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PITA IP-27C - PART II
INCREASED COOLANT FLOW - H REACTOR
OPERATIONAL PHYSICS REQUIREMENTS

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PITA IP-27C - PART II
INCREASED COOLANT FLOW - H REACTOR
OPERATIONAL PHYSICS REQUIREMENTS

PITA IP-27C - PART II
INCREASED COOLANT FLOW - H REACTOR
OPERATIONAL PHYSICS REQUIREMENTS

I. OBJECTIVE

A program for increasing the available coolant flow at the H Reactor has been proposed and supported by documentation^{1,2}. This Process Improvement Transition Authorization (being written in two parts) authorizes the initiation of an immediate phase of the program designed to increase total coolant flow by about 6,000 to 10,000 gallons per minute.

Part I of this PITA³ describes in detail the limitations and requirements peculiar to Process Engineering aspects of the proposed modifications and is presented as a separate document. This portion of the PITA, Part II, is written to establish and define conditions and restrictions in the area of Operational Physics, including loading procedures, instrumentation requirements, startup checks and procedures related to reactivity effects, total control and speed of control considerations, and other physics functions. The governing criterion shall be that nuclear safety is not compromised during the proposed transition, which includes a complete shutoff of reactor flow for a limited period of time under closely monitored conditions.

II. BASIS AND JUSTIFICATION

The economic justification for the modifications to the H Reactor cooling system and the particular manner proposed for their accomplishment has been described in Part I of this PITA. A significant increase in production can be realized by the increased cooling capacity, with an accompanying reduction in unit operating and maintenance costs. To accomplish the transition efficiently, H Reactor Processing has devised a set of procedures involving complete discharge of all irradiated fissionable material in the reactor by displacement with the new charge (with the exception of scattered central zone empty tubes); coolant flow through all process channels will then be interrupted while necessary hardware modifications are completed. The engineering and heat transfer aspects of this sequence of operation, including the associated flow interruption, are defined in references 1, 2, and 3, and accommodating procedures for engineering safety aspects are designated in reference 3. This part of the PITA designates the procedures to be followed in the shutdown loading and flux monitoring which will, as explained in Section III, ensure fulfillment of existing total control and speed-of-control criteria and their interpretation in Process Standards.

III. DISCUSSION

A. General

In assuring that no compromise in nuclear safety will result from the proposed modification scheme, it is necessary to provide sufficient control to hold the completely dry reactor subcritical at all times. This will be accomplished by utilizing combinations of supplementary control (i.e., lead cadmium columns) and in-place control and safety rods. In

addition, Process Standards require that the shutdown reactor be subcritical by 150 c-mk at all times, exclusive of the vertical safety system; this factor must be considered in all compensations.

Adequate operating and monitoring procedures must also be provided to preclude supercriticality in the event of gross loading or prediction errors. Of major importance is the requirement that nuclear instrumentation with satisfactory minimum sensitivity be in service at all times; special consideration is necessary in the unirradiated reactor loading to assure compatibility of standard instrumentation, which normally operates in a fairly high background flux.

In the freshly charged reactor, where the neutron flux results only from spontaneous fission and subcritical multiplication, the core flux level is expected to be of the order of 10^3 nv without the VSR's inserted. Subcritical monitors employ standard fission chambers as sensing elements, and characteristically have sensitivities of $\sim 5 \times 10^{-2}$ counts/sec/nv.⁴ These chambers are located in the reflector, and separated from the core by a blanket of Li-Al target material; effectively, they will be ~ 50 centimeters away from the active portion of the pile. An expected attenuation factor of e^{-3} would result in a flux of ~ 50 nv (~ 2 nv with VSR's inserted) at the chamber and a resulting count rate which may be less than 2 cps; the readings with VSR's inserted will be below the minimum for statistically valid count rates. Therefore, a neutron source (Pu-Be, $\sim 5 \times 10^6$ nv) will be utilized to provide an acceptable count rate on both subcritical systems; both systems are to be in service at all times that loading is proceeding. The source will be located in process channel #3594, which must be completely dried prior to insertion of the source; a minimum indication of 10-50 cps (with source in place) will be required for both instruments.

Subcritical count rates will be utilized during the entire transition period, to provide protection against a criticality occurrence. The inverse count rate ($1/n$) will be continuously plotted to aid in predicting the nearness of criticality at all times when potential reactivity is changing. The source will be removed as soon as background or low level count rates without the source would again be up to the 2 cps rate.

B. Reactivity Balance

Based on a large amount of operating data, a conservative estimate of the cold, clean, wet reactivity of the H Reactor E-N loading is 4275 c-mk⁵ (4.275 %k). The reactivity gain upon water loss for a natural uranium load is 3340 c-mk⁶ (3.34 %k); Process Standards require that the reactor be subcritical by 150 c-mk at all times, exclusive of the VSR's. Thus sufficient poison must be available in the wet reactor (i.e., full flow capability) to provide 4425 (4275 + 150) c-mk of negative reactivity. Similarly, the poison requirement in the dry reactor is 7765 (4275 + 3340 + 150) c-mk. Total control requirements are automatically satisfied when the dry reactor* is held 150 c-mk subcritical; they are satisfied in the wet reactor when the VSR system is completely inserted in addition to the specified 4425 c-mk of poison.

*i.e., in this dry, cold, green loading.

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Accordingly, a minimum of 40 full-length lead cadmium poison columns will be in place in the wet reactor, plus all VSR's; a minimum of 90 columns will be in place in the potentially dry reactor (i.e., flow interrupted). Subsequent to the designated withdrawal approach, the entire VSR system may therefore be held out of the reactor during the period when flow is blocked, to provide 40 mk of scrammable control.

C. Pile Physics Outage Procedure Summary

1. It is currently planned that the reactor be shut down early in January, 1964, as per normal procedures. During the first 40 outage hours, 40 full length charges of lead-cadmium poison will be charged in locations designated by the H Pile Physicist as in normal total control administration.
2. All irradiated uranium fuel will then be discharged by displacement of the new charge (except for scattered tubes left empty for probologging). Recharging of fresh fuel will be conditional upon maintaining statistically minimum indications on both subcritical monitors; to facilitate this, a neutron source will be placed in process channel 3594, which must be swabbed dry prior to installation of the source. An Operational Physics representative will direct the positioning of the source, and may request discharge of one or more fringe Li-Al charges (or possible source repositioning) to provide the necessary SCM response; a minimum count rate plus response to position changes is required.
3. The water shutoff process will begin after an additional 50 full length lead-cadmium columns (total of 90 in a pattern selected by the H pile physicist to be optimum in the dry reactor with safety rods inserted) have been charged; this will be verified by both the responsible Processing shift supervisor and the Operational Physics representative.
4. The horizontal control rods will be positioned for maximum worth, and the HCR power switch will be turned to the "off" position, locked, and tagged. The vertical safety rods will then be withdrawn by pairs as for a normal cold startup. Subcritical monitor chambers may be retracted during the rod withdrawal procedure if necessary to maintain reasonable count rates; "before" and "after" normalizing data is to be taken with each such chamber movement.
5. Water flow will then be shut off from the front face; this will be accomplished by valving off cross headers in groups of two, starting at the top of the unit. Subcritical counting (6 sets, 30-second counts) will follow the valving of each set of two headers. The Operational Physics representative will signify in writing that it is safe to proceed with the next pair of cross headers. As soon as the front cross header valves are closed, the rear caps will be removed from all tubes (except peripheral lattice N tubes) to permit the water to drain from the tubes. While the subcritical counting is being performed, each tube will be visually checked

for the presence of "red flag" (colored dummy) in the rear, using a flashlight; in addition, each tube will be checked with a radiation detection instrument (CP) to assure that no irradiated fuel charges remain. When this procedure has been completed for all headers, all rear caps will have been removed with the exception of the peripheral lattice tubes (blanket poison).

6. Subsequent to > five minutes of data taking after all cross headers are valved off, the VSR's will be re-inserted into the unit. The Operational Physics representative will be notified in advance of any subsequent flow, control, or loading changes.
7. When programmed outage work has been completed, full reactor flow will be restored, by re-opening all header valves.
8. Following assurance that full reactor flow has been resumed, 50 lead cadmium charges, as designated by the assigned physicist, may then be discharged in preparation for startup.

D. Startup Procedures - Physics Aspects

Due to the major changes which the reactor will have undergone during the outage, special conservative startup procedures are required:

1. Initial VSR pulls will be as per Process Standards, with Ball 3X lockbars removed and the system unbypassed, until three rods (Nos. 37, 38, and 39) remain in the unit.
2. After a three-minute wait, VSR #37 may be withdrawn; similar three-minute intervals are required between #37 and #38, #38 and #39, and #39 and the initial horizontal control rod pull. The Operational Physics representative will certify that it is safe to proceed through the last phases of the VSR withdrawal and the initial HCR withdrawal. He may recommend adjustment of the poison inventory if the observed differs from the predicted reactivity by more than 300 c-mk.
3. The source is to be withdrawn from the reactor when a count in excess of 2 cps has been observed with the source positioned far enough up or downstream from the fission chambers that its movement has essentially no effect. If the reactor was required to go supercritical to get sufficient count rate, it may be shut down*, the source removed, the process tube returned to normal flow and loading, and the normal cold startup procedure resumed.
4. Reactor power raises will be halted at levels of 50, 150, 250, 500, and 1000 MW for a complete temperature map and associated flow checking. The Process Technology representative and the H-Processing shift supervisor will certify that the reactor is in proper condition to proceed to the next higher level.

*Subsequent to observing the necessary count rate while supercritical with the source in an insensitive position.

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During the course of the outage, reactor coolant flow will be interrupted by progressively valving closed individual cross headers, two at a time, under closely controlled process limits. It is expected that the volume of coolant in individual tubes will decrease sharply to 40 per cent of normal, with an accompanying step increase in lattice reactivity. The increase in full pile reactivity for a total loss of coolant in a reactor fully loaded with natural uranium is 33.4 mk; in the E-N loading with a higher average neutron energy, the water loss increase is somewhat less.⁷

The occurrence of a critical state will be prevented at all times by having sufficient neutron absorbing material (poison) in the reactor to reduce the effective dry lattice multiplication factor to <1.00 . Poison requirements will be based upon a completely dry, xenon-free reactor.

Below are summarized the several conservative factors which have been incorporated into the procedures for this PITA to ensure against unintended criticality:

1. Complete coolant loss is assumed; a considerable volume, up to 40 per cent of normal, is expected to be residual in all tubes during the test.
2. The water loss effect is based on a natural uranium load; the E-N water loss effect is smaller.
3. The VSR system is not counted in any of the calculations; VSR's will generally be in place or (with high probability) insertable in short order if necessary for any reason. Thus, scrammable control is available at all times as an excess margin.
4. The Ball 3X system will be locked out, and thus not considered; it is probable that some or all of the channels could be reactivated on reasonably short notice.
5. Up to 400 scattered tubes may remain empty (uncharged) during water shut-off; a normal loading lattice "buckling" has been assigned to these process channels.
6. All reactivity additions, including water shutoff and rod withdrawal, will be restricted so as to add, in any one step, less than one-half the calculated reactivity increment to reach critical.
7. Process water return will be possible within 30 minutes at any time that the VSR's are out of the unit (with VSR's inserted there is a 40 mk safety factor).
8. Continuous monitoring, including source multiplication and/or inverse count rate predictions, will be in effect during all periods of reactivity adjustment; around-the-clock physics coverage will also be provided during these periods.

*The term "reactivity adjustment" to include charge-discharge operations.

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Any other hazards are either peculiar to the charge makeup or to normal reactor operation, and are covered in PITA IP-22 (and supplements)⁸ and/or Process Standards.

V. RESPONSIBILITIES

Manufacturing Section

H Reactor Processing will be responsible for maintaining the operational safety of the reactor, for planning and scheduling outage work, for maintenance of normal nuclear instrumentation, and for handling the neutron source.

Research and Engineering

Operational Physics Subsection will be responsible for procurement and positioning of the neutron source, for providing continuous physics coverage during periods of potential reactivity increase, for monitoring and assisting in the timing of the flow interruption, for providing loading information to ensure Total Control and compliance to other Process Standards and for normal plant assistance on the ensuing startup.

Process Technology Subsection is responsible for establishing operating and shutdown limits and monitoring special procedures as detailed in Part I of this PITA.

VI. REFERENCES

1. HW-79465, Increased Coolant Flow for H Reactor, IL Huffman, 10-23-63
2. HW-79794, PT IP-637-I, Modification of Inlet and Outlet Hardware on One Header - H Reactor, RE Spicka and WV Thompson, 12-3-63
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4. Personal Communication, RR Cone to EL Conner, 12-19-63
5. HWN- Personal Notes, EL Conner
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7. Personal Communication, R Nilson to CE Bowers, 12-19-63
8. HW-79797, PITA IP-22, Sup. III, E-N Demonstration Load, EL Conner, 12-3-63

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