130,097	3	11,063
Orders closed during month	38	82,912*	1	4,505*

* Face Value of Orders Closed

Project CG-744 - 306 Building Addition

All 17 major pieces of equipment are now in their final location in the building except for the Roller-Leveler. This equipment piece cannot be set for about two weeks because of lump sum contractor work in this area. Acceptance tests have been run on five pieces of equipment and five more are scheduled. J. A. Jones work is 80% complete.

Project CG-747 - 308 Building

All but three of the punch list items have been completed. Of these three items one was deleted, another is 60% complete and the other one will be completed this month.

The work order to plant forces for removal of equipment in 231-Z and transport to 308 Building has been closed out.

FACILITIES ENGINEERING OPERATION

Projects

There were 17 authorized projects at month's end with total authorized funds of $6,418,765. The total estimated cost of these projects is $8,257,765. There were no new projects authorized, and none completed or submitted to the Commission for approval this month.

The following summarizes the status of HLO project activity:

Number of authorized projects at month's end:	17
Number of new projects authorized during month:	0
Projects completed during the month:	0
New project proposals submitted to AEC during month:	0
New projects awaiting AEC approval:	3

CGH-832, Full Scale Physical Constants Testing Reactor
CGH-874, Consolidation of Plutonium Metallurgy Facilities
CGH-896, Stress-Rupture Testing Facility

NOTE: New proposals ready for transmittal to the AEC are:
Uranium Scrap Burning Facility
Structural Material Irradiation Test Equipment - "ETR"

The attached project report details the status of individual projects.

Engineering Services

Engineering work performed during the month included the following listed major items as well as scope engineering for project proposals.

Title	Status
329 Building Cooling Problem	Field work is progressing. Scheduled completion is June 30.
Electric Hoist - Graphite Shop 3730-C Building	Crane, hoist and rails have been received. Field work has started.
Refrigerated Air Conditioning Room 130 - 146-FR Building	Work complete.
Pressure Vessel Study	This is a continuing work program involving HLO vessels, pressure systems and related safety devices.

Title	Status
Coaxial Cable Between 325 and 329 Buildings	Field work has started.
Additional Improvements to Air Supply - Rooms 204 and 206 - 3706 Building	Filters have been received. Installation to start during June.
Laboratory Furnace Installation Room 39-B, 326 Building	Engineering complete. Materials on order.
Alterations to Negative Ion Accelerator - 3745-A Building	Design complete. Installation work complete.
Glove Boxes - 325 Building	Engineering design is complete and fabrication has started.
Equipment for Critical Mass Studies	Materials on order. Detail design is about 50% complete.
Study Potable and Process Water System - 325 and 329 Buildings	Work in progress.
Fire Detection System - 314 Building	Material on order. Installation to start June 15, 1960.
Criticality Alarm - 300 Area	Installation work started during May.
Reactor Effluent Filter - Pilot Test Facility - 100-D	Design and fabrication has started.
Improvement to Animal Waste Disposal System	Design work started.
Atmospheric Physics Service Center	Engineering study is complete.
Electrified Fenced Animal Pens and Pasture	Field work has started.

Drafting and Design Services

Work load is constant with heavy backlog. Branch offices in 306 and 308 Buildings are busy with steady work loads. The central drafting room has been performing an increasing amount of work for the recycle program.

Major design and drafting work in progress includes the following:

1. Break away Corrosion Loop (6 drawings - 50% complete).
2. Special Tools - Scope - High Level Utility Cell - 327 Building (30% complete).
3. PRTR Fuel Element Rupture Facility - Scope.
4. PRP Critical Facility - Details of in-cell piping, ventilation and electrical work (10 drawings required).
5. Loading Dock Enclosure - 321 Building (3 drawings - 90% complete).
6. A, B, and G Hand and Shoe Counter - (approximately 16 drawings - 98% complete).
7. Ultrasonic Test Tank - (8 drawings required - 50% complete).
8. Physical and Mechanical Properties Test Cell - 327 Building - Equipment Scope (6 work sheets completed).
9. Extrusion Tools for 700 Ton Press (8 drawings required - 6 drawings completed).
10. Design for Pyro-Chemical Test Facility (50% complete).
11. PRTR - PFPP Grounds Improvement (4 drawings - 100% complete).
12. "In-Pile" Test Loop - "C" or "K" Reactor (12 drawings required - 90% complete).
13. Remote T.V. Inspection of Process Tubes (7 drawings required - 30% complete).
14. Periscope Viewer - Reactor & Fuels (8 drawings estimated).
15. Scope design - Structural Materials Irradiation Test Facility - "ETR" - (15 drawings required - 10% complete).

In addition to the above work, miscellaneous small design-drafting jobs are in progress.

Approximately 250 drawings including sketches, work sheets, and formal drawings were completed during the month of May.

HLO Plant Maintenance and Operation

Costs:	March	$ 131,404
	April	107,505
	Total thru April	1,320,478

Analysis of Costs

The expenditures were + 4% of each category, and within 0.5% of the forecast total.

Improvement Maintenance

Item	April	FY thru April
Heating & Ventilation Correction	$ 1,589	$ 67,000
Relocation & Alteration	301	34,682
Paint	0	11,736
Electrical Improvements	0	1,342
Lighting	0	413
Crane Installation	480	25,390
Miscellaneous	3,754	8,298
Total	$ 6,124	$ 147,491

Miscellaneous

Approximately 23,400 square feet of prints were reproduced during the month.

The total estimated value of the 18 requisitions issued during the month was $6,000.

TECHNICAL INFORMATION OPERATION

Confirmation was received from the National Science Foundation, Washington, D. C. on scheduled dates for displaying two NSF exhibits at Hanford for a two-week period - July 28 to August 15, 1960. Exhibits are on "Foreign Science Literature" and "Progress in Information Processing." Both exhibits consist of attractive display panels occupying some twenty linear feet, with "give-away" material included. Exhibits will be set up alternately for one week each in the 3760 Building and the 703 Building lobbies. Local publicity is planned. The only cost to HAPO is shipping charges from nearby colleges and universities which have also scheduled the exhibits.

At the request of Nuclear Metals, Inc. we supplied glossy prints of several photographs from HW documents for use in a book on Fuel Element Metallurgy and Fabrication sponsored by the AEC.

In July 1959, a study was initiated of the procedures which govern the access to documents in the Classified Files. An interdepartmental task force, chairmanned by the Manager, Technical Information, was set up. The Task Force submitted its report in January 1960. The committee recommended the establishment of 4 sensitive categories of information for access purposes and these recommendations received HAPO endorsement. The Commission has requested HAPO to cooperate in working out the details with the AEC Divisions involved.

The 24th Edition of M-3679, Standard Distribution Lists for Classified Scientific and Technical Reports, was received in Files in late April and it represents a major revision of the Commission's report distribution system. A new category, C-44 Nuclear Technology, is to be used for distribution of all classified reports not directly revealing nuclear weapon technology

or actual production rates of fissionable materials. Reports on plutonium technology that reveal actual or planned plutonium production rate data are placed in another new category, C-65 Plutonium Production. Almost all HAPO classified reports will now fall into one or the other of these categories. Reports in these categories will also be made available to properly qualified Access Permit Holders.

Technical Information was asked in December 1959, to undertake a review of Hanford reports in categories C-66, C-67 and C-68. This review was part of the Commission's preliminary planning for:

(1) The recently announced changes in the access permit program.

(2) The changes in distribution of formal research and development reports as reflected in the latest edition of M-3679, Standard Distribution List for Classified Scientific and Technical Reports.

The purpose of the review was to determine whether the reports were obsolete, superseded, or to which of the new M-3679 categories, C-44 or C-65, it should be assigned. Over 700 Hanford reports were reviewed by Department representatives. The results were transmitted to HOO on May 6. Two microfilm copies of the review sheets were also prepared and will be retained by HAPO and HOO respectively for future reference.

Agreement on the "Proposed Guide to Atomic Weapon Data at Hanford", HW-63726, was reached. It has now been forwarded by HOO to Washington for approval.

In connection with our plans to automate certain Classified Files office routines, two meetings have been held with vendors of automation equipment. Others are planned. At the meetings, the vendors describe what they have to sell and we describe our needs and problems. Meetings with Underwood-Olivetti and Remington have been held and one with Friden is scheduled. It appears probable that any equipment purchased could also be used for other work within HLO.

The programming logic required for transferring the periodical subscriptions activity to tape has been worked out and the program itself is being written. The two subscription order forms (the fanfold form for IBM printing of renewal data, and the multiple form for new subscriptions) have been designed, reviewed by the plant Procedures Specialists, and given to Forms Control for ordering.

Work Volume Statistics

	April	May
Document Distribution and Files		
Documents routed and discharged (copies)	18,297	18,365
Documents issued (copies)	10,054	12,764
Documents sent off-site (copies)	3,821	3,000
Document reserves filled (copies)	844	615
Documents picked up and delivered	19,470	21,768

Document Accountability	April	May
Holders of classified documents whose files were inventoried	609	304
Documents inventoried in Files (copies)	11,777	15,206
Documents destroyed or retired (copies)	2,973	1,439
Documents revised (copies)	1,350	2,171
Documents pulled and documents filed (copies)	13,274	11,707
Documents reclassified	460	285
Accountable copies of SECRET and DOCUMENTED CONFIDENTIAL documents on-site	207,673	211,157
Reference and Publication		
Books cataloged (new titles)	140	101
Books added to the collection (volumes)	259	212
Ready reference questions answered by professional staff	125	140
Literature searches by professional staff	95	99
Reports abstracted (titles)	302	248
Formal reports prepared (titles)	8	14
Off-site requests for HAPO reports (copies)	325	388
Reports released to CAP (titles)	31	68
Library Acquisitions and Circulation		
Books ordered (volumes)	292	426
Periodicals ordered	59	286
Books circulated (volumes)	2,082	1,891
Periodicals circulated (issues)	3,208	3,052
Inter-Library loans	82	167
Films borrowed or rented	32	20
Industrial film showings	93	62
Bound periodicals added to the collection	81	292

Library Collection:

	Main Library	W-10 Library	108-F Library	Ind.Med.	Total
No. of books	29,410	8,395	1,601	2,013	41,419
No. of bound periodicals	13,781	1	1,431	96	15,309
Total	43,191	8,396	3,032	2,109	56,728

Classification and Declassification

	April	May
Documents, including drawings and photographs reviewed for downgrading or declassification	4	61
Documents and papers (intended for oral presentation or publication) reviewed for appropriate classification	46	24
Documents submitted to Declassification Branch, Oak Ridge	6	1

Manager,
Laboratory Auxiliaries

JL Boyd:jw

BUDGET CLASSIFICATION Improvements to Production and Supporting Facilities - 58-b-4

MONTHLY PROJECT REPORT
HANFORD LABORATORIES OPERATION

HW - 65459
MONTH May, 1960

PROJECT NUMBER	TITLE	EST. TOTAL PROJECT COST	AUTHORIZATION INFORMATION AMOUNT / DATE	PROJECT PROGRESS IN PER CENT DESIGN SCHED. / DESIGN ACTUAL	CONST. SCHED. / CONST. ACTUAL	STARTING DATE DESIGN / CONST.	DIRECTIVE COMP. DATE DESIGN / CONST.	ESTIMATED OR ACTUAL COMP. DATE DESIGN / CONST.
CG-731	Critical Mass Laboratory	$1,000,000	$1,000,000	100	89	5-22-58	- - -	2-24-59
			3-23-59	100	87	6-4-59	6-30-60	6-30-60*
		USING COMPONENT: Physics & Instruments R & D				FEO ENGINEER: D. S. Jackson		

REMARKS: The contractors work is essentially complete. Work remaining consists primarily of performance of acceptance tests and cleaning up minor punch list items. Acceptance tests not yet completed are the safety and interlock system (about 70% complete) and pressure testing the reactor room for gas tightness. The latter test has just started. The room has been pressurized to 1.5 psig so far. At this pressure some unsealed conduits were discovered and corrective action taken. It is anticipated the contractor will be complete early in June. J. A. Jones Company forces are currently installing glove ports on the mixing hood windows. It still appears Allied Engineering Company will not deliver the reactor control system until the end of June. Thus, installation of this equipment will extend through July along with planned start-up work.

CA-744	Metallurgical Development Facility - 306 Building	$2,650,000	$2,685,000	100	*	6-30-58	- - -	9-30-59
			11-5-58	100	**	3-20-59	9-1-60	9-1-60
		USING COMPONENT: Reactor & Fuels R & D				FEO ENGINEER: J. T. Lloyd		

REMARKS: Jensen-Rasmussen contract has a (official) completion date of May 13, 1960. He is now completing the paving, installation of cranes, fencing and laboratory furniture installation. General Electric is expecting delivery of all chemical processing tanks, prior to June 26, 1960, the date called for in the Frank Lohse contract. All other work is progressing on schedule. Installation of equipment is progressing satisfactorily.

*Total Project 83%; Jensen-Rasmussen 100%; J. A. Jones 65%; Frank Lohse 70%
**Total Project 84%; Jensen-Rasmussen 97%; J. A. Jones 75%; Frank Lohse 50%

CGH-790	High Level Radioactive Receiving and Storage Addition - 327 Building	$ 345,000	$ 345,000	100	100	6-23-58	- - -	12-31-58
			4-23-59	100	99	10-9-58	6-1-60	7-8-60
		USING COMPONENT: Reactor & Fuels R & D				FEO ENGINEER: J. J. Peterson		

REMARKS: Fixed price contract work has been completed. CPFF forces had to remove paint from new basin as blisters started appearing after the job was completed. The failure was caused by the catalyst between the prime coat and succeeding coats. This project will be closed out on June 1, 1960, with remaining work being completed as an accrual.

BUDGET CLASSIFICATION: General Plant Projects - FY 1959

MONTHLY PROJECT REPORT
HANFORD LABORATORIES OPERATION

HW - 65459
MONTH May, 1960

PROJECT NUMBER	TITLE	EST. TOTAL PROJECT COST	AUTHORIZATION INFORMATION AMOUNT / DATE	PROJECT PROGRESS IN PER CENT DESIGN SCHED. / ACTUAL	PROJECT PROGRESS IN PER CENT CONST. SCHED. / ACTUAL	STARTING DATE DESIGN / CONST.	DIRECTIVE COMP. DATE DESIGN / CONST.	ESTIMATED OR ACTUAL COMP. DATE DESIGN / CONST.
CAH-837	Animal Pens, Isolation and Examination Facilities	$ 78,000	$ 80,000 3-17-59	100 100	100 99	3-30-59 7-10-59	- - - 4-1-60	6-5-59 5-31-60

USING COMPONENT: Biology

FEO ENGINEER: J. T. Lloyd

REMARKS: The work authorized to Minor Construction by A.E.C. is 100% complete except for final check of steam injection system. Adjustments are being made to the temperature controls in the mouse rooms.

General Plant Projects - FY 1960

CGH-819	Increased Laboratory Waste Facilities 300 Area	$ 193,000	$ 193,765 2-19-60	100 100	N.S. 0	2-5-60* 6-15-60	- - - 5-31-61	5-1-60 3-1-61

USING COMPONENT: Chemical, R & D

FEO ENGINEER: J. J. Peterson

REMARKS: Field Work Release has been issued to J. A. Jones for construction. They are in the process of preparing bid packages for fixed price portion of the work. Field work is expected to start during June.

*Design started on revised scope.

CGH-860	Access for PRTR Fuel Elements - 327 Building	$ 81,000	$ 81,000 10-8-59	100 100	N.S. 50	10-19-59 1-4-60	- - - 8-15-60	4-1-60 7-1-60

USING COMPONENT: Reactor & Fuels, R & D

FEO ENGINEER: J. J. Peterson

REMARKS: Fixed price contractor has installed metal roof deck, metal siding and roll-up door. CPFF forces completed fabrication of cask cart except for final adjustments.

BUDGET CLASSIFICATION: General Plant Projects - FY 1960

MONTHLY PROJECT REPORT
HANFORD LABORATORIES OPERATION

HW - 65459
MONTH May, 1960

PROJECT NUMBER	TITLE	EST. TOTAL PROJECT COST	AUTHORIZATION INFORMATION	PROJECT PROGRESS IN PER CENT		STARTING DATE	DIRECTIVE COMP. DATE	ESTIMATED OR ACTUAL COMP. DATE
			AMOUNT / DATE	DESIGN SCHED. / ACTUAL	CONST. SCHED. / ACTUAL	DESIGN / CONST.	DESIGN / CONST.	DESIGN / CONST.
CAH-864	Shielded Animal Monitoring Station 100-F	$ 52,000	$ 52,000 4-18-60	100 100	1.1* 3*	10-22-59 5-5-60	- - - 7-24-60	2-4-60 7-24-60
		USING COMPONENT: Biology				FEO ENGINEER: J. T. Lloyd		

REMARKS:

The building site was adjusted. The excavation was completed on May 20, 1960, and footings were poured and walls forms were placed. The electricians have placed the grounding wires.

*Based on contractor's field progress.

CAH-874	Consolidation of Plutonium Metallurgical Facilities	$ 285,000	$ None None	0 0	0 0	1* 2*	- - - - - -	5* 11*
		USING COMPONENT: Reactor & Fuels, R & D				FEO ENGINEER: J. T. Lloyd		

REMARKS:

The A.E.C. has held the proposal since October 8, 1959, with no official explanation for the delay of approval.

*Months after authorization.

CGH-877	Pyrochemical Test Facility - 321-A Building	$ 70,000	$ 70,000 11-17-59	100 100	42 42	12-8-59 2-17-60	- - - 9-30-60	4-17-60 9-30-60
		USING COMPONENT: Chemical, R & D				FEO ENGINEER: R. C. Ingersoll		

REMARKS:

The halogen leak detection unit arrived on site 5-25-60. It is expected that Blickman Company's promised shipment of the hoods on or before 6-20-60 will be met.

BUDGET CLASSIFICATION: General Plant Projects - FY 1960

MONTHLY PROJECT REPORT
HANFORD LABORATORIES OPERATION

HW-65459
MONTH: May, 1960

PROJECT NUMBER	TITLE	EST. TOTAL PROJECT COST	AUTHORIZATION INFORMATION: AMOUNT / DATE	PROJECT PROGRESS IN PER CENT: DESIGN SCHED. / DESIGN ACTUAL	PROJECT PROGRESS IN PER CENT: CONST. SCHED. / CONST. ACTUAL	STARTING DATE: DESIGN / CONST.	DIRECTIVE COMP. DATE: DESIGN / CONST.	ESTIMATED OR ACTUAL COMP. DATE: DESIGN / CONST.
CAH-878	Additional Facilities for Isotope Study on Animals - 141-C Building Addition	$ 66,000	$ 66,000 4-18-60	100 100	1.1* 3.0*	12-7-59 5-5-60	- - - 7-24-60	4-17-60 7-24-60
		USING COMPONENT: Biology				FEO ENGINEER: J. T. Lloyd		

REMARKS:

Foundation excavation is complete and forms and reinforcing were set. Building shop drawings were presented and returned with comments. Larger door openings in the north end of new addition cannot be had due to conflict with existing structural columns.

*Based upon contractors construction report (no official schedule received to date).

CAH-885	Geological & Hydrological Wells - FY-1960	$ 84,000	$ 69,000 2-5-60	100 100	0 0	2-15-60 6-1-60	- - - 11-15-60	4-1-60 2-15-61
		USING COMPONENT: Chemical, R & D				FEO ENGINEER: H. E. Ralph		

REMARKS:

Hatch Drilling Company was low bidder with a bid of $77,430 on May 3, 1960. This contractor will perform drilling work on this project as well as two others. Breakdown of costs by projects: CAH-885 - 73%; CAC-843 - 19%; CGI-791 - 8%. Contractor's equipment is due to arrive week of June 1 - three weeks behind schedule. Two rigs, one for Project CAH-885, and one for CAC-843, will start initially. Third rig is due July 1, 1960.

CGH-896	Stress - Rupture Testing Facility	$ 80,000*	$ None None	0 0	0 0	6-30-60** 12-1-60**	- - - - - -	8-1-60** 6-1-61**
		USING COMPONENT: Reactor & Fuels, R & D				FEO ENGINEER: R. K. Waldman		

REMARKS:

The Project Proposal submitted to AEC - HOO April 25, 1960, is scheduled for the review board meeting June 2, 1960.

*Includes Transferred Capital Property valued at $500.00
**Based on AEC authorization by June 15, 1960.

1249634

BUDGET CLASSIFICATION Improvements to Production and Supporting Facilities - 60-a-1

MONTHLY PROJECT REPORT
HANFORD LABORATORIES OPERATION

HW - 65459
MONTH May, 1960

PROJECT NUMBER	TITLE	EST. TOTAL PROJECT COST	AUTHORIZATION INFORMATION AMOUNT / DATE	PROJECT PROGRESS IN PER CENT DESIGN SCHED. / ACTUAL	PROJECT PROGRESS IN PER CENT CONST. SCHED. / ACTUAL	STARTING DATE DESIGN / CONST.	DIRECTIVE COMP. DATE DESIGN / CONST.	ESTIMATED OR ACTUAL COMP. DATE DESIGN / CONST.
CCH-866	Shielded Analytical Laboratory - 325 Building	$ 750,000	$ 60,000 5-31-60	0 0	0 0	N.S. 4-1-61	- - - - - -	N.S. 12-1-61

USING COMPONENT: Chemical, R & D

FEO ENGINEER: R. W. Dascenzo

REMARKS:

Approval has been received by HOO - AEC for $60,000 for detailed design. A Directive dated May 31, 1960, has been received by G.E. The A.E.C. has changed this project to AEC managed and a Work Authority has not yet been issued. The detail design will be by an Architect-Engineer instead of G.E. The previously completed design criteria is being revised to reflect this condition.

PROJECT NUMBER	TITLE	EST. TOTAL PROJECT COST	AUTHORIZATION INFORMATION AMOUNT / DATE	PROJECT PROGRESS IN PER CENT DESIGN SCHED. / ACTUAL	PROJECT PROGRESS IN PER CENT CONST. SCHED. / ACTUAL	STARTING DATE DESIGN / CONST.	DIRECTIVE COMP. DATE DESIGN / CONST.	ESTIMATED OR ACTUAL COMP. DATE DESIGN / CONST.
CAH-870	Facilities for Recovery of Radioactive Materials - 325-A Building	$ 486,000	$ 486,000 3-22-60	100 100	0 0	9-18-59 6-1-60	- - - 6-1-61	3-1-60 6-1-61

USING COMPONENT: Chemical, R & D

FEO ENGINEER: R. W. Dascenzo

REMARKS:

Bids were opened on May 10, 1960, for the lump sum construction work and were as follows:

Fair Cost Estimate	- $360,000	Jensen-Rasmussen Const. Co.	- $404,500	The Timber Co.	- $374,900
W. G. Clark Const. Co.	- 388,000	S & E Const. Co.	- 399,076	Frank Lohse Const. Co.	- 406,900
Mowatt Bros. Const. Co.	- 379,275	Lewis Hopkins Co.	- 384,900	Geo. A. Grant Const. Co.	- 358,300
Teller Const. Co.	- 351,900	Tri-Angle Const. Co.	- 351,551		

The Tri-Angle Construction Company was awarded the low bid and given the Notice to Proceed on May 16. Equipment has been moved in and construction will start on May 31. Several discussions have been held with the contractor and his

USING COMPONENT

FEO ENGINEER

REMARKS:

stainless steel vendor fabricator. It has been proposed by the contractor to weld the vault liners in one piece to eliminate the field weld and also provide a better anchoring system. The vault liners are one of the first items of installation and require 17 - 20 weeks delivery. Another item reviewed with the contractor was relocating the dumping of his excavated dirt surplus to a site east of the high tank for the mutual benefit of the Government and the Contractor. G.E. Plant Forces have decontaminated all Government furnished tanks and J. A. Jones Company is modifying them (45% complete) Work Authority CAH-870 (2) dated 3-31-60, authorizes $45,000 to G.E. to exercise technical direction of the A-E, perform Title III and related management services, and to decontaminate, renovate and modify the six transferred tanks.

BUDGET CLASSIFICATION: Installation for Support of Bio-Medical Research - 60-h-1

MONTHLY PROJECT REPORT
HANFORD LABORATORIES OPERATION

HW - 65459
MONTH: May, 1960

PROJECT NUMBER	TITLE	EST. TOTAL PROJECT COST	AUTHORIZATION INFORMATION AMOUNT / DATE	PROJECT PROGRESS IN PER CENT DESIGN SCHED. / ACTUAL	PROJECT PROGRESS IN PER CENT CONST. SCHED. / ACTUAL	STARTING DATE DESIGN / CONST.	DIRECTIVE COMP. DATE DESIGN / CONST.	ESTIMATED OR ACTUAL COMP. DATE DESIGN / CONST.
CGH-838	Biology Laboratory Improvements	$ 300,000	$ 30,000 4-18-60	N.S. Des. I-95	- - - - - -	5-13-60* - - -	- - - - - -	11-1-60 - - -
		USING COMPONENT: Biology				FEO ENGINEER: J. T. Lloyd		

REMARKS:

The A.E.C. Directive, dated May 4, 1960, requested General Electric Company to manage the project, perform design and authorized the expenditure of $30,000. Schedules and cost estimates are to be established at a later date. The design criteria is essentially complete. Detail design is expected to start June 6, 1960.
*Scope Design.

Improvements to Production and Supporting Facilities - 61-a-1

CGH-832	Full Scale Constants Testing Reactor	$ 915,000	None None	0 0	0 0	- - - - - -	- - - - - -	- - - - - -
		USING COMPONENT: Physics and Instruments, R & D				FEO ENGINEER: R. W. Dascenzo		

REMARKS:

The Project Proposal requesting preliminary engineering funds is still being reviewed by A.E.C.

Equipment Not Included in Construction Projects - Program Class 2900

CG-785	In-Reactor Studies Equipment - 105-KW Building	$ 325,000*	$ 276,000 12-8-58	100 99	40** 40**	1-5-59 3-22-60	- - - 12-31-60	9-1-60* 2-28-61*
		USING COMPONENT: Reactor & Fuels, R & D				FEO ENGINEER: H. Radow		

REMARKS:

The two major instrument panel assemblies have been installed and work on the electrical runs and equipment is progressing. The valve rack assembly has been witness tested at the vendor's site and is being readied for shipment. On-site fabrication of the capsule removal facility is progressing favorably. The project proposal revision requesting authorization of the helium conservation modification and additional funds has been submitted for comments.
*Estimated total cost and completion dates per cost-to-complete estimate and revised project proposal. Will pertain if revised scope and additional funds are authorized.
**Per construction status schedule which has been submitted to the Commission for approval. The percent progress shown reflects receipt of instrument panel assemblies.

AM-7300-Div (4-

BUDGET CLASSIFICATION: Equipment Not Included in Construction Projects - Program Class 2900

MONTHLY PROJECT REPORT
HANFORD LABORATORIES OPERATION

HW - 65459

MONTH: May, 1960

PROJECT NUMBER	TITLE	EST. TOTAL PROJECT COST	AUTHORIZATION INFORMATION AMOUNT / DATE	PROJECT PROGRESS IN PER CENT DESIGN SCHED. / ACTUAL	PROJECT PROGRESS IN PER CENT CONST. SCHED. / ACTUAL	STARTING DATE DESIGN / CONST.	DIRECTIVE COMP. DATE DESIGN / CONST.	ESTIMATED OR ACTUAL COMP. DATE DESIGN / CONST.
CGH-805	High Temperature Tensile Testing Cell 327 Building	$ 170,000	$ 150,000 2-25-59	100 100	0 0	8-26-58 8-20-60	- - - 3-1-60	6-15-59 3-1-61
		USING COMPONENT: Reactor & Fuels, R & D				FEO ENGINEER: R. W. Dascenzo		

REMARKS: The revised project proposal requesting additional time and funds has not been approved by local HOO - AEC. After review of the Washington Iron Works shop drawings of the cell structure a trip was made to the vendor's plant by E. C. Watts and R. W. Dascenzo on 5-5-60 to clarify some differences and discrepancies in the design. An inquiry to change from a No.125 to a No. 63 finish on all exposed surfaces was abandoned as the machining would cost too much.

At AEC's request (B. F. O'Mealy) additional information was furnished to them concerning the capabilities and limitations of the existing tensile testing machines and cost and time of delivery for a new high temperature tensile testing machine.

Six cans were shipped on 5-26-60 to United Products for testing purposes in conjunction with the can sealer and opener that they are fabricating. Seven viewing plugs with protective glass and one without have been received from Penberthy Instrument Company. Nine solid and one sample entry plug has been received from United Products Company.

A review of theestimate for installation of the cell was made by J. A. Jones and Construction Operation and the new figure is $43,003, which is approximately $15,000 higher than the project estimate.

CGH-834	Modifications and Additions to the High Pressure Heat Transfer Apparatus - 189-D Building	$ 700,000	$ 700,000 4-8-59	100 99	75 75	4-20-59 4-22-59	- - - 10-15-60	7-1-60 10-15-60
		USING COMPONENT: Reactor & Fuels, R & D				FEO ENGINEER: H. Radow		

REMARKS: Material problems and design details still unresolved on the various vessel orders are being reviewed and steps taken in an effort to keep fabrication progress moving. Progress on the high-speed valve assembly order appears favorable and vendor has placed orders for the valve body castings.

Rate of field progress depends upon receipt of the off-site fabricated heat exchangers and storage vessels.

BUDGET CLASSIFICATION Equipment Not Included in Construction Projects - Program Class 2900

MONTHLY PROJECT REPORT
HANFORD LABORATORIES OPERATION

HW - 65459 II
MONTH May, 1960

PROJECT NUMBER	TITLE	EST. TOTAL PROJECT COST	AUTHORIZATION INFORMATION AMOUNT	AUTHORIZATION INFORMATION DATE	PROJECT PROGRESS IN PER CENT DESIGN SCHED.	PROJECT PROGRESS IN PER CENT CONST. SCHED.	STARTING DATE DESIGN	STARTING DATE CONST.	DIRECTIVE COMP. DATE DESIGN	DIRECTIVE COMP. DATE CONST.	ESTIMATED OR ACTUAL COMP. DATE DESIGN	ESTIMATED OR ACTUAL COMP. DATE CONST.
CGH-857	Physical and Mechanical Properties Testing Cell - 327 Building	$ 500,000	$ 75,000	10-1-59	7*	7*	10-20-59	N.S.	- - -	- - -	12-1-60	1-1-62
			ACTUAL		0	0						

USING COMPONENT: Reactor and Fuels, R & D

FEO ENGINEER: R. W. Dascenzo

REMARKS: The General Manager approved the project proposal revision changing the scope of work on this project but it has not been approved by HOO - AEC as yet.

Information has been received from the Instron Engineering Corporation regarding the Universal Testing Machine and the Arc Weld Sales Company concerning the Creep Testing Machine. As soon as information is received from the Budd Company concerning the fatigue testers scoping can proceed on this cell. Detail design is continuing on the impact tester.

*Equipment scope design; cell design not started.

PROJECT NUMBER	TITLE	EST. TOTAL PROJECT COST	AUTHORIZATION INFORMATION AMOUNT	AUTHORIZATION INFORMATION DATE	PROJECT PROGRESS IN PER CENT DESIGN SCHED.	PROJECT PROGRESS IN PER CENT CONST. SCHED.	STARTING DATE DESIGN	STARTING DATE CONST.	DIRECTIVE COMP. DATE DESIGN	DIRECTIVE COMP. DATE CONST.	ESTIMATED OR ACTUAL COMP. DATE DESIGN	ESTIMATED OR ACTUAL COMP. DATE CONST.
CGH-858	High Level Utility Cell - 327 Building	$ 500,000	$ 70,000	10-1-59	15*	15*	10-20-59	N.S.	- - -	- - -	11-1-60	11-1-61
			ACTUAL		0	0						

USING COMPONENT: Reactor & Fuels, R & D

FEO ENGINEER: R. W. Dascenzo

REMARKS: Detail design is being performed on the milling machine. Scoping design is continuing on the lathe.

*Equipment design; cell design not started.

USING COMPONENT

FEO ENGINEER

REMARKS:

PROFESSIONAL PLACEMENT AND RELATIONS PRACTICES OPERATION

MONTHLY REPORT

GENERAL

As of May 31, 1960, the staff of the Hanford Laboratories totalled 1310, including 619 exempt and 691 nonexempt employees. Of the total, 528 possessed technical degrees, including 313 B.S., 114 M.S., and 101 Ph.D.

HEALTH, SAFETY AND SECURITY

The medical treatment frequency for May was 1.77 as compared with 1.68 for April. There were no disabling injuries or serious accidents during the month. There was 1 security violation, bringing the total for the year to date to 10.

Two papers on the investigation and control of pressure equipment accidents were presented at the AEC and Contractors' Annual Safety Conference.

PROFESSIONAL PLACEMENT

Three graduates from the Advanced Engineering and Creative Engineering Programs and 7 graduates of the Company's Manufacturing Training Program visited for employment interviews. Six offers for HAPO's Technical Graduate Program remain open. All of these men are summer graduates and are outstanding candidates worthy of consideration. For the recruiting year to date, there have been a total of 194 offers extended resulting in 81 acceptances.

Five Technical Graduates were added to the Program rolls and 6 accepted permanent assignments during May. At month's end there were 38 Technical Graduates, including 9 members of the Engineering and Science Program and 5 Technician Trainees on Program rolls.

Six Ph.D. candidates visited Hanford for employment interviews. Four offers were extended and one acceptance was received from an ecologist for assignment with Biology. For the year to date there have been 8 Ph.D. acceptances received.

EMPLOYMENT

Twenty-nine nonexempt vacancies were filled during the month. With the receipt of 33 new requisitions and the cancellation of 4, there are currently 37 nonexempt vacancies for which 23 candidates are in process and 5 transfers are pending, leaving 9 candidates yet to be procured.

COMPENSATION

A 2% increase in the exempt salary structure was approved, effective June 1, 1960. A 4% trend will continue to be used.

COMPENSATION (Cont.)

Clarence H. Ham, a machinist trainee in Technical Shops, died on 5/24/60.

Manager
Professional Placement
and Relations Practices

TG Marshall:bt

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TABLE II NONEXEMPT EMPLOYMENT

Nonexempt Employment Status	April	May
Requisitions		
At end of month	28	37
Cancelled	4	4
Received	25	33
Filled	7	20

Nonexempt Transfer Request	April	May
Transfers		
Active cases at end of mo.	74	73
Cancelled	1	3
New	8	4
Effected	1	2

TABLE III. 3SIONAL PERSONNEL PLACEMENT

A. Technical Recruiting Activity - HAPO - September 1, 1959 to Date

	Cases Considered	Visits to Richland: Invited	Visited	To Visit	Offers*: Extended	Accepted	Open	On the Roll**
Ph.D.	637	147	46	24	24	8	3	4
Exp. BS/MS	412	94	62	7	83	45	6	35
Prog. BS/MS	481	-	-	-	194	81	6	23

*Offer totals include offers open on 9/1/59
Ph.D. 3
Exp.BS/MS 6

**On the Roll totals include 1958/59 Carryover acceptances and one 1957/58 Ph.D.Carryover.

B. Technical Recruiting Activity - HLO - September 1, 1959 to Date

	Cases Considered	Visits to Richland: Invited	Visited	To Visit	Offers*: Extended	Accepted	Open	On the Roll**
Ph.D.	637	147	46	24	20	7	2	3
Exp. BS/MS	249	35	20	2	16	11	-	2

*Offer totals include offers open on 9/1/59
Ph.D. 3
Exp.BS/MS 3

**On the Roll totals include 1958/59 Carryover acceptances and one 1957/58 Ph.D. Carryover.

In addition to the above activity, 15 exempt employees have transferred into HLO from other HAPO departments and 21 technical graduates have accepted off-Program placement in HLO to date.

C - Technical Graduate and Technician Training Program
Month ending May 31, 1960

	TG Program	TT Program
Number of Personnel on Assignment	38	5
(HAPO Tech Grad Program 29		
(Western District E. P. 9		
Distribution of Assignments by Departments		
HLO	19	1
CE&UO	1	0
FPD	1	0
IPD	12	4
CPD	4	0
C&AO	1	0
Distribution of Assignments by Function		
R&D or Engineering	26	5
Other	12	0

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FINANCIAL OPERATION MONTHLY REPORT
MAY 1960

Personnel

There were no personnel changes during May.

Activities

GENERAL ACCOUNTING

Estimates of HLO requirements for Assistance to Hanford work in FY 1961 were secured and forwarded to Contract and Accounting for consolidation and submission to HOO-AEC for approval. Authorizations expiring June 30, 1960, are being reviewed to determine if renewals should be negotiated. Letters will be written in June to Company components doing ATH work for HLO requesting estimates of total costs to June 30, to facilitate fiscal year end accruals.

A revised list of professional and trade societies approved by the HAPO General Manager for travel purposes was received and distributed to HLO management as Appendix "A" to the Travel and Living Expense Manual.

Travel activity is summarized below:

	Number of Trips Started	
	FY 1959	FY 1960
First Six Months	527	605
Third Quarter	353	283
April	164	160
May	123	152
June	218	200 Est.
Total	1 385	1 400

Based on eleven months actual experience and an estimate for the final month, it appears that total travel activity in FY 1960 will not vary significantly from that experienced in FY 1959.

Weekly detailed reporting of equipment acquisition activity has been established for the 2000 Program. We are currently taking steps to include the 4000 Program in this weekly report.

May expenditures including a $39,000 accrual for equipment received not billed totaled $311,000.

The billing for the neutron dosimeters ordered by the AEC, to be funded by HLO, has been received. The amount of this billing is $70,402, as compared to previous estimates ranging from $39,000 to $61,000. An accrual of $61,000 was set up for these dosimeters when they were received earlier in the year.

A meeting was held with a representative of the IBM Company to investigate the feasibility of using a new machine to handle the accumulation of detail for equipment acquisitions. The machine could not meet our reporting requirements.

Sixty-six items valued at $34,294, were received at the Laboratory Equipment Pool Building during the month of May. One item valued at $260 was withdrawn and two items valued at $1,236 were transferred in lieu of placement of requisitions. There are 296 items valued at $140,799, currently located in the storage area. Nine hundred and fifty-one pounds of zirconium valued at $16,886, was received for storage and issuing during the month.

In response to a request of Accounts Payable, a list of returnable containers received at HAPO prior to February 1, 1960, was forwarded to custodial personnel for review and verification of containers. A consolidated report of findings was prepared and submitted to Accounts Payable.

Effective July 1, the Specialist - Property Accounting will act as Central Control Custodian of all Reactor and Other Special Materials with the exception of radium. Chapter 4 of the HLO Property Management Manual was revised and distributed indicating the new requirements affecting the control of materials.

The regular quarterly inventory of Other Special Materials will be taken as of June 30, 1960. Arrangements were made for this inventory to include both Reactor and Other Special Material and the furnishing of sufficient information to enable us to implement the revised procedure outlined in Chapter 4 of the Property Management Manual.

Nuclear Materials Accounting advised us of the continuation of Survey 17 with a verification of HAPO inventories of Plutonium as of the end of June 1960. All material custodians were advised of the survey and requested to submit inventory information to enable us to prepare and submit a physical inventory schedule for HLO.

SS Material Custodians were advised that a representative from Nuclear Materials Measurements Operation will witness all HLO SS material inventories to extend through July 1960. The main objective of this program is to observe the Custodian's routine inventory procedure and measurement methods.

A Project Unitization Report was issued on Project CGH-829, "Building 325 Basement Improvements" during the month.

Reconciliation of the physical inventory of movable cataloged equipment in custody of Reactor and Fuels R&D and in the custody of Chemical R&D continues.

COST ACCOUNTING

The Hanford Laboratories operating cost control budget for May reporting was adjusted as follows:

(Dollars in Thousands)	Adjustment	New Total
4000 Program		
Plutonium Recycle Program	$ 12	$ 5 591
GCR - Physics	(12)	165
5000 Program		
Actinide Element	(2)	98
Isotopic Analysis	(15)	125
Radiochemical Analysis	(10)	220

(Dollars in Thousands)	Adjustment	New Total
Transplutonic Elements (Fabrication)	$ (40)	$ 135
DMA - Pu 240 Elements (Fabrication)	(80)	270
Total Hanford Laboratories	$(147)	$24 728

Revised Work Identification Code pages 7c and 7c-2 for the Uniform Cost Code Handbooks were distributed during the month.

A rough draft of a letter to HOO-AEC transmitting our estimates of the cost to duplicate the first fuel loading of the PRTR has been circulated for comments.

Due to the strong emphasis on financial costs for the Joint Committee on Atomic Energy's Hearings on Radiation Protection Standards, additional data were developed for the Radiation Protection Operation. This material consisted of:

(1) narrative comparisons of cost information of the various Commission sites, and

(2) a detailed breakdown by department and function of Fiscal Year 1959 operating costs at HAPO generated by radiation and safety activities, which had previously been included in the AEC's preprint material in summary form.

Annual review of routine work orders was accomplished during the month which resulted in some cancellations, supplements, and revisions to bring routine work orders up to date.

Action as indicated occurred on the following projects during the month:

Physical Completion Notices Issued

CGH-840 Sheet Metal Shop Annex - 328 Building.
CGH-879 High Temperature, High Pressure Autoclave Facility, 306 Bldg.

Construction Completion and Cost Closing Statements Issued

CA- 681 Hanford Equipment in the ETR (AEM Services Only)
CGH-801 X-Ray Diffraction Cell
CAH-828 Central Storage Facility - 300 Area
CGH-838 Fission Product Volatilization Studies Test Facility - 292-T Building

Arrangements have been made with J. A. Jones Construction Company which will result in their accruing and costing in June business all materials and equipment received and not billed or in transit where FOB is vendor's plant. Contracts and fabrication orders will also be reviewed and costing will be effected where possible.

PERSONNEL ACCOUNTING

Personal Share in GE Employee Benefit Plans statements were delivered to employees at work on May 13, 1960. Included with these statements was a letter indicating designated beneficiaries in each of the following plans: Pension, Insurance, and

Savings and Security. Few errors were reported on the information furnished on the Personal Share Statement. Many employees requested and were given forms to change beneficiaries of record as a result of the letter on designated beneficiaries.

A study of the increased cost in exempt overtime if the $7,500 control limit was eliminated was prepared. The elimination of the $7,500 control would have increased HLO's exempt overtime cost for calendar year 1959 approximately $6,000.

April Share Owners Quarterly Reports were delivered to participants in the Savings and Security Plan on May 13, 1960.

Approximately 20 non-exempt employees were overpaid week ending May 15, 1960. The overpayment was due to payment of isolation pay instead of shift premium. The overpayment amounted to approximately $2.88 per employee, adjustment was made in May 22 salary payments disbursed on May 29, 1960. Employees were notified of this overpayment by means of a note prepared by C&A Personnel Accounting and included with May 15 salary payments.

Payroll Statistics

Number of HLO Employee Changes During Month	Total	Exempt	Non-Exempt
Employees on Payroll at Beginning of Month	1 304	620	684
Additions and Transfers In	21	5	16
Removals and Transfers Out	15	6	9
Employees on Payroll at End of Month	1 310	619	691

Overtime Payments During Month	May	April
Exempt	$ 4 122	$ 4 205
Non-Exempt	14 344	10 508
Total	$18 466	$14 713

Gross Payroll Paid During Month		
Exempt	$528 733	$525 934
Non-Exempt	342 092	326 254
Total	$870 825	$852 188

Participation in Employee Benefit Plans at Month End	May		April	
	Number	Percent	Number	Percent
Pension Plan	1 152	99.5	1 155	99.5
Insurance Plan				
Personal Coverage	1 297	99.8	1 300	99.8
Dependent Coverage	922		926	
U.S. Savings Bonds				
Stock Bonus Plan	80	40.4	79	39.9
Savings Plan	91	7.0	91	7.0
Savings and Security Plan	1 023	87.9	1 021	88.0

Insurance Claims	May Number	May Amount	April Number	April Amount
Employee Benefits				
Life Insurance	-	-	-	-
Weekly Sickness & Accident	25	3 353	30	2 100
Comprehensive Medical	34	2 017	125	12 863
Dependent Benefits				
Comprehensive Medical	178	18 076	188	10 443
Total	237	23 446	343	25 406

Good Neighbor Fund	May	April
Number Participating	916	915
Percent Participating	70.1	70.2

W. Sale
Manager - Finance

W Sale: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
G. B. Hatcher	Resistance Heating Brush Holder.
F. B. Quinlan	The Art of Expanding or Contracting (Sinking) Tube Diameters
J. P. Pilger	A Gripping Device for Round Material
C. A. Rohrmann	A Process for the Destruction, Deactivation and Modification of Pathogenic Viruses - May 12, 1960.
	Foamed Insulating Resins of Improved Thermal Stability - May 17, 1960.
L. H. McEwen	Plutonium-Uranium Bearing Fuel Element of Potentially Reduced Cost - April 28, 1960.
	Vapor-Liquid Mixtures as Working Fluids in Magneto-Hydrodynamics Power Recovery Devices - April 29, 1960.
L. L. Ames, Jr.	The Removal of Zn^{65} from Reactor Cooling Water.
H. L. Brandt	A Continuous Countercurrent Ion Exchange Using Solid Granular Exchangers for Processing Liquid Feeds.

INVENTIONS OR DISCOVERIES (Contd.)

INVENTOR	TITLE OF INVENTION OR DISCOVERY
B. M. Johnson, Jr.	Chemical Process Equipment - A Design to Reduce Turbulence in the Nozzle Zone of the Radiant-Heat Spray Calcination Reactor (HW-65331).
R. H. Moore	A Method for Scavenging Fission Products from Molten Salt Solution (HW-65423).
R. W. Wirta	Automatic Flow Diverter for a Turbine Type Pump.
R. W. Wirta	Miles per Gallon Indicating Instrument.
R. F. Maness	The Use of Low Temperature Acidic Fluoride Solutions for Preferential Decladding of Zircaloy-clad UO_2 Fuels.

H M Parker