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REVIEW OF FEASIBILITY OF HIGH TEMPERATURE
FULL PILE GRAPHITE BURNOUT TEST

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January 5, 1955

TO: L. P. Bupp

FROM: D. H. Curtiss *DHC*

REVIEW OF FEASIBILITY OF HIGH
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REVIEW OF FEASIBILITY OF HIGH
TEMPERATURE FULL PILE GRAPHITE BURNOUT TEST

INTRODUCTION

The program of the Pile Graphite Studies Unit over the past two years has been directed toward relaxed graphite specifications. The ultimate goal of these studies was to insure that the heat generation in the graphite moderator associated with tube powers of 1000-1200 KW attainable after Project CG-558 could be dissipated without deleterious effects to the graphite. The philosophy of this program has been to develop laboratory or single tube in-pile experiments which would yield sufficient data to provide a basis for full pile tests of relaxed graphite specifications. The main emphasis in these studies has been on the feasibility of higher permissible maximum graphite temperatures and higher percentages of helium in the gas system. The success of this program is evidenced by the potential pile power levels permitted by present process specifications.

The present graphite Process Specifications will not permit heat generation associated with tube powers above 800 KW at B, D, and F Piles. Therefore, further relaxation is necessary if tube powers of 1000-1200 KW anticipated after completion of the water plant expansion program are to be realized.

It is anticipated that maximum graphite temperatures and pile gas composition required for the heat generation associated with a tube power of 1200 KW will be in the range summarized in the following table:

If helium is limited to (%)	Maximum Graphite Temperature will be (°C)
60	650
70	635
80	620
90	600
100	580

These relations are obtained from a revision to Fletcher's document, HW-31125, "Graphite Temperature Predictions".

In extending the present program to permit these anticipated tube powers, production tests authorizing full pile tests for raising permissible maximum graphite temperatures and increasing the percentage of helium are necessary. A production test authorizing the operation of D Pile at sufficient constant power level to attain graphite temperatures of 460-500 C with 60 ± 5 per cent helium has been agreed upon and is now circulating for final approval. A production test has been prepared to evaluate graphite burnout rates at maximum temperature of 600 C with localized regions of up to 680 C. It was originally proposed to do this test at H Pile but was subsequently shifted to C Pile in view of the delay in removing the thimbles. Considerable discussion has evolved over the feasibility of such a test at C Pile. The following is a review of the pertinent points concerning the feasibility of this test.

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RECOMMENDATIONS

Based on information developed in the following sections, it is the recommendation of Pile Graphite Unit that a full pile graphite burnout test be conducted at C Pile as soon as possible to investigate (1) high temperature burnout at 600-680 C, (2) effect of increased neutron temperature on the concentration of Pu^{240} in the low exposure metal.

DISCUSSION

Justification of the Test

The basis for process specifications, actual specifications and proposed revision to specifications as well as potential power levels of all piles has been extensively reviewed in HW-33842. In order to meet these proposed levels, the need of higher maximum graphite temperature is self evident. The data, summarized Table I, indicate the potential maximum temperature that would be required if the helium concentration in the pile gas is limited on the basis of pile distortion. On the basis of present knowledge, it is unlikely that helium concentrations above 60 per cent would be permissible for maximum temperature of 500 C. It is doubtful that tube powers above 850 KW would be permissible under these gas and temperature limits. Under these values (60 per cent helium, 500 C maximum temperature), and assuming that permissible maximum graphite temperature would not be raised until a full pile test was accomplished at H Pile after CG-558, calculations indicate that a production loss equivalent to about 4 million dollars would be incurred based on \$10/MWD. If some relaxation in temperature was permitted by a full pile test at a lower temperature (CA-550C), this loss would be decreased by approximately a factor of 2.

If it is assumed that after a successful test at H Pile during the winter of 1955-1956, maximum temperatures could be relaxed to 580 C, the estimated production loss which would occur only at H Pile during 1955 would be equivalent to \$250,000.

If it is assumed that the test is successfully completed at C Pile by April or May, 1955, and that maximum graphite temperature was raised to 600 C, there would be no production loss as a direct result of graphite limits at any pile based on present power level estimates.

In addition to the production gains possible as a result of increased maximum graphite temperature, an experimental investigation of the effect of neutron temperature on product purity is essential to evaluate future operation conditions. Firm commitments of low exposure material have been made for FY 1955 and tentative commitments have been made for FY 1956. Since the metal costs, metal supply, separations capacity, production level, and product purity are interrelated, factors influencing product purity must be thoroughly evaluated if optimum operating conditions are to be attained. Operation of C Pile at the proposed 100 °C increase in neutron temperature would lead to a 13 per cent increase in the ngs count if theoretical calculations are valid. By reducing the exposure level from 210 to 200 MWD/T it is believed that product purity can be maintained within specifications. Evaluation of the ngs data from metal exposed during the period of the test should provide conclusions as to the effect of neutron temperature on product purity, which would be of fundamental importance to future programming.

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Desired Test Conditions

The desired test conditions for high temperature burnout test are:

1. Graphite temperature - a maximum graphite temperature of 600 C is desired with localized exceptions immediately adjacent to J-Q or J-N tubes where temperature may be as high as 630 C and in the center of a 13 tube J-Q diamond array where the temperature may be as high as 680 C. There should be a sufficient number of reliable thermocouples available to give a good overall temperature distribution. The temperature distribution should be held as uniform as operationally feasible.
2. Facilities should be available for the exposure of full sized graphite bars. These bars would be used as samples to give data on burnout as well as demensional stability at these high temperatures.
3. Pile should be capable of running at a reasonably constant power level and gas composition and therefore a constant graphite temperature for a period of four to five months so that sufficient reliable data can be obtained to evaluate the test conditions.
4. In order to evaluate the effect of increased reaction temperature on product purity, it is necessary to have a large backlog of data on product purity as a function of pile condition.

Potential Area

The attached graphs indicate the potential power level for B, D, F, DR, and H Piles for various graphite conditions, bulk and outlet water temperature limits, and rupture limits. From these graphs, it is obvious that of these piles only H Pile might attain test conditions during the winter of 1955-1956.

The power level at C Pile is presently limited by lack of reactivity. Maximum graphite temperatures, except adjacent to J-Q tubes, is 500 C with 40 ± 5 per cent helium. Test conditions could be obtained here by simply removing the helium and letting temperatures rise.

It would be possible to attain test conditions at KW or KE Pile if current estimates of power level, temperature distributions, and gas composition are correct. However, in view of the number of uncertainties in the planned operation of K Piles, it is very questionable as to the wisdom of planning on using either of these piles.

Choice of Area

Each of the potential areas has some disadvantages. These will be discussed individually.

Because of the delayed thimble removal and rod conversion, it is not possible to do the high temperature test at H Pile before winter of 1955-1956. If H Pile is converted to a whole or partial low g/t program, then arguments concerning product purity vs graphite temperatures would apply. Latest information from

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Manufacturing Department indicates that H is definitely committed to low g/t program but how much and for how long has not yet been decided.

In view of all considerations, it is my opinion that C Pile is the logical choice of areas. Operation is more or less currently stabilized. Graphite temperature monitoring and distribution is good. With added reactivity, nuclear control would be good and thus a stable temperature distribution could be maintained. The increase in temperature, with the test, would be equivalent to 125 ih or a decrease in required enrichment equivalent to approximately \$100,000.

The disadvantage of the use of C Pile is the cost of an increased through put of metal caused by the reduction of goal exposure. Such a reduction would be based on a theoretical calculation of the concentration of Pu^{240} as a function of neutron temperature where the calculations are based on the variation of neutron capture cross section of Pu as a function of neutron temperature. It is the general opinion of all physicists contacted that this neutron temperature effect is real, but of an unknown magnitude. The neutron counts obtained on Pu buttons are understandably scattered since they reflect the spread of total exposure in any given batch and chemical purity (concentration of light elements such as magnesium undergoing alpha-n reactions) as well as any neutron temperature effect.

The theoretical calculations predict that for a 100 C rise in neutron temperature associated with the increase in maximum graphite temperature to 600, a 13 per cent reduction in goal exposure would be necessary to maintain some ngs counts. However, it is generally believed that this is a pessimistic calculation. The present goal exposure is 21.0 MWD/. The optimum exposure is not clear cut since the ngs data are so scattered and there is some possibility of relaxation of the specifications to read 20 ± 1 rather than 20.0 ngs counts. In addition to these unknowns, the picture is further confused by the recent data obtained on exposure of 20 tons of metal to 220 MWD/T. The initial counts on a button of this product was 20.3 ngs. Upon subsequent repurification this dropped to 19.9 ngs indicating a large percentage of the ngs was not Pu^{240} but light metals undergoing alpha-n reactions. In view of all these uncertainties, it is the best opinion of Pile Physics Sub-Unit that a goal exposure of 200 MWD/T would maintain product purity within specifications under the high temperature test conditions. Such a goal exposure would result in a real increase in through put of approximately 37.5 tons of metal over the five month period of the test. At a cost of \$4.80/lb. this would amount to a total metal cost of \$360,000. Subtracting the savings in decreased enrichment requirements of \$100,000, the net cost of the production test run at C Pile is \$260,000.

Based on present estimates of initial operation of KW and KE, it would be possible to attain the desired 600 C maximum graphite temperature at these piles. Likewise, the piles are equipped with adequate temperature monitoring instrumentation and test hole facilities for the exposure of full sized bars. However, a number of uncertainties exist concerning the operation of K Piles and the applicability of the data that would be obtained. It is planned that the initial operation of KW would be limited to an arbitrary 1500 MW. With operating experience this would be raised to approximately 2000 MW in about 3 months. All other limits permitting, maximum level during the first year's operation would be limited to 2600 MW by slug corrosion (outlet temperature 98 C) and exposure levels (600 MWD). Thus for the period of the test a continuous change of gas composition would be necessary in order to maintain a reasonably constant temperature. If improved water quality and metal quality were obtained, power levels could rise substantially

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above 2600 MW. This would further complicate the gas picture. It therefore appears that planning on the use of K Piles for the site of a high temperature graphite burnout is not desirable.

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