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TEST PROGRAM AT MTR

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INTERIM REPORT OF APPR IRRADIATION
TEST PROGRAM AT MTR

I. Introduction

It is the purpose of this memo to clarify and revise burnup calculations for the APPR irradiation program and to present a proposed irradiation schedule. The report will also be in the nature of a review of the program.

II. Burnup Data

Enclosed are two graphs which relate percent burnup of B^{10} atoms vs integrated flux for the APPR control rod which is being tested under Irradiation Request ORNL-MTR-29 and for the miniature samples which are being tested under Irradiation Request ORNL-MTR-28 Phase I.

The first graph concerns the burnup of the APPR control rod. The solid curve in Fig. 1 is a theoretical estimate, the theory being outlined in ORNL CF 57-1-32. The average thermal diffusion length for the MTR core used in the above report was 1.65 cm. We later received a value for the diffusion length from D. R. Metcalf of MTR of 1.88 cm which is the value used to obtain the solid curve in Fig. 1. Increasing the diffusion length from 1.65 cm to 1.88 cm increases the burnup on the rod by 3%.

The dotted curve in Fig. 1 also represents the burnup expected on the test rod but it is based on the experimental burnup of MTR shim rod No. 163 reported in TID-7515 (Pt. 1). The dotted curve takes into account the differences in thickness and in neutron poison density of the MTR cadmium shim rod and the APPR test-29 boron rod. The use of the experimental data to obtain the burnup of test-29 is explained in detail in ORNL CF 57-1-32.

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Fig. 2 concerns the burnup of the APPR miniature B¹⁰ samples. The dotted curve in Fig. 2 refers to the original burnup calculations reported in CF 56-6-173. These calculations approximated the miniature samples by a sphere with the same volume as the poison volume in the samples but made use of the sample thickness where the radius of the equivalent sphere was called for. The dot-dash curve in Fig. 2 is a revision of the dotted curve in which the spherical model described above is applied in a consistent manner. It may be argued that it is more appropriate to approximate the miniature sample by a spherical shell with the same outside surface area as the surface area of the actual samples. This is because these samples are so black that most of the absorptions take place within a very short distance of the outside surface. This model would replace a sample by a spherical shell of radius $a = 1.39$ cm and thickness $s = 0.087$ cm. Using this spherical model, the nuclear constants for the reflector material used in CF 56-6-173, and the burnup formula reported in CF 57-1-32, we obtain the burnup for the miniature samples represented by the solid curve in Fig. 2. The use of the two models was discussed with H. L. McMurray of MTR.⁽¹⁾ He concurred that approximating the miniature samples by a spherical shell which has the same surface area as the actual sample was a more valid approximation.

As the theoretical burnup calculation of these samples is very sensitive to the model selected, we feel that it is important to have an experimental determination of the burnup of a sample. Therefore, we plan to determine spectrographically and chemically the burnups on the three irradiated samples which are awaiting shipment from MTR to ORNL.

1. McMurray, H. L., Private communication on ORNL-MTR-28, Phase I, January 17, 1957.

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Without an experimental burnup determination on the APPR type miniature samples, we feel that the best burnup information on the miniature samples is represented by the solid curve in Fig. 2. We have already examined a miniature sample which, on the basis of this curve, has a much greater burnup than will be accumulated by the APPR type shim rod in 3000 MWD in the MTR core (5 complete MTR cycles). This burnout data obtained from the solid curves in Figures 1 and 2, is summarized as follows:

	<u>nvt</u>	<u>% B¹⁰ Burnout</u>
Miniature Sample No. 8	15.45×10^{20}	44
APPR Shim Rod (3000 MWD)	16.20×10^{20}	19.5

Therefore, since the operational stability of the APPR absorber core has been demonstrated beyond a burnup of 19.5%, the APPR shim rod under irradiation test ORNL-MTR-29 can be continued in the MTR core without interruption for 5 complete MTR cycles or a total of 3000 MWD.

It should be pointed out here, that the solid lines of Figures 1 and 2 can be related as follows:

Since the poison section is so black to thermal neutrons, the absorption rate of a given volume of poison should be proportional to the surface area of the volume. As mentioned previously, this explains the difference between the solid and the dot-dash curve of Fig. 2. The solid curve of Fig. 1 represents the burnup of the absorber in a cylindrical shell of radius = 3.14 cm, and of thickness = 0.228 cm -- the cylindrical equivalent of the APPR test absorber rod. The burnup calculation of this rod includes the absorptions which occurred due to the water hole within the rod and takes into account the absorption which takes place at the rod tip because of flux peaking. Comparing the surface area of the spherical

shell (model for determining solid curve Fig. 2) with the surface area of the cylindrical shell (model for determining solid curve Fig. 1), it is found that, for the same poison volume, the spherical shell has a surface area about 2.5 times greater than the cylindrical shell. (The cylindrical shell surface area includes the inside surface area because of the water hole in the rod.) The ratio of absorption obtained by comparing the two solid burnup curves in figures 1 and 2 is 2.32 which is in good agreement with the above argument.

III. Irradiation Program

There have been 5 miniature APPR type absorber samples inserted into the MTR beryllium section for irradiation testing under Irradiation Request ORNL-MTR-28, Phase I. These samples were irradiated from July 2, 1956 to September 3, 1956, at which time 4 samples were discharged because the cap of one sample had come off and the remaining three could not be relocated because their capsule numbers had been worn off while in-pile. The only remaining capsule in-pile, No. 8, was removed after it had been irradiated to an nvt of 15.45×10^{20} . It, along with the sample whose cap had come off while in-pile, was examined in the MTR hot cell. The results of the examination of both samples, No. 8 and the other identified as No. 6, were that neither sample had developed any cladding defect or significant dimensional variance during irradiation. The accrued nvt on each of the 5 samples before being initially discharged was:

<u>Capsule No.</u>	<u>nvt</u>
1	4.0×10^{20}
5	4.54×10^{20}
6	3.81×10^{20}
7	1.38×10^{20}
8	15.45×10^{20}

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The three capsules not examined were 1, 5, and 7. Since the original numbers on these samples were worn off due to vibration of the capsules in-pile, they were arbitrarily renumbered capsules 1-1, 1-2, and 1-3, and reinserted into the reactor for further irradiation. (The additional nvt requested on each sample was chosen so that the total burnup values would be as well distributed as possible under the circumstances.) The original number, although it could not be seen as it was on the sample in the capsule, could be determined once the capsule was opened. Being able to do this, the nvt accrued before renumbering can be added to the nvt obtained after renumbering. Summarized below is the status of these three samples:

<u>Capsule No.</u>	<u>Additional nvt request</u>	<u>Removal Date</u>	<u>Remarks</u>
1-1	26.5×10^{20}	4/1/57	in-pile
1-2	19.5×10^{20}	1/28/57	in-pile
1-3	6.5×10^{20}	12/17/56	Removed 12/17/56 additional nvt received 10.55×10^{20} , capsule being shipped to ORNL

As the above capsules are discharged from the reactor they will be shipped back to ORNL where, when they are opened a total nvt will be determined. The post-irradiation program on all of the samples will include detailed measurements and experimental burnup analysis.

The APPR type absorber rod being tested under Irradiation Request ORNL-MTR-29 was inserted into the MTR core in lattice position L-24 November 26, 1956. It will be operated there as a shim-fuel rod, ganged with the other three MTR shim-fuel sections for the equivalent of 3 MTR cycles after which it will be programmed into L-22 for 2 MTR cycles. The absorber rod after it is removed from the core, will be cut from the fuel assembly so that the

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absorber section can be removed from its aluminum housing for inspection. After inspection, the absorber section will be transferred to ORNL where it will be measured and analyzed in the manner established in the absorber sample studies.

At present we have in-pile two miniature samples and the shim rod. Due to the revision in the burnup calculations, a revised irradiation schedule has been prepared and is presented on the following page.

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PRESENT AND PROJECTED INTEGRATED THERMAL
FLUX OF APPR ABSORBER TESTS IN MTR

January 15, 1957

<u>Cycle Date</u>	<u>MTR Cycle No.</u>	<u>Capsule 1-1</u>			<u>Capsule 1-2</u>			<u>ORNL-MTR-29</u>	
		<u>nvt**</u>	<u>% B¹⁰</u>	<u>burnup</u>	<u>nvt**</u>	<u>% B¹⁰</u>	<u>burnup</u>	<u>nvt**</u>	<u>% burnup</u>
11-5-56									
	79							0	0
11-26-56									
	80	12.11	34		13.22	37		3.00	3.6
12-17-56									
	81	15.03*	42		16.02*	44		5.85	7.0
1- 7-57									
	82	17.95*	49		18.82*	51		8.85*	11.0
1-28-57									
	83	20.87*	55		21.62*	57		11.85*	10.5
2-18-57									
	84	23.79*	61		24.42*	63		14.05*	17.0
3-11-57						Remove		Remove	
	85	26.71*	67						
4- 1-57									
	86	29.63*	72						
4-22-57									
	87	32.55*	77						
5-13-57									
	88	35.47*	81						
6- 3-57			Remove						

* Projected values assuming constant integrated thermal flux in any given cycle.

** nvt in terms of 1×10^{20} n/cm².

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