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REVISION 1

LOSS-OF-PRESSURE ACCIDENT
HOT LEG PIPING FAILURE

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LOSS-OF-PRESSURE ACCIDENT

HOT LEG PIPING FAILURE

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SEE PREFACE NOTE

APPROVED

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NOTE :

Subsequent to the preparation of this study, motion limiters were included in the design such that complete lateral displacement of severed pipe ends could not occur in the hot leg of the reactor coolant system piping.

LOSS-OF-PRESSURE ACCIDENT
HOT LEG PIPING FAILURE

I. OBJECTIVE

The objective of this study is to determine if a circumferential rupture in the hot leg piping just downstream of the block valve, accompanied by complete lateral displacement of the pipe ends such that the exhaust flows do not oppose each other, will result in excessive pressure differentials across the reactor core.

A secondary objective of this study is to validate the conclusions of Study IV-303-2, in which a complete circumferential failure downstream of the attenuator was considered. This validation is necessary because of design changes in the attenuator.

II. CONCLUSIONS

1. For a circumferential failure with an exhaust area of twice the cross-sectional flow area of the hot leg piping at the isolation valve, the pressure differential across the reactor core exceeds 38 psi (Figure 1).

2. The pressure differential across the core reaches a maximum of 31.5 psi (Figure 1), 250 milliseconds following the same type piping rupture at the exit of the attenuator.

3. In the first case, the maximum pressure differential across the reactor core exceeds the pressure differential required to lift the core; for the second case, the pressure differential nearly equals the pressure differential which results in lifting the core.

III. RECOMMENDATIONS

To prevent the pressure differential which results in lifting the core, motion limiters should be installed around the reactor outlet piping to minimize piping displacements in the event of a circumferential piping failure. The limiters should extend from the reactor vessel outlet connection to a point downstream of the attenuator, in each coolant circuit. The limiters should be installed around the coolant system hot leg piping from the reactor vessel outlet connection to the steam generator inlet connection in both coolant circuits. If limiters are not installed for the total length of each hot leg piping circuit, additional analysis should be performed to determine the exact location beyond which motion limiters are not required.

IV. GIVEN DATA

1. Reactor coolant-loop piping fluid-flow resistances are determined from the following pressure drops at 215,000 lb/hr:

a. Vessel outlet to and including isolation valve	0.48 psi
b. Valve to bypass connection	0.25
c. Bypass to attemperator	0.0
d. Attemperator	0.25
e. Attemperator to steam generator	0.35
f. Steam generator to blower	0.56
g. Blower to bypass connection	0.0
h. Bypass to isolation valve	0.59
i. Isolation valve (included) to vessel inlet	0.28

(Reference 1 - verified by Reference 2).

2. Reactor-vessel volumes are as follows (Reference 1 verified by Kaiser Engineers' TWX 3, November 7, 1961):

a. Top plenum	3200 cu ft
b. Between temperature barrier and reflector	2200
c. Bottom plenum	2900

3. The total pressure drop in the reactor plenums is 0.45 psi at 427,000 lb/hr (Reference 1 verified by Reference 2).

4. The core design pressure drop is 10.25 psi at a helium flow of 427,000 lb/hr.

5. The steam-generator volumes are:

a. Outer shell	1100 cu ft
b. Tube field	220
c. Inlet and distribution shroud	160

(Reference 1 verified by Reference 2).

6. The volume of the coolant-loop piping is as follows for each loop:

a. Reactor vessel to isolation valve	122 cu ft
b. Isolation valve to attemperator	12.5
c. Attemperator	47
d. Attemperator to bypass line	3.5
e. Attemperator to steam generator	56.5
f. Blower	51.7
g. Steam generator to blower	125
h. Blower to isolation valve	112
i. Isolation valve to vessel inlet	56

(Reference 1 modified by Reference 2)

7. Steam generator pressure drop at 215,000 lb/hr is 2.0 psi (Reference 1 verified by Reference 2).

V. ASSUMPTIONS

1a. Rupture occurs instantaneously in one hot leg immediately downstream of the loop isolation valve. The total exposed flow area is equal to twice the cross-sectional area of the pipe and the ends are displaced such that the exhaust flows do not oppose each other.

1b. Rupture occurs instantaneously in one hot leg immediately downstream of the attemperator. The total exposed flow area is equal to twice the cross-sectional area of the pipe and the ends are displaced such that the exhaust flows do not oppose each other.

2. Reactor coolant undergoes adiabatic processes.

3. No flow is assumed through the blowers during the accident.

4. The reactor coolant system is idealized as several gas volumes and fluid flow resistances. Those items considered as gas volumes are:

a. The reactor vessel top plenum

b. The reactor vessel bottom plenum.

- c. The attenuators
- d. The steam generator in the sound loop.

Those items considered as fluid flow resistances are:

- e. The reactor core
 - f. The coolant loop piping including the bypass lines and valves.
5. Coolant escapes from the piping rupture with sonic velocity.

VI. DISCUSSION

This study covers credible circumferential type failures in the hot leg piping in two specific locations. The first is a rupture in one hot leg immediately downstream of the loop isolation valve. The second is a rupture in one hot leg immediately downstream of the attenuator.

The analysis of the second case is similar to that performed in Study IV-303-2. The change that has been made in the analysis is the result of a change in the piping and attenuator design which reduced the volume of gas contained in the coolant system external to the pressure vessel.

The reactor core pressure differential and flow leaving the reactor coolant system through the rupture are shown in Figures 1 and 2 for the two cases analyzed.

The pressure differential across the steam generator in the unruptured loop reaches a maximum of 4.37 psi, 80 msec after the hot leg rupture located immediately downstream of the block valve. The maximum pressure differential across this steam generator following the rupture at the exit end of the attenuator was calculated to be 2.48 psi. The maximum pressure differential occurs 72 msec following the rupture.

The method of analysis used in this study is identical to that used in Study IV-303-2. The derivations contained in Study IV-303-2 also apply to this study.

The calculated pressure differential that will cause lifting of the core is 32.4 psi (Reference 3). The cases examined in this study either nearly equal or exceed this lifting pressure differential. Consequently, motion limiters must be installed in the coolant system to limit the piping displacements to values which do not result in pressure differentials approaching 32.4 psi. The exact location beyond which motion limiters are not required has not been considered. Additional analyses would be required to determine the exact location if motion limiters are not installed around the entire hot leg piping.

VII. REFERENCES

1. Allis-Chalmers Study IV-303-2, Loss of Pressure Accident - Hot Leg Piping Failure (June 17, 1960).
2. Kaiser Engineers TWX 3, November 7, 1961.
3. Letter, Mr. Jackson to Mr. Bush, dated October 8, 1962.

FIGURE 1

FIGURE 1

FIGURE 2

FIGURE 2

Core Levitation Hazards Analysis

Total weight of fuel	234 channels	66,771 lb.
Weight of 234 top dummy assemblies @ 115.7# each		27,071 "
Weight of Top plate-grid structure		350 "
Weight of intermediate plate-grid structure		1396 "
BSD piping		800 "
Fuel channel extensions		4,444 "
Top grid and ring girder		25,830 "
Grid to temperature-barrier baffle		1950 "
Weight of bottom dummies	234 @ 85# each	19,890 "
2 - 9½" graphite plugs @ 1700# each		3400 "
2 - 9" graphite plugs @ 1500# each		3000 "
2 - 5½" graphite plugs @ 600# each		<u>1200 "</u>
Total Weight		156,102 lb.

Area for 232 fuel channels	=	4550 in ²
Area for 2 fuel channels	=	40 in ²
Area for 2 - 9½" plugs	=	157 in ²
Area for 2 - 5½" plugs	=	<u>56.5 in²</u>
		4803.5 in ²

$$\frac{156,102 \text{ lb.}}{4803.5 \text{ in}^2} = 32.4 \text{ psi}$$