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GOAL EXPOSURE FOR CENTRAL ZONE BLOCK DISCHARGE
AT DR REACTOR

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GOAL EXPOSURE FOR CENTRAL ZONE BLOCK DISCHARGE
AT DR REACTOR

by

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Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

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April 27, 1960

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GOAL EXPOSURE FOR CENTRAL ZONE BLOCK DISCHARGE
AT DR REACTOR

As requested, a study has been made to determine a method for calculating optimum goal exposure for central zone block discharge. It was assumed in this study that operational severity index will remain essentially constant during the irradiation cycle and that all or nearly all of the I & E natural material is in the central zone block.

The net return concept⁽¹⁾ does not depend on a particular type or method of operation and is applicable to any operation where the objective is to maximize net return. In applying the net return concept it would be desirable to have a model specifically describing block discharge operation; however, until operating experience has been obtained, it would seem reasonable to use the present model, provided the errors incurred are not prohibitive.

The present net return equation is essentially an equation for optimizing a three sector (or three tube) reactor. The I & E natural, I & E enriched, and solid natural charges are assumed to be separate homogeneous groups and comprise the three sectors. The central zone block discharge plan fits this three sector concept as well as the variable goal exposure plan, provided the assumption is valid that all or nearly all of the I & E natural material is in the central zone block.

Since the three sector concept is reasonably valid, it can be seen that with the possible exception of miscellaneous losses,* the present net return equation is consistent with central zone block discharge operation. It is probable that some of the miscellaneous losses are exposure dependent; however, such dependence should be slight compared with exposure dependence associated with rupture loss. It is felt that any errors incurred by using the present net return equation will be small compared to the errors incurred in estimating the values of the various coefficients. In view of this, it is recommended that the goal exposure for central zone block discharge be based on the present net return equation, as an interim measure, until sufficient operating experience is gained to correlate the loss terms with operating parameters.

In applying the net return equation the following should be considered:

- (a) The rupture loss term is probably the controlling loss term. In regard to

(1) HW-61579, JF Music, et al, "Reactor Process Optimization," 8/17/59,
(Secret Red Label).

* Miscellaneous losses include all losses except charge-discharge, tube replacement and rupture losses.

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rupture rate, central zone block discharging is only a different goal exposure plan, provided OSI is held reasonably constant, and the present rupture rate equation (2) $RR = k M^{5.7} P^{8.3}$ is applicable. It follows that the present form of the rupture loss term, (1) Pile CR $P_{max}^{12} M_{avg}^4 P_{maxNT}^4$, and that Pile CR = αY Tube C_R , where α is the Pile C_R factor, (1) holds for block discharging.

In order to make an optimization run on the computer, it is necessary that α be known. For variable goal discharge, α has been correlated with reactor parameters such as ECT; however, these correlations hold only for variable goal discharging and must not be used for block discharge operation. The general equation (3) for α which holds for all discharge plans is as follows:

$$\alpha = \frac{\sum_{i=1}^n (f_i^{13} m_i^4)}{f_{max}^{12} \sum_{i=1}^n f_i} \left[\frac{\sum_{i=1}^n \frac{f_i}{m_i}}{\sum_{i=1}^n f_i} \right]^4$$

Where: f_i = individual tube factor

m_i = individual tube exposure at discharge

n = number of I & E natural tubes

f_{max} = average factor of the ten highest powered tubes.

For central zone block discharge $m_i = c f_i$ where c is a constant for all central zone I & E natural tubes. Substituting $m_i = c f_i$ we obtain

$$\alpha = \frac{c^4 \sum_{i=1}^n f_i^{17}}{f_{max}^{12} \sum_{i=1}^n f_i} \left[\frac{\sum_{i=1}^n \frac{f_i}{c f_i}}{\sum_{i=1}^n f_i} \right]^4 \quad \text{or} \quad \alpha = \frac{\sum_{i=1}^n f_i^{17}}{f_{max}^{12} \sum_{i=1}^n f_i} \left[\frac{\sum_{i=1}^n \frac{1}{f_i}}{\sum_{i=1}^n 1} \right]^4$$

Using this equation, α may be readily evaluated for any factor distribution.

- (b) It is a possibility that, due to a change in axial flux or other controlling conditions, the present tube C_R value may not be applicable to the central zone block discharge plan. The possibility of a large change in tube C_R appears to be small; however, if desired, a decision rule could be used to determine when you will conclude that tube C_R for I & E natural material

(2) HW-66377, Bloomstrand, RR and WI Neef, "Analysis and Correlations of HAP0 Rupture Experience with Natural Uranium Material," 4/23/58, (Secret).

(3) HW-64454, Cremer, BR, "Alpha Correlation," 3/24/60, (Secret).

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has changed and the magnitude of the change. Decision rules of this nature are discussed in an undocumented letter⁽⁴⁾ from J. L. Jaech to R. R. Bloomstrand.

A decision rule can be set up using a table such as Table I. Table I shows the upper and lower limits at the 95 per cent confidence level,** based on a Poisson distribution of the observed number of ruptures. It should be noted that five per cent of the time, due to chance alone, the observed number of ruptures will fall outside of upper and lower limits of Table I. One example of a decision rule using Table I would be that whenever the observed number of ruptures falls outside of the limits as shown in Table I you would conclude that a real change in tube C_R has taken place and further that the magnitude of such a change is a factor of 1.5. The three possible decisions based on this would then be:

- (1) If at any time during a given central zone irradiation cycle the observed number of ruptures is greater than the upper limit, as shown by Table I, conclude that there has been a factor of 1.5 disimprovement in tube C_R and adjust goal exposure accordingly.
- (2) If after reaching goal exposure, the observed number of ruptures is less than the lower limit conclude that there has been a factor of 1.5 improvement in tube C_R and adjust goal exposure accordingly.
- (3) At all other times, (lower limit $\leq$ observed ruptures $\leq$ upper limit), conclude that there has been no change in tube C_R .

This is, of course, only one of a large number of possible decision rules and is not necessarily the best one; however, it appears to be a reasonable one and its use is recommended for the present situation. It should be realized that while a decision rule of this type can be very useful, it is of doubtful or negative value if it is not set up in advance of any problem that might arise and is not rigorously applied. By rigorous application it is meant that if an accepted decision rule indicates that a change has occurred, you must conclude that a real change has occurred, and, conversely, if no change is indicated, you must conclude that no real change has occurred. The action taken when a change is indicated should, however, depend on judgment or subjective analysis. For instance, it may be that based on available data it appears reasonable to assume that the change that occurred was transient in nature and will not affect the next operating cycle, in which case it would be reasonable and prudent to use the original tube C_R value for the next operating cycle. The factor change as set up in the decision rule should be used unless there is sufficient information to reasonably determine other appropriate action. The point is that judgment does not enter into concluding that a real change has occurred, except in the

(4) Unclassified letter from J. L. Jaech to R. R. Bloomstrand, "Evaluating Decision Rules for Changing Reactor Operating Conditions," 11/10/59.

** This assumes that there is no uncertainty in the expected number of ruptures; since this is not the case, the confidence level is really less than 95 per cent.

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original choice of a decision rule; however, when it is concluded that a change has occurred, judgment should be used to determine the appropriate action.

TABLE I

<u>Expected Number of Ruptures at Goal</u>	<u>Upper and Lower Limits (95% level) of Observed Number of Ruptures</u>
2.0	0 - 5
2.2	0 - 6
2.4	0 - 6
2.6	0 - 6
2.8	0 - 7
3.0	0 - 7
3.2	0 - 7
3.4	0 - 8
3.6	0 - 8
3.8	1 - 8
4.0	1 - 8
4.2	1 - 9
4.4	1 - 9
4.6	1 - 9
4.8	1 - 10
5.0	1 - 10
5.2	1 - 10
5.4	1 - 11
5.6	2 - 11
5.8	2 - 11
6.0	2 - 11
6.2	2 - 12
6.4	2 - 12
6.6	2 - 12
6.8	2 - 12
7.0	2 - 13

- (c) The decision to shut down at goal and discharge, or to keep operating until the reactor is shut down for some other reason, depends mainly on the desirability of having a scheduled rather than an unscheduled outage. If the downtime in either case will be identical, there is a slight advantage to continued operation.

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RD Shimer:md

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END