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OPERATIONAL PHYSICS COMMENTS ON FULL
PILE OPERATIONAL CHARGE-DISCHARGE

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July 15, 1959

OPERATIONAL PHYSICS COMMENTS ON
FULL PILE OPERATIONAL CHARGE-DISCHARGE

INTRODUCTION

This document has been written in part to answer questions contained in reference (1) concerning the feasibility and advisability of "quickie" discharge of ruptures at C Reactor. Justification of full pile operational charge-discharge (OC-D) is based in part on outage savings resulting from improved rupture removal. Since a portion of the rupture removals might be accomplished within the scram recovery time (quickie) it is necessary to consider recovery time as a function of anticipated future power levels.

In addition to answering the questions mentioned above, it was felt worthwhile at this time to discuss equilibrium control problems associated with OC-D which have been apparent during operation of prototype equipment, and on the basis of this information to consider reactor control with full pile OC-D.

SUMMARY AND CONCLUSIONS

Under present recovery procedures and reactivity status the amount of time available for "quickie" discharges is estimated to vary from 0 to 5 minutes without a CO₂ purge to 5 to 15 minutes with a CO₂ purge, depending on the power level.

The gross type of control represented by the control rods cannot precisely compensate for reactivity changes in a region of the reactor. With full pile OC-D such reactivity

- (1) Letter from C. G. Lewis to G. C. Fullmer, Full Pile Operational Charge-Discharge - C Reactor, May 28, 1959.

SUMMARY AND CONCLUSIONS (Continued)

changes will be constantly occurring. The "temperature bounce" or tube temperature changes during full pile OC-D operation will be at least 3-5 degrees for normal operation and up to at least 7 degrees when the discharge-charge cycle is interrupted. If tubes are limiting and it is not permissible to exceed tube limits a loss of at least 5 per cent in equilibrium power will result.

Flattening with the OC-D should not be any better than with a spline system.

Startup control should be easier than with any type of supplementary control. Savings over present startups should be approximately 1000 MWD per startup.

DISCUSSION

I. SCRAM RECOVERY

None of the scram recovery procedures should be affected by the OC-D facility except for rupture handling. Some ruptures will be flushed during operation. Others will be discharged by displacement within the scram recovery time ("quickie" discharge). As stated in the reference letter justification of full pile OC-D is partially based on outage savings resulting from improved "quickie" discharge procedures.

The probability of a successful "quickie" discharge is, however, dependent on the scram recovery time. Scram recovery time may be increased by purging with CO₂ just prior to shutdown providing the shutdown is anticipated - normally true for rupture shutdowns. Listed below is the estimated maximum available time for "quickie" discharges (or any other type of work within the scram recovery time) assuming a shutdown over a 10-minute period:

<u>Equilibrium Level</u>	<u>"Quickie" Time W/O CO₂ Purge</u>	<u>"Quickie" Time With CO₂ Purge</u>
1900	2-5 Min.	10-15 Min.
2000	1-4 Min.	9-14 Min.
2100	0-2 Min.	7-12 Min.
2200	0 Min.	5-11 Min.

The following additional assumptions were used in calculating the above data:

- (1) 350 inhours in rods at equilibrium.
- (2) A metal coefficient of -0.12 ih/MW.
- (3) Recovery level 65 per cent of equilibrium level.
- (4) Rate of rise during recovery of 100 MW/min.
- (5) All rods out at recovery level.
- (6) Ten minutes from initiating the VSR pulls to one MW.

The fifth assumption results in the maximum available "quickie" time. However, an all-rods-out recovery is usually inadvisable because the large number of near-side enrichment columns necessary for proper equilibrium operation causes a flux distortion in this region. Thus, either recovery cannot be made within normal tube power limits or else tube powers are so close to limits at the recovery level there

DISCUSSION (Continued)I. SCRAM RECOVERY (Cont'd)

is a good chance of inadvertently exceeding these limits. It is probable that this condition will become worse as equilibrium levels increase. This distortion may be reduced by requiring 50 to 100 inhours in control rod at recovery level which, however, imposes a loss of 3-7 minutes in "quickie" time.

The "quickie" time may be increased by adding spike enrichment to the reactor and consequently operating with more control rods at equilibrium. Approximately 6 enriched uranium columns are required per minute increase in "quickie" time. The addition of enrichment in the center of the pile for this purpose for up to 10 minutes increase might require a reduction in flattened zone size from total control consideration which would cause a loss of about 20 effective central tubes. Handling any poison necessary at startup for the increase in total control requirements should be painless with OC-D operation.

II. MINIMUM OUTAGES

In considering the economics of OC-D the minimum outage time associated with a scram caused by OC-D failure should be considered. With the increased power levels the length of minimum outages is extended. Following is a list of minimum outage times as a function of power level. Twenty enriched uranium columns would be required to reduce these times by one hour. No uranium discharge was assumed since this would be obviated if one adheres to the OC-D concept.

<u>Power Level</u>	<u>Minimum Outage Time</u>
1900	40 hours
2000	42 hours
2100	44 hours
2200	46 hours

III. EQUILIBRIUM CONTROL

The method of control used during OC-D is to pull control rods during the discharge cycle and to return the rods as close to their previous position as possible during the charge cycle, attempting to maintain the reactor power constant. The rods used are those that will result in the least disturbance to the local tube temperatures.

With the prototype array, tube temperatures increased at least 3-5 degrees and reactor power varied from 50 MW below to 15 MW above equilibrium levels during a normal OC-D cycle. Tube temperatures increased up to a maximum of 7 degrees when the OC-D cycle was interrupted between the discharge and charge operations. The average of the 10 highest tube powers (the present limit) increased at least 20 kw. These were maximum values observed; there could have been greater changes.

The present prototype facility, because of its location and intermittent discharging, produces fewer control problems than could be expected with the full pile array. With the full pile OC-D facility operating continuously, smooth equilibrium operation would be essentially non-existent and control would obviously be more difficult. The above operational temperature "bounce" would become normal and limits would have to be adjusted accordingly. If the data given is assumed to be true for full pile

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DISCUSSION (Continued)

III. EQUILIBRIUM CONTROL (Cont'd)

OC-D (a conservative assumption) then it must be presumed that tube temperatures would oscillate continuously to such an extent. For operation on limits that may not be exceeded, such as TAI limits, a loss in equilibrium power level of at least five per cent would result.

Improved flattening from OC-D operation would certainly result and this might be presumed to reduce the loss. It should be noted, however, that splines should improve flattening equally well.

Temperature cycling should be more prevalent with OC-D operation, but it is probable that the magnitude of the OC-D temperature "bounce" would be great enough to overshadow the effect of cycles on power level.

IV. STARTUP CONTROL

Turnaround control should be no problem. The reactor should be able to start up to 90 per cent of the equilibrium level. Any poison tubes necessary for turnaround control could be easily charged at any time. The non-equilibrium operating loss should be less than 200 MWD indicating a saving of about 1000 MWD per startup compared to current procedure. While splines could theoretically allow a similarly efficient procedure the difficulty of using the splines at the rate required appears to be a major problem, although splines would certainly reduce present losses by at least half. In addition, using the OC-D facility for poison would present a reduced radiation problem. It is believed, therefore, that the OC-D facility would be more efficient for startup control than any supplementary poison system.

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