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PHYSICS AND INSTRUMENTS DEPARTMENT

MONTHLY REPORT

JULY 1965

Compiled by Members of the
PHYSICS AND INSTRUMENTS DEPARTMENT
BATTELLE-NORTHWEST

Submitted by: R. S. Paul

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PHYSICS AND INSTRUMENTS DEPARTMENT

MONTHLY REPORT

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FISSIONABLE MATERIALS - O2 PROGRAM

REACTOR

NPR Separate Target Coproduct Supercell

Power density distribution within the proposed NPR separate target-coproduct-supercell is being calculated in a four-group diffusion theory model by using the two-dimensional IBM code 9-ANGIE. The target-cell-to-driver (fuel) cell ratio is 1 to 6. Cell geometries, energy group structure, nuclei densities, and physical temperatures are from design calculations performed on the IBM code FLEX III.

Macroscopic group constants for 9-ANGIE are being calculated with TEMPEST and GAM by using S-4 TRANSPORT disadvantage corrections. Iterations between TEMPEST and S-4 are being employed to obtain a "converged" set. It is recognized that such converged sets may have systematic errors. Hence, sensitivity to changes in the most important parameters is being investigated.

This work is approximately 50% complete. To date, homogenized and semi-homogenized analyses have been completed on driver and target cells separately. These homogeneous cells have been assembled in a supercell array, and calculations are complete. The worth of the target cell obtained by using 9-ANGIE in the manner described above, is in agreement with P-3 results from FLEX III.

Power density distributions from these homogeneous supercell calculations appear acceptable and suggest that calculated power density distributions for the heterogeneous cells will also be acceptable.

Development of Computational Methods for Tube-in-Tube Geometry in a Graphite-Water System

An informal report is being prepared on the comparisons of the calculational techniques which were summarized in the June 1965 Monthly Report.

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Theory-Experiment Correlation

Calculations have been initiated in an attempt to predict the thermal neutron activation distributions for N-Reactor standard fueled lattice cells. THERMOS, a thermalization transport theory code, is being used with the Parks kernel for graphite and the Nelkin kernel for water. The results of these calculations will be compared with the experimentally determined activation distributions measured in the PCTR.

Coproduct Striped Load

Although the original striped load one-dimensional slab diffusion theory calculations, as previously described, did not completely converge, the results do indicate that a slab loading (identical axial positions of coproduct slugs in each process tube) may not be feasible because of excessive flux depression in the coproduct regions. Therefore, two-dimensional diffusion theory reactor calculations in R-Z geometry have been initiated for various idealized staggered striped loadings. The preliminary goals are to determine the over-all neutron multiplication and flux shapes for several target-to-driver ratios.

Coproduct Experiments for N-Reactor in the PCTR

Calculations have again been resumed to determine the infinite medium multiplication factors and thermal utilizations in the wet and dry coproduct lattice. Detailed flux traverses have now been completed for all cases and region averages are being determined. A computer program, P-3, is being used to fill in the detailed flux shape between experimental points from the target through the process tube. The cross section and volume information for each region has been completed. This information will be combined with the average regional fluxes in order to evaluate the thermal utilization (f) and the infinite medium multiplication factor (k_{∞}).

Experimental Program for NPR Supercell

Brief consideration has been given to a possible supercell experimental program in the PCTR and N-Reactor exponential assembly. Experiments for k_{∞} might resemble the EGCR control rod experiment.

An exponential measurement for supercell material buckling and differential control rod buckling can be expected to be more difficult and less precise than ordinary buckling experiments. Further consideration of the feasibility and probability of success for exponential experiments is being discussed. One common problem to these experiments is that the expected target-to-driver ratio is difficult to simulate experimentally. Hence,

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significant theoretical interpretation of any results will probably be necessary.

Pu-Al Thoria Experiments

A series of separate target k_{∞} measurements for a Pu-Al-Th-fueled, graphite-moderated lattice is in progress in the PCTR. The first measurements are being made in the dry condition (no water in the cooling channel). The lattice has an 8" square pitch, and is loaded with 6.5 w/o Pu-Al and thoria at 77% theoretical density in alternate cells. Measurements are being made on a 4 x 5 cell array, and the center cell is a supercell consisting of one Pu-Al-fueled cell and one thoria target cell. The amount of copper required to poison the supercell to a multiplication of unity in the spectrum of an infinite lattice is to be determined.

System Studies

Analog simulation analysis of transients occurring in N Reactor plant with the system delivering steam to the electrical generating plant has elucidated the effect of turbine generator tripoff on system stability. Studies were made simulating six primary loops with the export steam loop. These studies included the addition of the charge-discharge valves to the control of pressurizer level and the addition of rate action to the charge-discharge valve control circuit. It was found that the inclusion of the rate action was desirable. Trends for pressurizer controller settings were defined.

SEPARATIONS

Neutron Interaction Experiments with Arrays of Plutonium Metal Ingots

Subcritical neutron interaction experiments were performed with bare and Lucite reflected arrays of plutonium metal ingots. These experiments provide data for nuclear safety guidance in handling, storage, and shipment of the Pu metal, and for checking interaction calculations.

The ingots (2.57 in. diam., 1.82 in. high) were canned in aluminum cans (0.012 in. wall) with steel tops (0.008 in.). The average ingot weight was 3027 grams.

The canned ingots were stacked in arrays on the Remote Split-Table Machine, using inverse neutron multiplication techniques to estimate the number of cans for criticality. Extrapolations were also made on the spacing, from which the critical spacing could be determined for a fixed number of canned ingots.

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For the reflected arrays the Lucite was placed touching the can surface-- boxing in the array. To obtain accurate spacing between units, aluminum shims were used, and the units were held in position by aluminum frames which were mounted on a 0.03 in. base plate. Aluminum honeycomb was used to support the base plate and to provide separation between layers of ingots.

The heat generated in the Pu was dissipated by air cooling. Bare arrays were maintained at about 42°C. Temperatures as high as 56°C were reached in the reflected arrays.

The results of the measurements are presented in the following table. Calculated values obtained with the simple density analog method are also shown for comparison.

CRITICALITY OF ARRAYS OF PLUTONIUM METAL INGOTS

	Reflector	Critical ^(a) Spacing (in.)	Critical No. of Ingots	Critical Mass (kg)	Calculated ^(b) Critical No. Ingots
Triangular Lattice, 2 High	Bare	0.0	6.07	18.37	--
Square Lattice, 2 x 2 Base + 2 Ingots Second Layer	Bare	0.0	7.2	21.79	6.0
Square Lattice, 2 x 2 x 2	Bare	0.17	8	24.21	8.6
Square Lattice, 3 x 3 Base (2 Layers)	Bare	0.58	18	54.48	16.2
Square Lattice, 2 x 2 x 2	Lucite	2.47	8	24.21	23.7
Square Lattice, 3 x 3 Base + 6 Ingots Second Layer	Lucite	~ 3	15	--	--

(a) Surface-to-surface spacing between closest points on the can surface.

(b) Calculated by Density Analog Method.

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For the bare systems, the density analog calculations give reasonable estimates of the measured critical number; but for the reflected array the method gives very poor results (highly non-conservative). In the case of an 8-unit reflected array, all units are of equal importance and each is reflected on one end and along its side. Thus, one would expect the empirical density analog method to give poor results in this situation, which it does. The density analog method does not appear to be applicable to this kind of system where the number of units is small and the array is reflected.

It would be most useful and desirable to obtain further experimental data on reflected arrays with larger numbers of units.

Neutron Interaction Between Multiplying Media Separated by Various Materials

In a series of critical experiments just completed, the thicknesses of various materials required for neutron isolation have been studied. The quantity of material to effectively prevent neutron interaction is of interest for criticality control in the shipment, storage and processing of fissile materials. The materials studies were inserted at the interface of the two multiplying media comprising the PuO_2 -polystyrene core ($\text{H/Pu} = 35$) of the split table assembly. The critical length of the fuel core was then determined as a function of test material thickness, with the effective isolation thickness being defined as that thickness for which the critical core length approaches an asymptotic value. During the month, measurements were made with lead, concrete, and borated concrete. The results of these, and previous measurements, are summarized in the following table:

<u>Material</u>	<u>Effective Isolation Thickness (in.)</u>
Polyethylene	6.5 ± 0.5
Polyethylene*	3.5 ± 0.25
Polyethylene**	3.0 ± 0.25
Borated Polyethylene	3.5 ± 0.25
(10 wt% boron in polyethylene)	
Compressed Wood	8.0 ± 0.5
Concrete	9.0 ± 1.0
Borated Concrete	5.0 ± 0.5
(2½ wt% boron in concrete)	
Lead	8.0 ± 0.5

* .02 in. cadmium sheet inserted between variable core and polyethylene.

** .02 in. cadmium sheet inserted at both core-polyethylene surfaces.

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A Kaman Nuclear Model A-808 neutron generator has been received at the Critical Mass Laboratory. The new unit is designed to produce a maximum yield of greater than 10^9 , 14.5 MeV neutrons per second at a repetition rate of 100 pulses per second. This neutron yield exceeds that of the existing pulsed neutron generator by more than ten. The new unit also has a more flexible yield and repetition rate. This neutron generator is expected to extend the capability of performing pulsed neutron source experiments at the CML.

Critical Mass Laboratory Instrumentation

H ₂ O	3.989 cm
Paraffin	3.927 cm
Polystyrene	3.942 cm
Polyethylene	3.901 cm
Plexiglas	3.817 cm

Critical Radius of Pu²³⁹ Metal Spheres

Criticality parameters for nuclear safety guidance are usually given for conditions of full water reflection. Several common hydrocarbons frequently encountered that are better reflectors than water need also be considered. A series of DTF transport calculations have been initiated to evaluate the effectiveness of Plexiglas (C₅H₈O₂), polystyrene (CH), polyethylene (CH₂), and paraffin (C₂H₅) as reflectors. The initial calculations for Pu²³⁹ metal spheres indicate that all four of the above hydrocarbons are better reflectors than water. The results of the calculations are summarized below:

Evaluation of Hydro-Carbon Reflectors

A new version of the DTF code (a multigroup S_n transport code) has been received. This version of DTF corrects several errors that existed in the original code. Also, the modified version permits the utilization of higher order terms in the Legendre expansion of the scattering functions. DTF-II is presently being compiled with the Hanford monitor system. Also, the GAMTEC-II code is being modified to punch the cross section data into DTF-II format.

DTF-II, New Version of DTF Transport Code Received

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Consulting Services on Nuclear Safety - Criticality Hazards

1. Nuclear Safety in Pacific Northwest Laboratory

The following nuclear safety specifications were reviewed:

- a. Temporary Specification No. 12 for Ceramic Research and Development to cover a special batch of highly enriched UO_2 .
- b. Temporary Specification No. 13 for Metallurgy Development to cover the processing of a special 4.2 kg casting.
- c. Specification No. C-20 for Critical Mass Physics to cover handling of special 3.0 kg Pu metal ingots.
- d. Specifications Q-1, Q-4, and Q-5 revised for Ceramics Research and Development covering plutonium and PuO_2-UO_2 work.

2. Criticality Safety of FFTF Reactor Fuel

A series of calculations have been made to provide criticality data for nuclear safety guidance in the design engineering phases of the FFTF. Critical parameters were calculated for moderated and un-moderated driver fuel elements (15-20 vol% PuO_2 -stainless steel cermet). The results of these calculations, and recommended safe limits for handling, processing, and storing the proposed fuel elements, will be issued in a separate document.

3. Nuclear Safety of Off-Site Shipment of Fissile Material

The nuclear safety of shipping 133 g Pu in the form of four PuO_2 fuel pins (0.3 in. diam. and 18 in. long), together with one 93 wt% enriched UO_2 fuel pin containing 25 g U, under Class II to ANL was reviewed and approved.

Separations Plant Instrumentation

Field testing work was continued on the Am^{241} monitor developed for a chemical process cation column. Tests to define measurement limits under field conditions are now being made.

METALLURGY - Nondestructive Testing

N Reactor Fuels

Following recent in-reactor fuel failures, a three-channel ultrasonic test

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was devised to inspect Zircaloy-clad components for discontinuities on an emergency basis. The test station, comprised of temporarily available laboratory equipment, will be replaced with specially designed equipment as time permits.

A portable, ultrasonic, end cap thickness tester has been provided N Fuels for use in inspecting a backlog of stored material. The application is significant in that it monitors pulses reflecting from a well-bonded zirconium-uranium interface.

Progress on the construction of the experimental co-extruded fuel tester has been delayed due to slow delivery of power supplies.

N Reactor Plant

An ultrasonic technique which utilizes interaction between the fifth longitudinal back-surface reflection and the shear waves generated by a flat transducer inside a Zircaloy tube is presently being developed to detect hydride in Zircaloy tubes. Work has progressed to the point where the fifth pulse can be selected by a series of gates and detected to produce two pulses. The spacing between the pulses is related to hydride. Commercial digital logic circuits are being employed in the gating circuits. Work is continuing on a readout device, rotating transducer probe, and testing of different samples in the laboratory.

Installation and evaluation of the Eddy Current Spacer Motion Indicator was conducted on the Full-Scale Facility of the NRD Prototype Concept Evaluation Loop, 189-D Building, 100-D Area. The instrument appears capable of detecting movement of the spacer, either in a rotational or longitudinal vibration, within 0.005 inch.

IPD Fuels

Fabrication of an instrument to measure the thickness of nickel plated on uranium has been initiated. The design of the instrument is based on the Hall effect. When the instrument is completed, its performance will be compared to the results obtained with Dermitron eddy current tester (currently used on the production line), Industrial Control Company's Nickel Detector, and the X-ray fluorescence test.

IPD Plant

The occurrence of hydriding in Zircaloy-2 tubes has indicated a need for a rapid, accurate, nondestructive method of detecting the presence of hydriding in installed tubes. A prototype 5 Mc eddy current tester has

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been developed for this purpose. Preliminary laboratory testing indicated that this instrument can differentiate between nominally hydrided samples and nominally clean samples. The equipment was recently shipped to 105-KW and four installed tubes were tested during a scheduled outage. Although some drift was noted, the tester appeared to operate substantially as predicted. The large amount of data taken will, after analyses, be compared with destructive metallographic examination of the tubes.

Old reactor process tubes are frequently replaced as localized areas corrode to the point of being dangerously thin. A program is under way to develop ultrasonic testing methods for detecting and measuring the thin areas, thus providing guidance to tube replacement programs. A commercially available pulse-echo tester capable of resolving echoes in an 0.022 inch aluminum plate proved to be limited in practice due to surface roughness of the tube samples. Attempts to overcome this difficulty with more efficient transducers and higher gain signal amplification are now being made under reactor conditions. If the technique proves to be acceptable, a more complex system will be developed for complete scanning of the tube wall.

NEUTRON CROSS SECTION PROGRAM - 02/04 PROGRAM

Triple-Axis Spectrometer

An analyzer crystal has been assembled from five thin slices of copper single crystal. The mounting device for the crystals allows each crystal to be adjusted separately to minimize secondary extinction and optimize the effective angular width of the composite crystal rocking curve. The resulting analyzer gives a reflectivity somewhat greater than the previously used beryllium crystal reflection but with a significantly narrower angular width. Measurements are in progress to determine the characteristics of the analyzer in scattering experiments.

Neutron Scattering from Zirconium Hydride

An additional measurement of the one-phonon scattering from ZrH was made for an incident energy of 0.24 eV. In this measurement a bank of He³ counters was used to detect scattered neutrons at an angle of 15 degrees and with the longer flight path of 1.5 meters. No difference was discernible in the shape of the one-phonon peak from the shape observed in previous measurements. A manuscript, "A Multiphonon Neutron Scattering Study of Hydrogen Bonding in Zirconium Hydride," was prepared for submission to the forthcoming Brookhaven Symposium on the Inelastic Scattering of Neutrons by Condensed Systems.

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Neutron Scattering from H₂O

More scattering experiments were performed at incident energies of 0.15- and 0.30-eV. Measurements were made to study the different components of background which occur. The data have not yet been analyzed in detail.

Fast-Neutron Cross Sections

Considerable progress has been made in the preparation of heavy element samples for 3- to 15-MeV total cross section measurements. Suitable samples of Th²³² and U²³⁸ have been prepared. Samples of U²³³, U²³⁵, and Pu²³⁹ have been procured and are presently being fabricated in suitable form. We have been unable to obtain release of a sample of Np²³⁷. The data reduction program BIG NED has undergone extensive modification in order to perform the complete matrix error analysis of total cross section data.

REACTOR DEVELOPMENT - O4 PROGRAM

PLUTONIUM RECYCLE PROGRAM

Experiments with H₂O Moderator

CAF Experiments with 2 w/o PuO₂-UO₂ Fuel

Experiments to measure critical masses, bucklings, and reflector savings of 2 w/o PuO₂-UO₂ fuel rods, 1/2" in diameter and 36" long, are continuing in the Critical Approach Facility. Three additional experiments have been completed this month. The results obtained this past month as well as that previously reported are summarized in Table I.

TABLE I

RESULTS OF SUBCRITICAL EXPERIMENTS WITH 2 W/O PuO₂-UO₂ FUEL

Pu Isotopic Composition (% Pu-240)	Triangular Lattice		Critical Number of Rods	Reflector Savings (cm)	Bucklings (M ⁻²)
	Temperature (°C)	Spacing (in)			
8	20.2	0.93	193.0 ± 0.1	7.65 ± 0.02	102.1 ± 0.2
8	27.8	1.143	146.8 ± 0.3	7.42 ± 0.05	95.0 ± 0.4
8	23.6	1.320	165.8 ± 0.4	7.02 ± 0.05	74.5 ± 0.3
16	20.0	0.93	241.2 ± 0.3	8.22 ± 0.04	85.1 ± 0.3
24	24.7	0.93	286.7 ± 0.4	7.65 ± 0.03	79.1 ± 0.2
24	26.3	1.386	366.7 ± 0.4	5.29 ± 0.03	44.4 ± 0.1

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Pu-Al Experiments with H₂O Moderator

A rough draft summarizing the results from critical experiments with 1.8 w/o Pu-Al and H₂O moderator in the PRCF has been completed. The report summarizes results of critical loadings, worth measurements of control elements, spectrum studies, reactivity coefficient measurements of various reactor materials, and kinetics studies.

Experiments with D₂O Moderator

Calculations for the HPD Core

Reactivity calculations for the 55 element HPD core of the PRTR have been made using the two-dimensional model (r,z) of the 9-ANGIE code. The reactivity worths of specific regions external to the 55 element zone (e.g., weir, dump chamber, reflectors, etc.) have been determined. The calculated multiplication of the 55 element core, which includes these external regions, agrees within 0.5% with that calculated previously using a one-dimensional model. Calculations of flux and power density distributions using this two-dimensional model are being done for a variety of expected reactor conditions.

HPD Core Experiment in the PRTR

Rough draft outlines of the critical, power, and burnup experiments to be conducted with the HPD core in the PRTR have been circulated for comment. Some comments have been received and are being considered for incorporation into the outline.

Calculations of criticality data obtained at the time of original startup of the PRTR are being made using Program SWAP. Comparison is being made between results obtained using cross sections generated using THERMOS and HRG, and those used in early SWAP runs which match experimental data quite well.

Burnup Analysis of the HPD Core

A burnup analysis of the High Power Density Core for the PRTR using Program B-XIII has begun. Parameters of interest will be isotopic concentration of all elements, amount of boron in the moderator for the just critical condition, fission reactivity, and kinetics information. The burnup analysis will simulate one year of full power operation of the PRTR.

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Measurement of α^{241} by the Destructive Analysis of Irradiated Pu²⁴¹

The experiment to measure α^{241} by irradiating pure Pu²⁴¹ samples during the high power density core loading of the PRTR has been abandoned. A similar experiment already under way at Idaho Falls will yield an accurate value of α^{241} in the near future. This result will satisfy the needs of our burnup analysis program. Hence, no further effort toward this experiment is required at this time.

Critical Experiments with a Two-Zone Loading in the PRCF

An experiment to determine spectral indices in an unirradiated 19-rod cluster of Pu-Al was completed in the PRCF moderated with D₂O. The same experiment was done last month using a cluster irradiated for 86 MWd. Lutetium foils, both bare and cadmium covered, were placed in identical positions in the two cases. The foil activities have been counted and the data are being prepared for analysis with Program LULU.

An experiment to measure the reactivity worths of selected PuO₂-UO₂ fuel elements in the center of the PRCF was completed. The results are shown in the following table for a value of 4.631×10^{-3} for the delayed neutron fraction.

REACTIVITY WORTHS OF MIXED OXIDE FUEL ELEMENTS

<u>F.E. No.</u>	<u>w/o PuO₂</u>	<u>% Pu-240</u>	<u>Worth Relative to #5184 (mk)</u>	<u>Worth Relative to D₂O (mk)</u>
5184	0.9	7.75	--	16.5
FD9-3	0.48	7.5	-5.76	10.74
FD9-1	0.48	13.61	-6.67	9.83
FD9-2	0.48	17.77	-7.40	9.10
6011*	2.0	8.0	+6.22	22.72

* Short element for HPD core of the PRTR.

The values in the last column are based on the best available value for the worth of fuel element #5184, which contains considerable uncertainty. The relative worths given in column 4 are more accurate since they do not contain the large error of the absolute measurement. The error analysis is in progress.

An experiment to measure the increase in absorption of a safety rod in the PRCF due to the presence of an internal moderating material has been

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completed. A spare safety rod was placed in the center of the reactor and its worth was determined subcritically to be 44 ± 4 mk ($\$9.50 \pm .86$). A lucite sleeve 2.24" O.D., 1.550" I.D., and 84" long placed inside the safety rod was found to increase its worth by $2.36 \pm .02$ mk ($51.0 \pm 0.4\%$). A lucite rod filling the interior of the sleeve increased the worth an additional $1.40 \pm .01$ mk ($30.1 \pm 0.2\%$). Over-all enhancement was then 8.5%.

Irradiated Fuel Element Measurements in the PRCF

The reactivity worth of an irradiated 19-rod Pu-Al fuel element (86 MWd) relative to an unirradiated fuel element was measured in the center of the D₂O-moderated PRCF. The irradiated element was found to be 11.3 mk less reactive than the unirradiated element. This same measurement, involving the same two fuel elements, was made in October, 1963, and resulted in a difference of 10.9 mk. A correction due to temperature differences, and an error must be calculated for the more recent measurement before any difference can be determined.

Measurements were begun with UO₂ fuel elements which have received various amounts of exposure in the PRTR. The reactivity worths of these elements are being measured relative to an unirradiated UO₂ fuel element. Two UO₂ elements with exposures of 24 and 98 MWd have been measured. Other selected irradiated fuel elements are to be measured before the start of an experiment which is scheduled to begin next month with 2 w/o PuO₂-UO₂ fuel elements.

Spectrum Measurements in a Pu-Al-D₂O System

Program LULU has been used to calculate neutron temperatures from activities of bare and cadmium covered lutetium foils which were activated in a Pu-Al cell in the PRCF moderated with D₂O. The foils were positioned at ten radial positions in the center cell. The first three positions correspond to the three-rings of fuel rods in the 19-rod cluster. The other positions are in the moderator. The results are shown below for a moderator temperature of 297°K.

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NEUTRON TEMPERATURE IN A Pu-Al-D₂O CELL

<u>Radius (cm)</u>	<u>Tn (°K)</u>
0	330 ± 6
1.60	341 ± 6
3.21	333 ± 5
8.34	320 ± 4
10.52	314 ± 4
12.69	310 ± 4
14.86	317 ± 4
17.04	307 ± 4
19.21	311 ± 4
21.39	309 ± 4

The spectral indices Tn which characterize the thermal component of the neutron spectrum were calculated assuming that the thermal and slowing down components of the spectrum were joined by means of four different functions. Three of them were calculated for the neutron flux in each ring of a 19-rod Pu-Al cluster and emphasize the depletion of neutrons of energies near 0.3 eV because of the Pu-239 resonance. The fourth function was that measured for D₂O by Johanson, et al.

Reactor Kinetics Measurements with Pu-Al Fuel in D₂O

A recording of the power noise in a Pu-Al loading in the Plutonium Recycle Critical Facility moderated with D₂O has been analyzed with a ten-channel frequency analyzer. Data for 40 frequency points of the noise spectrum have been obtained using four tape transport speeds in conjunction with the ten frequency channels.

The frequency data from reactor noise from the PRCF is presently being analyzed to obtain the magnitude squared of a reactor transfer function. The analytical function is being fit to the data using the least squares fitting method. This process will yield the delayed neutron fractions and the neutron lifetime.

The data from the different channels are normalized using a uniform frequency distribution "white noise" source of Co⁶⁰.

Oscillation Experiments*

Use of the oscillator system in the PRCF initially scheduled for the first part of July was postponed several times before it was finally installed in the reactor. The oscillator failed to operate well enough to proceed

* This work by J. D. Lodge is in partial fulfillment of the requirements for an M.S. degree from the U. of Washington.

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with the experiment. The lower shaft was believed to be whipping excessively at high speeds causing some binding. It has been removed from the reactor for inspection and modification. The experiment has been rescheduled for the first part of August.

Critical Experiments with 2 w/o PuO₂-UO₂ Fuel

Several calculations of parameters associated with an experiment planned for the D₂O moderated PRCF with 2 w/o PuO₂-UO₂ fuel elements have been completed. These results were used in a review of the safeguards for the PRCF. The calculations were performed using Programs SWAP and HPN with cross sections obtained from Programs THERMOS and HRG. No changes are expected to be necessary in the PRCF Operating Limits. The inherent shutdown mechanisms, fuel temperature coefficient and moderator void coefficient with boron, are stronger than those of D₂O systems without boron which have been reviewed previously. The other parameters, moderator temperature coefficient, moderator void coefficient, delayed neutron fraction, and neutron lifetime are in the range of those of previous systems.

Physics Code Developments

1. Program THERMOS

Program THERMOS has been converted to FORTRAN IV for use on the Univac 1107 computer. Data tapes have been transmitted to Los Angeles for use with this version. A test case is being run to assure the program has successfully been compiled on the Univac 1107.

2. KINETICS Code

A program is being written to calculate delayed neutron functions, inverse mean life for the delayed neutrons, and prompt neutron lifetime from data of flux vs. time after reactivity changes in a reactor. The inverse mean lives seem to be quite easy to evaluate, but problems in evaluating the delayed neutron fractions and prompt lifetime remain to be solved.

3. Cross Section Chain

A chain program utilizing THERMOS and HRG is being developed to calculate and punch cross sections for Program S-XIII. Options are available to use EPITHERMAL THERMOS and to compute the matrix which defines the induced transmutation yields for Program S-XIII.

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4. RBU Code Development

The burnup code ALCHEMY has been converted to machine language for use in the burnup portion of the RBU code and tested against the original FORTRAN II version. The two codes give identical results. The changes to the RBU code necessary to incorporate the ALCHEMY code were written and are being debugged. Two problems designed to test the RBU input power definition and the RBU burnup code operation were prepared. One problem has been run and the results are being analyzed.

5. Buckling of Truncated Spheres

Further improvements are being made to code TRUNK, which uses a two-dimensional quadratic flux approximation to calculate the buckling of bare truncated spheres. The flux pattern is slightly distorted at the top surface. It appears to pass through an inflection point, which would indicate neutrons returning from the void, an impossible condition. This distortion affects the buckling by only 1/2%, however.

The model is being altered from a zero flux to a zero return current boundary condition for the bare case. The flux at the top surface is expanded in a Taylor series which can be evaluated without the need for elimination of hypothetical fluxes in the void region. This boundary condition will make it simple to convert the code for use in the reflected case.

6. Program UPDATE

The printing and punching options of UPDATE have been converted for use on the Univac 1107. The updating option requires a system subroutine that has apparently been coded at Computer Sciences Corporation, but is not released for use.

7. BNW Master Library

The high energy neutron cross sections of U-235 and U-238 have been updated to include an improved table of differential neutron scattering coefficients. The coefficients were obtained from a recent publication by G. D. Joanou and M. K. Drake (NASA-CR-54263), and are in the center of mass coordinate system.

8. ZODIAC2

An economics facility has been added to ZODIAC2, while maintaining compatibility with previous features. The user may specify a "fake"

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counterpart for any or all of the burnable isotopes in any region or regions. The burnup of these "fake" isotopes occurs independently from that of the real isotopes. Results of the "fake" burnup are written to tape each orbit in a format acceptable to the economics code, QUICK. Preliminary testing of the new feature is complete and production testing is in process.

9. LISTIV

Polishing of the 1107 version of LISTIV is complete. Users should retire their present 1107 LISTIV decks and request new ones. The bulk of the delay in releasing an authorized LISTIV for the 1107 involved the 1004 and 1974 treatment of the plus as a carriage control character. The problem is still with us, but some hope exists for its eventual eradication.

10. TRIP

Conversion of TRIP005, TRIP105, and TRIP205 for 1107 use is complete. Successful test runs have been made on TRIP005, but no production testing will be done until the code is required. TRIP105 and TRIP205 have not been tested.

11. HFN

The 1107 version of HFN has been checked out and appears to be in good working order. The most current absolute version will be kept on tape 678 under the name HFNABS for customer use.

HFNABS uses LISTIV rather than LISTIN for input so users should consult the LISTIV document, BNWL-41, and ignore Appendix C of the HFN document, HW-71545. For most runs the only difference from LISTIN input will be in the handling of the repetition control.

For those runs involving the adjoint calculation where scratch tape A4 would be used on the 7090, no tape need be specified as a portion of the drum is used in its stead.

12. PHYSICS CHAIN

Cases have been successfully run on the 1107 version of the PHYSICS CHAIN. The code has been forced to make these runs and running times are longer than on the 7090. However, many changes are being made to take better advantage of the features of the 1107 system which should result in an appreciable decrease in running time over the 7090.

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13. Program THETA

A Univac 1107 computer code, THETA, has been written to analyze the problem described elsewhere in this report under the title, "High Temperature Reactor Physics Program." The program is designed to analyze the temperature distribution in a control rod fuel that consists of spherical pellets of fuel embedded in a matrix of non-fuel material. The final value of θ gives the temperature increase over ambient in degrees centigrade when the power excursion is terminated. Physical constants; density, heat capacity, and conductivity of both materials, and power density in the pellet, reactor power level trip, and instrument delay time are in a block data routine. The code requires two sets of input data: One set containing the desired values of ω , the inverse reactor period, and a second set containing desired values of the radii from the center of the fuel pellet to a point midway between the center of two pellets. Any number of ω s and radii, from 1 to 100, may be used in the problem, with the program giving a solution of θ for each ω at each radius.

The Importance Function with Density Restrictions

Derivations of the adjoint equations from physical arguments, using the importance concept, have been attempted for problems where a limitation or boundary is imposed on the density or state variables. Such a problem involves a type of non-linearity or feedback since, if a perturbation is made, some compensating change in the properties or control variables of the system is normally required to satisfy the density boundary conditions⁽¹⁾.

The specific example used is the xenon override problem where (in its simplest form) the xenon concentration is to be brought to a given final value at a specified time using minimum nuclear energy in the control period. The adjoint equations for the importance functions for xenon and iodine have been found, along with an explicit boundary condition for the iodine importance; the boundary condition for the xenon importance depends on a further specification. Introduction of an internal boundary point in the time interval leads to continuity of the iodine importance, but a discontinuity in the xenon importance; the magnitude of the discontinuity depending on the selection of the compensating control.

The most obvious application of the result is to improve our understanding

(1) J. Lewins, "Importance; the Adjoint Function," Pergamon, Oxford, 1965.

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of Pontryagin's optimal control theorem⁽²⁾; the equations, boundary conditions, discontinuities, and undetermined magnitudes for the importances are exactly those for the adjoint function in Pontryagin's method. It is possible that the basic theory may have other uses.

Calculation of the Temperature Field Due to a Hemispheroidal Heat Source

In an investigation of the thermal consequences of leaks in radioactive storage tanks, Jansen (HW-80848) is led to the consideration of the temperature field due to a uniform hemispherical heat source in an infinite medium, a problem which he treats numerically. The points of greatest interest are those on the axis of symmetry, since the maximum temperature must occur there. For these points, a simple analytical expression has been obtained for the temperature. As a generalization of this problem, analytical expressions have been obtained for the temperature fields due to oblate and prolate hemispheroidal heat sources for all interior and exterior points along the axis of symmetry.

Instrumentation and System Studies

A six-point, prototype, reed-relay signal scanner is being fabricated to demonstrate its capabilities and advantages over the stepping-switch scanner presently employed in the PRTR fuel element rupture monitoring system.

Most of the problems associated with the development of the experimental time-to-power reactor startup instrument were satisfactorily resolved during the month and portions of the instrument were completed in experimental form. Plans were established to conduct extensive tests at the 305 Test Pile following completion of the prototype instrument. Laboratory tests conducted to date on the various completed circuits indicate that it may be possible to achieve readout errors of less than $\pm 1\%$.

Preparations were started on the analog programming of a study of radial heat transfer of a proposed fuel pin arrangement in the PRTR. The study will determine the effects of operating at temperatures high enough to melt the fuel core.

The PRTR startup period control simulation analyzed on the analog computer revealed the moderator transfer function was not completely specified. Additional information is necessary to complete the simulation.

(2) L. S. Pontryagin, et al., "The Mathematical Theory of Optimal Processes," Interscience, New York, 1962.

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Isotopic Analysis of PRTR Samples

Isotopic analyses were provided on five burnup samples of PRTR-irradiated fuel elements: One uranium sample from UO_2 fuel element No. C-1101-1, three plutonium samples from UO_2 fuel element No. 1099, and one uranium sample from $\text{PuO}_2\text{-UO}_2$ fuel element No. 5185.

PRP Fuel Cycle Analysis

RBU Calculations

The RBU Monte Carlo calculations of the interrelationship of fissile content, fissile placement, and ratio of water-to-fuel volume to the alpha of fissile isotopes have been extended. There are now 80 calculations representing four enrichments of plutonia in natural urania (0.5%, 1%, 2%, 4%), four configurations of these enrichments, and five water-to-fuel volume ratios (0.625, 0.94, 1.18, 1.44, 1.72) of these enrichments and configurations. The four configurations represented in the 80 calculations are as follows: (1) A tight pencil configuration (plutonium placed in the center of the rod) consisting of plutonia at 95% theoretical density along the axis of the rod, (2) a 10% pencil configuration (plutonium diffused over 10% of the central rod volume) consisting of 10% plutonia and 90% urania along the axis of the rod, (3) an annular configuration consisting of plutonia at 95% theoretical density in an annulus around the surface of the rod; and (4) a uniform, or reference, configuration consisting of plutonia and urania of the desired enrichment. In the three nonuniform configurations, the desired enrichment was obtained by varying the relative volumes of the two fuel regions. The 64 calculations started last month have been extended to 40 minutes in Monte Carlo; and 16 calculations at water-to-fuel volumes of 0.625 were prepared and now have 20 minutes each in Monte Carlo.

Since the computation time in Monte Carlo is short, the error of any one of the 80 calculations is large. However, the data for each configuration have been tabulated and are being fitted to produce reliable trends and comparisons, because, as a group, each configuration represents more than 12 hours of 7094 computer time.

Efficiency of MELEAGER Moderator Fuel Coefficient

A review of the fuel and moderator temperature coefficient option in MELEAGER has been undertaken to determine the range of applicability of the current methods and to evaluate the degree of accuracy obtainable.

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As a part of this study, ALTHAEA calculations are being compared with the experimental data from the Yankee reactor. Preliminary results indicate reasonable agreement for the fuel temperature coefficient and considerable disagreement for the moderator temperature coefficient. The basic assumptions and calculational methods are being examined to determine these differences.

SPECIFIC FUEL CYCLE ANALYSIS

Fuel Utilization Studies

The date when breeder reactors are introduced into the nuclear power economy is not nearly as important as the type of breeder introduced. The type of thermal reactor built before breeders become economical may also be of secondary importance to conservation. For example, heavy water reactors (HWR) require only slightly less and sodium-graphite reactors (SGR) require only slightly more natural uranium than pressurized water reactors (PWR). The SGR is a less efficient plutonium producer and limits the rate at which breeder reactors can be built. On the other hand, the HWR, which is an efficient plutonium producer, burns its plutonium in situ in preference to exporting it for breeder inventories. The main advantage to an HWR is that it has lower separative duty requirements than other reactors: The maximum separative duty required by PWR and SGR systems is two and four times our present capacity, respectively; that of an HWR system does not even exceed our present capacity.

However, within any certain type of reactor--PWR, SGR, HWR--variations in the specific power and in alpha, the capture-to-fission ratio of plutonium, are more important to uranium consumption than the type of thermal reactor used. Although an increase of specific power reduces total reactor and pipeline inventory requirements, it favors more in situ burning of plutonium available for breeders. But low values of alpha, which is a parametric representation of plutonium recycling techniques, allow a 7 to 10% reduction in uranium consumption.

Lower out-of-reactor processing costs--fuel fabrication, jacketing, and separation--result in lower optimum enrichments reducing the uranium required and increasing the amount of salable plutonium. The over-all effect is a 10% reduction in the uranium consumption when processing costs are reduced by two-thirds.

Resource conservation and cost economy are conflicting optimization criteria. For if thermal reactors are operated at an enrichment corresponding to a fuel cycle cost 0.1 mill/kWh_e above the minimum, the uranium used would be nearly 20% less than the amount used at the enrichment cor-

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responding to the minimum fuel cycle cost.

During the next several years, thermal reactors may recycle the plutonium they produce, and plutonium will probably be priced at its value as a thermal reactor fuel. Later, while breeders are being introduced, thermal reactor operators may prefer to sell rather than to recycle temporarily scarce plutonium. The fast reactor operators buying the plutonium would pay a price perhaps twice as high as the value of plutonium used as a thermal reactor fuel. Still later, when breeders are self-sustaining, plutonium will become a surplus commodity, and its price may drop to perhaps half its value as a thermal reactor fuel. Differences in these pricing strategies affect uranium utilization by about 7 to 10%.

A summary of these data has been written and submitted to the American Nuclear Society for its Winter 1965 Meeting.

Analysis of HWO CR Concepts

Two proposed HWO CR concepts were evaluated. The concepts pertain to fuel cycles using: (1) A 37-rod cluster using slightly enriched uranium oxide fuel, and (2) 6 concentric cylinders containing thorium metal enriched with U^{233} . The fuel cost of the uranium fueling system was lower (0.1 mill/kWh_e); however, the thorium system has possibilities for increased specific power and a lower fabrication cost. If these possibilities are fulfilled, the thorium fuel cycle cost would nearly equal that of the uranium fuel cycle.

Effect of Fuel Assembly Size on Excess Reactivity for Pressurized Water Reactors

To provide accurate measure of the neutron losses into the control system during burnup, using a zero-dimensional code, the amount of excess reactivity must be known. The loss of neutron in a reactor core with complete neutron interaction is calculated by the PROTEUS code to augment data from zero-dimensional burnup data from ALTHAEA. However, the size of a fuel assembly affects the average excess reactivity and, thus, the neutron economy. As the assembly size increases, the excess reactivity and neutron loss to the control system increases as shown in Figure 1. The one-dimensional version of ALTHAEA when used to calculate this effect for a PWR where the region width is equal to the assembly width. The fuel was slightly enriched uranium with each newly fueled assembly between a one-third burned assembly and a two-third burned assembly.

A reactor operator makes the choice between neutron economy and reduced fuel handling and fabrication cost. Recent designs call for assembly as large as 16 rods.

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EFFECT OF FUEL ELEMENT ASSEMBLY ON INITIAL K INFINITE

FIGURE 1

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EBWR PROGRAM

EBWR Burnup Calculations

Reactivity changes because of burnup of the core for the plutonium experiment in the EBWR have been calculated with ZODIAC. Calculations show that Sm-149 which is a burnable poison in an enriched UO_2 zone will be 75% burned out after 60 days of operation at 40 MW. Another burnable poison, Eu-151, in the enriched UO_2 zone will be 75% burned out after 420 days. As these poisons are burned, the reactivity of the core increases 25 mk before decreasing. The calculations were done assuming 30% moderator void in the $\text{PuO}_2\text{-UO}_2$ zone and the enriched UO_2 zone, and no void in the natural UO_2 zone and the reflector. The initial reactivity of the core with Xe in the saturation state was calculated to be 1.05. This is 2% higher than previous calculations using programs THERMOS, HRG, and HFN, and for the same conditions. Since GAM is used for the slowing down portion of the calculations in ZODIAC self-shielding factors for Pu-240 must be furnished as input. The self-shielding factors used were high for large concentrations of Pu-240; hence, the macroscopic epithermal cross sections were too small. The effect on the results has not yet been evaluated.

A study of special rods to be irradiated in the core has continued. The microscopic cross sections of the $\text{PuO}_2\text{-UO}_2$ zone will be used for the special rods. The problems of correctly handling the thermal self-shielding and the Pu-240 epithermal self-shielding have not been resolved.

EBWR Experiment

At various stages of burnup of the fuel elements in the EBWR, selected elements will be transported to Pacific Northwest Laboratory for reactivity measurements and chemical and isotopic analysis. The elements are to be shipped in a cask which is used for shipment of fuel elements from the Yankee Reactor. There are two new basin areas in which it may be possible to unload the fuel element from the cask. The new 324 Building (FRPP) has a large enough basin, with easy access, ample overhead clearance, and a large and small crane. A new basin area at the PRTR is another possibility if sufficient overhead clearance is made available. The cask would be unloaded the easiest and most inexpensively at the PRTR. Problems are expected to arise at either location, but none which cannot be resolved.

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PHOENIX FUEL PROGRAM

Analysis of Pu-Al Polyethylene Experiments in the PCTR

An informal report, "Physics Analysis of a U-Al-Polyethylene System," BNWL-CC-148, has been issued.

The summary of a paper entitled "Physics Analysis of Some Pu-Al-Polyethylene Experiments in the PCTR" has been submitted to the ANS for presentation at the ANS November meeting.

A 200°C polyethylene kernel for use in THERMOS has been obtained. A recalculation of the thermal microscopic cross sections is now under way for some of the Pu-Al-polyethylene systems.

Pu-Be Studies

Survey calculations for PCTR critical experiments for Pu-Be systems have been finished, and the results are available in rough draft report form. For 8% Pu-240 Pu-Al discs, less than 0.7 kg of pure plutonium, and 200 kg of metallic beryllium would be required. With increasing fuel-to-moderator ratio and increasing Pu-240 concentrations, the required plutonium eventually reaches 30 kg. Thus, PCTR Pu-Be critical experiments for at least some fuel-to-moderator ratios would be possible with the Pu and Be inventories currently on hand.

Phoenix Test Core

The study of the neutronic aspects of utilizing the APFR as a possible Phoenix fuel test bed has been completed. The report of this study is currently in rough draft form.

Time-dependent reactivity variations for various U-235 and plutonium core loadings have been obtained. The U-235 inventory in this 140 g, 10 MW, steel matrix, fully enriched core, was varied from 10 to 40 kg. Three compositions of plutonium, containing 8, 19, and 27% Pu-240, respectively, were examined in loadings of 10, 20, and 30 kg.

It is possible to get more exposure from the 8% Pu-240 than from a comparable inventory of U-235 as long as the inventory does not exceed about 24 kg fissile. This same crossover point occurs at about 17 kg fissile fuel for the 19% Pu-240 case. The amount of fissile material burned per unit exposure is virtually identical for all of the uranium and plutonium systems studies. There is not enough Pu-240 conversion to offset the large disadvantage of the high Pu-239 α value. A typical Pu-239 burnup α is 0.5

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compared to 0.25 for U-235. The very soft spectrum of the standard APPR core, metal-to-water of 0.262, does not enhance the Pu-240 resonance. If the core were redesigned to a metal-to-water ratio of about unity, one might possibly achieve more favorable results using plutonium. The heat transfer or hydraulic problems associated with such a conversion have not as yet been considered.

Use of UH_x-Pu in U-235 Reactors

One way of enhancing the Pu-240 to Pu-241 conversion is to reduce the formation of Pu-240 from Pu-239. This could be accomplished if ultra high exposure plutonium (UH_x-Pu) were used in conjunction with U-235 as the main fissile material. Calculations along these lines have been started using plutonium compositions of 15/40/30/15 and 0/40/20/40. These compositions are typical of what might be obtainable from plutonium irradiations in compact, water-moderated reactors.

Pu-Al-Polyethylene Experiment in the PCTR

The experiment using 19% Pu-240 with H/Pu = 214 and 0.020" fuel thickness was completed. The critical boron concentration for this system was found to be: $B^{10}/Pu = 0.197 \pm 0.004$. Additional work will be done to reduce the experimental uncertainty. The gold cadmium ratio for this system was the same as for the 27% Pu-240 case - 1.61.

A summary describing the Phoenix experiments has been submitted to the ANS for presentation at the 1965 Winter Meeting, Washington, D. C.

FAST REACTOR STUDIES

FFTF Nuclear Design and Analysis

Nuclear design and analysis of the FFTR is continuing. During this report period, main emphasis has been placed on the analysis of zoned cores. Considerable power flattening can be obtained this way with relatively minor reductions in flux-to-power ratios.

Fast Reactor Cross Sections

A code is being written to compute resonance-shielded, temperature-dependent microscopic cross sections using a 26-group Russian data compilation. A comparison of the Russian cross sections with other well-known compilations is being carried out.

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Fast Reactor Fuel Cycle Calculations

Comparison of plutonium vs. U-235 fueling for a large, fast spectrum oxide breeder reactor has been started. The model for this study is the large, fast spectrum, annular reactor proposed by Allis Chalmers.

Two types of calculations are being carried out. In the first approach, a highly idealized reactor point model is being used, where breeding in the blanket can be estimated from the core neutron leakage. To date only batch cycle results for a wide range of enrichments are available. The burnup code PYRE is being used for this approach. Concurrently, a more realistic one-dimensional burnup calculation has been started using the ZODIAC burnup routine.

FFTF Instrumentation and System Studies

Results of FFTF analog simulation and control studies reported last month were summarized for inclusion in the program progress report. These studies elucidated the effect on total fuel cost of burn-up and fuel design. The number of fuel pins for minimum cost was approximately defined, and the relation between number of pins per fuel subassembly and the fuel temperature was determined.

Future tests considering other fuel systems and extending the simulation models to include plant capital, operating, and other costs are planned.

Information regarding FFTF shielding considerations and probably future shielding experimental work was developed. Concepts for monitoring neutron flux over the full range of power levels were developed, as were methods of detecting fuel cladding failures in closed and open loops. The over-all Instrumentation and Control sections for the three volumes of the FFTF progress report were completed and submitted on schedule.

HIGH TEMPERATURE REACTOR PHYSICS PROGRAM

Mockup and Materials Studies

Examination of the prototype control rod, following a run at 1000°C for 265 hours, has revealed severe corrosion of the one-half inch diameter T.D.-nickel rod that is its axial structural element. The control rod consists of alternate 6" long cylinders of UO₂ graphite and B₄C graphite matrix materials held on the T.D.-nickel rod. The corrosion was most severe under the UO₂-graphite. The UO₂-graphite material used in the run was prepared at Hanford, and may not be typical of the material called for in the design which is to be a Union Carbide product or equivalent. Some cylinders of the Union Carbide material are now on hand, and a comparison test of the two materials has been started. In the test a pair of short sections of

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control rod, constructed of each type of material, are being maintained at 1000°C in an atmosphere of nitrogen with 300 ppm water in a small furnace. Chemical analysis of corrosion products and metallographic analysis of sections of the T.D.-nickel rod are in progress. Similar analyses will be made following testing of the short sections of control rod.

Present design calls for a double layer of thermal insulation between the graphite stack and the outer steel shell of the HTLTR. The inner layer is insulating firebrick 18" thick, and the outer layer is a 3" blanket of alumina-silica fiber.

It was proposed that consideration be given to casting the inner layer of insulation in place. Tests of the same type as previously run on insulating firebrick were run on small samples of the cast material. Upon initial evacuation, large volumes of water came off the green castings and water continued to evolve strongly when the sample was heated in a vacuum until a temperature of about 400°C was reached. From 400°C to 1000°C a relatively small quantity of water was released. These results confirmed the idea that the use of castable material would require a preliminary bake-out procedure by which the inner wall of the insulation would be heated to 1000°C. This bake-out would have to be done before the graphite stack was in place with some vendor-supplied auxiliary heating system. From the test results, the residual water in the cast insulation after initial bake-out is estimated to be more than five times the comparable quantity for an insulating firebrick structure. Presumably the residual water eventually evolves and may corrode the graphite stack. A decision based on these results was made to proceed with the insulating firebrick presently specified and to use castables very sparingly, if at all.

Small quantities of boron in the form of B_2O_3 which converts to a compound in our application may be present in the candidate materials for the outer layer of thermal insulation. Tests have been started to find out how much boron will be released from these materials in a simulated reactor environment.

Safeguards Analysis

A calculation was made to find what temperature increase would be attained in the UO_2 -graphite matrix fuel of the horizontal control rods in an exponential power rise. Assuming the reactor scrams at 3 kW, and allowing a total of 0.6 seconds more for instrument delay and control rod actuation, the temperature at the boundary of the UO_2 pellets will not increase more than 2.3°C for the shortest (0.190 sec) period allowed by reactor kinetics and excess reactivity limits. With an initial ambient temperature of 1000°C,

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an increase of 700-800°C at the boundary of the pellet would be of concern. Such an increase would require an excursion period some three times shorter than the shortest allowable.

Sections of the Safeguards Report were completed and submitted to Nuclear Safeguards and Engineering for compilation into the final draft copy. Several items yet remain to be added: (1) A description of the safety rod, (2) a detailed description of the control rod safety circuit and the reliability test data on PMACS instrumentation, and (3) final design of the driver fuel rods.

HTLTR Calculations

A calculation to determine the reactivity effect of flooding the HTLTR with H₂O has been made for use in safeguards analysis. The reactor multiplication changed from 1.122 to 0.807 when N¹⁴ gas in a driver fuel zone of 68 elements was replaced with H₂O.

Experimental Techniques

Experimental and interpretive procedures have been outlined, in principle, for a new method of measuring the excess multiplication of reactor lattices (or homogeneous multiplying media). In the event that the lattices being tested are poisoned to a k_{∞} of unity, the new technique reduces identically to the older, null-reactivity method used in the past in the PCTR and other test reactors. The advantages of the suggested procedures are: (1) Measurements are made using the (unpoisoned) lattice of interest; (2) there is no need for iterating on the quantity of poison to be added so the experimental measurement is simplified; and (3) the directly measured quantities are, in principle, directly obtainable from modern multi-group calculations.

Experimental Core Fabrication

The 3-3/4" and 4-3/16" graphite cores for the HTLTR are being fabricated. A review of the details of their design is also being made to insure that versatility is maximized and that they are capable of being used in the new technique of using unpoisoned lattice cores. This technique should simplify some of the experimental procedures.

Core Dolly

A vendor's design is being prepared to accompany a letter to potential vendors to determine costs for a core dolly. Purchasing personnel were contacted and suggested that we proceed in this manner.

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Chromatograph

One chromatograph which is excess to IPD needs has been delivered to the 314 Bldg., and a second has been promised for immediate delivery.

Instrumentation

Considerable improvement of the experimental, low-level, current-to-frequency converter instrument, being developed to measure input currents from 10^{-5} to 10^{-9} A, is expected as recent developments are included in the prototype instrument. Definite reductions in both 60 Hz and random noise were achieved along with improved linearity of operation.

Critical evaluation on the linearity of the neutron-sensitive ionization chambers was conducted following incorporation of modifications to the associated instrumentation. Tests were made in the Hanford Test Reactor up to a level of 9 kW, which corresponds to a central flux of about 4×10^9 n cm⁻² sec⁻¹. The higher-power tests indicated that the BF₃-filled chamber is seriously non-linear above 10^{-5} A with 940 Vdc applied. A boron-lined chamber demonstrated marked superiority in performance under the same conditions. More tests are planned. Consultation was provided the project architect-engineer regarding ionization chamber specifications.

An algorithm for simulating a proportional-integral-derivative, analog controller is being developed for use on the G.E. 412 process computer. This is being done to gain experience in simulating continuous controllers on a digital computer, and to allow for possible testing of a heater control system for HTLTR using non-interacting controllers. The 412 was considered rather than the PDP-7, because input-output facilities are available. The computer will be used to control a system simulated by an analog computer.

HTLTR Construction

Construction for Phase I work generally is on schedule. The ventilation duct work remains behind schedule. The painter's strike, mentioned last month, did not delay the job.

Exterior piping is progressing with the compressed air, steam, and steam condensate lines in. The sanitary water line is in, and work is in progress on the fire protection water line, the sanitary sewer, and the process sewer outside lines. The process water break tank is installed and outside connections complete. Some prefabricated interior piping sections are on the construction site.

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The service building steel framework is up and the concrete floors are poured. The roof is being installed. The basement NVAC partition is up. The ventilation exhaust filter vault concrete is poured. The reactor room shielding door has been filled with concrete, and the shielding plugs for the north, east, and south sides have been poured.

The contractor is preparing to sandblast the interior of the reactor room.

NEUTRON FLUX MONITOR PROGRAM

Regenerating Detectors

Two regenerating (U^{234} and U^{235}) neutron flux detectors installed in a KW test facility continue to provide long term exposure data. These are now being analyzed in an attempt to confirm theoretical predictions. Plans are being firming for the design and fabrication, possibly offsite, of two or more new regenerating units.

Beta Current Detectors

A prototype beta-current generator chamber, employing cylindrical quartz elements in a pure iron absorber, was completed, tested, and made nearly ready for irradiation tests at KW Reactor. The measured insulation resistance was a satisfactory 10^{11} ohms. The remaining six twin-wire cables were received from the vendor and insulation resistance tests indicated values in excess of 10^{12} ohms. One of these cables will be used to complete another detector assembly, which was fabricated using parallel plate iron elements. Plans were formulated for the in-core tests.

Microwave Detectors

Data were compiled from the previous in-core experiment conducted at KW Reactor. This experiment employed both the in-line attenuation and phase shift techniques. The parameters are being carefully plotted on a graph to permit easier visualization of the complex relationships existing among temperature, neutron flux levels, and microwave detector response. This laborious work has not been completed as yet; however, evaluation of the data was initiated in an attempt to make it more meaningful. It appears that further study will be required for maximum benefit of future in-core experiments.

DETECTION OF COOLANT IMPURITIES AND HIGH TEMPERATURE PROGRAM

Microwave techniques of possible usefulness in measuring elevated in-reactor temperatures were reviewed. Results of this study suggested that

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techniques utilizing the spectral line broadening due to Doppler shifts within a gas plasma, and the selective absorption of microwave energy propagating at two frequencies through a plasma are promising candidate methods. Black body radiation, and resonant cavity techniques are other methods under consideration.

The infrared analyzer, which has been on order for several months, has not been received, but is expected shortly. Because of the lack of availability of this item, experimental work has not been initiated regarding the infrared techniques. Design has been completed on the required experimental loop to be employed in the studies.

NONDESTRUCTIVE TESTING RESEARCH PROGRAM

Electromagnetic Testing

Several small test coils for use in the crack velocity measurements have been wound and used at test frequencies between 18 and 30 Mc. The test coil serves as an inductor in an oscillator resonant circuit. This high operating frequency has been chosen to reduce side band attenuation for the crack propagation modulating frequencies up to 1 or 2 Mc. The oscillator tuned circuits are adjusted so that signals due to variation in spacing between the test specimens and the test coil (lift-off effect) are minimized, leaving mainly the signal due to the presence of the crack.

Both transistor and vacuum tube circuits have been designed for this project; the latter gave better results.

The linearity of the relationship between signal output and crack position (propagation) is next to be determined for several different test coil lengths and winding densities. It may be necessary to modify the design of the test coil to give the desired degree of linearity.

During the tests of the small test coils in the region of 15 to 30 Mc, some anomalous behavior of coil impedance was observed. Measurements using a radio frequency bridge showed that the test coil impedance lift-off locus curvature was unusually high when the test specimen was a short distance from the test coil. For one coil, the maximum curvature occurred at spacing distance of about 3 to 4 mils and the direction of the lift-off locus at spacings less than 2 mils was more than 90° different from the expected lift-off locus direction. The cause of this anomaly has been found to be due to changes in distributed capacitance of the test coil as it approaches the test specimen. Tests with electric shielding show that this effect can be reduced, and the use of Faraday shields is now being evaluated for this purpose.

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This capacitance effect may be the cause of similar, but less extreme, anomalies in the lift-off locus previously observed in high sensitivity tests at lower frequencies. It is known from the application of induction theory that the lift-off locus should vary smoothly without extremes for small values of test coil-to-test specimen spacing. Thus, such anomalies must be due to some effect, such as capacitance variation, which is not accounted for in the usual development of electromagnetic induction theory.

Fundamental Ultrasonic Studies

The new set of measured pulses when compared with calculations based on latest computer techniques failed to give favorable results. Efforts to explain the relatively large discrepancies between the calculated and measured results are continuing.

A much improved statistical fit of the data was obtained by plotting log-log graphs of the attenuation data. With this type of curve fitting, all but the lowest and highest frequency attenuation data points were well represented, and the new results were subsequently incorporated into the wave model program.

The study to determine if future attenuation measurements can be made easier by calculating attenuation coefficients with a computer program is complete. Heretofore, the attenuation coefficients were calculated with equations which only approximated the actual relations. Although approximations were used, the calculations were nevertheless laborious. The new program was tested and found to be functioning properly. Also, it was determined that the previously used approximations were in excellent agreement with the exact equations in the assumed range of validity.

Infrared and Thermal Testing Research

Application studies on thermal wave testing methods require equipment that can be used to test practical samples. Design of two non-contacting thermal transducers using thermoelectric heat pumps is complete, and one transducer has been fabricated. The completed transducer has an exciter area of 0.09 in².

An all electronic driver and data acquisition system has been designed to replace the earlier partially mechanical system. The new system will be capable of greater dynamic range, better accuracy, and will be more convenient to adjust.

Although much improvement will be obtained with the new system, accuracy of the old system was good enough to permit experimental confirmation of

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the theory. Thermal surface impedances have thus far been measured at 1/30 cps for a 0.036 in. thick layer of steel on a thick layer of quartz, window glass, and teflon; and for a 0.177 in. thick layer of steel on the same materials. Measurements were also made at 1/65 cps on a 0.036 in. layer of steel on window glass, at 1/82.5 cps on a 0.177 in. layer of steel on quartz, and at 1/30 cps on solid stainless steel and teflon. All measurements except those for solid teflon at 1/30 cps and for 0.177 in. thick steel on window glass agree with theory within about 10 percent (limit of the experimental accuracy is believed to be about ± 4 percent), and many of the measured impedance values were in even closer agreement with theoretically predicted values. The difference between quartz and window glass under 0.036 in. of steel was detectable, even though their thermal properties are not too different. The lack of agreement in the cases of solid teflon and 0.177 in. thick steel on glass at 1/30 cps was believed due to a poor thermocouple bond and thermal transients resulting from inadequate adjustment of the equipment.

BIOLOGY AND MEDICINE - 06 PROGRAM

Atmospheric Physics

Computation and organization of power spectra of velocity data collected in 1964 and 1965 were completed. The components of the wind velocity were measured with the Wind Component Meter during diffusion experiments conducted on the Hanford grid. Calculations of spectral densities from these data performed on the analog computer permit the quantitative characterization of the air turbulence. Relatively few data of this kind have been obtained by researchers because of the complexities inherent in the development of the sensor system. A preliminary evaluation of the Hanford data indicates great potential for investigating the high frequency portion of the energy spectrum and obtaining new insights into the basic mechanisms of atmospheric diffusion.

Further progress was made in July with the completion of the third xenon-133 release. The first release made in January led to the modification of the air samplers to overcome the problem of icing at the air intake. Data from the second test conducted in February showed that the twelve samplers used were not sufficient to define the distribution of the plume. The number of samplers were, therefore, increased to 24 and further modification was made to facilitate handling of the devices in the field. In the test this month, samplers were positioned crosswind on arcs 0.2, 0.8 and 1.6 km from the source. Assay of the samples is under way and it is known from an analysis of wind data that positive samples were obtained near the distribution peak. These data will be compared with those of two other tracers, zinc sulfide and fluorescein, which were released simultaneously. This was

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the first Hanford experiment involving a three-tracer release.

Analysis of Hanford elevated source diffusion studies continued. For elevated releases in daytime, unstable conditions, the effect of the source height is quite important close to the source; but theory predicts that effect should become insignificant with increasing diffusion time (or distance). Analysis of data obtained from releases at 200 feet on the Hanford tower confirms the theoretical expectations. Elevated source axial exposures are indistinguishable from ground source axial exposures at times longer than 200 seconds, if the turbulent intensities are the same for both. Just as was found in stable conditions, an increase in turbulent intensity decreases exposures at any given time.

Radiological Physics

Radiation Physics

Repetitions of pulse-averaging measurements of the decay time of the scintillations from NaI improved the confidence of the result but did not change its numerical value. Poor high-frequency response interfered with measurements of faster scintillations such as those from stilbene. Much of this is probably due to the photomultiplier tube and will require obtaining a better, high-frequency tube.

A study was completed of the requirements on the optical spectrometer portion of a time-resolved optical spectrometry system for radiation studies with the Van de Graaff. Specifications were prepared for the device.

Improvements in the operation of the optical discrimination experiment reduced the energy of the protons that could be studied from about 1 MeV down to 0.1 to 0.2 MeV. The relative absorption of filtered and unfiltered light in the material of the scintillator was measured for NE 102 plastic scintillator and for stilbene.

Radiation Dosimetry

A redesigned, small tissue-equivalent ion chamber for neutron measurements is being fabricated. -

A Richland Fellow completed an extrapolation chamber system that he will use to measure doses from beta and gamma rays in the transition zone between two materials.

More measurements of monoenergetic neutrons extended the catalog of reference pulse-height spectra of the local-energy-density spherical proportional

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counter to 4 MeV. Shifts in gain of the counter by as much as 15% indicated a need for better regulation and measurement of the pressure of the gas in the counter.

The Columbia University group has pointed out that very strongly scattered charged particles distort the pulse-height spectra obtained with the local-energy-density counter. This led us to construct a theoretical model to study the extent of this distortion. The only case studied so far tended to overestimate the extent of the scattering; it showed a substantial distortion. In general, there was some cancellation of the effects of the scattering throughout the spectrum, but some of the small and intermediate size pulses were replaced by abnormally high pulses.

Work on calorimetry was suspended in March to permit an educational leave of absence. The calorimeter is now back in operation and equaling its previous performance. Studies with electrical-circuit analogs of the calorimeter are showing the effects of modifications being considered to apply the calorimeter to absorbed dose measurements.

Investigation of a coincidence method of neutron flux standardization showed the method to be inapplicable to our problem of providing standards for Van de Graaff produced neutrons.

Setting up the shielding for the University of Washington spermatogenesis experiment is nearly complete. Installation of the neutron generator was delayed by an unevenness in the floor of their laboratory which required modification of the accelerator mount. With the concurrence of the UW staff, the initial experiments will be done with $D(d,n)$ rather than $T(d,n)$ neutrons. These neutrons have lower energy and should produce a larger RBE; hence, they are a desirable substitution. The UW observations of spermatogenic effects at low X-ray doses made acceptable the use of the relatively low neutron dose rates from the $D(d,n)$ reaction. The change also avoids the radiation hazards in using tritium.

Whole Body Counting

It was estimated that, using only the X-ray counts, at a count rate at which 2.5% of uncontaminated persons would erroneously be judged contaminated, 50% of persons containing 16 nCi of plutonium would be detected with the plutonium whole body counter; at 46 nCi, 97.5% of such persons would be detected. No similar result is available yet in which higher energy data are employed, because of the remaining non-statistical variations in these data. A study of the effect of correcting for the presence of barium X-rays following Cs^{137} decay in the body did not reduce the variation in backgrounds among people containing normal amounts of Cs^{137} .

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Development of auxiliary counters for localization of plutonium in the body moved ahead with the design of a xenon-filled proportional counter for this purpose by a Richland Faculty Fellow.

An AEC Radiological Physics Fellow is designing a proportional counter for an X-ray/alpha-particle coincidence system for determining the ratio of the number of X-rays and alpha particles in plutonium samples of unknown isotopic composition obtained from people being studied.

Very thin scintillators are useful in X-ray counting; some of these scintillators are no more than a layer of powder. Immersing such powders in a liquid of matching index of refraction did not increase the amount of scintillation light that they released. Apparently the powdered materials are too badly fractured internally for this treatment to help.

Operating a large NaI scintillation counter in anticoincidence with a large plastic scintillation counter partially surrounding it did not reduce the background for whole body counting very much.

The use of a scintillation-counter image-converter combination is being studied to see if it is applicable to differential scanning whole body counting at near-background levels.

An alteration designed for the shadow shield counter to drive the bed at a speed proportional to the live-time rate of the multichannel analyzer will eliminate data distortions due to high counting rates.

The Scripps Institute of Oceanography sent us samples of tuna obtained in the northern Pacific and in a spot near the Samoan Islands. The sample from the northern Pacific contained more than ten times the activity density of Fe^{55} of the other (and of a tuna sample we obtained from a local store). The Fe^{55} densities paralleled those of the Cs^{137} in the samples. This should further encourage the use of Fe^{55} to supplement or even replace measurements of other activities in marine ecology studies.

Instrumentation and System Studies

Improved circuitry performance was achieved on several portions of the experimental animal physiological function and radionuclide uptake telemetry system. Both signal stability and isolation were improved and general laboratory performance demonstrated excellent promise.

Accomplishments were made on the assembly of the specialized chamber housing for lithium-drifted germanium and silicon solid state detectors, which will be employed in beta-gamma detection and spectral studies.

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All major fabrication work was completed and most of the items ordered from offsite, including the vacuum valve, the cold-trap reservoir, and the preamplifier, were received. Following receipt of the pump flanges and a molecular sieve, assembly of the complete system will commence. Barring excessive leakage difficulties, it is expected that the system will be in operation early in August.

Improvements were incorporated in the circuitry to be used in the experimental raindrop charge and velocity measuring instrumentation. Both a charge-sensitive amplifier and voltage-sensitive amplifier are being developed simultaneously to provide comparison data for the eventual selection of the optimum approach. To date, lower noise levels are being obtained with the voltage-sensitive approach; however, the charge-sensitive amplifier is considerably less disturbed by capacitance variations. The best detection sensitivity achieved thus far equates to about 3.3×10^{-14} coulombs; however, a ten-fold improvement will be required before proper operation can be achieved. Rather than provide automatic readout of raindrop charge over three decades, individual (switched) readout for each decade is provided. Measurement of raindrop velocity appears to have been accomplished, although this needs to be confirmed with further experimentation.

Engineering work was satisfactorily completed on the developmental "parallel T" selective amplifier to provide stable 5 to 10 percent band pass amplification from 500 Hz to 1 MHz. In addition, development was essentially completed on the low-noise, charge-sensitive, solid state preamplifier, which employs metal oxide insulated field effect transistors. Both regular junction FET and MOS-FET transistors were employed in the tests for noise versus filter time constant and noise versus input capacitance. Tests were made from room temperature down to about -148°C . At the low temperature, the noise level equated to about 600 electrons RMS with a total input capacity of about 60 pF.

The moderated neutron detector assembly for the mixed-field, neutron-gamma dose rate instrument was nearly completed and operational tests were conducted on the solid state circuitry to be used in the neutron channel. Only the preamplifiers for the neutron portion remain to be completed for that channel of the instrument. Development work is in progress on the gamma measurement channel; however, it has not, as yet, been decided which gamma detector will be employed.

The rodent whole body counter, being developed for biological studies, was extensively modified to overcome the source position sensitivity problem. A constant field potential was employed around the center anode by surrounding the anode with a concentric ring (screen) of secondary anodes.

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About 2 kV is applied between anode and cathode. The original tungsten anode was also replaced by a 1 mil stainless steel wire. Initial tests following the modifications revealed a resolution of about 3 keV and the 13.6, 17.4, and 20.5 keV peaks for Pu^{239} X-rays were resolved adequately. Work is being continued to optimize the anode-to-screen and cathode-to-screen voltage ratios.

The completed algae radionuclide uptake monitor was installed at a Biology laboratory following initial testing. The GM tube detector was placed in the test stream and normal algae samples were introduced around the tube to observe the uptake of radionuclides in the effluent. General operation appeared to be satisfactory.

Need exists for practical methods of measuring biological work expended by caged animals. Investigations have begun on a promising method of accomplishing this based on the rise in body temperature which accompanies animal activity. Calculations show that an average size rat at normal body temperature radiates infrared energy at a peak wavelength of $9.35 \times 10^4 \text{ \AA}$, at a level approximately equal to $10^{-13} \text{ WH}_2^{-1} \text{ sec}^{-1}$. This power appears sufficient for detection with horn antenna of reasonable size when positioned at practical monitoring distances. Continuing effort will further evaluate feasibility of this approach.

A biological system radioisotope model analog simulation was used to study the case of a human ingested with Zinc⁶⁵ through eating contaminated oysters. This study is being made in an attempt to reproduce three years' accumulated data obtained from a Washington State Department of Health employee who had volunteered to eat oysters supplied by the Columbia River Fisheries.

WASHINGTON DESIGNATED PROGRAM

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

The mass spectrometer for this program was returned to routine operation. Fabrication of components for the new mass spectrometer was initiated by Technical Shops.

EXPERIMENTAL REACTOR PHYSICS FACILITIES

PRCF

Irradiated fuel element reactivity measurements were continued in the two-zone D_2O core. One Pu-Al element with 86 MWt exposure, and two UO_2 elements

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with 24 MWd and 98 MWd exposures were measured against non-irradiated standards. D₂O degradation and losses averaged two-three pounds per irradiated fuel transfer, a factor of five better than previous transfers.

Reactivity measurements were made on safety rod worth enhancement due to internal moderation. Lucite sleeves capable of use with present safety rods and total lucite moderation were used in the internal scatter experiment. Three 0.48 PuO₂ mixed oxide fuel elements were measured. The elements had varying Pu-240 content ranging from 7.5 to 17.7 w/o. A 2 w/o PuO₂ high power density fuel element was measured in the center lattice position relative to D₂O.

Preparations for the HPD physics testing in PRCF are near completion. The hardware is complete and the boric acid has been ordered. A minor holdup is anticipated in the boron shipment.

Status of CAH-119, PRCF New Addition: Interior siding has been installed. Completion date is not yet firm.

PCTR Operation

The PCTR was shut down for a thirteen day maintenance outage to repair a broken control rod and to replace the bushings on the remaining control rods.

The Pu-Al-Th supercell experiment was partially completed.

TTR Operation

The TTR was not operated.

CAF Operation

Measurements were completed for the 0.93" lattice using both 2% PuO₂-UO₂ with 16% Pu-240, and 2% PuO₂-UO₂ with 27% Pu-240 fuel.

Measurements were also completed for the 1.386" lattice using both the 2% PuO₂-UO₂ with 16% Pu-240, and 2% PuO₂-UO₂ with 27% Pu-240 fuel.

COMPUTER FACILITIES

Analog computer utilization was as follows:

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EASE 1132

264

32

6

418

720

EASE 2133

248

88

6

378

720

Hours Up Time

Hours Scheduled Down Time

Hours Unscheduled Down Time

Hours Not Utilized

Hours Total (30 days x 24 hours)

Problems considered during the month were:

1. N Reactor Conversion.
2. FFTF Design Optimization.
3. FFTF Dynamics.
4. Meteorology Study.
5. D-Vibration Study.
6. PRTR Pressurizer.
7. RTD Study.

Operation of the EASE 2133 Computer continues to be troubled with persistent 1.5 Mc oscillations. Extensive efforts to locate and correct the difficulty have not been successful.

CUSTOMER WORK - Meteorology

Weather Forecasting and Meteorological Services

Meteorological services, viz., weather forecasts and observations, and climatological services were provided to plant operations and management on a routine basis. Special consultation was provided (1) the N-Reactor Department on a problem concerning Columbia River temperatures in relation to tank storage, IPD in planning and executing containment studies and (3) CPD and HUPO on NO₂ release from 244 AR Vault. In the containment studies Atmospheric Physics Section obtained samples of the stack effluent by supporting a sampling tube with a blimp.

Weather Summary

<u>Type of Forecast</u>	<u>Number Made</u>	<u>% Reliability</u>
8-Hour Production	93	86.2
24-Hour General	62	88.8
Special	111	94.6

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Though July temperatures averaged near normal there were some extremely warm and cool periods during the month. Precipitation of 0.11 inch was near normal.

CUSTOMER WORK - Mass Spectrometry

Isotopic analyses were performed on ten uranium samples in support of Purex U²³³ production studies and on one plutonium standard for the Analytical Laboratories. Nine uranium and four plutonium isotopic analyses were performed for Fission Product Chemistry in support of a study of burnup in NPR fuel. Analyses were also provided on two uranium and seven plutonium samples as a service to Ceramic Fuels Design and Evaluation.

CUSTOMER WORK - Instrumentation and System Studies

Assault Mask Scintillation Probe

Fabrication was completed on a three-detector scintillation probe assembly to be used with the assault mask surface contamination monitoring system, which is being developed for use at the Hanford Laundry Facility. Tests indicate considerably improved detection efficiency for fission products, especially for monitoring the sides of the masks. Over-all detection sensitivity should be better than 10 nCi of Pm¹⁴⁷.

Laundry Monitors

Development engineering is in progress on a specialized laundry monitoring system for small items such as hoods, shoe covers, gloves, etc. The system, being developed for use at the Hanford Laundry Facility, will be of the conveyor type using alpha-beta-gamma scintillation detectors, solid state circuitry, and including automatic rejection of contaminated items.

Physiological Telemetry System

Satisfactory laboratory operation was achieved on the demodulator portion of the physiological function telemetry system, which is being developed for use by Industrial Hygiene in remote measurement of human temperature and heart action under environmental stress. A two-channel chart recorder was ordered for incorporation. When the recorder is delivered, the system will be made ready for field demonstration.

Irradiated Fuel Beta Monitor

Development work was initiated to develop an instrument for use by Photography personnel in measuring beta flux from sections of irradiated test fuel samples. Both cadmium-sulfide photocells and several small photo-

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multipliers are being used with a thin plastic scintillator to provide the detection. Tests with the electron Van de Graaff will be conducted to determine the detection sensitivity.

Swelling Capsule Instrumentation

A tandem swelling capsule, containing tests P6 and P8, will be inserted into the K reactor test facilities during August. Since the equipment required for a third system may not arrive in time for the start of the test, spare parts will be used temporarily. When the two new systems are completed, the system will accommodate four capsules with ample spare parts.

Production Reactor Instrumentation

A study of resistance temperature detector functionability versus electrical resistance to ground continued during the month. The analog computer program is being modified and debugged for analysis of the problem on the EASE 1132 computer. Approximate models for a strap-on resistance temperature detector (RTD) and an immersion RTD were developed to assist IPD personnel in evaluating the relative response characteristics of these two devices. This work is being done in an attempt to eliminate difficulties with RTD's located on the rear face of Hanford's older production reactors.

Mass Spectrometer

The assembly of the interface between the mass spectrometer and the computer is in progress. The wiring of the mounting panels for the logic modules is about 50 percent complete. Additional device selectors have been installed in the computer, and the system is ready to begin testing some of the functions of the interface.

Containment Systems Experiment

The PDP-7 computer for the Containment experiment arrived during the month. Original installation checkout was accomplished by the computer manufacturer. Wiring of the interface between computer and pulse-height analyzers was completed and is now under test.

CUSTOMER WORK - Nondestructive Testing

Work has continued on a nondestructive method of determining the thickness of a zirconium-oxide layer on small zirconium coupons. The methods investigated included ultrasonic, eddy current, capacitive, and optical techniques.

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Ultrasonic techniques were not feasible due to the thin layer of oxide coating; eddy current methods were not feasible due to varying resistivity of the zirconium oxide which depended upon the oxygen content of the oxide layer.

Experiments were performed using electrical resonance phenomena with the zirconium oxide coupon as the capacitive element. Definite resonant effects were observed, but the results were not conclusive.

One optical method employing a spectrophotometer will be investigated as necessary equipment becomes available.

Thin Wall Tubing Tester

Checkout of the thin wall tubing tester that will replace the present one in operation in the 308 Building continued. At the present, the amplifiers need more modifications to prevent distortion of a nonsinusoidal signal at the upper end of the amplifier's band pass.

Laboratory Eddy Current Tester

A prototype eddy current tester embodying several concepts developed at Hanford over the past several years has been built and is presently being checked out. This tester will demonstrate an improved testing concept and will serve as a laboratory tool for investigating various testing problems.

Plutonium Thickness Measurements

A study has been completed and an informal report drafted describing the feasibility of using a gamma scintillation spectrometer to measure the thickness of plutonium plated on a metallic substrate. An 8-15 mil thickness range of plutonium can be measured with an estimated error of 5-7 percent.

A flux collimator with a 1/8 in. diameter aperture was used so that direct comparison of performance could be made between this, ultrasonic, and eddy current methods for testing the same size area.

Isotope Heat Sources

Weld penetration measurements have been conducted on simulated isotope heat sources supplied by the 3M Company. Data have been recorded using various ultrasonic test methods and measurement techniques. The sample heat sources will be destructively tested to obtain data correlation.

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Prior to receiving the isotope heat source samples from the 3M Company, two mock samples were fabricated onsite to simulate the sources to be tested. The onsite fabrications were performed by one-pass of a tungsten arc welder. These samples were scanned using different testing methods, measuring techniques, and transducers. Data were recorded using the most promising methods, and a sample was destructed for data correlation.

The 3M sources possess an extremely rough surface condition. Also, the caps and cylinders are approximately twice the thickness anticipated. The weld, which attaches the source cap to the cylinder walls, was performed by multiple passes of a tungsten arc weld. The ultrasonic tests used employed 15 and 10 Mc longitudinal waves, and a shear wave test. Results of each will be compared with destructive test results.

High Temperature Elastic Properties Program

A wide band transistor amplifier with a gain of 40 db has been completed and tested. Planned for use in amplifying the low amplitude signals produced by the electrostatic transducer, this amplifier will accommodate frequency bandwidths from 50 cps to over 30 Mc. A switch has been built into the input to allow insertion of a clipper circuit when necessary. Maximum input signal amplitude that can be amplified without distortion is 8 millivolts. An attenuator has been incorporated to accommodate signals larger than this value.

Work is now being conducted to fabricate a prototype instrument package especially designed for use with the electrostatic transducer. This unit will contain a high voltage power supply for the pulser and a reversible polarity bias supply.

Plutonium Properties Program

Due to poor beam symmetry and general low quality of industrially acquired ultrasonic transducers, it became necessary to construct and evaluate improved quality transducers for use on this program. Material properties measurements are expected to be significantly enhanced with the new units.

A bid for fabrication of a mechanical manipulator has been let offsite, and the delivery date will be the middle of August. Two more weeks will be needed to check out all equipment before installation in an actual plutonium handling facility. It is anticipated that routine operational use will begin near September,

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CUSTOMER WORK - Nondestructive Testing Service Application

Nondestructive testing services continued to be provided plantwide customers at a level approximately equal to preceding months. Major projects included the inspection of several thousand N fuel end caps with dye penetrants, in which well over 100 rejects were found. In support of Ceramic Fuels programs a series of tests were made on nine cermet billets to determine core length and cladding wall thickness, and other tests were made on three cermet extrusions to determine core location and cladding wall thickness. A two core extrusion was also checked for the same properties. The effect of vibratory composition on depleted UO_2 pellets during loading operation was elucidated by radiographic inspection of fuel rod ends.

Other noteworthy test services provided were the measurement of the calining storage tank wall thickness, strain gage measurement of stresses in the 333 Building extrusion press, detection and location of flaws in 105-C downcomers, radiographic inspection of N Reactor steam valves and the inspection of a welded platinum melting crucible.

CUSTOMER WORK - Optics

Zoom Lens

A project has been initiated to study and estimate the fabrication costs of a zoom lens for the Purex crane periscope. The zoom lens is to replace the present three power optic heads and is to cover the same magnification range. This work will be conducted using the LASL lens design program.

Photographs of Reactor Safety Rod Channels

Photographs of the layout of channels in a production reactor are needed to assist in planning alterations and to locate trapped materials if and when this becomes necessary. Existing photographic equipment was designed especially for smaller channels such as process tubes. Design and fabrication of equipment to permit rapid sequence photographic and motion picture surveys of the entire surface of the channel have been initiated.

Laboratory Work

During the five-week period covered by this report, the following work was performed:

1. Three alumina rings were fabricated.
2. Two quartz seals were fabricated.
3. Two 100-N Area periscope prisms were fabricated.
4. Two borescopes were repaired.

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5. Three sets of glass bearings were fabricated.
6. A movie camera adapter was fabricated.
7. A light pipe was fabricated.
8. Four nondarkening lenses were fabricated.
9. Several quartz windows were fabricated.
10. Two thermal transducers were fabricated.
11. A Redox optic head was repaired.
12. A Purex optic head was repaired.
13. A monocular eyepiece was fabricated.
14. Two ground glass screens were fabricated.

INSTRUMENT EVALUATION

Evaluation testing was initiated on 37 or 60 Model II "Scintrans" that were fabricated offsite for use in plant radiation monitoring. To date, considerable fabrication and component errors have been recognized, and corrective action started. Same errors are occurring in all units; this will simplify the corrections.

Acceptance procedures were outlined for possible purchase of 10 Model II "Scintrans" fabricated as "extras" several years ago by a commercial source.

Tests and modifications were continued on six combination alpha-beta-gamma hand and shoe contamination monitors, which were fabricated offsite. One unit was completed; this will be used as a reference model for modifications on the other five.

RS Paul

Manager
PHYSICS AND INSTRUMENTS DEPARTMENT

RS Paul:mcs

END

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**DATE
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8/20/92**