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SENSITIVITY STUDY OF MAIN STEAM FLOW
CONTROL VALVE CLOSING AND OPENING TIMES

LABORATORY.

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SUMMARY

The sensitivity of the LOFT plant to different main steam flow control valve closure and opening times is examined using a hybrid computer simulation. Results for seven valve opening rates and seven valve closing rates are presented and discussed. Comparisons are made between this analysis and the current FSAR which assumes a 20 second full stroke motion rate. While full-stroke valve motion times of 1 to 40 seconds are shown to be acceptable with respect to safety margins, a motion time of 10 to 30 seconds is recommended to allow for adequate control sensitivity.

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The analysis of the plant response to the closing time of the MSCV relates to Section 15.2.7 of the FSAR, Loss of Steam Load. The analysis of the plant response to the opening time of the MSCV relates to Section 15.2.11, Steam Load Increase. Analysis of all other transients reported in the FSAR are not affected by the opening or closing time of the MSCV.

The main steam stop valve has a stroke time of 20 seconds. It can be concluded that the consequences of inadvertant opening/closing of the main steam stop valve are also bounded by this analysis for the following reasons. The main steam stop valve is a gate-type valve and hence there would be little variation in steam flow, as the valve closes, until the final portion of the stroke. This implies that a 20 second full-stroke closure of the stop valve could be equivalent to a 5 to 10 second full-stroke closure of the MSCV. Since it was shown that even a one second closure of the MSCV presents no safety concerns, it can be concluded that the closure analysis presented here for the main steam control valve sufficiently covers the safety concerns of an analysis of main steam stop valve closures.

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SENSITIVITY STUDY OF MAIN STEAM FLOW
CONTROL VALVE CLOSING AND OPENING TIMES

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March 1978

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1.0 INTRODUCTION

The LOFT Technical Specifications {Spec. 3.4.3(6)} require the main steamflow control valve (CV-P4-10) to have full-stroke opening and closing times greater than 20 seconds. Reference (1) states that the valve actually opens and shuts in less than 20 seconds, thus the results of transients initiated via an opening or closing of the main steamflow control valve (MSCV) are possibly more severe than those presented in previous analyses, e.g. Reference (2). The purpose of this study is to determine the sensitivity of the LOFT plant to the rate of motion of the MSCV. From this sensitivity study, maximum and minimum opening and closing times for the MSCV will be recommended, and the impact on the safety margins established in the FSAR will be assessed.

The hybrid computer simulation of the LOFT plant was used to perform this analysis. DNBR values reported in this study were calculated using a simplified "best-fit" model and so should be used only as a basis for qualitative comparisons between the various transients presented. The effects of seven full-stroke motion times were examined for both closing and opening of the MSCV.

2.0 MSCV CLOSURES

2.1 Description and Consequences {Reference (2)}

The steamflow control valve is used to regulate the heat removal rate from the primary coolant system. Inadvertant operator action or spurious control action that closes the steamflow control valve causes a loss of primary coolant system heat removal capability. Unless terminated by automatic or manual action, this load imbalance could result in system overtemperature and overpressure.

Following a reactor scram, the steamflow control valve is automatically controlled to remove residual heat from the primary coolant system. The steam generator safety relief valves will provide the means for removing the residual heat if the MSCV is inoperative.

2.2 Method of Analysis

For the MSCV closure simulation, assumptions were made such that a maximum system pressurization would occur. This is achieved by assuming the pressurizer spray and power-operated relief valves in the primary system are inoperative. The Doppler reactivity coefficient ($-1.5 \times 10^{-5} \Delta\rho/^{\circ}\text{F}$) and moderator density coefficient ($2.0 \times 10^{-3} \Delta\rho/\text{lb}/\text{ft}^3$) were selected to give conservative results and are identical to those used in the FSAR [Reference (2)]. Initial plant parameters used for the MSCV closing transients were a power level of 53.2 MW, a primary loop flow of 3.4×10^6 lb/hr, a primary pressure of 2262 psia, a secondary steam pressure of 830 psia, an average core temperature (T_{AVE}) of 577°F , and an initial MSCV position of about 77% of full-open.

The transient is initiated by ramping the steamflow control valve shut from its initial position at a constant rate equivalent to some specified full-stroke closure time (e.g. a 20 second full-stroke closure time implies a ramp rate of 5%/second); in this study, full-stroke closure times of 1, 5, 10, 15, 20, 30, and 40 seconds were examined. The resulting loss of heat removal capability following the valve closure causes the primary coolant system to heat up. The MSCV is assumed inoperable as soon as it closes, therefore the steam generator safety relief valves are used to keep the steam generator from overpressurizing and to remove residual heat following a reactor scram. The transient is terminated by a high primary pressure scram (setpoint = 2440 psia).

2.3 Results

Figures 1 through 7 display the effects of closing the MSCV at different rates. The same general trends are seen in each of the seven transients: the large power steamflow mismatch caused by the closing valve results in a large increase in primary coolant pressure and a decrease in reactor coolant differential temperature. A reactor scram is initiated on high pressurizer pressure and the primary relief valves open at the setpoint of 2525 psia, effectively limiting the primary system pressure. It is also seen that although the MSCV was not available to remove residual heat, the steam generator relief valves limited secondary pressures to a maximum of about 1175 psia for the 1 second closure case.

The faster closure times result in transients with steeper slopes in each data trace during the initial 10 seconds, i.e. both primary and secondary pressures rise faster, initiating a reactor scram faster, and reactor coolant temperatures increase at a faster rate. In no case, however, are any large overshoots introduced into the data traces by the faster valve closures; peak values of temperatures, reactor power, and pressurizer pressure are nearly identical for each closure rate. Secondary system peak pressures vary from 1175 psia for a 1 second closure rate to 1136 psia for the 40 second full-stroke closure, but the steam generator relief valves compensate for the higher pressures by simply opening a second valve. Table I summarizes the significant results of each closure transient, presenting the minimum DNBR, maximum steam generator pressure, and maximum hot leg pressure attained.

The initial DNBR values reported in Table I for each transient vary slightly due to the inability of the hybrid simulation to initialize at exactly the same conditions for each run. Because of this, the minimum DNBR values given should not be used as a basis for comparing the transients, but rather the Δ DNBR values. Even then, only qualitative comparisons can be made since the DNBR values were, as stated earlier, calculated using a "best-fit" correlation and not COBRA-IIIC. Examining the Δ DNBR values in Table I shows that faster valve closures are more severe with respect to DNBR decrease.

2.4 Conclusions

For each closure rate simulated, the reactor shutdown system and the primary coolant system pressure relief valves protect the plant from over-pressurization during closure of the main steamflow control valve, even without taking credit for the pressurizer spray and power-operated reliefs. Pressurizer pressure is limited to a maximum of about 2530 psia in each case. System overtemperature is also prevented by the reactor safety systems.

With regards to safety margins, it is noted that in the FSAR, the 20 second closure transient resulted in a minimum DNBR of 1.25 (as calculated using COBRA-IIIC). Using the Table I results, a 1 second closure will result in an additional 0.06 decrease in DNBR ($0.115 - 0.057 = 0.058$), or a minimum DNBR of 1.19 which is still within acceptable limits. Since the 1 second closure

results in the lowest DNBR, all closure rates studied are acceptable with respect to DNBR safety margins.

3.0 MSCV OPENINGS

3.1 Description and Consequences (Reference (2))

Any inadvertent operator action or spurious control action that opens the MSCV will cause a power mismatch between the reactor core power and the steam generator load demand. This load imbalance causes a decrease in the primary coolant system temperature and pressure. Unless terminated by manual or automatic action, the load imbalance would cause system overpower.

3.2 Method of Analysis

In simulating the opening of the MSCV, the same hybrid model parameters used in the FSAR analysis of the increased steam load transient were used. A maximum moderator density coefficient $\{9.1 \times 10^{-3} \Delta\rho/(\text{lb/ft}^3)\}$ was used in the analysis to enhance the increase in power as the valve is opened and a Doppler coefficient of $-0.3 \times 10^{-5} \Delta\rho/^\circ\text{F}$ was assumed. Initial plant parameters used for the MSCV opening transients were a 51 MW power level, a primary loop flow of $3.4 \times 10^6 \text{ lb/hr}$, a primary system pressure of 2262 psia, a steam pressure of 810 psia, an average core temperature (T_{AVE}) of 578°F , and an initial MSCV position of 77% of full-open.

The transient is initiated by ramping the steamflow control valve from its initial position to full-open at a constant rate corresponding to some full-stroke opening time; full-stroke opening times of 1, 5, 10, 15, 20, 30 and 40 seconds were studied. The opening of the valve causes a reduction in both primary system pressure and temperature and in this analysis, the MSCV is assumed to fail at the full-open position. The transient is terminated by a high reactor power scram (setpoint = 55MW).

3.3 Results

Figures 8-14 present the results of simulating the MSCV opening at seven different rates. The effects of the opening are nearly identical for each rate: the increased steamflow causes a steamflow-reactor power mismatch which results in a reduction in coolant temperature and pressure and, through the large (absolute value) moderator density coefficient, causes an increase in reactor power. The power rise is terminated by a high power scram and the only appreciable difference between the seven transients is when the scram occurs, i.e. the slower openings result in a slower cooldown and hence a slower power rise. Following the scram the loop temperatures and pressure continue to decrease since the MSCV is assumed to fail in the open position.

DNBR values for each transient are presented in Table II. The previous comments regarding the DNBR values in Table I also apply to the values here, i.e. they are only to be used for qualitative comparisons between transients. Also note that the initial values vary slightly due to the inability of the hybrid simulation to initialize at exactly the same point for each transient. In Table II, it is seen that for opening times less than 20 seconds, no drop in DNBR below the initial value is predicted. For times greater than 20 seconds, the drop in DNBR increases as the opening times increase.

3.4 Conclusions

In each MSCV opening simulated, the high power scram provided adequate protection against system overpower, limiting power rise to about 55 MW in each case.

In the FSAR, where a 20 second opening rate was assumed, a minimum DNBR of 1.34 was calculated using COBRA-IIIC. From Table II, the 40 second opening rate will result in an additional 0.01 decrease in DNBR (When compared to the 20 second case) or a minimum DNBR of 1.33. Hence, each opening rate is adequate with regard to DNBR margin.

4.0 RECOMMENDATIONS

Reference (1) requested that new maximum and minimum MSCV motion times be recommended and also states that the valve opens and closes in less than 20 seconds. On the basis of the sensitivity study performed here opening and closing times of less than 20 seconds should present no problems, with regard to system overpressure, overtemperature, overpower, or DNBR limits.

In fact, it was seen that all motion times from 1 to 40 seconds are acceptable, but it is recommended that motion times of 10 to 30 seconds are more practical with regard to MSCV controllability. The technical specifications and FSAR should be revised to reflect this recommendation.

The effects of this newly recommended range of MSCV motion times on the current FSAR analysis are minimal. For the closure analysis, a 10 second closure rate (as opposed to the 20 second rate assumed in the FSAR) would only decrease the DNBR an additional 0.01 to 1.24, as seen in Table I. A 10 second opening rate is more conservative than a 20 second rate (Seen in Table II), hence, the reported minimum DNBR of 1.34 in the FSAR is conservative. Based on these results, the DNBRs for the opening and closing accidents of the MSCV are not significantly different from the FSAR values.

Finally, it should be noted that in addition to the main steamflow control valve, the main steam stop valve (CV-P4-11) could also be used to close off the secondary system steamflow, and it is possible that a stop valve closure would initiate a more severe transient than an MSCV closure. The closure characteristics (other than a full-stroke closure time of about 20 seconds) of the stop valve are not available to allow a direct comparison of the system transient response to an MSCV closure with the response to the closure of the stop valve, but a few qualitative conclusions can be drawn. The main steam stop valve is a gate-type valve and hence there would be little variation in steam flow, as the valve closes, until the final portion of the stroke. This implies that a 20 second full-stroke closure of the stop valve could be equivalent to a 5 to 10 second full-stroke closure of the MSCV. Since it was

shown that even a one second closure of the MSCV presents no safety concerns, it can be concluded that the closure analysis presented here for the main steam control valve sufficiently covers the safety concerns of an analysis of main steam stop valve closures.

5.0 REFERENCES

- (1) J. C. Stachew, "LOFT Phase-C Technical Specifications Action Items," JCS-5-78, January 27, 1978
- (2) "LOFT Integral Test System Final Safety Analysis Report," Revision 1, August, 1977

FIGURE 1. MAIN STEAMFLOW CONTROL VALVE CLOSURE --
1 SECOND FULL-STROKE CLOSURE TIME

FIGURE 2. MAIN STEAMFLOW CONTROL VALVE CLOSURE--
5 SECOND FULL-STROKE CLOSURE TIME

FIGURE 3. MAIN STEAMFLOW CONTROL VALVE CLOSURE--
10 SECOND FULL-STROKE CLOSURE TIME

FIGURE 4. MAIN STEAMFLOW CONTROL VALVE CLOSURE--
15 SECOND FULL-STROKE CLOSURE TIME

FIGURE 5. MAIN STEAMFLOW CONTROL VALVE CLOSURE --
20 SECOND FULL-STROKE CLOSURE TIME

FIGURE 6 : MAIN STEAMFLOW CONTROL VALVE CLOSURE --
30 SECOND FULL-STROKE CLOSURE TIME

FIGURE 7. MAIN STEAMFLOW CONTROL VALVE CLOSURE--
40 SECOND FULL-STROKE CLOSURE TIME

FIGURE 8. MAIN STEAMFLOW CONTROL VALVE OPENING--
1 SECOND FULL-STROKE OPENING TIME

FIGURE 9. MAIN STEAMFLOW CONTROL VALVE OPENING--
5 SECOND FULL-STROKE OPENING TIME

FIGURE N. MAIN STEAMFLOW CONTROL VALVE OPENING --
15 SECOND FULL-STROKE OPENING TIME

FIGURE 12. MAIN STEAMFLOW CONTROL VALVE OPENING -
20 SECOND FULL-STROKE OPENING TIME

FIGURE 13. MAIN STEAMFLOW CONTROL VALVE OPENING --
30 SECOND FULL-STROKE OPENING TIME

FIGURE 14. MAIN STEAMFLOW CONTROL VALVE OPENING--
40 SECOND FULL-STROKE OPENING TIME

TABLE I

SUMMARY OF RESULTS OF MSCV CLOSURE TRANSIENTS

Full-Stroke Closure Time (Seconds)	Initial DNBR	Minimum DNBR	$(\Delta \text{DNBR})_{\text{Max}}$	Maximum Steam Generator Pressure (psia)	Maximum Hot Leg Pressure (psia)
1	1.388	1.273	-0.115	1173.6	2523.5
5	1.389	1.298	-0.091	1172.8	2510.2
10	1.402	1.334	-0.068	1171.8	2519.8
15	1.382	1.319	-0.063	1174.6	2517.1
20*	1.385	1.328	-0.057	1156.0	2516.9
30	1.400	1.363	-0.037	1136.6	2522.4
40	1.415	1.388	-0.027	1136.2	2514.0

* The 20 second closure is the case analyzed in the FSAR, where a minimum DNBR of 1.25 was calculated using COBRA-IIIC.

TABLE II
DNBR VALUES FOR MSCV OPENING TRANSIENTS

Full-Stroke Opening Time (Seconds)	Initial DNBR	Minimum DNBR	$(\Delta \text{DNBR})_{\text{max}}$
1	1.460	1.460	0.000
5	1.451	1.451	0.000
10	1.458	1.458	0.000
15	1.457	1.457	0.000
20*	1.458	1.452	-0.006
30	1.461	1.444	-0.017
40	1.455	1.436	-0.019

* The 20 second opening is the case analyzed in the FSAR where a minimum DNBR of 1.34 was calculated using COBRA-IIIC.