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INTERNAL GRAPHITE MODERATOR FORCES STUDY
SUPPLEMENTAL INFORMATION

By

D. E. Cooley
Reactor Design
DESIGN ENGINEERING
FACILITIES ENGINEERING SECTION

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INTERNAL GRAPHITE MODERATOR FORCES STUDY
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To: Distribution of HW-79120

Reference: HW-79120 - Internal Graphite Moderator Forces Study
C & K Reactors, D. E. Cooley dated 10-28-63

I. Comments Received on HW-79120

Of the comments received to date on the referenced document, two have mentioned the existence of forces other than those discussed in the document. The first of these inquiries as to the effect of forces imposed by tube blocks on VSR channel sleeves during such operations as broaching, tube removal and rupture removal. The second comment hypothesizes the existence of high forces in the region of the high temperature gradient just inside the reflector.

VSR channel enlargement, as presently conceived, will involve cutting into the majority of the tube blocks adjacent to the VSR channel. In some instances the curvature of the channel will be such that the enlargement reamer will not cut into certain tube blocks, but in the majority of cases any sleeve inserted into an enlarged channel will key the tube block to the surrounding filler blocks. In these latter cases, any force applied to a tube block sufficient to move the block enough to take up the clearance ($1/8"$) between the sleeve and the block, will load the sleeve.

The force required to move the tube block is that necessary to overcome the frictional resistance generated between the point of application of the force and the sleeve. In the worst instance this is zero (i.e. no trunnion blocks between the force and the sleeves). Since the tube blocks have contracted due to irradiation, the horizontal keys at the front and rear of the stack do not support a compressive load on the tube block column. The magnitude of the force which a sleeve loaded in this manner can withstand has not been determined, although tests with candidate sleeve designs and materials are planned. It has been estimated that a polycrystalline graphite sleeve loaded in this manner could withstand a force of at least 1500 pounds. Although this may be sufficient for many operations, the pushing of a stuck rupture or removal of a bulged tube may transmit higher forces to the sleeve. Under these conditions a sleeve of almost any design or material would be destroyed. This reaffirms the importance of ease of removal of any sleeves installed in a reactor.

The second comment hypothesizes that the temperature gradient between the hot central zone of the reactor and the cool fringe zone occurs within the mass of blocks represented by A in Figure 5 of the referenced document. Assuming this to be the case, the right hand side of mass A will rise and fall relative to the left side the full .878 inches as the reactor is cycled (see page 9 of HW-79120). Assuming mass A to be 11 layers high, this results in a horizontal motion ($3/4$ inch) at the top right hand corner of mass A. Graphite distortion data indicate that a mass height of 11 layers is a reasonable assumption. The temperature gradient is high in this region, although not quite as sharp as indicated by this assumption. Although the tube layers can be

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allocated in a discrete "mass A", the filler blocks of "mass A" extend into the reflector and into mass B. Assuming that mass A acts as hypothesized, the maximum force which can be brought to bear at the upper right corner of mass A is something between 4000 and 4500 pounds. The high strength polycrystalline sleeves presently being considered for installation in C and K Reactors are capable of withstanding forces of this magnitude in this loading.⁽¹⁾ The presence of the filler blocks connecting mass A with the reflector and with mass B will undoubtedly reduce this force to lower values in actual operation.

II. Sleeve Test Channel Inspection

The test sleeves installed in channel 28 at C Reactor were inspected during December 1963, four months after installation. All sleeves were in excellent condition with the exception of the second sleeve from the top of the channel. Two hairline cracks of unknown depth were seen in this sleeve, both about $1\frac{1}{2}$ inches long as shown in Figure 1. This particular sleeve is the only one which was left full length ($17\frac{3}{8}$ inches); the rest of them having been cut in half to permit their insertion past sharp channel curvatures.

A sharp discontinuity existed in the channel at the junction of the thermal shield and the graphite which caught every sleeve during installation. The sleeve and insertion tool had to be bounced and jiggled at this point in order to clear this junction. Cracks of the nature shown in Figure 1 could easily have been made at this point during installation. The nature and location of these cracks with respect to the stack layer interfaces is not that which would be expected if caused by high stack forces. In any event, there is little reason to believe that these cracks were caused by high internal stack forces and significant reason to believe that they could have occurred during installation. A second inspection of this test channel is scheduled for the next outage at C Reactor.

III. BDF Reactor Distortion

Since the issue of HW-79120 an inspection has been made of three VSR channels at B and D Reactors. Typical observed damage to the VSR liner blocks is shown in Figure 2. Analysis indicates that these fractures can be explained as being a likely consequence of the structure of the moderator in the immediate vicinity of the VSR channels and its distortion due to irradiation.

Figure 3 shows the layup pattern in the vicinity of the VSR liner blocks. The tube and filler layer blocks to which the liner blocks are keyed are parallel to each other. As originally constructed the clearance as represented by $L_1 - L_2$ in Figure 3 was $\frac{.080}{.000}$. As the reactor is brought up to operating temperatures, the $\frac{.080}{.000}$ filler blocks expand more than the tube blocks reducing the clearance to $\frac{.073}{-.007}$, resulting in a possible interference as high as .007 in. As irradiation proceeds, the tube blocks, being at lower temperature and in a higher fast neutron flux, contract at a faster rate than the filler blocks above and below further

(1) HW-79642 Summary Report Flexible VSR's and VSR Channel Sleeve Development Program, F. J. Kempf - 11-15-63.

reducing the clearance ($L_1 - L_2$). Inasmuch as the distance between keys is about 7-3/8 inches, a divergence of distortion between the tube and filler blocks of 1% would consume the maximum clearance provided at original construction.

W. C. Morgan of Graphite Research and Development, Hanford Laboratories indicates there is every reason to believe that this divergence has been attained if not exceeded by this time. The history of the exposure and temperature experienced within these reactors is so complex and varied that it would be virtually impossible to calculate at what point in time this clearance is consumed. As the clearance ($L_1 - L_2$) is consumed the keys are loaded as the alternate tube and filler blocks try to move the keys one way or the other loading the liner blocks as shown in Figure 4. This prying action can cause the failures observed in the liner blocks shown in Figure 2. The forces required to cause these failures have been calculated and are shown in Figure 4.

The manner of loading described above can occur in 86 1/2% of the cases where a VSR channel intersects a tube layer. Between tube rows 11 and 36 in the central near-far row of VSR channels, the remaining 13 1/2% of the cases, the tube blocks are arranged in such a manner that a junction of tube blocks occurs between VSR liner block keys. The tube blocks are contracting faster than the filler blocks and create a tension force between VSR liner block keys. When the junction is situated between VSR liner keys, this tension cannot be supported, so the keys, and therefore the liner blocks, cannot be loaded in the manner described above.

The fact that this manner of liner block loading is peculiar to the B, D, and F Reactor VSR channel design indicates that it will not occur at any reactor not of this same design. Therefore there is no reason to believe that the VSR channel sleeves installed in the C and K Reactors will be subjected to the same forces which broke the liner blocks at B, D and F Reactors.

Acknowledgement

We gratefully acknowledge the comments received on HW-79130 and are willing to discuss any further questions on HW-79120 or the above.

D. E. Cooley

Reactor Design

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FIGURE 1

DAMAGE TO VSR SLEEVE IN
CHANNEL 28 AT C REACTOR

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OBSERVED DAMAGE :

1 (FULL LENGTH)

2 (FULL LENGTH)

1 & 3

2 & 3

4 (?)

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FIGURE 2

DAMAGE TO VSR LINER BLOCKS, B AND D REACTORS

FIGURE 3
TYPICAL LOCAL VSR CHANNEL MODERATOR
LAYUP, B,D,F REACTORS

VIEW B-B

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FORCES APPLIED ON
THESE SURFACES.

Method of
Breakage
(See Fig. 2)

1

2

1 & 3

2 & 3

4

LOAD REQUIRED

One Key

Equal Forces on
Both Keys

$F = 225 \text{ lb/in}$

$F = 190 \text{ lb/in}$

$F = 240 \text{ lb/in}$

Not applicable

$F = 225 \text{ lb/in} +$
Moment = 10,000 in.lb.

$F = 190 \text{ lb/in} +$
Moment = 10,000 in.lb.

$F = 240 \text{ lb/in} +$
Moment = 10,000 in.lb.

Not applicable

Moment = 17,000 in.lb. Moment - 17,000 in.lb.

FIGURE 4

FORCES APPLIED BY VSR KEYS TO VSR LINER BLOCKS

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