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PRODUCTION TEST PTA-002INCREASED GRAPHITE TEMPERATURE LIMIT -
B, C AND D REACTORS

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PRODUCTION TEST PTA-002
INCREASED GRAPHITE TEMPERATURE LIMIT - B, C AND D REACTORS

I. OBJECTIVE

The fundamental objective of the graphite temperature limit is to prevent excessive oxidation of the graphite moderator blocks with carbon dioxide and water vapor in the reactor atmosphere. Laboratory tests have shown that ten per cent uniform oxidation of graphite results in a loss in strength of approximately 50 per cent.¹ This value of a strength loss of 50 per cent has been arbitrarily established as the limit to graphite oxidation over the lifetime of the reactor stack. This limit has been further arbitrarily interpreted as an oxidation rate of not more than two per cent per thousand days of reactor operation. At this rate limit, the reactor stack could be operated for 15-20 years before the graphite strength was reduced 50 per cent.²

As with any chemical reaction, the rate of reaction of graphite with oxygen, carbon dioxide, and water vapor increases with increasing temperature. While all three oxidants are present to some degree in the reactor gas system, the reaction between graphite and oxygen at the present temperatures is so rapid that all practical precautions must be taken to exclude it from the gas system. In addition, reaction with water vapor is sufficiently low at present temperatures and concentrations that it does not significantly contribute to the over-all stack oxidation. The graphite temperature limits presently in effect at the smaller reactors were therefore primarily established to hold the reaction rate between graphite and carbon dioxide to not more than two per cent per thousand operating days.

Production Test IP-7253,⁴ was conducted at F Reactor for a period of six months at graphite temperatures approximately 50 and 100 C higher than the present graphite temperature limit of 650 C. The results from the F Reactor test suggest that an increase in the graphite temperature limit from 650 C to 700 C is technically feasible from the standpoint of oxidation of the graphite moderator with CO₂. Any significant additional increase was shown to lead to excessively high oxidation rates and is therefore not considered feasible.

The objective of this test, therefore, is to extend the higher temperature investigations to B, C, and D Reactors. For the duration of this test, the graphite temperature limit will be increased from 650 C to 700 C, corresponding to an increase in the graphite stringer temperature limit from 735 C to 790 C.

II. BASIS AND JUSTIFICATION

The current Process Standards graphite temperature limit of 650 C is based on extrapolations of laboratory and in-reactor tests at conditions which differ from those which currently exist in reactor. To investigate the effects of higher temperature operation on oxidation rates, the graphite temperature limit was increased at F Reactor first to 700 C, then to 750 C.

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Analysis of the F test results⁵ indicated that up to a temperature of 650-700 C the reaction between graphite and CO₂ is controlled primarily by a radiation induced reaction rather than by graphite temperature and thus to date has been the principle cause of stack oxidation with CO₂. Above this temperature, however, oxidation proceeds exponentially with increasing temperature. An increase in temperature of ~50 C increased the F stack oxidation rate with CO₂ by less than a factor of two and was still within the currently accepted criteria of limiting stack oxidation to not more than two per cent per thousand operating days (2%/KOD). The F Reactor test also demonstrated that continued operation at a graphite temperature ~100 C higher than the present 650 C limit is not feasible because of excessive oxidation rates. Thus, the successful operation of F Reactor at a graphite temperature limit of 700 C is believed sufficient basis to extend testing at this temperature to B, C, and D Reactors.

While the primary incentive for increasing the temperature limit at F Reactor was to determine the upper temperature limit compatible with a He-CO₂ atmosphere, the incentive for increasing temperature at B, C, and D Reactors is to reduce helium loss. The initial temperature increase of 50 C at F was accomplished by reducing the helium concentration ~25 per cent and resulted in a reduction in helium loss by a factor of about two. Similar helium savings are expected at B, C, and D. It should be noted that while a 50 C increase in temperature appears technically feasible for continued operation from the standpoint of stack oxidation, the economics of reduced helium loss at the expense of the higher metal throughput which will be necessary to maintain the Pu-240 concentration within the current product specification have not yet been defined. Thus, while increased temperature appears technically feasible, it may not necessarily be economically justified. Economic studies are presently in progress to determine the optimum graphite temperature increase.

III. TEST DETAILS

A. Procedure

Upon approval of this production test, the graphite temperature limit at B, C, and D Reactors will be increased from 650 C to 700 C, corresponding to an increase in the graphite stringer temperature limit from 735 C to 790 C. It is estimated that this can be accomplished by a reduction in helium percentage in the order of 25 per cent. Throughout the test period the reactor gas composition will be monitored by Process and Reactor Development Subsection to ensure that the increased oxidation rate is comparable to that observed in a similar test at F Reactor. In addition to the increased graphite oxidation with CO₂ the higher graphite temperatures will also increase the reaction rate between graphite and water vapor. So long as all water entering the stack enters in the inlet gas stream, oxidation will essentially be spread over the entire reactor block and can be effectively monitored by the gas composition and the oxidation monitor samples. Localized leaks, such as rear Van Stone leaks or small tube leaks, however, may result in relatively higher local oxidation rates, depending upon

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whether the steam contacts an appreciable portion of the hot graphite or is simply swept into the rear plenum. The presence of these types of leaks is difficult to detect by gas composition analysis because the reaction products of CO and H₂ are so greatly diluted in the bulk volume of the gas system. It will, therefore, be necessary to examine leaks on an individual basis during the test to judge whether or not excessively high local oxidation could be occurring and whether graphite temperatures should be lowered until the leak is corrected.

B. Instrumentation

1. Burnout Monitor Samples

Two process tube channels will be needed in each reactor for burnout monitoring samples. Two channels are currently available at C Reactor and will be sufficient for monitoring purposes. One additional channel will be needed at B and D Reactors and should be located within the central zone, preferably near the reactor center. Channels presently containing monitor samples (3461B, 1889C, 1960C and 3478D) should be recharged as soon as practical following test approval. During the test, samples will be charged out when it is believed that sufficient oxidation has occurred to permit meaningful measurements. On the basis of the test at F Reactor, this is anticipated to be at intervals of approximately every three months.

2. Chromatograph

Reactor gas composition is continuously recorded in the control room by the gas chromatograph. Of primary interest during the test period will be the concentration of CO in the gas system, therefore, this component should be read as accurately as possible. Calibration of the chromatograph to read five per cent CO at full scale during normal operation should provide the desired accuracy.

IV. PROCESS STANDARDS

- A. Process Standards No. C-040, Section 40.01 which allows a 65 C extension to the stringer temperature limit for a period of seven days following a cold startup is waived for the duration of this test as any prolonged operation above ~800 C will result in excessive oxidation rates. The stringer temperature limit of 790 C may, however, be exceeded by 25° for a period up to 24 hours if a temperature cycle develops or if the reactivity status is such that power cuts, splining, helium addition, etc., would cause a reactor shutdown. It is not intended that continuous in-and out-of-limit operation be permitted by this flexibility proviso. The reactor should not be operated with a stringer temperature above 850 C for any period.

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- B. Process Standards No. C-040, Section 40.02, and Process Standards No. B-010, Section 10.03, requirements of permissible water vapor content after seven days following a cold startup are changed as follows:

Graphite Stringer Temperature Below 790 C - Normally maintain inlet dew point below -5 F. Shut reactor down within 30 minutes if the inlet dew point cannot be maintained below inlet water temperature.

Graphite Stringer Temperature Above 790 C - Shut reactor down if inlet dew points exceeds -5 F or exit dew point exceed +35 F for more than eight hours.

- C. Process Standard No. B-010, Section 10.03, which requires shutdown if the inlet dew point cannot be maintained below the inlet water temperature within the first seven days after a cold startup will remain in effect during the test period.

V. BIOLOGICAL SHIELD TEMPERATURE

The reduction in helium percentage is expected to increase the biological shield temperature by 20-30 C. Since shield temperatures at B and D Reactors are presently only ~30 C below the Process Standards limit of 160 C, shield temperature, rather than graphite temperature, may limit the amount of helium reduction. No increase in the shield temperature limit beyond 160 C is authorized for this test, however, since during the high temperature testing at F Reactor, the odor of decomposing masonite was distinctly evident when shield temperatures exceeded 160 C, indicating relatively rapid shield deterioration. Measurements of the neutron leakage rate through the far side biological shields are made routinely by gold foil activation at B and D Reactors. These data, which are normally taken three times per week, may be insufficient to adequately determine changes in the neutron leakage rate for the duration of the test. Therefore, it will be necessary that both neutron and gamma dose rates be measured at the surface of the far side biological shield on the same frequency as the gold foil measurements. The dose rate measurements should also be made at C Reactor. For purposes of evaluating shield deterioration as a function of shield temperature, it is necessary that data sheets 11 and 13 (B and D Reactors - see HW-82246) for biological shield temperatures be filled in three times each week. In addition, Design Change 942 - Revision 1, "Biological Shield Temperature Monitoring - C Reactor," ³⁴⁵⁴ should be completed before graphite temperature increases are made at C Reactor.

VI. GOAL EXPOSURE

The increased graphite temperature will necessitate a reduction in goal exposure to maintain Pu-240 content within the present product specifications. A reduction in average discharge goal exposure of four per cent is recommended for the duration of the test.^{6,7}

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VII. HAZARDS

Graphite temperature is considered to be one of the parameters in the deterioration of the present horizontal control rods. While the temperature effect has not been quantified, it is not expected that a 50 C increase in graphite temperature for the relatively short test period will substantially shorten the remaining useful life of the existing horizontal control rods. HCR deterioration has been occurring even at present operating conditions, and although it is possible that some additional HCR binding may result from the test, it is unlikely that this could be distinguished from the deterioration which would otherwise be expected from operation at present conditions. In any event, any acceleration in rod deterioration would be sufficiently small that no gross failure of the HCR system would be expected.⁸

VIII. LIMITS

The various temperature and gas system limits for this test are summarized as follows:

- A. Graphite Temperature Limit - 700 C in graphite filler blocks (corresponds to 790 C on front-to-rear thermocouple stringers).
- B. Over-Limit Provision - Limit of 790 C may be exceeded by 25 C for up to 24 hours. No special limit extension following startup.
- C. Biological Shield Temperature Limit - 160 C.
- D. Normal Nitrogen Limit - .1%.
- E. Normal Oxygen Limit - .02%.
- F. Startup Oxygen Limit - normal Process Standards requirement.
- G. Dew Point During First Seven Days after Cold Startup - normal Process Standards requirement.
- H. Dew Point After Seven Days Following Cold Startup -
 - 1. Graphite Stringer Temperature Below 790 C - Shut reactor down within 30 minutes if inlet dewpoint cannot be maintained below inlet water temperature.
 - 2. Graphite Stringer Temperature Above 790 C - Shut reactor down if inlet dewpoint exceeds -5 F or exit dew point exceeds +35 F for more than eight hours.

IX. TEST DURATION

This test is expected to last approximately six months but may be terminated early at any or all reactors:

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- A. If the generation of CO (as indicated by the CO concentration in the gas system and the total gas loss rate) indicates that oxidation is proceeding at an unacceptable rate.
- B. If biological shield temperatures cannot be maintained below 160 C.
- C. Upon mutual concurrence of the Managers of B, C, or D Processing Operation, Process and Reactor Development Operation and Process Technology Operation.

A Russell

A. Russell, Senior Engineer
Process and Reactor Development
Research and Engineering

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IX. RESPONSIBILITIESA. Manufacturing Section

1. B Reactor Operation, C Reactor Operation, and D Reactor Operation will be responsible for:
 - a. Providing sufficient outage time for change out of oxidation monitoring samples.
 - b. Operation within the current Process Standards Limits except those specifically exempted by this production test.
 - c. Taking biological shield data specified in Section V.

APPROVED: *W. Palan*APPROVED: *J. J. Baker*APPROVED: *E. J. Filip*B. Research and Engineering Section

1. Process and Reactor Development Subsection will be responsible for:
 - a. Evaluation and interpretation of oxidation sample results.
 - b. Interpretation of reactor gas composition during the test to ensure that termination of the test, if necessary, can be initiated if excessive oxidation rates are observed.
 - c. Issuance of final report.

APPROVED: *W. D. M. Reed*

2. Process Technology Subsection will be responsible for:
 - a. Auditing compliance with the provisions of the test.
 - b. Analysis of neutron leakage rate through the biological shields and recommending termination of the test if unacceptable leakage rates are observed or anticipated.
 - c. Assisting in scheduling change out of oxidation monitor samples.
 - d. Specifying details of biological shield measurements to B, D, and C Processing Operation.

APPROVED: *W. D. M. Reed*

3. Testing Subsection will be responsible for change-out of oxidation monitor samples.

APPROVED: *C. G. Lewis***DECLASSIFIED**

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