EVALUATION OF MILLSTONE UNIT 1

CONTAINMENT ISOLATION FAILURE

By

Yehia F. Khalil

Probabilistic Risk Assessment

Northeast Utilities
Hartrford, CT 06141-0270

April 1991

EXECUTIVE SUMMARY

Containment isolation is important during accident sequences in which radioactivity is released to the primary containment, and this isolation may prevent the transport of radioactivity to the reactor building. Furthermore, failure to isolate during the course of an accident could affect the accident progression and the severity of the accident, for example, adverse environmental conditions in the reactor building could fail safety-related components, such as emergency core cooling pumps.

The quantification of containment isolation failure probability consists of the two following steps:

1. Identification of the penetrations (potential leakage paths) which may not isolate following an accident in order to prevent, or minimize, radioactivity releases outside the primary containment.

2. Estimation of the frequency of failure to isolate. There are several factors that should be considered in the course of quantifying the probability of containment isolation failure, these factors include:

   - Number, types, and failure modes of the isolation valves.

   - Types of the automatic isolation signals that are generated.

   - Failure of the operator to manually isolate (if possible) and mechanical fooleries of the isolation valves.

   - Operator maintenance errors. These are errors during maintenance or testing in which the operator fails to restore the valves to their proper positions, or in some other way defeats the isolation capability of the valves.

The results of calculating the Millstone Unit 1 containment isolation failure probability show that this probability is dominated by the failure to isolate the main steam line and failure to isolate the containment during plant startup.

The total containment isolation failure probability for Millstone Unit 1 is 5.6E-4.

EVALUATION OF MILLSTONE UNIT 1

CONTAINMENT ISOLATION FAILURE

The Millstone Unit 1 primary containment is inerted with nitrogen gas. The primary containment oxygen concentration is usually measured and recorded on a weekly basis, and it must be maintained less than 4% by volume whenever the reactor coolant pressure is greater than 90 psig or when the reactor is in the "RUN MODE".

The differential pressure between the drywell and torus is maintained at 1.0 psid and nitrogen makeup is supplied to the containment whenever the differential pressure drops to $\leq$ 0.9 psid. The differential pressure between the drywell and torus is recorded once per shift (8 hours). The conditions where the differential pressure is allowed to be lower than 1.0 psid include the following:

1. Twenty four hours prior to a scheduled shutdown.

2. A maximum of four hours during operability testing of the vacuum breakers and during venting and purging of the containment.

3. A maximum of 48 hours for purposes of conducting a drywell entry.

The rate at which the drywell pressure drops, in the case of an isolation failure, affects the operator detection time. Large changes in the containment pressure are more likely to be detected by the operator than the very slow depressurization rates. Conversely, large depressurization rates correspond to large leak paths and, therefore, the operator is more likely to detect large leak paths than small ones.

Calculations show that for a leak size of 3/4 inches, which is typical of a recirculation loop sample line, it would take about 9 hours to drop the drywell pressure 1 psi. The leak path corresponds to a loss of the drywell nitrogen gas at a rate of 70 lb/hr. Since the maximum allowable leak rate from the primary containment corresponds to about 18 lb/hr of the contained nitrogen gas, then a 3/4 inch leak path could result in a leak rate that is four times higher than the maximum allowable leak rate. Consequently, it is likely that the operator will detect this leakage.

The operating conditions in the primary containment, which are considered in calculating the isolation failure probability, can be summarized as follows:

<u>DRYWELL</u>

Operating Pressure, psig	(low) 0.9 - 1.0 (high)
Operating Temperature, °F	135 160 (max)
Free volume, ft^3	146,900
Design Leakage Rate, % free volume/day	

<u>SUPPRESSION CHAMBER</u>

Operating Pressure, psia	(low) 14.4 - 14.6 (high)
Operating Temperature, °F	(low) 80 - 90 (high)

Free Volume, ft^3	108,194 - 110,600 (high)
Minimum Pressure Differential for Opening Hotwell to Drywell Vacuum Breakers, psid	0.5

The containment isolation failure probability is calculated as follows:

A - The containment penetration [as listed in Tables 3.7.1, 6.2-3, and 6.2-4 of the Millstone Unit 1 Updated Final Safety Analysis Report "UFSAR"] are classified into the following groups:

1 - Closed systems inside and outside containment with two normally closed isolation valves.

2 - Closed systems inside or outside containment with two normally closed isolation valves.

3 - Closed systems inside or outside containment with one normally closed isolation valve.

4 - Open systems inside and outside containment with two normally closed isolation valves.

5 - Open systems inside or outside containment with two norally closed isolation valves.

6 - Open systems with one normally closed isolation valve (e.g., the main steam drain lines).

7 - Open systems with two normally open isolation valves (e.g., main steam line).

B - The failure modes of the containment isolation valves that are evaluated include:

1 - A normally open valve fails to close .

2 - A normally closed valve fails to remain closed, (disc rupture).

Typically, isolation arrangements have two valves in series and, therefore, both valves must fail for isolation failure to occur.

Based on reviewing the major penetrations classification, as described in Table 6.2-3 of the Millstone Unit 1 UFSAR, the largest penetration size is 20 inches [for the main steam lines]. In addition, there are two sets of 2-20" vacuum breakers between the reactor building and the suppression chamber. The smallest penetration size is 3/4 inches (recirculation loop sample line). The instrument lines are 1 inch in diameter.

C - After reviewing the containment penetrations as described in the Millstone Unit 1 UFSAR, the following assumptions are made:

1 - Containment isolation failure is dominated by lines with two normally open isolation valves.

2 - Containment penetrations involving normally closed "double" isolation valves are not risk significant.

3 - Closed systems with or without normally closed isolation valves are not risk significant.

4 - Open systems with small line sizes (< 2 inches in diameter) are not risk significant.

D - The probability of containment isolation falure "P_{CI}" is expressed as follows:

$$P_{CI} = P_{PE} + P_{CIV} + P_{SU} \quad \ldots\ldots (1)$$

where:

P_{PE} = Probability of preexisting containment isolation failure.

P_{CIV} = Probability of failure of isolation valves.

"P_{CIV}" is dominated by the failure of the Main Steam Isolation Valves "MSIV's" and the failure of the Reactor Building/Suppression Chamber Vacuum Breakers "P_{RB-SC}".

P_{SU} = Probability of containment isolation failure during startup.

Note that the probability of containment isolation failure during shutdown is negligible because the high likelihood of detecting isolation failure with the reactor in the "RUN MODE."

The total probability "P_{CI}", as described in Eq. (1), can be calculated as follows:

I. PROBABILITY OF PREEXISTING CONTAINMENT ISOLATION FAILURE "P_{PE}":

$$P_{PE} = f_{CI} * [P_R . t_R + \bar{P}_R . t_{NR}] \quad \ldots\ldots (2)$$

where:

f_{CI} = frequency of loss of containment integrity

= [1/20 yrs] = 0.05 yr^{-1}

P_R = Probability of restoring containment integrity within 1 hour after detection time.

= 90% (assumption).

$\bar{P}_R$ = $(1 - P_R)$ = 10%

t_R = Mean detection time (4 hrs) + isolation time (1 hr).

t_R = [8 hours per shift/2] + 1 hour = 5 hours.

t_{NR} = Mean time that containment integrity is not available before cold shutdown is achieved [assumed to be 24 hrs for detection and shutdown].

Substitution into Eq. (2) yields.

P_{PE} = $[0.05\ yr^{-1}]$ [1 yr/8760 hrs] $\left\{(5\ hrs)\ (90\%) + (24\ hrs)\ (10\%)\right\}$

P_{PE} = 4.0E-5 . . . . (3)

II. CONTAINMENT ISOLATION FAILURE PROBABILITY DURING STARTUP "P_{SU}":

$$P_{SU} = P_{CI} . f_{su} . t_{su} \qquad \text{. . . . (4)}$$

where:

P_{CI} = Probability of a containment isolation failure during startup. This is assumed to be 1 per 40 startups (i.e., over a period of 20 years) = 2.5E-2

f_{su} = Frequency of plant startups = 2 per year.

t_{su} = Time during which the containment is not isolated during startup = 24 hours.

Then

P_{SU} = (2.5×10^{-2}) (2 startup/yr) (24 hrs/startup) (1 yr/8760 hrs)

$P_{SU} = 1.4E\text{-}4$ . . . . (5)

III. PROBABILITY OF FAILURE OF CONTAINMENT ISOLATION VALVES "P_{CIV}":

Failure of containment isolatior valves is dominated by failure to isolate the main steam lines (≈ 3.75E-4) and failure to isolate the reactors building to suppression pool vacuum breakers (≈ 1.0E-7).

$$P_{CIV} = P_{MSIV} + P_{RB\text{-}SP} \quad \text{. . . . (6)}$$

$$\textit{then,} \qquad P_{CIV} = 3.75E\text{-}4 + 1.0E\text{-}7 \quad \text{. . . . (7)}$$

where:

P_{MSIV} = Probability of failing to isolate the main steam lines = 3.75E-4.

$P_{RB\text{-}SP}$ = Probability of failing to isolate the RB/SP vacuum breakers = 1.0E-7.

Substitution of the values of failure probabilities, as given by Eqs. (3), (5), and (7), into Eq. (1) yields.

$P_{CI} = 4.0E\text{-}5 + 1.4E\text{-}4 + 1.0E\text{-}7 + 3.75E\text{-}4$

$P_{CI} = 5.6E\text{-}4$ . . . . (8)

A comparison among the four probabilities shown in Eq. (8) shows that the probability of containment failure to isolate is dominated by the failure to isolate the main steam lines and failure to isolate the containment during plant startup.

REFERENCES

1. Technical Specifications, Millstone Nuclear Power Station Unit No. 1, Docket No. 50-245.

2. Millstone Unit No. 1, Updated Final Safety Analysis Report, MNPS-1, UFSAR.