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DOCUMENT NO.

TI-696-160-001

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DOCUMENT TITLE

Water Flooding Criticality Study for ZrH Flight Reactor

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SUPPORTING DOCUMENT

NUMBER

TI-696-160-001

REV LTR/CHG NO.

SEE SUMMARY OF CHG

PROGRAM TITLE

ZrH Reactor Development

DOCUMENT TYPE

Technical Information

KEY WORDS

Core flooding, reactor submersion

DOCUMENT TITLE

Water Flooding Criticality Study for ZrH
Flight Reactor

ORIGINAL ISSUE DATE

10/29/70

GO NO.

7759

S/A NO.

12340

PAGE 1 OF

TOTAL PAGES

6

REL. DATE 11/6/70

PREPARED BY

R. V. Anderson 10/29/70

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ABSTRACT

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Five analytical criticality calculations were performed to study the effects of: 1) water reflection only (no core flooding), 2) water reflection with 10% core flooding, 3) water reflection with 35% flooding, 4) water reflection plus complete core flooding, and 5) the negative reactivity feedback associated with rapid core expansion induced by a destructive transient.

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I. INTRODUCTION

Safety evaluation for the reactor requires analysis of possible accidental submersion and/or flooding of the core/reflector vessel. There exists a minimum flooding level in the core (assuming the vessel is submerged) after which criticality occurs. Four criticality calculations have been performed to scope the submersion-flooding situation. These were: 1) water reflection only (no core flooding), 2) water reflection plus 10% flooding, 3) water reflection plus 35% flooding, and 4) water reflection plus complete core flooding. These conditions were considered to determine the worth of water reflection and flooding and the effect on the axial power profile.

Additionally, the reactivity change associated with a step increase in core/internal reflector radius (with a stationary control drum/reflector region) has been calculated. Typically, a radial increase results from a submersion/flooding criticality that leads to a destructive excursion. The negative reactivity feedback associated with rapid expansion of the core boundary limits the excursion and energy generated.

II. APPROACH

The APC-II computer code with radial/axial buckling iterations was chosen as the best method of solution to the problem. The geometric model used in flooding cases is shown in Figure 1. The LiH neutron shield is assumed destructively removed from the vessel (by rupture and/or water reaction). The TalOW shield remains intact and is surrounded by infinite water. Control drums are assumed to remain in their least reactive (poison-in) positions. The coolant passages within the reflector/dry-well region are either NaK or water filled depending upon the situation modeled.

The reactor core is the two-zone (radial), 295 element ZrH core, with 0.650 inch element-to-element pitch and 0.025 inch wall Incoloy 800 clad. The active core length is 18 inches. Samarium and Europium are used as burnable poisons. In partially flooded core cases, water is assumed to fill channels beginning at the lower gridplate. The unflooded core section is assumed to have voided channels.

The lower plenum region is assumed to be water or NaK filled in all cases. In partially flooded core cases, the upper plenum contains low density water, (water volume percent determined by the steam quality, assuming core criticality).

An axially reflected core/reflector/control drum buckling iteration was performed to determine the destructive transient expansion reactivity coefficient. The NaK-filled core model is identical with that described above. The core radius was expanded by 0.450 cm. Core densities were reduced to compensate for increased areas. The first radial control/reflector zone was decreased in area to accommodate core expansion. Material densities in this zone were not increased by area weighting, thus eliminating the reactivity increase associated with a high density reflector material surrounding the core.

III. RESULTS

Table 1 summarizes the four flooding situations and resultant effective neutron multiplication factors (K_{eff}). Figure 2 shows the axial power profiles for these situations (assuming a critical reactor).

Submersion with intact coolant lines (Case 1) produces a subcritical reactor. However, the water is not fully shielded by the TalOW slab and has a net worth of \$0.93 above the base case (vacuum operation).

Cases 2 and 3 (10 and 35% core flooding) scope the critical situation. The associated power profiles show the large power peaking occurring in the water flooded region. The additional worth of the water in the core, lower plenum, and control region is \$0.91 and \$6.08 (cases 2 and 3 respectively). Unfortunately, determination of the worth of each separate region cannot be calculated due to the small number of cases considered.

Case 4 (total flooding) sets the upper limits of the reactivity worth of water at \$14.96. The flatter power profile (with respect to NaK filled core) is due to reflection from the flooded plenums.

The additional calculation for a 0.450 cm core radius step increase resulted in a $K_{eff} = 1.02288$. This gives an expansion coefficient of $-\$11.97/\text{inch}$ (using $\beta = 0.0078$, $K_{eff, \text{unexpanded core}} = 1.0405$, $P = (K_1 - K_2)/(K_1 K_2 \beta)$). This result has been linearly extrapolated to a one inch step (from the actual ~ 0.2 inch calculation.)

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CHECKED BY:		REPORT NO. <u>TI-696-160-001</u>
DATE: <u>10/21/70</u>	TABLE <u>1</u>	MODEL NO.

<u>Region</u> **	<u>Case 1</u>	<u>Case 2</u>	<u>Case 3</u>	<u>Case 4</u>
Lower Plenum }	NaK	H ₂ O	H ₂ O	H ₂ O
Core Channels {	NaK	H ₂ O/10% VOID/90%	H ₂ O/35% VOID/65%	H ₂ O/100%
Upper Plenum }	NaK	H ₂ O/1%	H ₂ O/5%	H ₂ O/100%
Drum/Reflectors }	NaK	H ₂ O	H ₂ O	H ₂ O
K _{effective}	0.97515	0.98192	1.02237	1.09164
$\rho_{excess} (\$)^{\dagger}$	-3.27	-2.36	+2.81	+10.76
Water * Worth (\$)	0.93	1.84	7.01	14.96
Water Worth (\$) above submersion }	—	0.91	6.08	14.03

$\dagger$ based on $\beta = 0.0078$; $\rho = \frac{K-1}{K\beta}$

* Assuming \$ - 4.20 for unsubmerged, intact reactor, cold, poison-in.

** All cases surrounded by 20 cm (infinite equiv) of water.

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CHECKED BY:		REPORT NO. TI-696-160-001
DATE: 10/21/70	FIGURE 1	MODEL NO.

Radial/Axial Reactor Model For Criticality Study (WATER FLOODING)

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