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**JUSTIFICATION FOR EXTENDING SCRAM
RECOVERY TIME AT C REACTOR**

AUTHOR

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JUSTIFICATION FOR EXTENDING SCRAM RECOVERY TIME AT C REACTOR

INTRODUCTION

Slug ruptures at C Reactor are costing a considerable amount of production and are limiting reactor power levels. A large portion of this production is lost because the "quickie" procedure cannot be used with unstuck ruptures. Currently there are two reasons for this condition:

1. Insufficient reactivity is available to recover after a rupture is removed with the "quickie" equipment.
2. If the "quickie" method were attempted, there would be many failures due to stuck rear caps and improperly functioning equipment.

With the current emphasis being placed on improving the "quickie" equipment and procedures, it is reasonable to assume that in the near future nearly all unstuck ruptures can be removed with this "quickie" procedure. However, the C Reactor does not possess sufficient excess reactivity to recover from a "quickie" rupture discharge following a shutdown from equilibrium conditions. This study outlines a procedure for extending the scram recovery time at C Reactor and an economic justification for buying the added reactivity necessary to carry out the procedure.

SUMMARY AND CONCLUSIONS

It is proposed that sufficient enrichment be charged in the central flux zone of C Reactor to provide the scram recovery time required to achieve power recovery

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following "quickie" rupture discharges. Certain preliminary tests and studies should be undertaken immediately to ascertain optimum enrichment methods and a firmer understanding of the feasibility. These tests should be conducted as soon as possible so that enough scram recovery time will be available to make "quickies" feasible by the time the C Reactor goal exposure is raised above 260 MWD/ton. The study was based on the projected concentration of 450 MWD/ton. Two cases were considered: all the excess reactivity can be carried in the HCR's, and only 250 inhours of the required flexibility would be carried in the HCR's with the remainder in the poison column control facility. The net gains, respectively, for the two cases considered are:

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DISCUSSION

Production losses resulting from fuel element failures place a definite limit on reactor production and optimum power levels. With the projected increase in goal exposure at C Reactor from 260 MWD/ton to about 450 MWD/ton, the rupture rate can be expected to increase at current tube powers. To minimize this loss and thus permit continuance of present operating levels and production, it will be necessary to reduce the rupture frequency and/or the production loss per rupture. This report discusses the gain to be achieved by reducing the production loss per rupture at C Reactor.

The C Reactor must remain down for a minimum outage (about 30 hours) following each rupture sustained at equilibrium power level due to lack of excess reactivity. The majority of ruptures at C Reactor are not stuck in the tube and can be discharged with the "quickie" equipment. Recovery could be achieved in most cases if 40 - 50 minutes of scram recovery time were available.

The C Reactor is currently carrying 130 inhours of excess reactivity in the HCR's. At 450 MWD/ton exposure, there will be about 250 inhours of excess reactivity in the HCR's. With the present power levels, a total of up to 400 inhours of flexible reactivity control would be required to provide the 40 - 50 minute scram recovery time necessary to permit utilization of the "quickie" discharge technique. The additional 150 inhours of reactivity required could be provided by central enrichment. It is expected that all this reactivity could be carried in the HCR's. If control problems should dictate less than 400 inhours in the HCR's is desirable, the remaining reactivity flexibility could be carried in the poison column control facility. The poison column control system is now being installed and will be in operation in the Fall of 1956.

The application of central zone spike enrichment to increase reactivity has never been used. Several problems would have to be examined in detail before such a procedure to extend scram recovery time could be incorporated. The most prominent of these are as follows:

1. Flux peaking adjacent to enrichment columns could be of sufficient magnitude to restrict the power level. To evaluate this effect, an enrichment column should be charged in the central flux zone to ascertain the magnitude of flux "humping". Theoretical calculations indicate, however, that if the central lattice buckling is great enough to sustain the reaction, this "humping" of the flux would be

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negligible and no serious limitations are expected.

2. Process Standards limit the rod withdrawal rate to critical more severely if poison in addition to that in the HCR's is removed from the reactor. In utilizing the poison column control facility, up to ten minutes extra would be required to achieve critical under the present process standard limitations.
3. Placement of the enrichment and poison column control tubes would have to be carefully planned to optimize their usage.
4. Pile safety considerations with "C" metal in the central lattice would have to be evaluated. Preliminary examination indicates this should create no limitation.
5. A serious limitation would exist if the "C" metal were to prove excessively rupture prone in the higher power central zone tubes in C Reactor. While "C" metal ruptures are usually discharged at subsequent outages, thus requiring negligible outage time, the enrichment throughput could increase significantly.
6. The radiation level on the rear face during "quickie" discharges is relatively high. The burnout of manpower would increase and could be excessive.

Before the poison column control facility could be used to extend the scram recovery on a continuous basis several potential problems must be considered.

1. Additional manpower would be required to recharge the poison column control tubes 4 - 5 hours after the outage.
2. Poison costs have not been considered but are thought to be negligible in comparison with the potential gains.
3. Following start-up the radiation background could limit accessibility to the front face, thus restricting the recharging of the poison column control tubes. This background is high because of gas leakage as the reactor heats up.

C Reactor was chosen for this study because the maximum reactor production gains can be achieved by extending the scram recovery time there. The other reactors either have sufficient flexible control now to provide the scram recovery time necessary to permit "quickie" discharges, or should have after the poison column control facilities are installed. However, since less excess reactivity is available at higher power levels and lower goal exposures, enrichment may be attractive for extending the scram recovery time under projected operating conditions at all reactors.

Alternate Method of Providing Required Reactivity Flexibility

The method of increasing the scram recovery time discussed above is the most easily adaptable with the present status of the technology. However, the cost of this procedure could be greatly reduced if it were possible to either irradiate the enrichment only when the excess reactivity is required or use the excess neutrons produced under normal operation for useful irradiation.

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Utilizing a system which could insert the enrichment into the reactor only when the excess reactivity was required, the only significant enrichment cost would be that of maintaining the large inventory. There would be negligible burnout. Although no system has been perfected to accomplish this, the proposed poison column displacement system (1, 2) possibly could be adapted for displacing enrichment in and out of the central flux zone.

Rechargeable material, such as lithium can be irradiated profitably in poison column control tubes; however, non-rechargeable material such as cobalt and thorium would have too uncertain an irradiation continuity to be of value. If it is desirable to use non-rechargeable poison for this reactivity flexibility, two systems probably could be developed, either one of which would provide reactivity flexibility while maintaining the continuity of irradiation.

1. Poison column displacement facility.
2. A limited number of reconstructed vertical safety rods loaded with useful material for irradiation during normal operation.

These alternate systems are attractive from a long range basis and should be pursued. However, in view of the potential gains to be achieved now and in the near future, the proposed method of extending the scram recovery time should be developed and put into effect as soon as possible at C Reactor.

Detailed Justification

The principal justification for extending the scram recovery time at C Reactor is to reduce the production loss per rupture. Since the C Reactor power levels will be restricted by rupture considerations, the gain can be realized in any one or combination of three ways.

1. Higher power levels.
2. Decreased metal throughput (higher discharge exposure).
3. Increased time operating efficiency.

The calculated gains for this report are based on increased time operated efficiency. This is probably the most conservative of the three possible approaches.

This study was based on the projected discharge concentration of 450 MWD/ton. The gains and costs are summarized in the following table.

-
1. HW-33422, "Production Test 105-9-MR, Poison Column Displacement During Reactor Operation," P. C. Walkup, February 1, 1955.
  2. HW-42076, "Interim Report, Production Test, 105-9-MR, Poison Column Displacement During Reactor Operation," G. F. Owsley, March 21, 1956.

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TABLE

CASE

ANNUAL COSTS

	<u>Enrichment</u>	<u>Tubes Out Of Service</u>
		<u>MWD</u> \$
1. (400 inhours in the HCR's)	\$119,000	
2. (250 inhours in the HCR's; 150 inhours in the FCC)	\$196,000	

CASE

ANNUAL GROSS GAIN

ANNUAL NET GAIN

	<u>\$</u>	<u>MWD</u>	<u>\$</u>	<u>MWD</u>
1.	1,137,600	113,760		
2.	1,137,600	113,760		

The assumptions and detailed calculations are contained in the Appendix.

Proposed Tests

Two tests should be conducted before full utilization of the proposed method of enrichment is incorporated. These are as follows:

1. A production test to evaluate the reactivity and flux "humping" effects of single and multiple enrichment columns in the central lattice should be initiated. Such a test will determine the extent of flux peaking adjacent to enrichment and, to a limited extent, the practicality of absorbing all the excess flexible reactivity in the HCR's and the optimum placement of the enrichment columns.
2. As the reactor gains flexible reactivity control (from stepwise addition of enrichment and the increase in residual exposure) scram transient tests should be conducted to accurately determine the amount of flexible control which will be required to provide sufficient scram recovery time to achieve "quickies".

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Reactor Operations Engineering
Process Sub-Section
REACTOR SECTION

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APPENDIX

ASSUMPTIONS

1. Operating level - 1600.
2. Coal exposure - 450 MWD/ton.
3. Five unstuck ruptures/month.
4. One enrichment column is worth 9 effective inhours in the central flux zone.
5. Remaining downtime after one unstuck rupture each month could be used for other necessary work.
6. Non-equilibrium losses:
  - a. Short outage - 200 MWD.
  - b. Minimum outage - 600 MWD.
7. Minimum downtime - 30 hours (1920 MWD).
8. Downtime for quickie - 0.7 hours (50 MWD).
9. Equilibrium inhours in ECR's without enrichment - 250 inhours.
10. Equilibrium inhours in ECR's with enrichment.
  - a. 400 inhours.
  - b. 250 inhours (150 inhours of flexible control in poison column control tubes).
11. Cost of U-235 burned up in C Columns - \$30/gram.

Calculations

1. Cost of one enrichment column per year:
 $365 \times 0.8 \times 0.9 \times 0.9 \times 0.9 \times 0.9 \times 1.21 \times 30 = \$7,000$
365 - days in year.
0.8 - time operated efficiency.
0.9 - operating level efficiency.
0.9 - average central tube power in megawatts.
0.9 - average enrichment tube power/average tube power.
0.9 - portion of power produced in C tube which is produced in enriched material.
1.21 - enrichment burnout in gram/MWD.
30 - cost of one gram of enrichment in \$.

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2. Enrichment Requirements:

- a. With 400 inhours in the HCR's
150 inhours - 17 columns.
- b. With 250 inhours in the HCR's
250 inhours required to buy 150 inhours of flexible control
in poison column control facility - 28 columns.

3. Annual Costs:

- a. With 400 inhours in the HCR's
  - Direct: 17 columns x \$7,000 = \$119,000
  - Indirect: 17 columns out of service from production.
17 x 0.8 x 0.9 x 0.9 x 365 = 4,000 MWD.

17 - process tubes removed from production
0.8 - time operated efficiency.
0.9 - average tube power in MWD.
0.9 - operating level efficiency.
365 - days in year.

Total Cost:

MWD

4,000

- b. With 250 inhours in the HCR's:

Direct:

28 columns x \$7,000 = \$196,000

Indirect:

28 columns out of service from production - enrichment.
10 columns out of service from production - poison.

38 Total

38 x 0.8 x 0.9 x 0.9 x 365 = 9,000 MWD

Total Cost:

MWD

9,000

4. Annual Gain:

a. Gross Gain:

48 ruptures due to which full minimum outages are lost.
12 ruptures to which only difference in non-equilibrium losses
can be charged.

48 (1920 / 600 - 200 - 50) / 12 (600 - 200) = 113,760 MWD

b. Net Gain:

1) With 400 inhours in HCR's:

Production: 113,760 - 4,000 = 109,760 MWD

Dollars: = \$851,600

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2) With 250 inhours in HCR's:
Production: 113,760 - 9000
Dollars:

= 104,760 MWD
= \$851,600

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