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MTR TECHNICAL QUARTERLY REPORT FOR
FIRST QUARTER—1954

By
J. R. Huffman

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Consolidation of this material into compact form to permit economical and direct reproduction has resulted in multiple folios for some pages, e.g., 10-11, 27-30, etc.

MTR TECHNICAL QUARTERLY REPORT

First Quarter - 1954

By

J. R. Huffman
-----I. SUMMARY

During the first quarter of 1954 considerable progress has been made on the design, construction and testing required to initiate work on new programs. Thus, the Reactivity Measurement Facility, which was authorized in February, has been under design and construction with completion expected in early August. The Hot Cell has been placed on a limited operating basis after some shielding checks, and procurement of equipment for complete metallurgical examination has been underway. The Organic Circulating Loop in the Gamma Ray Facility was tested and then placed in position. Its operation has been delayed by considerable trouble with the circulating pump. Design for the Film Boiling Experiment was completed and purchase orders for fabrication have been placed with the Oak Ridge National Laboratory. The Time-of-Flight Spectrometer has been undergoing check-out experiments and is currently being used to measure silver cross sections as a test of the equipment.

The non-destructive fuel assaying technique which was successfully applied to MTR fuel assemblies has been demonstrated to apply to the analysis of solutions of U-235 of CPP product strength. Work is in progress to determine its application to solutions of process strength.

Total cross sections for silver, copper, iron and hafnium have been obtained on the Crystal Spectrometer. Exploratory work and experiments are under way to establish a feasible technique for the measurement of fission cross sections on both the Crystal and the Time-of-Flight Spectrometer. An automatic printer and an analog computer, to be used on the Crystal Spectrometer, have been developed.

Radiochemical studies have been made to determine the activation cross section of the A+1 species of yttrium, praseodymium, tantalum and terbium and work is under way on the absorption cross section of Pa-233. Work is continuing on graphite damage studies.

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II. INVESTIGATIONS AND CALCULATIONS ON THE MTR

A. Thermal Neutron Flux Measurements

The method for obtaining full power flux values from low power runs has been modified to reduce the reactor times required. The old procedure was to bring the reactor up to constant power and determine the power level by foil measurements in standard positions. This necessitates corrections for the varying flux level during approach to constant power and also requires that the power be held essentially constant, which is not easily done at low power. The new procedure is to insert cobalt monitors in the locations to be measured and also in two "standard" locations (selected VH positions). The reactor is then operated for a total of about five megawatt minutes without regard to constancy of power or total time of exposure. The monitors provide the ratio of the nvt's between the unknown and standard locations. Since the flux versus time function is identical except for a constant, the ratio of neutron fluxes in these locations is also known. A second exposure is then made at full power to determine the flux in the standard position and the unknown flux is computed from the ratio. Because of the simplified requirements on reactor operation, the total time for a measurement is considerably reduced. The method will be suitable for most flux measurements.

The integrated nvt in reflector position A-20, with DPSR-1 samples in place, has been obtained for reactor cycles 26 and 27 by means of cobalt-aluminum alloy monitors. The nvt at the point of maximum flux was 4×10^{20} , corresponding to an average flux of 1.3×10^{14} nv $\pm$ 15 per cent. The average flux over the whole assembly agreed within 10 per cent of the value calculated from the heat generation. The method can be extended to a total nvt of about 2×10^{21} with the present facilities.

As reported in the last quarterly report and in IDO-16128, the heat generated by Po-210 decay in a bismuth sample has been under study as a method of measuring the average thermal neutron flux. The results obtained by this method for reactor cycle 26 (5 x 6 loading) are given in the following table.

TABLE I

Average Thermal Neutron Fluxes
Determined by Bismuth Flux Monitors

<u>Location</u>	<u>Distance from Centerline (in.)</u>	<u>Dosage (nvt)</u>	<u>Flux (nv)</u>
A-3	-10-1/16	4.6×10^{19}	3.0×10^{13}
A-33	-1	1.7×10^{20}	1.1×10^{14}
L-29	-3/4	4.4×10^{20}	2.9×10^{14}
L-31	-3	2.9×10^{20}	1.9×10^{14}
L-32	-9	3.4×10^{20}	2.3×10^{14}
L-41	-4	3.4×10^{20}	2.2×10^{14}
L-49	0	4.7×10^{20}	3.1×10^{14}
VH-1	0	2.1×10^{20}	1.6×10^{14}
VH-3	0	4.2×10^{20}	3.2×10^{14}
VH-4	0	4.0×10^{20}	3.9×10^{14}

The flux depression produced by the FW-1 capsule in reflector position A-38 has been remeasured. Unperturbed measurements were made in A-31, A-38 and A-39, giving flux values of 2.8×10^{14} , 2.8×10^{14} , and 1.4×10^{14} nv, respectively. The perturbation flux at the fuel position inside the FW-1 capsule was 1.4×10^{14} nv. These values are believed to be accurate to ± 20 per cent.

The unperturbed values check with the values given in IDO-16047 for the depleted core. The perturbed flux is about 10 per cent higher than that calculated from fission product analyses on previous FW-1 fuel samples.

B. Fast Flux Measurements

In order to test the use of sulfur as a fast flux monitor a small number of 28 aluminum tubes 0.100 inch o.d. x 0.010 inch wall were filled with powdered sulfur. No difficulty was encountered in handling these detectors and the method appears satisfactory from a mechanical standpoint. Test exposures were made in VH-2, A-20, A-27 and A-30 at the start of reactor cycle 29. The following preliminary results were obtained for the integrated flux above one Mev.

TABLE II

Estimated Fast Neutron Flux
(> 1 Mev) From Sulfur Thresholds

<u>Location</u>	<u>Maximum Fast Flux</u>	<u>Distance from Centerline (in.)</u>	<u>Fast Flux at Centerline</u>
A-20	1.5×10^{12}	-6	1.3×10^{12}
A-27	3.4×10^{12}	-12	7.5×10^{11}
A-30	4.6×10^{12}	-10	1.1×10^{12}
VH-2	(18" spacers)		1.2×10^{13}

Fast flux profiles for the above A-pieces were obtained.

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Eight determinations of the flux above one Mev have been made in VH-2 using the $Al-27(n, \alpha)Na-24$ reaction as a threshold detector. The average value obtained was 1.6×10^{13} neutrons/cm²sec, assuming a fission spectrum. This value is slightly high due to the contribution from a long-lived activity produced in some unknown impurity in the aluminum. The exposures ranged from 13 hours to 110 hours in length and covered two operating cycles. The maximum spread in flux values was 30 per cent. This includes one low point obtained at the beginning of a cycle, the significance of which is not known.

C. Uranium Assaying

The general problem of applying and developing techniques which depend on fissions, neutrons and gamma rays to analytical problems in the Chemical Processing Plant has been started. After some exploratory tests to study feasibility, the fuel assembly assaying technique was applied to CPP product solutions as a check on the methods used at CPP. By this technique, the relative uranium content of a thin sample of solution is determined by measuring the number of fission neutrons produced when the sample is exposed to a beam of thermal neutrons. Absolute values are found by calibrating with standard solutions. The method is similar to that reported in "A Non-Destructive Method for Fuel Assaying," IDO-16114.

In order to check the CPP assays, nine samples from three shipping bottles were taken. The first group of three were taken from bottle No. 104. These were diluted to cover a small range of concentrations and used as temporary "standards" for calibration purposes. The second and third groups came from bottles No. 119 and No. 121. These solutions were diluted by about a factor of 10 from the original concentrations. One other standard solution was used at 1/6 full strength to provide a fourth point on the calibration curve. The fuel content of the unknown was then determined by comparison with the standards. It was known that the unknown samples had suffered small losses of uranium from previous handling and this effect was estimated as less than five per cent. Other errors were relatively small so the standard error was assumed to be five per cent. The results are tabulated below.

TABLE IIIU-235 Assay

<u>Original Bottle</u>	<u>CPP mg/g</u>	<u>Sample</u>	<u>CPP mg/ml</u>	<u>MTR mg/ml</u>	<u>MTR CPP</u>	
104	219.2	1	15.9	Std.		
		2	34.6	"		
		3	61.4	"		
119	263.4	4	37.7	38.0	1.008	0.993 Average
		5	45.2	45.7	1.001	
		6	46.4	44.6	0.961	
121	246.0	7	39.1	38.3	0.980	0.973 Average
		8	40.6	39.3	0.968	
		9	43.0	41.8	0.972	

It is evident that the experimental errors are less than the five per cent estimate and also that, within experimental error, the MTR results are in complete agreement with those of CPP. More precise work will be possible when a permanent facility is established for this purpose and dilution, with its attendant errors, will not be required. A more precise set of standard solutions will also be necessary. The counting rate for the fast neutron detector is about 200,000 c/m which assures a minimum of statistical uncertainty. The limits of accuracy are dictated primarily by the precision of the standards and the degree of reproducibility in the preparation of the samples. This work is reported in IDO-16165. Extension of the method to process solution analysis is now under way.

The data on the non-destructive assaying of MTR fuel assemblies taken from May 1953 to June 1954 have been summarized in report IDO-16179. Results are tabulated for over 300 assemblies. Comparisons are made between MTR and ORNL assays.

III. CROSS SECTIONS PROGRAMA. Crystal Spectrometer1. Measurements

Total cross section measurements have been made on silver, copper, iron and hafnium during the past quarter. Silver, copper and iron have been measured from 0.03 to about 0.4 ev. Hafnium measurements have been completed from 0.04 ev up to 0.2 ev with survey runs extending to 10 ev (see Fig. 1). The cross section of hafnium below the 1.09 ev resonance

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is about 27 to 47 barns lower than the Harwell data in AECU-204 (see Fig. 2) but agrees with the Argonne and Oak Ridge pile oscillator measurements. Good data have been obtained over the first two resonances with a metal sample 0.0093 inch thick. The preliminary experimental isotopic cross sections at the peak are $18,300 \pm 500$ barns and $18,900 \pm 700$ barns for the 1.095 ± 0.005 ev and the 2.378 ± 0.016 ev resonances, respectively. These energy values are based on a value of 1.458 ev for the first indium resonance. The 2.378 ev peak is asymmetrical and may consist of two or more resonances.

Total cross section data for indium, tantalum, titanium, zirconium and chlorine from about 0.025 ev to about 50 ev have been compiled and sent to the Cross Section Compilation Group at Brookhaven.

An attempt is being made to find the Breit-Wigner characteristics of the first indium resonance. The primary purpose is to learn the techniques of correcting for Doppler broadening and instrument resolution. Some work has also been done on fitting the chlorine data with the characteristics of a negative energy resonance.

A report presenting contour diagrams of thermal neutron absorption cross sections has been prepared and is now being reproduced. A striking feature of the study is that in nearly all cases there is a gradual change of cross section values from one nucleus to an adjacent nucleus of the same type. The diagrams should prove helpful in estimating cross sections of nuclei for which no measurements exist if the thermal cross sections of some of its neighbors are known.

2. Apparatus

During the operation of the crystal spectrometer it has been necessary twice to replace the BF_3 detectors on the spectrometer arm because they no longer had acceptable pulse height distributions. These are two-inch diameter, 22-inch long counters with 0.002-inch center wires. The trouble is attributed to a high concentration of the disintegration products of the BF_3 molecules. Three one-inch diameter 18-inch BF_3 counters with 0.006-inch center wires similar to the counters being used on the fast chopper have been installed. An increase of about tenfold in useful life for these counters is expected.

A back-to-back fission chamber has been constructed which has a good pulse height distribution and a background of about 0.02 counts per minute in a reactor beam which gave 10^5 counts per minute with a 0.1 mg/cm^2 foil of U-235 in place. A counting rate of about 20 counts per minute has been obtained in the thermal region with the 0.1 mg/cm^2 foil. Material for a 0.5 mg/cm^2 is now on order. Specifications for uniform foils of U-233, U-235, and Pu-239 have been sent to IDO for procurement.

A die and heater for making Hornyak buttons have been completed and some 1-3/4-inch diameter buttons have been made. All equipment is on hand for preliminary $1/\lambda$ measurements.

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3. Analog Computer

An analog computer was designed and constructed which calculates neutron cross section from data accumulated by the crystal spectrometer. The heart of the device is a special capacitor which has polyethylene insulation which obviates the effect of dielectric absorption or "soak-in." A clock measures the time required for the capacitor to discharge, through a resistance, from one potential to another. The data are cranked in manually and the cross section is read directly from the clock. This computer is being tested now and it is anticipated ultimately a computer will be made which operates automatically from the crystal spectrometer.

4. Data Printer

Construction of the automatic data printing system was completed and the unit was laboratory tested using commercial pulse generators to simulate the actual signal pulses. This test gave satisfactory results in both the data printing and operation sequence control. When the unit was tested under actual operating conditions with the crystal spectrometer it was found that with minor adjustments to some of the units, the printing operation was quite reliable. It was determined that a better system must be devised for generating pulses for the arm angle indicator because the precision with which the cross section measurement is made depends upon the accuracy of measurement of the spectrometer arm angle. The pulse generator should give one pulse for every 10 seconds of arc of the spectrometer arm but, due to contact noise in the generator, several pulses were received for each 10 seconds of arc. Therefore, a different system will be utilized.

B. Time-of-Flight Spectrometer

1. General

During this quarter the check out of instruments has been continued and the transition to actual data collection by the time-of-flight spectrometer has been taking place. Measurements of the cross section of silver have been made as a test of the equipment and are in reasonable agreement with those in AECU-2040.

In order to reduce the background from other sources in the building shielding was erected in the vicinity of the counters. The effect of the shielding however was to scatter and moderate neutrons causing delayed detection and hence a false background which could not be accounted for by a simple interpretation of the data. The removal of this shielding resulted in improved cross sections but at the sacrifice of raised room backgrounds and of poor accuracy due to variability in this background.

A second factor which has been a greater cause of delay in getting the instrument "producing" has been circuit "bugs". Reliable data have not been obtained for more than short times with long delays in between. Although these features have not yet been eliminated, they are at least now well understood and reliable data can be obtained without undue delays by careful surveillance of tubes and scalars.

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Three reports have been prepared on development phases of the chopper: IDO-16110 which describes the tests on the counters for the chopper, IDO-16159 which describes the time-of-flight instrumentation in detail and MER-L-54-36 which describes the instrument response and will be issued as an IDO report later.

Plans for the immediate future are

- a. Instrument checkout and determination of better background values by measuring the silver cross section.
- b. Feasibility study to determine which fission cross section measurements can be made.
- c. Search for resonances in an available sample of Mg-237 .
- d. Moving the detectors outside the building. This appears desirable since it will minimize the effects of a variable room background.

2. Circuitry

A major effort has been made to complete all wiring in the motor control cabinet, the time analyzer cabinet and all interconnecting facilities with the chopper in order that convenient, continuous operation of the instrument may be obtained for long periods of time. A duplicate control panel now exists together with all warning lights at both the motor control cabinet at the face of the reactor and at the time analyzer at the end of the drift tube.

Emphasis has been placed on improvement of the scaling accuracy of the 100 scaling channels. Despite careful selection of sensitivities of the 313C cold cathode gas triodes which drive the registers, a characteristic response remained which indicated that the 313C threshold firing potential was just being exceeded. The results were occasional lack of firing and loss of information. By the judicious use of two condensers, one to couple more energy to the 313C firing anode and one to absorb the fast transient caused by the firing of the 313C, a reliable scaling resulted.

A comprehensive check of the accuracy of scaling versus 313C bias voltage was made. The results were gratifying, showing a flat curve for voltage versus counting rate, over a voltage range of three to four volts, common to all channels.

3. Speed Controller

The pilot model of the electronic chopper speed controller has been completed and aligned on the bench. It will be installed and tested during a future shutdown period. Any changes which are found to be necessary will be incorporated in the final model of the unit.

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B. Graphite Studies

Stored energy measurements have been obtained on graphite samples taken from several VG plugs at the end of cycle 26 (12698 MWD operation). The results are tabulated below. These samples are the same as those for which C_0 lattice spacings were reported last quarter. Included also are the results from VG-13 and VG-19 with a history of 3974 and 1754 MWD reactor operation, respectively.

TABLE V

Stored Energy in Graphite

<u>VG Facility Number</u>	<u>Cal/g</u>	<u>Cal/g/10,000 MWD</u>
1	1.4	1.1
2	1.5	1.2
10	14.0	11.0
14	8.8	6.9
23	<1.0	
30	<1.0	
55	1.2	0.95
13	16.0*	40.0
19	3.1*	18.0

*Average of several determinations

The stored energy is that released at 200°C. The graphite temperature during reactor operation runs at a maximum of about 70°C.

As part of the program to evaluate radiation damage as an index to fast flux, successive short-term exposures of graphite were made up to an accumulated exposure to date of about 350 hours in the hydraulic rabbit (VH-2). At least one virgin specimen was included in each exposure to detect any variations in flux. The data show an initial damage rate of 0.0097 per cent change in C_0 spacing per hour exposure and above 180 hours a constant rate of 0.0144 per cent per hour. In terms of integrated flux, these rates are 0.24 per cent and 0.36 per cent per 10^{18} nvt (above one Mev), respectively as calibrated with aluminum foil using the (n, α) reaction and the known fission neutron energy spectrum.

Series of 20 or more determinations per specimen on a number of samples indicated a standard deviation in C_0 spacing of about ± 0.02 per cent for virgin up to ± 0.08 per cent for heavily exposed samples.

Exposures up to 20 hours in VH-3 showed electrical resistance changes represented by the empirical equation

$$\log R = 0.77 \log T + 0.726$$

where $R = \Delta \% C_0$ is in per cent and T in hours exposure in VH-3. From the

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S-32(n,p)P-32 reaction the flux was calculated to be about 3.9×10^{12} neutrons/cm²sec. Using this value the expression may be written

$$\log R = 0.77 \log (nvt) - 11.73$$

The specimens were of CS-GBF graphite, machined to dimensions 0.125 inch by 0.550 inch by 1-5/6 inch, and chosen with initial resistances within ± 3.5 per cent of the average. The spread of R from the curve averages about ± 10 per cent of the value on the curve at that exposure.

Stored energy released at 200°C for exposures up to 200 hours in VH-2 gives an S-type curve of calories per gram versus exposure on a log-log plot. There is an approximately linear relationship between six and 60 hours exposure.

The above results must be considered tentative since the work is still in progress.

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D. Radiochemistry

Results have been obtained for activation cross sections of the $A + 1$ species of yttrium and praseodymium. The decay curves for yttrium and praseodymium are given in Figures 3 and 4, respectively. From the ratios of the $A + 1$ to $A + 2$ activities at zero time, the flux and the decay constants, the activation cross section of Y-90 was found to be 5.6 ± 0.9 barns. Similarly, the activation cross section of Pr-142 was found to be 18 ± 3 barns.

Counting is continuing on samples of tantalum and terbium for the determination of the activation cross section of Ta-182 and Tb-160.

A 20-milligram sample of U₃O₈ highly depleted in the U-235 isotope has been received from Oak Ridge. The sample has been enclosed in an aluminum jacket and will be inserted in one of the beryllium L-pieces during the next shutdown. The sample will undergo U-235 burnout for approximately one year, and will be used eventually for the determination of the fission cross section of U-239.

A five-milligram sample of Np-237 has been received from Argonne National Laboratory. This isotope will be used to study the feasibility of using Np-237 as a slow neutron flux monitor.

About one curie of Pa-233 has been separated from an irradiated sample of Th-232. The protactinium is being used in preliminary runs for the determination of the absorption cross sections of Pa-233 for the formation of the UX₂ and UZ states of Pa-234. Experimentation thus far has indicated that both of these measurements are feasible if small amounts of oxygen, nitrogen, carbon and sodium can be eliminated from the final Pa-233 fraction. Present efforts are being directed to the use of anion exchange columns to effect the removal of these low mass impurities.

E. Film Boiling Experiment

Purchase orders for fabrication of the test sections and modified dummy shim rod have been sent to Oak Ridge National Laboratory. It has been estimated that two months would be required for fabrication. All the instruments and valves are now on order. Four "Firebox" neutron flux monitors have been received from Savannah River. It is hoped that the monitors will give an indication of the change in the slow neutron flux due to local boiling.

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The detailed design of the piping leading from the dummy shim rod back to the process water system has been initiated. A 15-second delay time between the fission break monitor and the three-way valve has been provided by a 35-foot section of six-inch standard pipe. In case of a fission break in the test section, the water can then be diverted through a three-way valve to the hot drain without contaminating the process water system.

Detailed design of the aluminum-water reaction experiment is nearly complete. This experiment, which will precede the film boiling experiment, should provide information regarding feasibility of extending the film boiling experiment to burnout conditions. Under these conditions a steam blanket will form over the fuel plates resulting in reduced heat transfer and melting of the plates.

Present plans are to conduct the aluminum-water reaction experiment in the A-31 position. This position provides a sufficiently high neutron flux to completely vaporize the aluminum-uranium alloy sample in 10 seconds while the gamma intensity is sufficiently low to insure that the capsule temperature does not rise above 250°F in the same time. A 1.50-inch o.d. aluminum tube will be inserted through the north tank access hole into the aluminum A-piece. The pressure capsule can then be lowered into the active lattice through the aluminum tube.

The pressure capsule will be fabricated of 310 stainless steel. Its dimensions will be 1.250-inch o.d., 0.250-inch wall thickness and a 2-inch long reaction chamber. It is planned to use a Model EP-10,000 pressure pickup unit manufactured by the Control Engineering Corporation to follow the pressure change. An oscilloscope will be used to record the output of the pressure pickup unit.

F. Organic Fluid Circulating Loop

Pre-operational testing of the equipment for the MTR gamma facility loop has been completed and the equipment placed in its operational site adjacent to the MTR canal.

Equipment performance tests covered pump capabilities, heater operation, and system tightness under pressure. The Dowtherm system performs according to design, giving satisfactory flow rates with pressure drop well within the rated pressure head for the pump. The heaters for the irradiation coil and riser tube operate satisfactorily. Heating for the deposition test section is limited by the supplying powerstat. While considered adequate for the first run, this heating will be stepped up at the end of the run. The organic pump does not give desired flow rates, the maximum flow being approximately half of the specified capacity. Arrangements have been made with the pump supplier to replace pump components to increase the flow rate. These parts are expected to be available for changeover following the first run. Previously, a defective end plate casting on this pump required returning the piece to the supplier for repairs. Replacement was secured from the factory when the repaired part proved unsatisfactory.

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Considerable difficulty was encountered in calibrating the flowmeter and the continuous viscometer. The former appears to be a great deal less rugged than was hoped for and may require appreciable attention during test runs.

The first fluid to be tested will be alkylbenzene (MW 250), a quantity of which has been received from CRC. It is planned to irradiate this fluid for three weeks at 450°F. The next run scheduled is the irradiation of M-terphenyl for four months at 750°F.

V. DEVELOPMENT OF NEW INSTRUMENTS AND FACILITIES

A. MTR Hot Cell

The MTR hot cell was placed on a limited operating basis during the past three months. Work performed included opening, disassembling and resealing irradiated capsules as well as dimensionally checking and visually examining irradiated thorium slugs.

Lack of equipment for the hot cell handicaps its use for operations other than those involving simple manipulation and visual examination. Dollies for moving shielding containers into the cell and tables for placing work are under construction in local shops. It is aimed to equip the cell for the following operations: 1) macro-photography, 2) cutting, lapping, polishing, washing and etching of metallographic samples, 3) micro and macrohardness testing, 4) metallographic examination, 5) weight and density determinations, 6) dimension and profile measurements, 7) annealing, 8) tensile, yield and ductility measurements, 9) machining by sawing, milling, turning and drilling, and 10) chip disposal.

The shielding effectiveness of the cell was checked with a Co-60 source estimated at 2000 curies. The survey revealed the following:

Radiation through windows, doors, cell walls and service plugs	None detectable
Radiation through telescoping shield (around manipulator)	About 2 mr/hr with source moved to top of windows
Radiation beneath steel charging doors	200 to 300 mr/hr
Radiation along sides of charging door	Maximum of 50 mr/hr

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Of these leaks, the most difficult to stop are those along the edges of the sliding steel charging doors. The leaks under the door can be checked with a row of lead bricks or shot-filled bags. As personnel are not in the vicinity of the door during cell operation, the leaks are not of great concern. The leaks in the telescoping shield are through slits above and below the steel blocks and are well above head level. These will be stopped by welding plates on the bottom and top of the manipulator slab. With the leaks through the manipulator slot stopped, radiation in the working area of the cell will be about background level when a source of the size used in testing the cell is being worked on in the cell.

B. Scintillation Techniques

The design of the basic circuitry for the multichannel pulse height analyzer has been completed. The system will constitute a 100-channel (20 at a time) analyzer, utilizing a 20-channel pulse sorter unit incorporating an expanded type threshold amplifier. This unit was originally designed as an integral part of a similar instrument and has been obtained from a commercial source. It is presently planned to provide 100 channels of scaling capacity, patterned after those developed for use in the time-of-flight analyzer.

Control and programming circuitry will be provided to permit maximum flexibility in the use of the 100 information channels. This equipment is in the preliminary design stage.

A proposal has been prepared for the construction of an automatic single-channel scintillation spectrometer for use by the analytical chemistry group at the Chemical Processing Plant. This instrument will be similar in design to that presently used by the special instruments group at the MTR.

C. Fission Break Monitor

Studies of the gamma spectrum of the MTR process water have been extended to include measurements at delay times as short as 20 seconds after leaving the active lattice. The buildup of particulate activity on filters placed in the sample stream has been observed for various energy regions to demonstrate the difficulties inherent in the filter type monitoring systems. Various source-detector configurations were studied to obtain information necessary to permit design of detector assemblies for operational monitors.

The fission break monitoring system for the Sylvania experiment (SEP-1) has been completed and tested and is now awaiting installation. The system consists of two NaI scintillation detectors, each of which drives a linear pulse amplifier and a single-channel pulse height analyzer. The two detectors view a water chamber which continuously samples the cooling water stream. The outputs from the two analyzers are in turn fed to a difference count rate circuit which indicates the relative activity levels in the two channels. The difference between gamma counting rates in the two channels is recorded and suitable alarm circuits provided. One channel examines only the H-16 activity induced in the cooling water and the other a region of predicted maximum sensitivity to fission product gamma activity.

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An experimental setup to permit determination of the sensitivity of fission break monitoring systems to fuel rupture has been designed and will be inserted in the L-42 position of the reactor late in April. This facility will simulate actual fission break conditions by irradiation of minute samples of unclad fuel. Data on fission product gamma spectra a few seconds after fission will also be obtained from this facility as time permits.

D. Reactivity Measurement Facility

During this quarter design and construction of the Reactivity Measurement Facility has been proceeding as rapidly as possible. Approval to proceed on this project was given in February. The RMF will consist of an MTR core suspended in the canal with proper controls to permit operation at low power (watts) and to make measurements on materials previously irradiated in the MTR. A more detailed description will be given in future quarterly reports.

1. Calculations

The critical mass versus fuel assembly spacing curve has been calculated for two water reflected cores composed of 19-plate 200-gram fuel assemblies. One core contains a central water column with area equal to the cross sections of four fuel assemblies. The other core has no central water column.

Standard two-group methods were employed to obtain the critical radii of cylindrical reactors simulating the RMF. The nuclear constants age (τ), and slow and fast diffusion coefficients (D_s , D_f) were obtained assuming a homogeneous core by using the known dependencies of these constants on the volume ratio of aluminum to water (see IDO-16133). For the cases of Al/H₂O equal to 0 and 0.76 the critical masses using constants obtained in this way were close to those given by experiment (K-343-III, MonP-402).

The k_{∞} and L^2 values for the different spacings were obtained by a "cell" method. Each fuel assembly was assumed to be an infinite cylinder surrounded by its associated water. The flux distribution was then calculated assuming a spatially constant slowing down density and no thermal flux gradient at the cell boundary. This gave a thermal flux distribution within the cell. The k_{∞} was then obtained from the relation

$$k_{\infty} = \frac{2.091 \int_{\text{fuel}} \Sigma_u \phi dv}{\int_{\text{fuel}} \Sigma_a \phi dv + \int_{\text{water}} \Sigma_a \phi dv}$$

where

Σ_u = macroscopic absorption cross section for U-235 in the fuel region of the cell.

Σ_a = total macroscopic absorption cross section.

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$$L^2 = \frac{D_s}{\bar{\Sigma}_a}$$

$$\bar{\Sigma}_a = \frac{\int \Sigma_a \phi dv_{\text{fuel}} + \int \Sigma_a \phi dv_{\text{water}}}{\int \phi dv_{\text{fuel}} + \int \phi dv_{\text{water}}}$$

D_s is the slow diffusion coefficient for the homogeneous core. The present cell method ignores the effect of finite thermal flux gradients at the cell boundaries. This effect may be significant in a reactor with a small core such as the RMP. However, it is felt that this method gives better results than calculations which assume a homogeneous core.

Minimum critical masses, the corresponding fuel assembly spacings and Al/H₂O volume ratios, outer core radii, and k_{∞} values are given in Table VI for the two cases.

TABLE VI

Critical Data For RMP Cores

Configuration	Fuel Assembly Spacing (cm)	Volume Ratio Al/H ₂ O	Minimum Critical k_{∞}	Minimum Critical Mass (kg)	Outer Core Radius (cm)
No central water column	1.3	0.358	1.622	2.1	16.3
Central water column equal to 4 fuel assemblies	0.60	0.447	1.699	4.1	23.0

* The Al/H₂O volume ratio is based on a homogeneous core.

For the cases where spacings between fuel assemblies are those for the minimum critical masses, curves showing δk_{eff} as a function of the core radius have been constructed. (δk_{eff} gives the amount by which the core is subcritical). These curves are roughly parabolic and follow the approximate equations

$$\delta k_{\text{eff}} = 7 \times 10^{-3} \Delta r^2 \quad (\text{no central water column})$$

$$\delta k_{\text{eff}} = 5 \times 10^{-3} \Delta r^2 \quad (\text{central water column equal to four fuel assemblies})$$

In these equations Δr is the change in radius from that corresponding to the minimum critical mass. These equations do not describe the asymmetry which is considerable.

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The sensitivities to fuel and poison were calculated for points in the midplane at the centers of the reactors, and at the flux peaks just outside the cores. The equations used to define these sensitivities were

$$W_p = \frac{\phi_f^+ \phi_s(r)}{\sum_a \int_{\text{core}} \phi_f^+ \phi_s r dr}$$

$$W_f = \frac{2.09 \phi_f^+ \phi_s(r) - \phi_s^+ \phi_s(r)}{\sum_a \int_{\text{core}} \phi_f^+ \phi_s r dr}$$

where

W_p = sensitivity to poison at position r in the midplane.

W_f = sensitivity to fuel at position r in the midplane.

$\phi_f^+ \phi_s(r)$ = product of the radial parts of the fast adjoint and slow flux at radius r .

$\phi_s^+ \phi_s(r)$ = product of the radial parts of the slow adjoint and slow flux at radius r .

$\sum_a$ = macroscopic absorption cross section in the core (cm^2/cm^3).

Results are given in Table VII.

TABLE VII

Sensitivities to Fuel and Poison for RMF Cores

Position in Midplane	No Central Water Column			Central Water Column Equal to Four Fuel Assemblies		
	Radius (cm)	W_p	W_f	Radius (cm)	W_p	W_f
Reactor Center	0.0	0.29	0.095	0.0	0.038	0.23
Flux Maximum Outside Core	18.6	0.040	0.070	25.4	0.026	0.076

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2. Temperature Regulation

To obtain the maximum sensitivity in reactivity measurements it will be necessary to closely regulate the temperature of the RMF. In order to determine what type of temperature regulating system will be required, preliminary temperature measurements have been made in the MTR canal. The results of these measurements to date show

- a. Over a two-week period the temperature at the surface and five feet from the bottom of the canal varied a maximum of 1°C .
- b. The maximum variation five feet from the bottom in 24 hours was 0.5°C and in general was much less than this.
- c. The temperature difference from the surface to the bottom of the canal is approximately 0.2°C but there is only a $0.005^{\circ}\text{C}/\text{ft}$ temperature gradient over the lower 10 feet.

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FIG. 4
DECAY CURVE OF THE A+1 AND
A+2 SPECIES
OF
PRASEODYMIUM

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END