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INTERIM REPORT PRODUCTION TEST IP-98-I (1)(2) REVISED TUBE CHARGE PATTERN FOR GRAPHITE ANNEALING

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INTERIM REPORT
PRODUCTION TEST IP-98-I(1)(2)
REVISED TUBE CHARGE PATTERN FOR
GRAPHITE ANNEALING

INTRODUCTION

Graphite distortion or growth at F Reactor has been cause for concern for several years. By June 1957, it appeared that charging the majority of tubes in the top-far region with four-inch metal would be required if graphite growth continued. The maximum distortion occurred at a location ten feet from the front Van Stone flange with up to 2.0 inches deviation from the normal tube channel center line observed from vertical traverse data on tube 4676-F. As an approach to the solution of the graphite distortion problem, the subject Production Test authorized skewing the neutron flux to the front of the reactor by the addition of two fuel

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elements to the upstream end of the metal column and favoring the use of downstream rods during equilibrium operation. It was believed that shifting the heat and flux to the front of the reactor would result in sufficient graphite annealing or shrinkage to alleviate the problem. Because of a similar problem at B Reactor, a production test⁽³⁾ authorizing the use of a 33 piece charge displaced to the front of the reactor (with one additional downstream dummy) was issued.

SUMMARY

Graphite shrinkage of 0.60 inches (approximately 30 per cent) has been observed at F Reactor in the region of maximum graphite distortion. A reduction of graphite distortion at B Reactor of 0.60 inches in the top-center and 0.32 inches in the top-far region also has been observed.

Analysis of the vertical traverse data indicates that continued graphite annealing with resultant decrease in graphite distortion might be anticipated although perhaps at a reduced rate. No significant detrimental effects have been observed from operation with either the increased charge length or the flux slightly skewed to the front of the reactor. Operation with severe flux skewing resulted in detrimental control effects.

It is recommended that operation with the flux skewed to the front of B and F Reactors through the use of a longer charge (centered slightly upstream of the graphite centerline) be continued subject to periodic review.

DISCUSSION AND RESULTS

F Reactor

Graphite distortion at F Reactor reached the point by June, 1957, that it appeared that the majority of tubes in the top-far region would require charging with four-inch metal unless the graphite growth trend could be curtailed. It appeared feasible to anneal the graphite in the distorted region by skewing the flux to the front of the reactor. Production Test IP-98-I⁽¹⁾ outlined a program for displacing the normal metal column two slug lengths to the front. This was accomplished by revising the normal charge length from 32 to 33 pieces and adding one additional dummy to the normal dummy train make-up. It was later decided, because of apparent production gains⁽⁴⁾, to substitute a heavy metal piece for the extra dummy; thus resulting in a 34 piece charge⁽²⁾.

A significant reduction in graphite stack distortion in the front region of F Reactor has occurred since the inception of the longer charge length and the use of downstream control rods to skew the flux to the front of the pile. As determined by vertical traverse data, illustrated in figure 1, a total shrinkage of 0.6 inches has occurred in the past year. It should be noted that the maximum shrinkage rate occurred between September and December, 1957, when the downstream rods were favored during equilibrium operation. From January, 1957, to date, a normal rod configuration has been used and the rate of graphite shrinkage appears to be about 0.43 inches per year. The vertical traverse results are confirmed by tube probing data. Although tube probe measurements are inexact, there has been a definite trend to the acceptance of longer probes than was possible prior to the initiation of the production test. If the present trend continues there will be virtually no further requirement for four-inch metal.

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The following factors are discussed briefly as they are affected by the increased charge length and skewed flux distribution.

(1) Reactivity Effects

The addition of two fuel elements to the front of the normal metal column at F Reactor was originally limited to the bottom 38 tube rows because of tube bowing in the top section of the pile. Based on cold, clean reactivity calculations with the first 38 tube rows charged with 34 pieces, a reactivity gain of approximately 50 I.h. was observed. This is in good agreement with initial reactivity gain estimates. (2)

(2) Control Effects

This production test initially recommended favoring the use of downstream rods to skew the neutron flux to the front of the reactor more radically than could be provided by the 34 piece charge length alone. The practice of favoring downstream rods was maintained for approximately three months, from October through December, 1957. Control problems were significant during this period because of the resultant extreme flux skewing depicted by flux traverse data shown in figures 4 and 5. This was accomplished by using number four control instead of number five rod during equilibrium operation. Rather severe graphite temperature cycles were experienced due to over compensation with the control rods; i.e., individual control rod strength changed materially. Start-up prediction errors were increased due to the new and more complex flux distribution which rendered existing calibrations inaccurate. Poison calibrations were also found to be inaccurate.

In January, 1958, it was decided to return to the normal equilibrium control rod configuration; i.e., to the use of number five rod for equilibrium control. In addition, the downstream dummy train in poison tubes was lengthened to place the poison pieces in a more favorable control position. As a result of this change, the flux was still skewed to the front of the reactor as shown in figures 6 and 7, but not to the extreme previously observed from rod manipulations. The resultant flux profile attributed almost entirely to the non-centered 34 piece charge length has not resulted in any significant control problems.

(3) Shield Deterioration

Front face shield deterioration with the increased charge length is not expected to increase sufficiently to warrant concern. (4)

(4) Radiation Leakage

Some increase in front face radiation has been observed during operation. It is estimated that both gamma and neutron levels increased approximately 40 to 60 per cent (or from 15 to 25 MR/hr.) over previous levels. It is also estimated that the dry unshielded tube beam intensities during reactor outage have increased two-fold over previous levels. There has been, however, no significant increase in front face radiation levels during shutdown and correspondingly no increase in total exposure requirements for front face

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outage work. Extraneous factors (gas leaks, power level increases, etc.) have prevented quantitative determination of the effects of increased charge length on radiation levels.

(5) Rupture Relationships

Initial studies⁽⁵⁾ of rupture relationships with the increased charge length indicated that the rupture rate would decrease with the longer charge length if tube power was held constant. This study neglected the effect of increased temperatures from a decrease in coolant flow with additional in-tube resistance. Recent studies⁽⁶⁾ indicate that outlet temperature has a significant effect on rupture rate which should be factored into any program requiring a reduction in coolant flow. The gains predicted in the referenced document appear to have been too optimistic and a new study taking the temperature effect into consideration would be required to define the theoretical effect of increased charge length on rupture rates. However, the nominal actual rupture experience at F Reactor during the past year would seemingly indicate little, if any, adverse effect on rupture rate through use of the longer length charge.

(6) Graphite Temperatures

Graphite temperature measurements were taken periodically throughout the production test. Though the data is far from being complete, the following graphite stringer temperatures are included below as a matter of interest. In each case, the indicated temperature is an average temperature for the period measured at a location 10 feet toward the front from the center line of the graphite stack or approximately within one foot of the point of maximum distortion. The period July and August, 1957, was prior to the start of the production test; October-December, 1958, the downstream control rods were favored; and January to August, 1958, represent the period where normal control rod positions were used.

<u>Stringer Number</u>	<u>Graphite Stringer Temperature, °C</u>		
	<u>July-August, 1957</u>	<u>Oct.-Dec., 1957</u>	<u>Jan.-Aug., 1958</u>
1284	357	404	396
3466	380	427	405
3484	376	434	414
3773	370	440	411

B REACTOR

A revised charge of 33 fuel elements per tube was used at B Reactor from January, 1958 until September, 1958, when loading of 34 piece I & E columns was initiated. Vertical traverse evidence shows that an improvement similar to that noted at F Reactor result

The standard 32 piece loading was replaced by 33 pieces and an additional eight-inch piece was added to the downstream dummy pattern. The front of the normal slug column was displaced 16 inches toward the front.

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Downstream rods were favored in an attempt to shift the flux peak toward the front of the reactor. The results of flux traverses taken late in June of 1958 showed some peaking above the normal cosine curve, and slightly upstream of center. A change from number four control rod to number five control rod was thought advisable from rupture control considerations. In spite of this however, subsequent flux traverses have shown that the maximum flux occurs upstream of center.

Test Results

1. The charge displacement was virtually complete by July of 1958. No significant improvement was noted in the vertical traverse data on the top center and far sides taken during the transition period. A slight improvement was indicated in the top-near, however.
2. Traverses taken in August of 1958 (see figures 8, 9, and 10) have shown a reduction in graphite distortion of 0.6 inches in the top-center, and 0.32 inches in the top-far.
3. It was necessary to charge eight partial-to-full length columns of four-inch metal during the transition period. No four-inch metal has been charged since the new loading was complete.
4. No significant increases in radiation leakage out the front face have been noted; although the high gas activity on the front virtually precludes an accurate measurement of radiation levels.
5. The rupture rate has been twice the expected value throughout the test period. Flux traverses taken during the report period have been very similar to those at F Reactor, which has had a low rupture rate. It appears reasonable to believe that factors other than the increased charge length have contributed to the higher rupture rate at B Reactor.

RECOMMENDATIONS

The following recommendations are made based on one year's experience at F Reactor with the flux skewed to the front of the pile through the use of a long charge length and control rod manipulation.

1. That the use of the longer charge length (centered slightly upstream of the center line of the graphite stack) be continued at F and B Reactors as long as there is continuing evidence of graphite shrinkage and annealing in the front region of the graphite stack, and providing no unforeseen detrimental effects occur.
2. A review of the graphite annealing program be made at such time as it appears that the increased charge length may adversely effect such power level limits, as TOA corrosion, bulk outlet, or rupture control limit.

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3. That continuation of this program be based on parameters and requirements outlined in the Process Standards and that operation on a production test basis be officially terminated.

Process Engineering Operation
Research and Engineering Operat
IRRADIATION PROCESSING DEPARTMENT

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- (1) HW-51341, Production Test IP-98-I, "Revised Tube Charge Pattern for Graphite Annealing," S. M. Graves, July 12, 1957.
- (2) HW-52893, Supplement A to Production Test IP-98-I, "Revised Tube Charge Pattern for Graphite Annealing," A. Russell, October 3, 1957.
- (3) HW-54215, Supplement B to Production Test IP-98-I, "Revised Tube Charge Pattern for Graphite Annealing," R. E. Gott.
- (4) HW-51165, "F Charge Displacement for Graphite Annealing," G. C. Fullmer.
- (5) "Effects of Varying Solid Slug Charge Length at CG-558 Reactors," P. C. Walkup, S. M. Graves, January 21, 1958.
- (6) HW-55377, "Analyses and Correlations of HAP0 Rupture Experience with Natural Uranium Material," R. R. Bloomstrand, W. I. Neef, April 23, 1958.

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FIGURE 1
VERTICAL TRAVERSE - 4676-F
F-REACTOR

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FIGURE 2
TUBE 1568, BEFORE DISPLACEMENT PROGRAM
F-REACTOR
JULY 1957

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FIGURE 3
TUBE 2773, DISPLACEMENT 70% COMPLETED
F-REACTOR
SEPT. 1957

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FIGURE 4
TUBE 3268, PROGRAM COMPLETE
FLUX SKEWING INCREASED BY CONTROL ROD MANIPULATION
F-REACTOR
NOV. 1957

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FIGURE 5
TUBE 2167, DISPLACEMENT PROGRAM COMPLETED
FLUX SKEWING INCREASED BY CONTROL ROD MANIPULATION
F-REACTOR
NOV. 1957

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FIGURE 6
TUBE 1185, DISPLACEMENT PROGRAM COMPLETED
CENTRAL ROD CONFIGURATION NORMAL
JUNE 1958

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FIGURE 7
TUBE 2867, DISPLACEMENT PROGRAM COMPLETED
CENTRAL ROD CONFIGURATION NORMAL
F-REACTOR
AUG. 1958

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FIGURE 8
TUBE TRAVERSE
B - REACTOR
TUBE 4454

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