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A PRELIMINARY REPORT OF BERYLLIUM DAMAGE
OBSERVED IN THE MTR REFLECTOR

MASTER

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ABSTRACT

Evidence of bowing was observed in an MTR beryllium shim rod section during the Cycle 184 shutdown. Inspection and measurements of this and other selected beryllium lattice pieces confirmed this observation. Preliminary measurements have been made along a vertical traverse between the north and south reflector walls with some bowing again noted. An inspection of the north wall revealed cracking and spalling of the beryllium sections, primarily in the vicinity of the HB-2 thimble.

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INTRODUCTION

It is the purpose of this report to provide preliminary information concerning recently observed evidence of beryllium distortion and failure in the MTR reflector. The problems associated with beryllium failure due to neutron damage under proper heat environment are especially significant in beryllium reflected reactors such as MTR, ETR, and ATR. It is well known that gaseous elements are produced by reactions of neutrons and gamma rays with beryllium metal. A program of experimentation to broaden existing knowledge concerning this subject is underway.

The following pages describe the limited number of observations and measurements recently made upon selected MTR beryllium lattice and permanent reflector pieces.

I. Cadmium-Beryllium Shim Rod

The first evidence of MTR beryllium deformation was seen in one of the beryllium shim rods. The rod, BE-1-1,* was discharged to the canal from Position L-46 during the Cycle 184 shutdown, December 10, 1962, to replace the poison section. There were no problems concerning the general performance of the rod. Drop times and reverse reactivity tests had been well within existing limitations. The need for information concerning the poison section life expectancy was the sole reason for the proposed change-out.

A new poison section was attached to the rod in the canal. Subsequent drop tests, however, indicated an apparent unsatisfactory fit between the new poison section and the beryllium section. An entirely new Rod BE-5-1 was inserted into Position L-46 for Cycle 184 and subsequent operation.

A detailed inspection of the BE-1 rod in the canal indicated slight bowing of the beryllium section. The bowing was verified with a straight-edge. Later, actual measurements were made to determine the extent of the deflection. A maximum deflection of .027 inches was measured as indicated in Fig. 1. It should be noted that the bowing is directed toward the high flux zone; i.e., toward the active lattice. As a result of these findings the fit between the new poison section and the beryllium was more than likely not the primary cause of the unsatisfactory drop tests. Instead, the beryllium deflection appeared to be the most probable cause. The irradiation history of the BE-1-1 rod is as follows:

<u>Position</u>	<u>From</u>	<u>To</u>	<u>Mwd</u>	<u>Acc Mwd</u>
L-48	7-11-60	2-6-61	6,358	6,358
L-46	2-6-61	12-10-62	20,835	27,193

* The rod numbering system uses two digits to identify the beryllium section and the poison section. The first digit applies to the beryllium section and the second digit to the poison section. The prefix "BE" is used to indicate a beryllium rod as opposed to a fuel rod.

Bowing Measurement, MTR Beryllium Sections

Fig. 1

II. Beryllium Lattice Pieces (LB Pieces)

As a result of the bowing noted in the beryllium section of Rod BE-1, an investigation of additional beryllium lattice pieces (LB pieces) was begun.

Piece LB-15, one of the original MTR beryllium lattice pieces, was also discharged to the canal during the Cycle 184 shutdown. This particular piece had been selected, based on fast flux nvt, for destructive testing in connection with the beryllium damage study program. The actual selection had been made several years ago and only coincidence prompted that both the LB-15 piece and the beryllium shim rod be discharged at the Cycle 184 shutdown. The study program on beryllium damage due to irradiation, in part, concerns the threshold swelling temperature as a function of gas content. It has long been postulated that these factors could produce beryllium deformation. Samples obtained from the LB-15 piece are to be used for gas analyses and threshold swelling temperature tests being conducted by the MTR-ETR Chemistry Group.

Measurements were made on the LB-15 piece in the MTR canal and bowing was indicated. Again, as in the case of the shim rod, the bowing was directed toward the active lattice. During the latter part of the LB-15 lifetime there was no evidence of any binding on insertion into or removal from the lattice positions.

The LB-15 piece was sent to the MTR Hot Cell for sample preparation. This work involved sectioning the piece along the length of the beryllium block to obtain test samples. During the sectioning both longitudinal and transverse cracks were noted in the various sections as illustrated in Figs. 2 and 3. It is quite possible that the cracks observed were the result of stresses incurred during the cutting operation. Some credence is lent to the above assumption by dye penetrant test results conducted on Pieces LB-16 and LB-4X-3. In both cases, the dye penetrant tests indicated no surface cracking.

A number of other beryllium lattice pieces were sent to the MTR Canal for measurement. All indicated bowing to some extent, and always in the same direction; namely, toward the active lattice. Results of all LB piece

Fig. 2

LB-15 Side View - Cut $16 \frac{13}{16}$ in. Down From Upper End Box

Fig. 3

LB-15 End View - Cross Section $16 \frac{13}{16}$ in. Down From Upper End Box

measurements and their irradiation histories are shown in Tables I and II, respectively.

III. Permanent Beryllium Reflector Inspection.

Subsequent to finding evidence of bowing in certain MTR beryllium lattice sections, work was immediately initiated to extend the inspection program to critical high exposure areas of the permanent reflector. Accordingly, preliminary measurements were made and photographs taken during the Cycle 187 shutdown.

The MTR permanent beryllium reflector occupies a volume of approximately 50 cubic feet between the active lattice and the tank wall. The total height of the reflector is $39 \frac{3}{8}$ inches. It is assembled from a large number of individual pieces as illustrated by Fig. 4. The key pieces, E-1 through E-4, contain large holes throughout their length for passage of the regulating rods. They are mounted and held rigidly in position by the regulating rod bearing mount in the lower grid. The "A" pieces are fitted with end boxes which lock into the lower support casting. The remaining larger blocks are machined to fit into their respective positions and are otherwise not rigidly held. Fig. 5 is a photograph looking down into the assembled reflector (prior to installation in the reactor) with the view directed toward the north wall. Note the trapezoidal shaped "E" pieces, with Piece E-1 yet to be installed.

During Cycle 187 shutdown a special tool was fabricated to make vertical dimensional traverses between the north-south and east-west walls. Because bowing would probably be most severe in pieces extending the full length of the core, the north-south measurements were made between the full length "E" pieces. With the gauge set at a fixed dimension, the tool was lowered (or raised) until it touched on both walls and the approximate elevations noted. Dimensional traverses were made in this manner between Pieces E-1 and E-3, and E-2 and E-4. As illustrated by Fig. 6, the severest bowing

TABLE IMTR "LB" PIECE BOWING MEASUREMENTS

<u>Piece No.</u>	<u>A</u>	<u>B</u>	<u>C</u>
LB-4	0.014 in.	0.031 in.	0.016 in.
LB-8	0.065 in.	0.065 in.	0.070 in.
LB-9	0.030 in.	0.039 in.	0.035 in.
LB-13	0.045 in.	0.047 in.	0.019 in.
LB-14	0.040 in.	0.047 in.	0.046 in.
LB-15	0.060 in. 0.100 in.*	0.065 in. 0.100 in.*	0.057 in. 0.100 in.*
LB-16	0.039 in. 0.047 in.*	0.062 in. 0.063 in.*	0.047 in. 0.063 in.*
LB-4X-3	0.031 in.*	0.031 in.*	0.031 in.*

NOTE: Measurement location key is indicated in Fig. I.

* Measurements made in Hot Cell; all measurements only approximate.

TABLE IIMTR "LB" PIECE IRRADIATION HISTORIES

<u>Piece No.</u>	<u>Mwd</u>	<u>Fast Flux nvt</u>
LB-4	52,613	4.20×10^{21}
LB-8	80,896	7.71×10^{21}
LB-9	85,198	4.28×10^{21}
LB-13	79,795	1.93×10^{21}
LB-14	45,045	7.10×10^{21}
LB-15	77,300	10.23×10^{21}
LB-16	52,113	7.37×10^{21}
LB-4X-3	39,703	3.91×10^{21}

NOTE: The accumulated Mwd totals and the fast flux nvt are complete through the end of Cycle 183, December 10, 1962. The fast neutron (<1 Mev) exposures are based on midplane flux values.

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Fig. 4

Top View Layout - MTR Permanent Reflector

Fig. 5

Beryllium Reflector Assembly

Fig. 6

MTR Beryllium Reflector Measurements
Vertical Traverse, E-1 to E-3

MTR Beryllium Reflector Measurements
Vertical Traverse, E-2 to E-4

existed between pieces E-2 and E-4, and approximated 90 mils, wall to wall.

Measurements between the east-west walls will not be completed until a special tool can be fabricated.

Following these measurements, additional core components were discharged preparatory to making a mirror inspection of the reflector inner walls. For this inspection an 18 x 24 inch sheet of 16-gauge stainless steel was fastened onto an aluminum plate and lowered into the reactor tank. Inspection of the north wall showed significant evidence of spalling and cracking, primarily in the face of reflector Pieces F-2 and F-6* in the region of the HB-2 thimble. Fig. 7 is a composite of three reflected images showing the main portion of the north wall where damage was most evident. The flat circular inner faces of the HB-1, HB-2, and HB-3 thimbles (left to right) are easily identified. Several wrinkles in the stainless sheet have distorted the image and do not reflect actual damage.

Fig. 8 is a photograph of two beryllium pieces which were retrieved from the flash evaporator spray headers during the shutdown for Cycle 185. The shape of the larger piece makes it a prime suspect as a piece broken from the F-2 slab.

Inspection of the reflector east and west walls showed no evidence of damage. Inspection of the south wall similarly revealed no cracking or spalling as illustrated by Fig. 9.

* Piece F-6 is the piece which fits beneath F-2 and the HB-2 thimble.

Fig. 7

Composite Photograph of North Wall

Fig. 8

Beryllium Pieces Retrieved from Flash Evaporators

Fig. 9

Reflected Image of South Beryllium Wall

CONCLUSION

It would be premature and not the purpose of this report to postulate the exact cause or mechanism of failure which resulted in the observations herein described. Further investigations which will hopefully provide this information will be vigorously pursued. In the meantime, operation of the Reactor can continue under a rigorous surveillance program without undue risk. Substantial changes in the condition of the reflector will require reconsideration of operability of the MTR until such time as replacement beryllium sections can be procured and installed.

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