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PROBABILITY OF INADVERTENT OPENING OF A
LOFT BLOWDOWN BY-PASS VALVE

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RESEARCH, ENGINEERING AND CONSTRUCTION REPORT
ENGINEERING ANALYSIS DIVISION
RELIABILITY AND STATISTICS BRANCH

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LOFT TECHNICAL REPORT

TITLE PROBABILITY OF INADVERTENT OPENING OF A LOFT BLOWDOWN

REPORT NO.

BY-PASS VALVE

LTR 112-128

AUTHOR C. J. Naretto

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RCSB mgr *BB mgr* *RSB mgr.*

Configuration V (see Table I, p. 4) was selected by the LOFT project since it (a) offers the best defense against common mode failures (electrical or pneumatic) permitting inadvertent actuations (common mode failures are not addressed statistically) and (b) the reduction of availability (a factor of 3) is not significant statistically.

RELIABILITY ANALYSIS SECTION

PROBABILITY OF THE INADVERTENT OPENING OF A
LOFT BLOWDOWN BY-PASS VALVE

by

C. J. Naretto

ABSTRACT

This report documents a series of calculations performed to evaluate the probability of the inadvertent opening of various LOFT blowdown by-pass valve control configurations.

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1.0 Introduction

The inadvertent opening of a blowdown by-pass valve would violate the pressure boundary of the primary system which could result in the release of primary coolant. This report documents the results of a study to determine the probability that a blowdown by-pass valve would be inadvertently opened. Also, the probabilities of inadvertent actuation of various alternate control configurations was evaluated. The probability that the by-pass valve would not open when required was evaluated for each configuration in addition to the above.

2.0 Analysis

An abbreviated fault-tree was used to analyze each valve control configuration. The probability that the valve would be actuated inadvertently and the probability that the valve would not actuate when required was determined for each control configuration. Probability values were also determined assuming first complete dependence and then complete independence where a common mode failure was possible. The configurations analyzed were as follows:

Case I: The system as it exists presently with one by-pass valve and one handswitch.

Case II: Two by-pass valves in series in the by-pass line, each with its own handswitch.

Case III: Same as Case I except the handswitch was replaced by a keyswitch.

Case IV: Same as Case III with the addition of another handswitch in series with the first handswitch.

Case V: Same as Case I with the addition of a 3-way isolation and vent valve and a key-lock control switch.

The failure rate data used in this analysis were taken from WASH-1400 Table III 4-1, 4-2, and 6-1 of Appendix III.

3.0 Results

3.1 Probability of Inadvertent Actuation of By-Pass Valve

The results of this analysis are summarized in the enclosed table (Table I).

In Case I, the existing configuration, the principle contributor to the probability of inadvertent valve actuation is an error on the part of the operator.

Case II, also dominated by operator error, has a potential for common mode failure. If the operator is convinced he should open the by-pass valve, he will not be deterred by the redundancy of the system. Two probability values for this case were calculated, one assuming complete independence of the fault-causing events and one assuming complete dependence of these events. Both are reported in Table I.

Case III, in which the handswitch of the existing system is replaced by a key switch, is dominated by operator error also. The probability of inadvertent actuation is an order of magnitude lower than for Case I because the failure rate for operator error for key switches is an order of magnitude lower than for non-key operated switches.

Case IV, in which a handswitch is added in series to the existing handswitch, is susceptible to common mode failure also. As in Case II, if the operator's perception is that the by-pass valve should be opened, he will open it regardless of the number of handswitches he has to activate to do so.

In Case V, human errors and potential hardware failures were equally dominant. The probability that a by-pass valve would fail in the open position

is approximately equal to the probability that the operator would operate both the key lock control switch and handswitch inadvertently.

The control configuration analyzed as Case IV consisted of the original system with an additional handswitch placed in series with the first handswitch. This configuration has a potential for common mode failure for the same reason Case II does: the simultaneous operation of both handswitches through operator error. The probability values for both the dependent and the independent mode are the same as for Case II.

3.2 Valve Unavailability

The probability that the valve would not open when required to do so was determined for each control configuration listed in Table I. The probability that this fault would occur is on the order of 10^{-3} for each configuration considered.

4.0 Fault Trees

The fault trees that were generated as part of this analysis are enclosed in the Appendix.

TABLE I
SUMMARY OF RESULTS

Case	System Configuration	Probability of Inadvertent Actuation (Assuming Independence)	Probability of Inadvertent Actuation (Assuming Dependence)	Improvement (Multiple of Case I)	Valve Unavailability When Required*
I	Existing configuration. One valve with one handswitch.	$3 \cdot 10^{-3}$	NA	1	$1 \cdot 10^{-3}$
II	2 valves in series with one switch for each valve.	$1 \cdot 10^{-5}$	$1 \cdot 10^{-4}$	300 (Independence) 30 (Dependence)	$2 \cdot 10^{-3}$
III	Existing configuration with key switch in place of handswitch.	$1 \cdot 10^{-4}$	NA	30**	$1 \cdot 10^{-3}$
IV	Existing configuration. Two handswitches in series.	$1 \cdot 10^{-5}$	$1 \cdot 10^{-4}$	300 (Independence) 30 (Dependence)	$1 \cdot 10^{-3}$
V	Existing configuration with the addition of a 3-way isolation and vent valve and an additional key-lock control switch.	$1 \cdot 10^{-5}$	$1 \cdot 10^{-4}$	300 (Independence) 30 (Dependence)	$3 \cdot 10^{-3}$

*The probability the valve will not open when required.

**Improvement depends entirely on administrative control of the key; may be greater or less.

5.0 References

1. Reactor Safety Study, An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, WASH-1400, U.S. Nuclear Regulatory Commission, October, 1975.

APPENDIX

A-1

CASE I: SYSTEM AS IS, ONE VALVE & ONE HAND SWITCH

CASE I: SYSTEM AS IS, ONE VALVE & ONE HAND SWITCH

$P(\text{II}) \approx 1 \cdot 10^{-4}$ (DEPENDENCE)

$P(\text{II}) \approx 1 \cdot 10^{-5}$ (INDEPENDENCE)

CASE II: TWO BY-PASS VALVES IN SERIES WITH ONE SWITCH FOR EACH VALVE

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CASE II: TWO BY-PASS VALVES IN SERIES WITH ONE SWITCH FOR EACH VALVE

CASE III: EXISTING SYSTEM WITH KEY SWITCH IN PLACE OF HAND SWITCH

CASE III: EXISTING SYSTEM WITH KEY SWITCH IN PLACE OF HAND SWITCH

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$$\underline{\underline{P(IV) \approx 1 \cdot 10^{-5}}} \quad (\text{INDEPENDENCE})$$

$$\underline{\underline{P(IV) \approx 1 \cdot 10^{-9}}} \quad (\text{DEPENDENCE})$$

CASE IV : EXISTING CONFIGURATION WITH TWO HAND SWITCHES IN SERIES

VALVE
DOES NOT
OPEN WHEN
REQUIRED

AOV
FAILS TO
OPERATE

$$\lambda = 3 \cdot 10^{-4}/d$$

HAND
SWITCH 1 FAILS
TO TRANSFER

$$\lambda = 1 \cdot 10^{-5}/d$$

HAND
SWITCH
2 FAILS TO
TRANSFER

$$\lambda = 1 \cdot 10^{-5}/d$$

OPEN
CIRCUIT

$$\lambda = 3 \cdot 10^{-6}/hr$$
$$\tau = 200 hr$$

$$\underline{\underline{P(IV) \approx 1 \cdot 10^{-3}}}$$

CASE IV : EXISTING CONFIGURATION WITH TWO HAND SWITCHES IN SERIES

CASE V: 3-WAY ISOLATION & VENT VALVE PLUS KEY-LOCK CONTROL SWITCH

CASE V
CONTINUED

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CASE V
CONTINUED

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CASE V
CONTINUED

CUT SETS FOR CASE II

$$X = A + B + 2(FC + FD + GD + HC + HD + FI + FG + GG, \\ + GI + GEI + HEI + HEG + HIG)$$

ONE AND TWO EVENT CUT SETS

$$X = A + B + 2(FC + FD + GD + HC + HD + FI + FG \\ + GG, + GI)$$

CUT SET PROBABILITIES

<u>CUT SET</u>	<u>PROBABILITY</u>
A	10^{-4}
B	10^{-4}
2FC	Nil
2FD	
2GD	
2HC	
2HD	
2FI	
2FG	Nil
2GG,	$< 10^{-4}$
2GI	Nil

OVERALL PROBABILITY OF
INADVERTENT VALVE OPENING
(DEPENDENT CASE) $\approx 10^{-4}$

$$\underline{\underline{P(V) \approx 3 \cdot 10^{-3}}}$$

CASE V: 3-WAY ISOLATION & VENT VALVE PLUS KEY-LOCK CONTROL SWITCH