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INCREASED PRODUCTION FROM DELIBERATE DISCHARGE CYCLING

INTRODUCTION

Considerable production gains might be attained if each reactor discharged its entire flattened region during one scheduled outage instead of utilizing several outages for this purpose. Several of the older reactors are now discharging a high percentage of their flattened zones in a single outage and could be put into this type of operation with relatively little difficulty. Production gains may be possible through better flattening efficiency, a more favorable rupture rate effect, fewer non-equilibrium losses, higher conversion ratio, and more efficient usage of outage work. Since this document is written primarily from the Operational Physics standpoint, some gains and pitfalls which must be evaluated by other affected groups will only be mentioned here as possibilities. The

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INTRODUCTION (Continued)

purpose of this document is simply to point out the potential gains in flattening efficiency from this method. Potential gains from improved fuel performance have been described in another document /1/.

SUMMARY AND CONCLUSIONS

Gains from discharging the entire flattened zone of a reactor in a single shutdown may be possible from all aspects of reactor operation provided that spurious scrams are largely avoided, that power limit conditions provide incentives for improved flattening, and that supplementary control and enrichment flexibility is available. The flattening of a reactor should be increased up to a maximum of three to four per cent with the average higher (one to two per cent) than with present operation. Gains in other areas due to work simplification, better scheduling, etc., appear possible. A more refined study should be made by all affected groups to determine the magnitude of these gains.

DISCUSSION

A. Method of Operation

As presently envisioned, the reactor would have a complete flattened zone discharge every scheduled charge-discharge outage. The fringe zone or zones would be discharged either during unscheduled outages or, preferably, provided that the unscheduled outages were few, every second and/or third scheduled outage.

A typical equilibrium operating period would show the reactor initially operating with poison splines, most of these being removed as samarium-149 poison approached saturation. (Additional E-metal enrichment might have to be added to compensate for this reactivity loss.) After the samarium became saturated and long-term reactivity increases began, splines would be inserted to nullify the gains and to flatten the reactor. When the flattened zone reached goal exposure the reactor would be shut down and the prescribed push taken. During the operating period any unscheduled outages would be used for maintenance, fringe discharges, or for discharge of the additional spike enrichment.

B. Flattening Gains

Uranium at goal exposure generates more power in a given neutron flux than it does at zero exposure. Since the spread of exposures currently is about 700 MWD/T it is obvious that this causes a difference in tube powers from tube to tube and that equalizing the exposure decreases this difference. Assuming individual tubes limit the reactor power level, decreasing the tube power variation results in higher average tube powers and a higher reactor power level. This has been observed at reactors with low goal exposures. For the discharge scheme contemplated, a gain of two to three per cent in flattening efficiency would be expected over the present range of reactor exposures.

The following illustration shows a comparison between the effect of present goal exposure and low goal exposures on tube temperatures along the flattened zone section of 33 row on C Reactor. The maximum variation between two adjacent tubes

/1/ HW-60398, "Rupture Potential Based on the Full Central Zone Discharge Concept," D. E. Goins, May 18, 1959.

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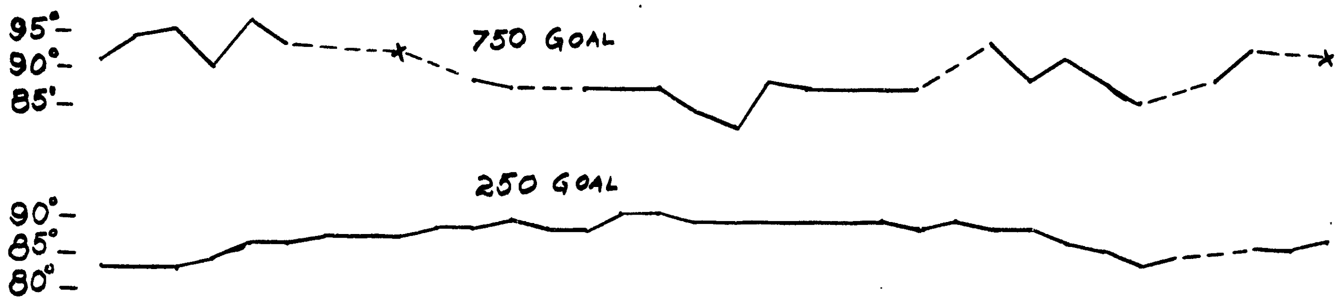
DISCUSSION (Continued)

B. Flattening Gains (Cont'd)

is 6 C for high goal and 2 C for low goal. Dotted lines indicate either bad thermocouples or poison columns. Some variation can be expected because of varying tube flows, but this should not affect the comparison to any great degree.



Since the reactor must operate over a long period of time, the use of a supplementary control system is mandatory to absorb long-term reactivity changes. These supplemental control systems should maintain a higher average flattening efficiency than is presently possible. This stems from two causes: (1) Continuous operation reduces the proportion of operating time required to set up a flattening pattern (the percentage of operation that large amounts of poison can be used is increased), and (2) the repetition of the discharge pattern results in a more predictable flattening pattern.

How the overall flattening efficiency would compare with the present is problematical. The pattern in flattening efficiency during an operating period would be to begin high, reducing as the samarium-149 poison approaches saturation, and then to increase to a higher value (three to four per cent) than at present. A comparison with the initial KW operation (which would be similar to the case in point) shows that originally the flattening efficiency was greater than the present average for KW pile. As the point of minimum reactivity approached, the flattening efficiency decreased approximately ten per cent. This large decrease was partially due to the fact that originally poison columns were placed in the reactor to compensate for the lack of samarium and they could not readily be removed, a condition which supplementary control would correct. The decrease in flattening efficiency would, therefore, be much less - particularly if enrichment were added to retain a near normal rod configuration - even though reactor power levels are now considerably higher. The average over the entire operating period should be higher than under present conditions.

C. Decrease in Non-Equilibrium Losses

Non-equilibrium losses per outage range from one-half to one equilibrium day. Since the proposed method of operation results in a scheduled outage every two to three months, a potential saving of one to three equilibrium days per operating period exists. Unscheduled outages would reduce such gains.

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DISCUSSION (Continued)

D. Effect on Rupture Rate

The rupture rate is presumed to be a function of uranium exposure, tube power and water temperature /2/. Providing that limits other than the rupture rate were not affecting pile power level it can be shown /1/ that with uranium exposures all zero the reactor could operate initially at a high power level, reducing level as uranium exposure increased. This type of operation would result in higher production for a rupture rate equal to the present rupture rate or, if the production in the two cases were equalized, in a reduced rupture rate. Although the applicability of the rupture rate equation might be questioned under such different operating conditions, it is reasonable to assume that tube power should be higher when uranium has better ability to absorb more punishment, and lower after radiation exposure, thermal and corrosion effects have reduced this ability.

For operation at a constant power level, the increase in flattening efficiency, particularly at the end of the operating period, would decrease the rupture rate for a power level comparable to present levels since the maximum tube powers would decrease.

E. Unscheduled Outages

The frequency of unscheduled outages would, of course, affect greatly the possible gains. To minimize production losses such outages could be used for discharging fringe tubes, enrichment tubes, and for maintenance which otherwise would have to be done during scheduled outages.

Whether a full charge-discharge would be done during an unscheduled outage when the reactor is near goal exposure would depend on how much other work needed to be done and on how the decreased rate of plutonium buildup would compare with the higher increase rate in low exposure uranium. With the proposed operation this might have considerable effect since the formation rate at 800 MWD/T is approximately two-thirds that at zero exposure. In addition the lower rupture rate of green uranium versus ripe uranium might make it more attractive to discharge early.

F. Other Advantages

As explained above, during an operating period there will be some exposure point at which it will become better production-wise to take a full discharge in case of an unscheduled outage. If an unscheduled outage does not occur at this time, however, the date of the scheduled shutdown may not depend on a calculated goal exposure but on the probability of a stuck rupture (not just a rupture) occurring and on the rate of plutonium formation. In other words, if the discharge region reaches 750 MWD/T, it might be better to continue to 850 MWD/T or even higher if the probability of getting a stuck rupture is low enough and the rate of plutonium formation high enough compared to that in a green charge.

The evaluation of any gains due to more efficient use of outage time, thereby increasing time operated efficiency, must be done by persons more closely allied with the problems. Some potential gains are: increased charge-discharge efficiency

/2/ HW-55377, "Analyses and Correlation of HAPO Rupture Experience with Natural Uranium Material," R. R. Bloomstrand, April 23, 1958.

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DISCUSSION (Continued)

F. Other Advantages (Cont'd)

because of favorable tube locations, more efficient usage of maintenance time because of reduced conflict with charge-discharge, and lower radiation exposure because of less supplementary poison handling with fewer outages.

In addition to the gains in production, a decrease in reactivity prediction uncertainties would result since the repeating discharge pattern should permit more accurate startup predictions.

The conversion ratio should increase if the spread of tube exposures decreases.

G. Factors Reducing Gains

1. Storage facilities for green uranium would have to be enlarged. Basin facilities might be strained.

2. Scheduling of the reactor loading to begin the operation could result in large economic losses.

3. The addition of enrichment to counteract the samarium transient.

4. Any limit that limits the bulk reactor power (as opposed to specific localized conditions) would deny increases from better flattening efficiency. This would be compensated for, at least partially, by a decreased rupture rate.

5. Since the chutes would probably not hold the full discharge, some metal pickup would have to be done during shutdown. The discharge rate of the reactor, and therefore the outage length, could then depend on the efficiency of the metal pickup.

6. Shortening of operating periods as a result of supplementary control malfunctions and/or frequent scrams could create outage situations in which time was not efficiently utilized.

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