LOFT TECHNICAL REPORT LTR 113-38
EG&G REPORT NUMBER RE-E-77-179
APRIL 22, 1977

MASTER

DETERMINATION OF REQUIRED DELAY TIME FOLLOWING
REACTOR SHUTDOWN PRIOR TO ACTUATION
OF LOFT ECCS BYPASS

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IDAHO OPERATIONS OFFICE UNDER CONTRACT EY-76-C-07-1570

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TECHNICAL REPORT NO. RE-E-77-179
DATE April 22, 1977
WORK REQUEST NO. 52191-124-385
LTR No. 113-38
Date Published by CDCS Oct. 17, 1977

TECHNICAL REPORT

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LOFT TECHNICAL REPORT
LOFT PROGRAM

TITLE DETERMINATION OF REQUIRED DELAY TIME FOLLOWING		REPORT NO. 113-38
REACTOR SHUTDOWN PRIOR TO ACTUATION OF LOFT ECCS BYPASS		
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PERFORMING ORGANIZATION Thermal Analysis	DATE Published by CDCS Oct. 17, 1977	
LOFT APPROVAL <i>GD [Signature] JKE [Signature] gca</i>	April 22, 1977	

Action

Incorporate required minimum times before actuation of ECC Shutdown Bypass
as calculated in this report in

- a) Technical Specification,
- b) Operating manual, and
- c) EOP.

Distribution

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TAB File

SUMMARY

The results of calculations are presented for the decay time required prior to LOFT ECCS Shutdown Bypass actuation following a reactor shutdown. These calculations are based on a LOCA occurring during hot shutdown which would void the core. Based on an operator response time of 20 minutes to manually establish ECC flow, the reactor decay time was calculated to prevent the fuel cladding temperature from exceeding 1100°F. Results show that 211 hours are required following normal reactor shutdown from 55 MW reactor power before ECCS Shutdown Bypass actuation can be allowed if the reactor is not in cold shutdown condition. One hundred (100) seconds are required following a LOCE before ECCS Shutdown Bypass actuation can be allowed.

[a] Decay time refers to the time after reactor SCRAM or shutdown.

1.0 INTRODUCTION

1.1 Description of System

The LOFT Emergency Core Cooling System (ECCS) provides a large volume of ambient - temperature water at low pressure (600 psig or less) which can be injected into the cold leg nozzles near the vessel in order to insure adequate cooling to remove core decay heat after a LOCE. The function of the ECCS Shutdown Bypass is to shut down automatic ECCS operation when no further requirement exists for automatic initiation of emergency core cooling.

1.2 Purpose of the Analysis

Calculations were necessary in order to determine the minimum time following reactor shutdown that a reactor operator could be allowed to activate the ECCS Bypass. The minimum time was calculated for two situations:

- (1) The level of decay heating with time and a conservative time allowance for operator response in reactivating the ECC System in the event that the core becomes uncovered due to a LOCA from hot standby; and
- (2) The time required to boil off all the water above the core following reactor shutdown assuming a LOCE.

1.3 Method of Analysis

A. The ECCS Shutdown Bypass actuation time estimate from the consideration of cladding temperature rise due to uncovering of the core following a LOCA during hot shutdown, was based on the following assumptions:⁽¹⁾

- (1) Clad temperature not allowed to exceed 1100°F.
- (2) Initial fuel pin temperature of 500°F at the time (shortly after reactor shutdown) when the fuel pins are uncovered.

- (3) Fuel pin assumed to be insulated when it is uncovered, i.e., no credit taken for heat transfer to air-steam atmosphere.
- (4) 20 minutes required⁽¹⁾ for operator response to reactuate ECCS once the Bypass has been activated.
- (5) Core fuel pin power peaking factors of APF = 1.61 (axial) and RPF = 1.63 (radial).
- (6) Fuel properties of 93% theoretical density (636 lbm/ft³) and specific heat value of $C_p = .07144$ Btu/lbm°F⁽²⁾.

With these assumptions the calculations are as follows:

$$\text{Fuel Volume} = V_f = (1300)(5.5)(\pi/4)(.3659/12)^2 = 5.221 \text{ ft}^3$$

$$(\rho C_p) = (636)(.07144) = 45.44 \text{ Btu/ft}^3\text{°F}$$

$$\left(\frac{dT}{d\theta}\right)_{\max} = \frac{(1100-500)}{(20)(60)} = 0.5 \text{ °F/sec.}$$

$$(\rho C_p) V_f \left(\frac{dT}{d\theta}\right)_{\max} = \dot{Q}_{T_{\max}} * \text{APF} * \text{RPF}$$

$$\dot{Q}_{T_{\max}} = \frac{(45.44)(5.221)(0.5)}{(1.61)(1.63)} = 45.2 \text{ Btu/sec. (the total core decay heat generation rate)}$$

In this range the uncertainty factor is $\pm 15\%$. When the apparent decay heating rate is $(1-0.15)(45.2) = 38.4$ Btu/sec., then the actual heating rate could be as high as 45.2 Btu/sec., due to the uncertainty factor of 15%. The allowable maximum value of $\dot{Q}_T$ therefore is 38.4 Btu/sec.

The corresponding elapsed time after reactor shutdown required before ECCS Shutdown Bypass actuation (from the ANS decay curve for 200 - hour operation) is 7.6×10^5 seconds = 211 hours = 8.8 days.

B. The ECC System also must be available for operation for 100 seconds following LOCE from consideration of the time required to boil off the water above the core after LOCE. This value is based on the following assumptions⁽¹⁾:

- (1) Cladding not to exceed 1100°F.
- (2) Fuel initially submerged, following 30- second LOCE from 55 MW.

- (3) Decay heat rate equal to boil off rate of saturated water.
- (4) Water level initially located at centerline of inlet nozzle
(37.98 ft³ of water between nozzle and top of core⁽³⁾).
- (5) 20 - minute operator response required.
- (6) Pressure = 50 psia after LOCE.
- (7) Clad temperature high enough to cause boiling at all times.

$$\dot{Q}_{\text{Decay}} = \dot{m}_{\text{BR}} h_{\text{fg}} \quad (\text{from item 3 above and ignoring energy stored in fuel})$$

$$h_{\text{fg}} = 924 \text{ Btu/lbm}$$

$$v_f = .017274 \text{ ft}^3/\text{lb}_m$$

$$V_w = \text{volume of water between top of core and centerline of inlet nozzle} = 37.98 \text{ ft}^3$$

$$\Delta M = \frac{V_w}{v_f} = \frac{37.98}{.017274} = 2200 \text{ lbm}$$

$$\Delta M = \dot{m} \Delta t = \frac{\dot{Q}_{\text{Decay}}}{h_{\text{fg}}} \Delta t = \frac{1}{h_{\text{fg}}} \int \dot{Q}_{\text{Decay}} \Delta t$$

$$h_{\text{fg}} \Delta M = \int \dot{Q}_{\text{Decay}} \Delta t = (924)(2200) = 2.03 \times 10^6 \text{ Btu}$$

This is the total heat that can be removed due to boiling, without uncovering the core, if the water level following LOCE is initially at the nozzles.

Table 1 below shows the time-integrated total decay heat versus time, assuming a 30-second LOCE which removes all decay heat to that point. The uncertainty factors of +50% from 10 to 100 seconds and +30% from 100 to 10,000 seconds are included, so that the table shows the maximum space-averaged values to each time. These values are plotted on Figure 1, which shows that the 2.03×10^6 Btu heat required to boil off the water above the core, would be generated between 100 and 1340 seconds, which allows 1240 seconds (20.7 min) for operator ECC System response. Therefore, the ECC System must be operational for 100 seconds following LOCE, in order to meet this requirement.

TABLE I

INTEGRATED DECAY HEAT STARTING 30 SEC. AFTER REACTOR SHUTDOWN

<u>Time (sec)</u>	$q_{\text{Decay}} \frac{\text{Btu}}{\text{sec}} \frac{[a]}{(\text{max})}$	<u>$[(\sum q \Delta t) - 42600.] (\text{Btu})$</u>
20	4470	89,400
30	4050	129,900
40	3900	169,400
60	3600	255,900
80	3450	330,400
100	3225	404,900
150	2470	589,400
200	2340	763,900
300	2080	1,153,900
400	1820	1,445,900
600	1625	2,274,900
800	1495	2,866,900
1000	1340	3,406,900
1500	1170	5,276,900
2000	1070	6,746,900
2500	990	7,936,900
3000	940	8,876,900
4000	830	10,546,900
5000	780	12,016,900
6000	715	13,296,900
8000	650	15,196,900
10,000	570	17,346,900

[a] Initial full power was assumed to be 55 MW.

2.0 RESULTS AND CONCLUSIONS

The required time following reactor shutdown before the reactor operator could be allowed to actuate the ECCS Shutdown Bypass, is estimated at 211 hours, based on the possibility of the core being uncovered if a LOCA occurred while in the hot shutdown conditions. The time following a LOCE before ECCS Shutdown Bypass actuation is 100 seconds.

3.0 RECOMMENDATIONS

It is recommended that the results of this analysis be used to determine the minimum allowable time following reactor shutdown prior to actuation of the ECCS Shutdown Bypass System.

4.0 REFERENCES

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