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SENSITIVITY TO VSR FAILURE - K PIPE BREAK ACCIDENT

R. H. Meichle

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SENSITIVITY TO VSR FAILURE - K PIPE BREAK ACCIDENT

INTRODUCTION

Reactor effects of failure of a safety rod to scram can be considered in two major respects:

(1) The reduction in total safety system strength which will affect the amount of "prompt drop" and subsequent flux decay rate of the <u>average</u> neutron flux level.

(2) The change in local flux distribution due to the absence of the particular rod which fails to enter the reactor.

The purpose of this memorandum is to describe the physical effects involved and to indicate the approximate magnitude of both reactor-wide and localized changes in event of failure of a VSR simultaneous with a K Reactor riser accident.

SUMMARY

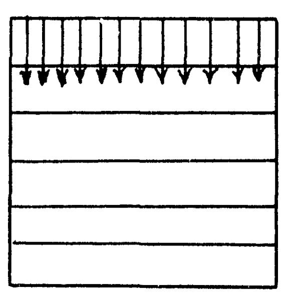
Peaking of the flux distribution in the central columns of a K Reactor due to boilout following a riser accident would result in those columns being most limiting to reactor operation, assuming the entire vertical safety system to act uniformly. The opposing effect on flux distribution following shutdown - central dishing due to the geometry of the VSR system - would, however, result in columns near the enrichment band ("E-ring") being nearly as limiting as the maximum columns in the calculated base case and slightly more limiting (calculated to be 1.3 percent) in case of a VSR of maximum effectiveness being out of service.

The bases for both static and kinetic physics calculations utilized in the K riser accident analyses and representative incremental results supporting the above sensitivity determination are included.

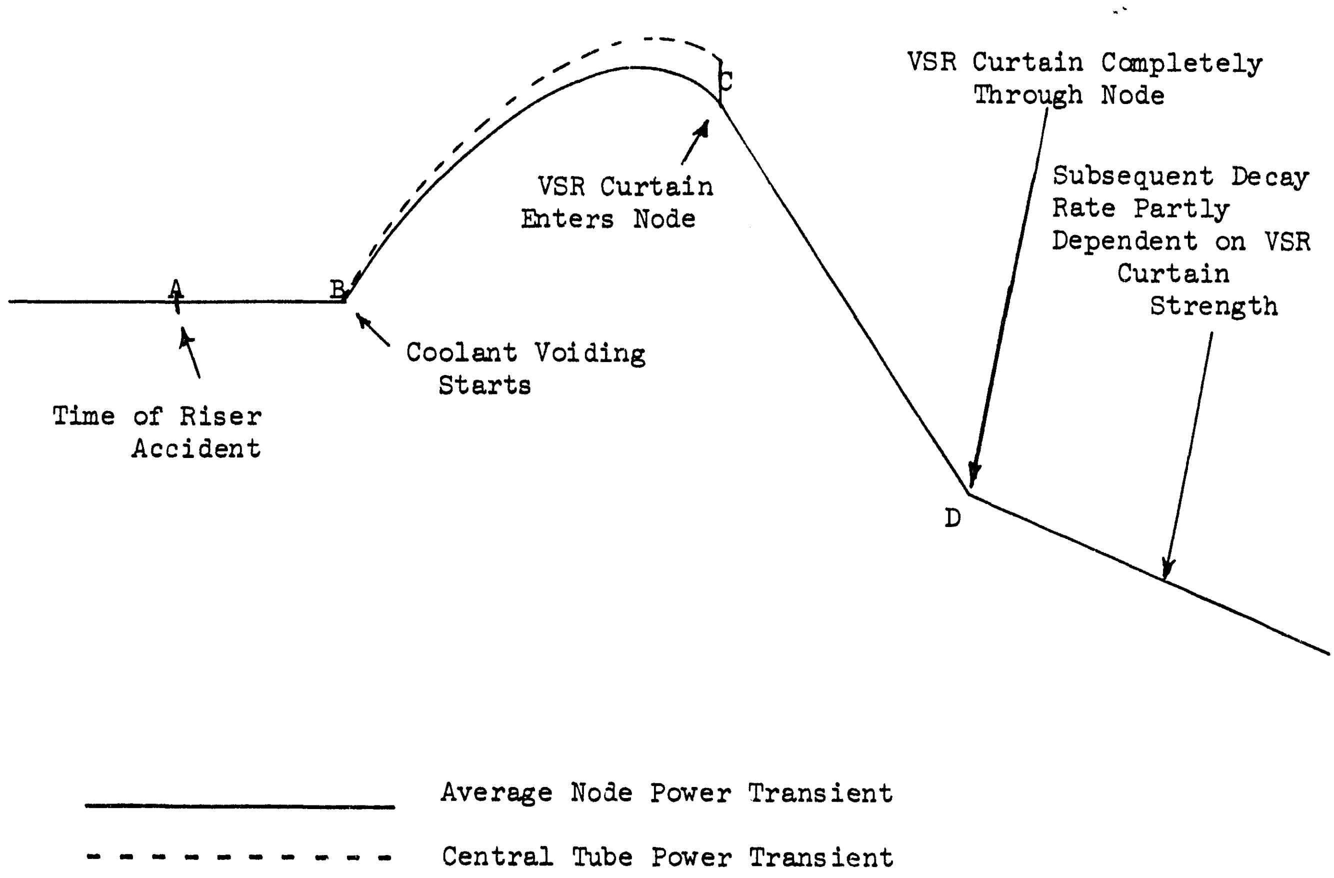
DETAILS

Total System Effect

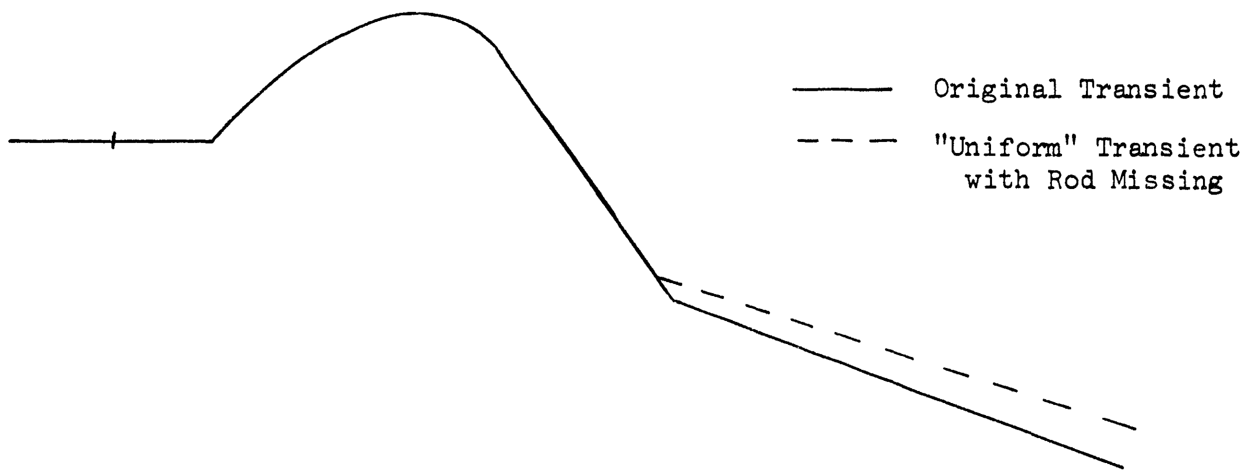
To a close approximation, a K Reactor kinetics problem may be viewed as one-dimensional in the vertical direction. The vertical rod system may be considered to enter as a uniform curtain, and reactor coefficient effects may be considered to act in a number of discreet horizontal nodes both previous to and subsequent to entry of the "curtain" into the node in question.



The "CLUMSY" kinetics code calculates the average side-to-side and front-to-rear power power transient for each node. Since calculations have consistently shown that during the partial depressurization following a riser break boiling would occur only in the higher power central tubes, voiding would be restricted to the flattened region. After the coolant voiding is calculated to start in any node, a power-normalizing constant is calculated to account for peaking in the side-to-side dimension due to the reactivity gain upon voiding in central tubes. This power-normalizing constant is then set equal to one when the rods enter the node in question (i.e., the operating side-to-side flux distribution is assumed to apply during the ensuing flux decay). No changes are made in the calculational program to account for differences in front-to-rear flux distribution; in other words, the axial flux distribution during operation is assumed in the calculations to apply during shutdown. The form of the power transients is shown in the following figure.



If a rod were left out of the pattern, the uniform effect on flux with time would be approximately as follows:



The above "uniform" effect of a rod missing has been calculated to decrease the tube power limit by only 0.3 percent.

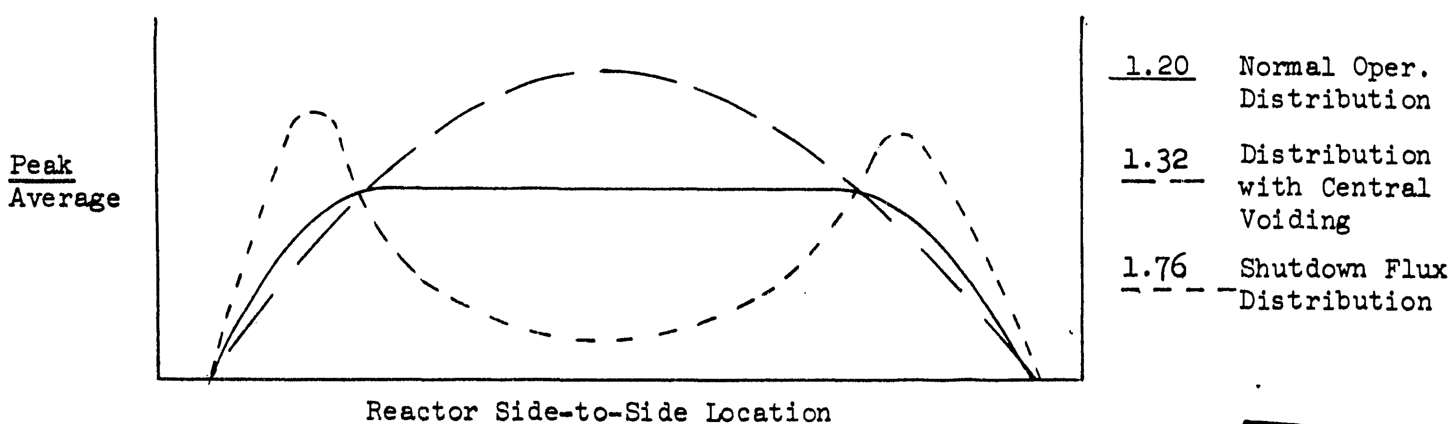
Side-to-Side Effect

The one-dimensional treatment of the kinetics problem in the vertical direction requires that side-to-side effects be "smeared" conservatively across the horizontal node. Two opposing effects take place under normal conditions which can be further affected by a missing rod:

(1) Reactor flattening, accomplished in part by the enrichment ring, and the geometrically centered rod system result in a shutdown flux distribution which is more peaked at the reactor sides than in the central region.

(2) Voiding in any given horizontal node would start within the flattened zone, causing the flux to peak more highly in the central region prior to rod entry into a given node.

Outside limits for the above two effects have been established for the static distribution case using the BUCK (buckling) code with the following results:



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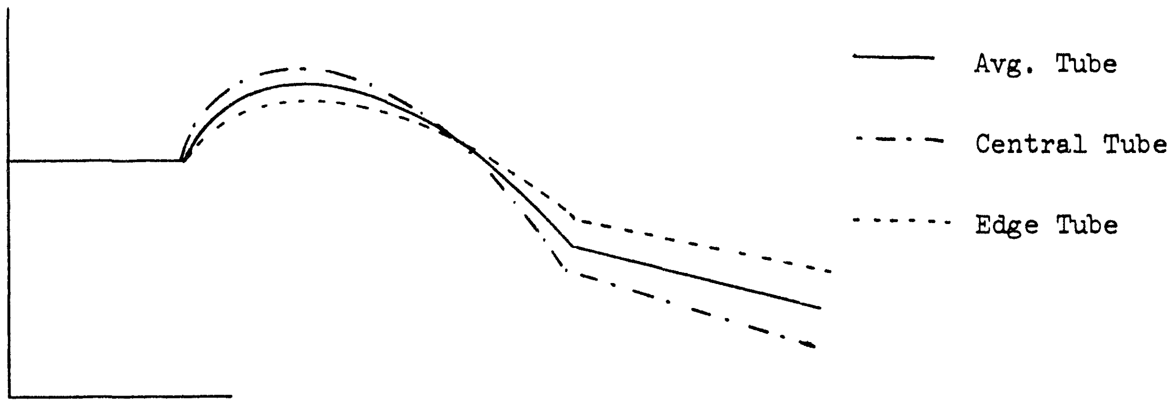
The CLUMSY kinetics code has been used in the side-to-side dimension to establish the effects of these distribution changes on the local flux transient in an isolated node in the vertical dimension. From these calculations the peaking caused by the reactivity gain upon voiding would decrease toward the edge of the flattened zone, becoming less than one at the inner edge of the flattened zone. The flux distribution then would dish when the VSRs entered the node vertically, with the flux peaked just outside the VSR control regions. The effect of a rod out of service in the outer edges of the control region would be to increase the relative flux at the edges of the flattened zone. The following figure shows schematically the power transients for the average tube, a central tube, and a tube at the edge of the flattened zone; the sketch includes side-to-side effects due to voiding and to the localized VSR pattern.



The calculational model used by not taking advantage of the dishing by the rods, results in generation of a limit for a central tube which is slightly more restrictive than that applicable to a tube at the edge of the flat zone; this model results in a conservative tube limit. The side-to-side calculation shows that the central tube actually would have experienced a smaller heating transient than an edge tube in the uniform rod case. In the case of the strongest edge VSR out of service, the edge tube is calculated to be 1.3 percent more limiting than it would have been with all VSRs in service, thus indicating the sensitivity of operating power limits to a VSR failure having maximum effect.

Front-to-Rear Effect

The axial flux distribution during operation approximates a cosine - slightly peaked by the normal operating control rod pattern and by the shortened enrichment columns in the E-ring. With the vertical rod system inserted during shutdown, however, the flux is depressed more at the center of the process column than at the ends. The associated effects are conservative relative to the assumption utilized in the calculational model that the shutdown case retains the axial flux distribution of the operating reactor. The following listing shows both the conservative effects and considerations which would qualify their numerical evaluation.

- The ultimate axial flux distribution in the static shutdown case would show a depression in the center of a process column.

[redacted]

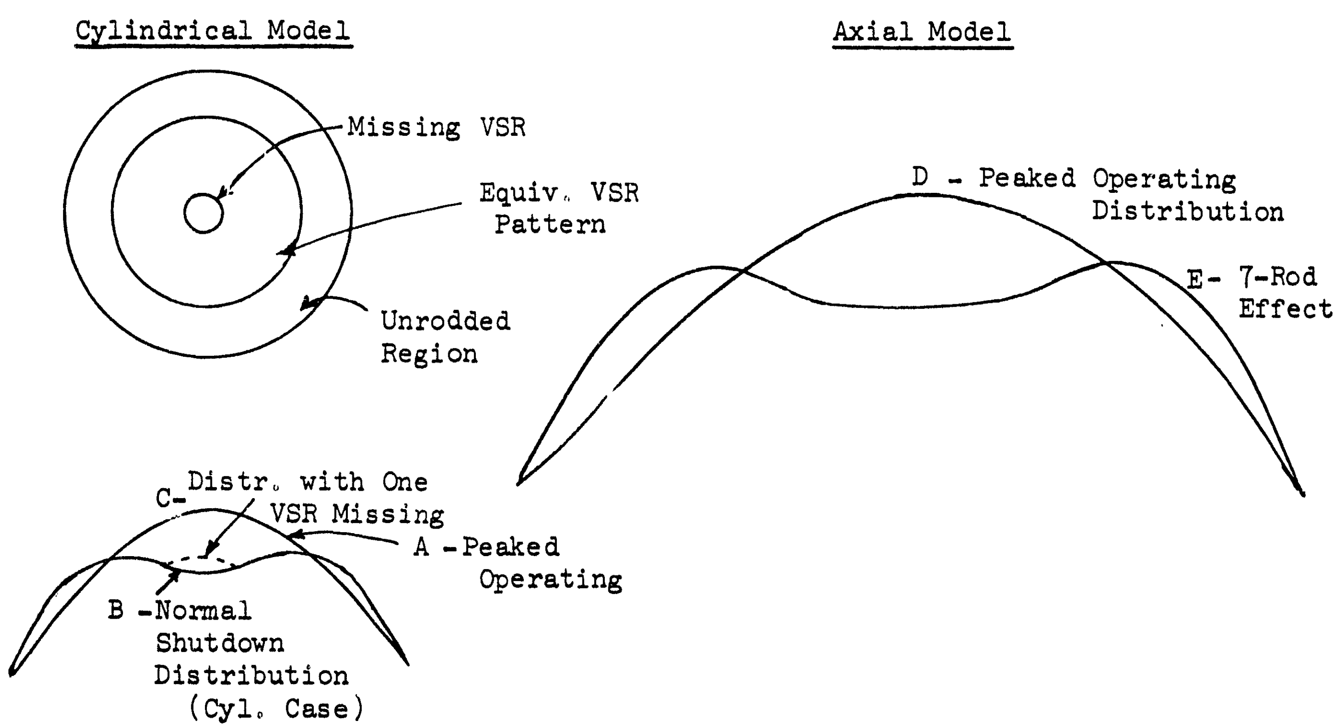
- Even with one VSR out of service in the most limiting location - at the center of the outer bank - the shutdown flux at the center of the column would be less relative to the average over the column than in the operating case.

- The axial flattening effect would be least at the sides of the VSR pattern as the front-to-rear flux at the extreme fringe of the reactor would approach a cosine distribution in either the operating or the shutdown case.

- The assumption of a falling curtain rather than a centered rod pattern previous to the VSRs entering the horizontal node under calculation would change the absolute values of both longitudinal and side-to-side effects slightly.

- Both prompt drop and subsequent decay effects would be larger at the center of the process channel than calculated but smaller at the front and rear. The net effect of the boilout and metal heating transients would be conservative, but determination of the amount of conservatism would be complex at best.

The method utilized for calculating front-to-rear effects of a missing rod in a manner which would best account for local leakage was employment of cylindrical geometry for both BUCK (static) and CLUMSY (kinetic) calculations. Incremental differences were then related to the operating and shutdown extremes of the normal front-to-rear distributions obtained with the BUCK code. These cases are indicated in the following figure:



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CALCULATED STATIC AND KINETIC VALUES - AXIAL DISTRIBUTIONS

Model	Configuration	Center-to-Average	Incremental
Cylindrical (BUCK - Static)	A - Operating	2.30	Base
	B - Normal Shutdown	1.33	-42%
	C - One VSR Missing	1.86	-19%
Axial (BUCK - Static)	D - Peaked Operating	1.56	Base
	E 7 - VSR Bank	1.31	-16%
Cylindrical (CLUMSY - Kinetic)	A - Operating	1.96	Base
	B - Normal Shutdown	1.56	-20%
	C - One VSR Missing	1.83	- 7%

R H Meichle

R. H. Meichle
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