NORTHEAST UTILITIES

THE CONNECTICUT LIGHT AND POWER COMPANY
WESTERN MASSACHUSETTS ELECTRIC COMPANY
HOLYOKE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

General Offices • Selden Street, Berlin, Connecticut

P.O. BOX 270
HARTFORD, CONNECTICUT 06141-0270
(203) 665-5000

August 7, 1985

Docket No. 50-245
B11633

Director of Nuclear Reactor Regulation
Attn: Mr. Christopher I. Grimes, Chief
Systematic Evaluation Program Branch
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Gentlemen:

Millstone Nuclear Power Station, Unit No. 1
Integrated Safety Assessment Program
Summaries of Public Safety Impact Model Project Analyses

On July 16-18, 1985, representatives of Northeast Nuclear Energy Company (NNECO) met with the Staff and their probabilistic risk assessment consultants, Science Applications International Corporation (SAIC), to review the Millstone Unit No. 1 Probabilistic Safety Study. During the meeting, and in accordance with our understanding of the ISAP process[1], NNECO was requested to provide the Staff with summaries of the public safety risk oriented analyses of a selected number of projects we are evaluating in the Integrated Safety Assessment Program (ISAP).

In order to facilitate the Staff review of our project analyses, we are providing the Staff, in Attachment 1, with summaries of the following projects we have evaluated for public safety impacts:

1) ISAP Topic No. 1.02 - "Tornado Missile Protection"

2) ISAP Topic No. 1.16.1 - "Millstone Unit 1/Millstone Unit 2 Backfeed"

3) ISAP Topic No. 2.06 - "Main Condenser Retube"

4) ISAP Topic No. 2.07 - "Sodium Hypochlorite System"

It is noted that since we have not completed our analyses of the entire set of ISAP projects, the public safety impact scores are to be considered preliminary at this time. Upon completion of our analyses of the entire ISAP project set, including all five attributes, we will review our analyses and revise our public safety impact results, if necessary, to assure consistency in the ranking of the ISAP projects.

(1) H. L. Thompson letter to J. F. Opeka, "Integrated Safety Assessment Program", July 31, 1985.

PA01
1/40

As further public safety impact analyses are completed, we will promptly forward summaries to the Staff for review.

In addition to the project analyses, we are providing the Staff, in Attachment 2, with draft documentation of the Public Safety Impact Model (PSIM) which we have developed and are using in the prioritization of the ISAP projects. It is intended that the PSIM documentation will facilitate Staff review of the public safety risk analyses of the ISAP projects.

In accordance with the provisions of 10CFR2.790, it is requested that Attachment 2 be withheld from public disclosure as it is considered to be proprietary to Northeast Utilities. The reasons for the classification of this material as proprietary are delineated in the accompanying affidavit.

Very truly yours,

NORTHEAST NUCLEAR ENERGY COMPANY

J. F. Opeka

J. F. Opeka
Senior Vice President

C. F. Sears

By: C. F. Sears
Vice President

cc: J. A. Zwolinski

NORTHEAST UTILITIES SERVICE COMPANY

AFFIDAVIT

I, Richard T. Laudenat, being duly sworn, depose and state as follows:

1. I am Manager, Generation Facilities Licensing Branch, Nuclear Engineering and Operations Group, Northeast Utilities Service Company, and as such I am responsible for the preparation and review of the proprietary information referenced herein sought to be withheld from public disclosure. I am submitting this affidavit in conformance with the provisions of 10 CFR 2.790 of the Commission's regulations and in conjunction with the application of Northeast Nuclear Energy Company for withholding this information.

2. The information sought to be withheld represents a portion of Northeast Utilities Service Company's (NUSCO) extensive development efforts regarding a process by which NUSCO plans to evaluate proposed plant betterment projects. This information is contained in this submittal.

3. This is information of a type customarily held in confidence by Northeast Utilities Service Company and, other than its disclosure to the Commission, is intended to be held in confidence and not disclosed to the public. Northeast Utilities Service Company has a rational basis for determining the types of information customarily held in confidence by it and evaluates each document or report which might contain proprietary information to determine whether the subject document should be accorded confidential treatment. This evaluation concluded that the subject document referenced herein does contain proprietary information which justifies it being withheld from public disclosure.

4. In determining whether information in a document or report is proprietary, the following criteria and standards are utilized by Northeast Utilities Service Company. A document or report is provided with confidential treatment if any one of the following criteria are met:

    (a) The information reveals the distinguishing aspects of a process, method, component, structure, equipment, or system where prevention of its use by any person or organization without license from Northeast Utilities Service Company might provide a competitive economic advantage over other companies.

    (b) It consists of supporting data, including test data, relative to a process, method, component, structure, equipment, or system, the application of which provides or could provide a competitive economic advantage to the Company. The availability of such information to any other person or organization would enable it to modify its product or to pursue marketing or other actions which would improve its products positions or impair the position of the product of Northeast Utilities Service Company and enable any such organization to avoid developing similar data and analyses in support of its process, method or apparatus.

(c) The development of the process, method, component structure, equipment, system or compilation of information required a significant expenditure of man hours of effort and dollars; a competitor would have to undergo similar expense to generate an equivalent formula, pattern, device, or compilation of information.

(d) Obtaining licensing approvals necessary for the application of the process, method, component, structure, equipment, or system would require a significant effort and expense. Avoidance of this expense would decrease a potential competitor's cost in applying or marketing the process, method, component, structure, equipment, system or product to which the information is applicable.

5. The information is being transmitted to the Commission in confidence pursuant to the provisions of 10CFR2.790 with the understanding that it is to be received in confidence and withheld from public disclosure by the Commission.

6. The information, to the best of my knowledge and belief, is not available in public sources, and any disclosure to third parties has been and will be made pursuant only to regulatory requirements or proprietary agreements which provide for the maintenance of the information in confidence.

Richard T. Laudenat, being duly sworn, deposes and says that he has read the foregoing affidavit and that the matters stated herein are true and correct to the best of his knowledge, information, and belief.

Executed in Berlin, Connecticut this 7th day of August, 1985

Richard T. Laudenat

Richard T. Laudenat

State of Connecticut

ss. Berlin

County of Hartford

Sworn and subscribed before me, a notary public, in said state and county, this 7th day of August, 1985.

Sheila M. Oates

Notary Public

My Commission Expires: March 31, 1986

Docket No. 50-245

Attachment 1

Millstone Nuclear Power Station Unit No. 1
Integrated Safety Assessment Program
Public Safety Impact Model Project Analyses Summaries

August, 1985

ISAP #1.02 **Tornado Missile Protection**

Safety Issue

There are four basic ways to remove core decay heat at Millstone Unit 1 and these are:

- o Feedwater and Main Condenser
- o Isolation Condenser
- o Shutdown Cooling System
- o Alternate Shutdown Cooling

In the event of a major tornado at the Millstone site, it is likely that a loss of offsite power would occur and result in unavailability of the Feedwater and Main Condenser systems. The potential for damage from tornado missiles to the other three decay heat removal schemes led to further evaluations under the Systematic Evaluation Program (S.E.P.). These evaluations identified that a tornado with sufficient wind speed could produce missiles which could penetrate the turbine building switchgear room, through which power cables from the diesel and gas turbine pass. This would eliminate the capability of using the Shutdown Cooling System or going on Alternate Shutdown Cooling. The only remaining decay heat removal system, the Isolation Condenser, was also assessed to be vulnerable to tornado missile induced failure due to the potential for missiles to penetrate the fire water and condensate storage tanks. In the final Safety Evaluation Report for Topic III-4.A (Tornado Missile Protection), the NRC concluded (Reference 1) that components inside the reactor building, including the reactor coolant pressure boundary and the Isolation Condenser (IC) system are adequately protected from the effects of tornado missiles. To resolve this issue it is necessary to develop a means of providing makeup water to both the Isolation Condenser and Reactor Pressure Vessel from tornado missile protected sources.

Proposed Project

The project under consideration proposes a design change to provide for a portable engine driven pump and a tornado missile protected water supply to provide makeup to the IC and the Reactor Pressure Vessel (RPV). The water supply to the latter may be needed to restore the RPV water level during

depressurization as the level drops due to shrinkage or possible leaks. The proposed design modifications would be used in the following manner.

Following a loss of normal power caused by the tornado, the IC will be initiated either manually or automatically to initiate depressurization of the RPV. As discussed in Section 2.1 of the Millstone Unit 1 PSS, makeup to the IC needs to be initiated within 40 minutes. The time available to initiate injection into the RPV to recover the water level is about 2 hours. During depressurization, the RPV inventory shrinks and the water level drops. However, the core remains covered until the RPV is depressurized to a pressure below 100 psia, which is estimated to occur in about 2 hours.

The normal sources of makeup water for the isolation condenser are the fire water system and the condensate transfer system. However, neither the fire water tanks nor the condensate storage tank are protected from tornado missiles. The proposed design calls for a portable engine driven pump which could supply flow to the IC and if needed, to the RPV. This pump and the required hose and fittings will normally be stored at a designated protected location in the condensate storage tank pump house or its own pump house.

The use of an offsite supply of make-up water necessitates that this supply not be susceptible to the effects of the same tornado. The source of city water for the Millstone site is Konomoc Lake, which is located approximately seven miles from the site. In the event of a loss of primary power, backup power to pump this water throughout the city water system is provided by a diesel generator. Therefore, this water supply is not susceptible to the effects of the same tornado. Supplying cooling water from this source to the Isolation Condenser will require the installation of an underground water hydrant and a fitting into an Isolation Condenser makeup line. The design for makeup to the RPV is not yet finalized. One option is to provide flow via existing control rod drive piping.

Analysis of Public Safety Impact

The public safety impact of the proposed project was assessed using Method A. The proposed project will provide benefits in two areas: improved capability to

achieve and maintain safe shutdown following severe tornado events and improved reliability of Isolation Condenser makeup following internal events. Each of these benefits are addressed separately.

A. Benefits From Mitigating the Effects of Tornado Missiles

The Millstone Unit 1 PSS did not include a specific evaluation of the effects of Tornado Missiles. The types of system failure sequences resulting from tornado missiles, however, are very similar to those evaluated for loss of normal power events. In a tornado with sufficiently high wind speed, the following failures can be postulated:

- Loss of normal power due to grid failure
- Loss of power from the Diesel Generator (DG) and the Gas Turbine (GT) when the missiles begin to penetrate the turbine building through which the power cables for the DG and GT are routed or the diesel/gas turbine enclosures through metal access openings, the structures themselves, or the intake/exhaust ducts.
- Loss of IC make-up due to missiles penetration of the fire water and the condensate storage tanks.

As discussed in section 2.4.2 of the Millstone Unit 1 PSS, this sequence leads to an early core melt with containment initially intact (TE1).

The method of analysis was to determine the frequency of the tornado which could result in the sequence discussed above. This sequence was then mitigated by crediting the availability of city water supply estimated from a simplified fault tree. The following assumptions were made in this analysis:

- It is assumed that city water supply will remain available following the tornado. The city water is supplied by Konomoc Lake. Konomoc Lake is located about seven miles from the Millstone site. It is very unlikely that Konomoc Lake will also be hit by the tornado at the same time as the Millstone site. A backup diesel pump is available in the event city power is lost.

- It is assumed that the operator actions necessary to provide city water to the IC can be completed within 40 minutes.

- It is assumed that the power supply from the DG and the GT and make-up to the IC will be lost if a tornado with sufficient high wind speed strikes the Millstone site. No credit is taken for the fact that all targets may not be hit by a damaging missile during a tornado.

Figure 1 provides the fault tree for failure to deliver city water supply to the IC and RPV. The fault tree includes the human error probability associated with the operator action of manually starting the portable pump and connecting the fire hoses. The unavailability of this connection to city water is calculated to be 0.2.

It is estimated that a tornado with a wind speed of 165 mph can lift missiles strong enough to fail the fire water and condensate storage tanks. The value for the wind speed is estimated from the analysis performed for the Connecticut Yankee (CY) Nuclear Power Plant (located at East Haddam) for the SEP Topic III-4A (Tornado Missiles). The power cables for the DG and the GT are estimated to fail at lower wind speed. The frequency of a tornado with a wind speed of 165 mph striking the Millstone Site is estimated to be 1×10^{-5}/year. This value is estimated from the tornado missile risk analysis performed for Millstone Unit 3 (Ref. 2) and would amount to the core melt frequency due to tornado missiles.

The tornado missile related core melt frequency after implementing the proposed project can be calculated as follows:

$$\lambda = \lambda_T (Q_{IC} + Q_{CW})$$

-where: λ = core melt frequency due to tornado missiles
$\lambda_T = 1 \times 10^{-5}$/yr, frequency of 165 mph tornado at Millstone
$Q_{IC} = 3.02 \times 10^{-3}$, unavailability of IC (Table 2A-5)
$Q_{CW} = 0.2$, unavailability of the city water connection.

Performing the calculations yields a revised core melt frequency due to tornado missiles of 7.8×10^{-6}/yr. This reduction is solely in the TE1 Plant Damage

State and hence the risk reduction would be roughly 300 Man-Rems.

B. Benefits From Mitigating Loss of Normal Power Events

For internal events, availability of city water supply will be beneficial in mitigating those station AC blackout sequences where IC is initiated but the make-up to the IC fails due to failure of the site fire water supply. The frequency of such a scenario is estimated by the following equation.

$$\lambda = \lambda_{LNP} \, Q_{AC.Rest} \, (P_{SS4} + P_{SS7}) \, Q_{FPS}$$

The failure probabilities are obtained from the Millstone 1. PSS as shown below:

λ_{LNP} = 0.124/year, (Section 1.2)

Restoration of AC: If IC is available, the restoration of AC can be delayed until 90 minutes. Probability of failing to recover offsite power in 90 minutes is 0.26 (Section 2.4.2 and Appendix 2A)

Split Fractions: For Support State 4 (14E*SW): $P_{SS4} = 1.22 \times 10^{-2}$
For Support State 7 (14E*14F): $P_{SS7} = 5.52 \times 10^{-3}$
(Section 5.2)

Millstone Site Fire Water
Supply Fails Auto initiation and restoration fails

$$Q_{FPS} = (8.54 \times 10^{-2})(8.49 \times 10^{-1}) \quad \text{(Section 3.2.15)}$$
$$= 7.25 \times 10^{-2}$$

The resultant core melt frequency would be:

$$\lambda = 0.124/\text{yr} \times 0.26 \times (1.22 \times 10^{-2} + 5.53 \times 10^{-3}) \times 7.25 \times 10^{-2}$$
$$= 4.1 \times 10^{-5}/\text{year}$$

The revised core melt frequency with implementation of city water supply hook-up is calculated by the following equation:

$\lambda = 4.1 \times 10^{-5}/yr\ (Q_{CW}) = 8.2 \times 10^{-6}/yr$

Q_{CW} = unavailability of city water supply (0.2)

The change in predicted core melt frequency would be roughly 3.28×10^{-5} which has a corresponding level of risk reduction of 1230 Man-Rems.

Results

If the city water supply hook-up is implemented, the core melt frequency decreases by 4.1×10^{-5}/year, a drop of 5%. About 80% of benefit in core melt frequency is from the internal event (i.e. LNP initiated sequences).

Almost all of decrease in core melt frequency is in the TE1 plant damage state (see MP1 PSS, Section 2.2 for definition of the plant damage states). This results in a decrease in public risk of about 1530 person-rem over the remaining life of the plant and therefore, a score of 3.75 out of 10.

References

1. Letter J.J. Shea (NRC) to W.G. Counsil,"SEP Topic III-4A, Tornado Missiles, Millstone Unit 1," May 25, 1982.

2. Letter W.G. Counsil to B.J. Youngblood (NRC),"MP3 Response to SER Topic Item (2)," Docket 50-423, B11521, April 26, 1985.

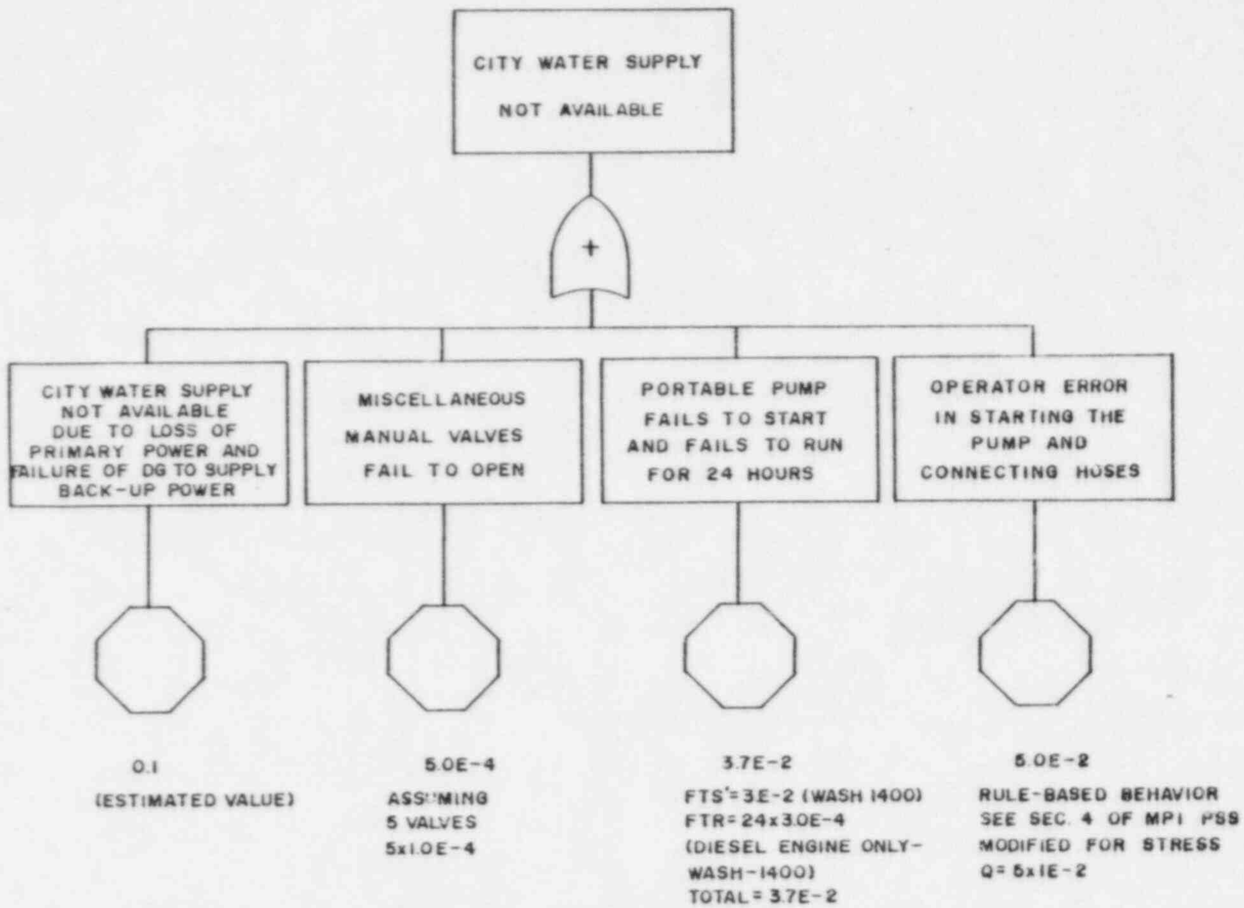

FIGURE 1. CITY WATER SUPPLY TO IC FAULT TREE

ISAP #1.16.1 Millstone Unit 1/Millstone Unit 2 Backfeed

Safety Issue

As currently designed, a number of Millstone Unit 1 core cooling and cold shutdown systems have pumps which are powered by the 4160V buses. The complete loss of these buses is a Station AC Blackout event which places total reliance on the Isolation Condenser in order to avoid core damage. In some cases this may not be sufficient if minor reactor coolant system leakage exists. The Millstone Unit 1 P.S.S. evaluated such sequences originating from internal events and concluded that loss of these buses is dominated by loss of normal power followed by failures of the diesel and gas turbine. The failure of the redundant AC buses due to random failures was assessed to be an insignificant contributor to Station AC Blackout. When external events, such as fires, are considered it is noted that a hypothetical worst case switchgear room fire could result in failure of the redundant buses needed to power core cooling and cold shutdown systems. This proposed ISAP project addresses the issue of being able to provide AC power from Millstone Unit 2 sources to the Control Rod Drive (C.R.D.) pump indefinitely through connections which do not pass through the switchgear room. Implementing this project would thus address mitigation of the hypothetical worst case switchgear room fires as well as events in which there is a failure of both Millstone Unit 1 onsite emergency generators.

Proposed Project

The conceptual design shown in Figure 1 calls for supplying power from Millstone Unit 2 emergency buses to 4160V bus 24F. A circuit breaker, controllable from the Millstone Unit 1 control room, will be added between the bus 24F and the Reserve Station Service Transformer (R.S.S.T.) to isolate the bus 24F from the offsite power source. The C.R.D. pump can be powered directly by bus 24F (thus bypassing the switchgear room) by installing a cable between bus 24F and the C.R.D. pump. Note that bus 24F is located outside the turbine building which houses the switchgear room.

The Isolation Condenser and IC Makeup, both of which can function independent of Station AC, can remove the core decay heat. However, the C.R.D. pump

operation may be needed to restore RPV water level during the depressurization as the level drops due to shrinkage or possible leaks.

Analysis of Public Safety Impact

The public safety impact of this project was assessed using Method A. The PRA assessment of the proposed project concluded that in addition to mitigating switchgear room fires the changes will result in the capability to provide power to the Unit 1 emergency buses following a Station AC Blackout caused by any internal event. Therefore, Millstone Unit 1/Millstone Unit 2 Backfeed has two benefits which are evaluated separately. (The additional benefit of backfeeding power to Millstone Unit 2 during an AC Blackout was not evaluated.)

A. Benefits from Mitigating the Effects of a Switchgear Room Fire

In the event of a fire induced Station AC Blackout, the IC and IC Makeup flow can be initiated independent of Station AC power. The makeup to the IC is provided by the diesel fire pump which can also be used to provide flow to the RPV to recover the water level over the long term. Injection into the RPV with the fire pump requires manually connecting a hose in the feedwater heater drain line in the turbine building. Following a switchgear room or feedwater pump area fire, however, the turbine building may not be accessible. The C.R.D. pump, which is located in the reactor building can be used to recover the RPV water level and provide long term makeup if needed.

A previous probabilistic analysis of fire events (Reference 1) has indicated that the switchgear room fire is a dominant fire induced core melt accident sequence. Therefore, the proposed backfeed could significantly reduce the frequency of fire induced core melt sequences. What is important to consider is the relative frequency of such fires compared to events already considered in the Millstone Unit 1 P.S.S. which result in similar equipment unavailabilities. The previous fire analysis indicated that the frequency of a switchgear room fire, with failure of detection (and hence manual suppression), and with a transient fuel loading available to allow fire spread throughout the zone is 3.5×10^{-5}/yr. Such a fire could result in the complete loss of both emergency AC

buses (Station AC Blackout). When this value is compared to the frequency of the equivalent internal event considered in the P.S.S., namely: loss of normal power in conjunction with either Support State 4 (14E*SW) or Support State 7 (14E*14F), the following frequency is obtained:

$$\begin{aligned} \lambda &= \lambda_{LNP} * (P_{SS4} + P_{SS7}) \\ &= (.124/\text{yr.}) * (1.22\text{x}10^{-2} + 5.52\text{x}10^{-3}) \\ &= 2.2\text{x}10^{-3}/\text{yr.} \end{aligned}$$

Even if offsite power recovery is credited, this value would remain significantly greater than fire induced events with similar consequences on equipment. Because of this, the benefit of the proposed project is more important to mitigation of internally initiated events than to fire initiated events.

B. Benefits from Mitigating a Station AC Blackout

As discussed in Section 2.4.2 of the Millstone Unit 1 P.S.S., following a Station AC Blackout and failure of the Isolation Condenser (an additional random failure), the core begins to uncover at 25 minutes due to cycling S/R valves. Core melt can be avoided if AC power is restored within 45 minutes. Therefore, the backfeed needs to be achieved within 45 minutes (to avoid core melt) and preferably within 25 minutes.

The method of analysis was to perform a sensitivity study using the Millstone Unit 1 P.S.S. as the base case. The split fractions of the support states which result in a Station AC Blackout (See Section 2.3 of the P.S.S.) were revised to include probability of being able to obtain power from the Millstone Unit 2 diesel generator. The core melt sequences were requantified with the revised support state split fractions. The following assumptions were made:

- o Although, the loss of power on 4160V buses 14E and 14F is possible following a reactor trip (e.g. due to failure of fast transfer), it is more likely following a loss of normal power. In the analysis it is assumed that at the time of backfeed, Millstone Unit 2 has also

experienced a loss of normal power.

- The backfeed will be attempted only if both diesel generators at Millstone Unit 2 successfully start and run.

- Following a loss of normal power, one diesel at Millstone Unit 2 can supply all necessary load. Therefore, it is assumed that the operator will disconnect the other diesel from Millstone Unit 2 loads and will dedicate it for the backfeeding of power to Millstone Unit 1.

- It is assumed that the procedures will be available to the operators of both Millstone Units 1 and 2 detailing the conditions in which backfeed can be used and the steps for accomplishing it.

- Although the design is not yet finalized, it is assumed that sufficient protective relaying (consistent with standard industry practice) will be built into the design and the operating procedures will be written to ensure that a potential fault can not be transmitted to Millstone Unit 2. The backfeeding will require at least 4 separate breakers in series to remain closed. If the Millstone Unit 2 diesel is connected to a faulted Unit 1 bus, opening of any one of these four breakers will prevent fault transmission. Also, since it is assumed that a Unit 2 diesel will be dedicated solely for backfeeding to Unit 1, any potential fault transfer (should it occur) will not fail the critical systems at Millstone Unit 2 except possibly the diesel and its 4160V bus involved in the backfeed operation.

- It is assumed that to energize an AC bus, the corresponding DC bus must be available (i.e. bus 101A for AC bus 14F and 101B for bus 14E). This is to ensure that all electrical manipulations are achievable from the control room.

- It is assumed that control room operation capability of the breaker between the bus 24F and R.S.S.T. will be available. The control room operation is necessary to ensure completion of backfeeding procedures within 25 to 45 minutes.

- o It is assumed that design modification for C.R.D. pump self-cooling has been implemented. This capability will be needed following the switchgear room fire, as only the C.R.D. pumps will be powered by the bus 24F and not T.B.S.C.C.W. and Service Water pumps which normally supply cooling flow to the C.R.D.

Results

Figure 2 provides the fault tree for failure to provide power from the Millstone Unit 2 diesel to the Millstone Unit 1 emergency buses. The top event unavailability is Q= 0.2.

Table 1 provides the split fractions for both LNP and non-LNP cases of the support states which are affected by the backfeeding. Both the base case values (obtained from the Millstone Unit 1 P.S.S., Section 5.2) and the revised values used in this analysis are provided. The following sample calculation depicts the method used in calculating the revised split fractions.

The base case values are:

$$P_{SS4} = 1.22x10^{-2}$$
$$P_{SS3} = 1.265x10^{-1} \qquad \text{- for LNP Table 5.2-1}$$

The revised values incorporating the benefits of the proposed project are:

$$P_{SS4} = 1.22x10^{-2} * Q$$
$$P_{SS3} = 1.265x10^{-1} + 1.22x10^{-2} * (1-Q)$$

- where Q = failure probability of backfeed including HEP's (Human Error Probability)

If the Millstone Unit 1/Millstone Unit 2 backfeed is implemented, the core melt frequency decreases from $8.07x10^{-4}$/yr to $7.52x10^{-4}$/yr (or about 7%). Almost all of the decrease in core melt frequency is in the TE1 plant damage state (See Millstone Unit 1 P.S.S. Section 2.2). This results in a decrease of

approximately 2000 Man-Rems over the remaining life of the plant and therefore an ISAP score of 5 out of 10.

References

1. W.G. Counsil letter to D.G. Eisenhut, dated March 1, 1982.

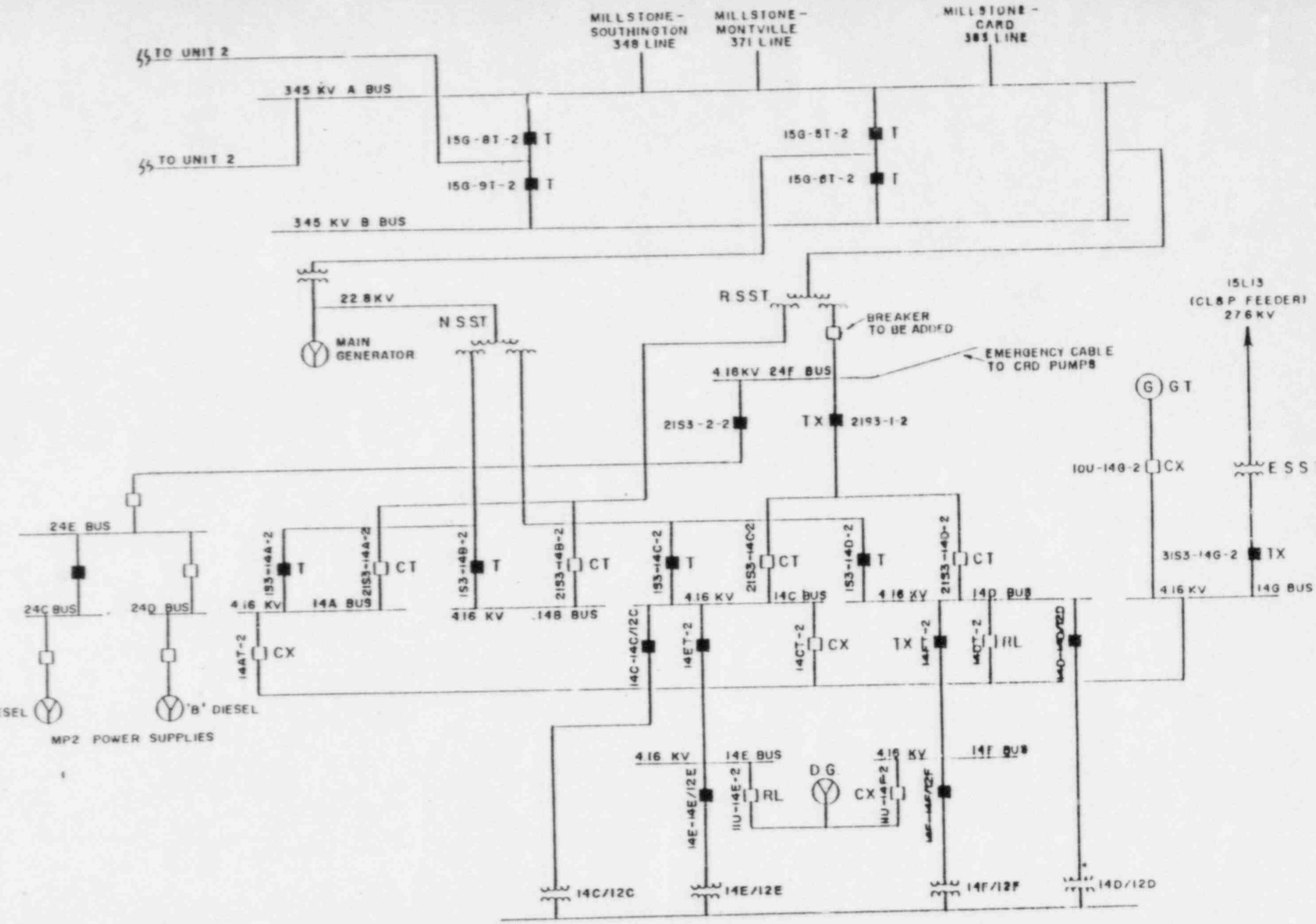

FIGURE 1. CONCEPTUAL DESIGN FOR MP1/MP2 BACKFEED

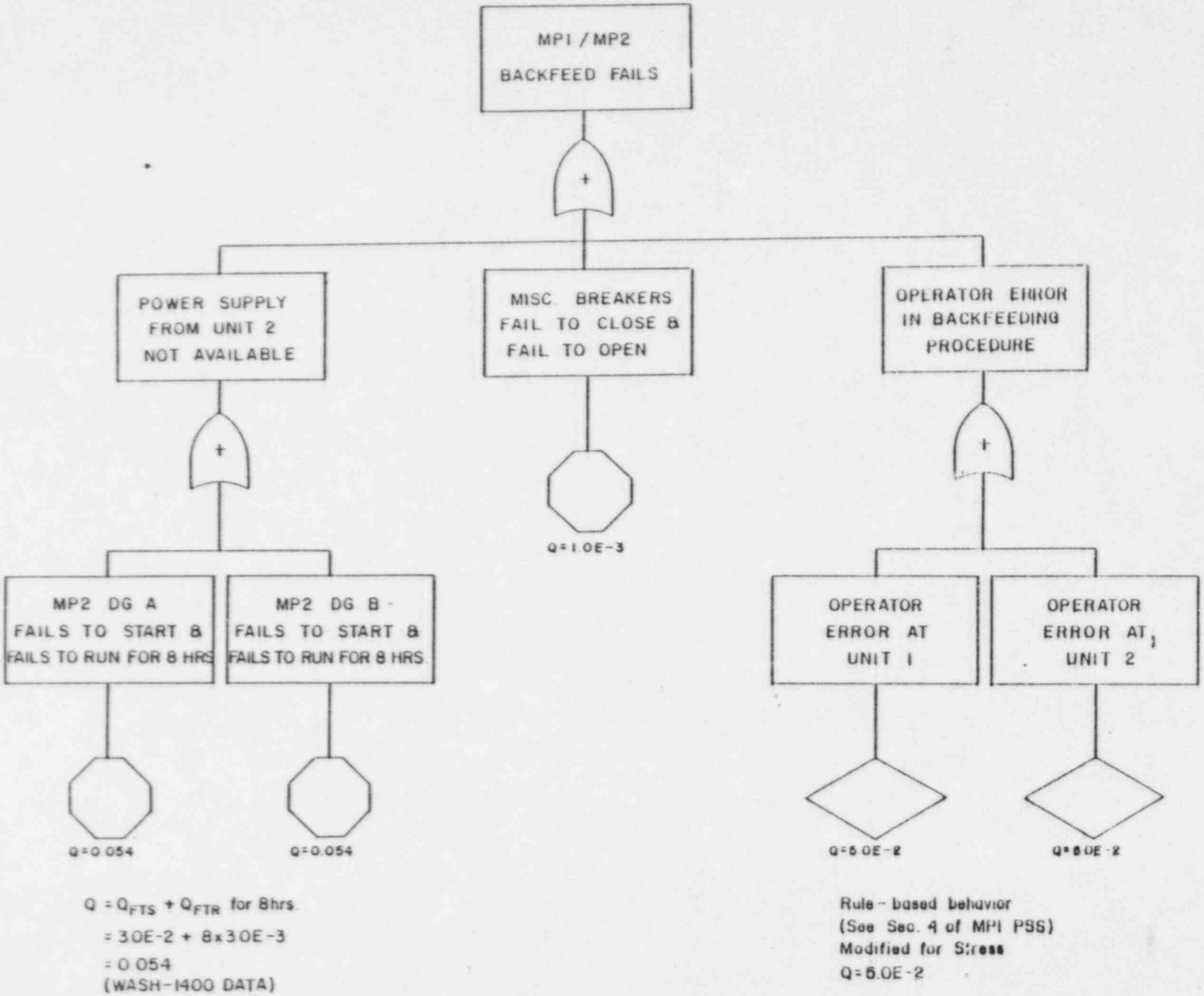

FIGURE 2. MP1/MP2 BACKFEED FAULT TREE

Table 1

Support State Split Fractions

Support State	Failed Systems	LNP Case Base (1)	LNP Case Revised	non-LNP Case Base (2)	non-LNP Case Revised
3	14E	1.265E-1	1.407E-1	4.029E-4	4.911E-4
4	14E*SW (2)	1.222E-2	2.444E-3	(4)	
7	14E*14F	5.521E-3	1.104E-3	1.076E-4	2.152E-5
9	101B*SW (3)	1.987E-5	3.974E-6	(4)	
10	101B*14F	8.445E-6	1.689E-6	2.597E-7	5.194E-8
13	101A*14E	3.369E-5	6.738E-6	9.732E-8	1.946E-8

Notes:

(1) From Section 5.2 of the Millstone Unit 1 P.S.S.

(2) In the case of a loss of normal power, loss of Service Water also implies loss of AC bus 14F (diesel bus).

(3) Loss of a DC bus implies the loss of the corresponding AC bus.

(4) Not a Station AC Blackout Sequence and therefore not modified.

ISAP #2.06 Retubing the Millstone Unit 1 Main Condenser

Safety Issue

There are four basic ways to remove core decay heat at Millstone Unit 1; these are:

- o Feedwater and the Main Condenser
- o Isolation Condenser
- o Shutdown Cooling System
- o Alternate Shutdown Cooling

From an operational point of view use of the Feedwater and Main Condenser is the preferred option because these systems match decay heat immediately and use systems the operators are very familiar with. Should the Feedwater and Main Condenser systems become unavailable, the operator would use one of the other available decay heat removal systems.

The condition of the present condenser tubing in the Millstone Unit 1 condenser is degrading with passing time as a result of erosion and corrosion. This necessitates periodic tube plugging and on-line sawdusting in the water boxes. The principle concern with allowing continued tube degradation is that condenser tube failures cause a decrease in plant reliability and availability. Condenser tube failures of significant magnitude can also pose a safety concern due to the fact that they result in high feedwater conductivity. Such a condition is alarmed and is procedurally responded to by isolating Main Feedwater and carrying out an emergency plant shutdown. Such events are Reactor Transients with the Main Condenser Unavailable and were evaluated in detail in the Millstone Unit 1 Probabilistic Safety Study (P.S.S.).

Proposed Project

The proposed project is to completely replace the existing condenser tubing with titanium tubes which are not subject to the same failure mechanisms which exist with the current tubing. Northeast Utilities is currently evaluating the retubing of the condenser mainly due to operational and economic considerations.

Analysis of Public Safety Impact

The public safety impact of this proposed project was assessed using Method A. Seawater intrusion from tube leakage can lead to a situation in which the Feedwater and Main Condenser must be isolated. Condenser isolation is accomplished by manually closing the M.S.I.V.s after high conductivity is alarmed. The Millstone Unit 1 P.S.S. showed that the Main Condenser is an important long term decay heat removal system and that unavailability of long term decay heat removal systems accounted for 64% of the predicted core melt frequency. A major concern is that if the Condenser has been isolated due to high conductivity and that backup decay heat removal systems become unavailable, it may not be possible to reopen the M.S.I.V.s and go back on the Condenser. It should be noted that given such circumstances the operators would not be prohibited from using feedwater with high conductivity (E.O.P.s also address use of the Service Water by cross-connecting it to injection systems should normal water sources be unavailable).

The analysis was performed using the Millstone Unit 1 P.S.S. as a base case to determine the sensitivity of the predicted core melt frequency to condenser unavailability due to seawater intrusion. There has been one known event (July 1982) in which seawater intrusion occurred necessitating plant shutdown and M.S.I.V. closure to isolate the Condenser. This event was considered in the data base used to calculate the initiator frequencies. Since the condenser tube degradation increases with time and there is reason to believe that a second event is likely to occur in the near future, the frequency of M.S.I.V. closure (in response to seawater intrusion) was increased to account for two such events in the last 15 years. This assumption yields a point estimate frequency of 0.13/yr for operator closure of the M.S.I.V.s in response to seawater intrusion to the condenser.

The Millstone Unit 1 P.S.S. models were then requantified by increasing the existing M.S.I.V. closure frequency from 0.435/yr by 0.13/yr to a value of 0.568/yr to account for an additional seawater intrusion event. Results of this analysis show a 0.74% increase in core melt frequency from 8.07×10^{-4} to 8.13×10^{-4} if no efforts are undertaken to improve condenser tubing. The public safety impact of retubing the Main Condenser was then equated with preventing

the 0.74% increase in predicted core melt frequency.

Results

Table 1 summarizes the results of the sensitivity study used to determine the impact of this proposed project. Approximately half of the change in the predicted core melt frequency is due to plant damage states that result in late core melt with the remaining half coming from plant damage states that produce early and intermediate core melt times. Computing the change in public risk as a result of retubing the Main Condenser results in avoiding an increase of 506.25 Man-Rems over the life of the plant. This equates to an impact score of approximately 1.25 on a scale of 10.0.

Table 1

Impact of Not Retubing the Millstone Unit 1 Condenser

	Base Case (As-Is)	Without Retubing
M.S.I.V. Closure Frequency		
	0.435/yr	0.568/yr
Plant Damage State Frequencies		
TE1	2.57×10^{-4}	2.59×10^{-4}
TE2	1.41×10^{-5}	1.44×10^{-5}
TI1	2.26×10^{-4}	2.27×10^{-4}
TL2	8.25×10^{-5}	8.58×10^{-5}
SE1	1.54×10^{-5}	1.54×10^{-5}
SE2	2.54×10^{-7}	2.54×10^{-7}
SI1	1.85×10^{-4}	1.85×10^{-4}
SL2	8.59×10^{-6}	8.59×10^{-6}
AE1	1.37×10^{-6}	1.37×10^{-6}
AE2	2.30×10^{-9}	2.30×10^{-9}
AI1	1.60×10^{-5}	1.60×10^{-5}

ISAP #2.07 Sodium Hypochlorite System

Safety Issue

Millstone Unit 1 currently uses a chlorine gas injection system to control biofouling growth in certain plant cooling water systems that use seawater for cooling (Service Water cooling for the diesel is a good example). At present, the source of the chlorine is a railroad tank car which holds 55 tons of chlorine gas in liquid form under pressure. In the unlikely event that this gas was released in large quantities and the wind direction and speed are within certain limits, the consequences to plant personnel and the public living in residential areas close to the site boundary could be significant. Replacement of this gaseous chlorination system is being considered because of the potential risk of a major chlorine gas release that would expose both plant personnel and the public to a non-radiological safety hazard.

Proposed Project

The proposed project addresses concerns raised by the chlorine gas storage issue through the development of an alternative system using liquid sodium hypochlorite. This project was initially proposed to address concerns for the safety of plant personnel.

Analysis of Public Safety Impact

The public safety impact of this proposed change was assessed using Method C. Public safety could be impacted in one of the following two ways:

- o the release of chlorine gas could incapacitate plant operations personnel and indirectly result in a core melt accident.

- o the release of the chlorine gas under certain weather conditions could directly cause offsite fatalities due to its toxicity.

Eliminating the inventory of chlorine gas would thus result in two sources of benefits which are evaluated separately.

A. Benefits From Avoiding Reactor Accidents Caused by Chlorine Release

For a chlorine gas release to result in significant public risk from radiation exposure the following chain of events must occur:

- o release of chlorine gas incapacitates the plant staff
- o plant trip as a result of a transient or operator actions responding to the chlorine release
- o failure of the feedwater system to continue to run after plant trip
- o failure of the isolation condenser
- o core melt and ultimate failure of the containment without the benefit of any risk mitigation actions by the operator.

In assessing the likelihood of this chain of events it is recognized that the frequency of chlorine release is common to both events in which the public is at risk due to chlorine toxicity as well as chlorine induced core melt events. The presence of chlorine is alarmed in the Millstone Unit 2 control room which is adjacent to the Unit 1 control room. This would lead to donning of protective breathing apparatus and further investigation. At this time a decision would be made to either continue operation or initiate a manual shutdown. If a decision to continue operation is made it would require an additional transient event occurring in addition to the chlorine gas release to initiate core melt. (This represents a highly unlikely coincidence.) An alternate path investigated using bounding type analysis involves the following:

- o operators initiate a controlled manual shutdown using the recicrculation flow control system and eventually trip the reactor from low power levels (this prevents the closure of M.S.I.V.s).
- o shortly after this they are overcome by the chlorine gas
- o feedwater fails to continue to run after reactor trip
- o failure of either the isolation condenser or makeup system

Such a sequence would result in a TE1 Plant Damage State as defined in the Millstone Unit 1 Probabilistic Safety Study. The overall frequency of this sequence would be calculated:

$$\lambda = \lambda_{CR} Q_{RT} Q_{FW/RT} (Q_{IC} + Q_{ICMUP})$$

-where: λ_{CR} is the frequency of chlorine releases

Q_{RT} = 1.0, given manual scram

$Q_{FW/RT}$ = 1.031×10^{-2}, unavailability of feedwater given reactor trip (Table 2A-8 Millstone Unit 1 PSS)

Q_{IC} = 2.19×10^{-2}, unavailability of automatic isolation condenser(Table 2A-5 Millstone Unit 1 PSS)

Q_{ICMUP}= 2.78×10^{-2}, unavailability of automatic isolation condenser makeup (Table 2A-6 Millstone Unit 1 PSS)

Combining these values yields the frequency of chlorine release initiated core melt events.

$$\lambda = \lambda_{CR}(5.124 \times 10^{-4})$$

The value of λ_{CR} is developed in the following section.

B. Benefits From Avoiding Public Exposure to Chlorine Gas

Chlorine gas in sufficient quantities can produce adverse health effects and death in humans. An additional analysis was performed to determine the public risk impact from exposure to a chlorine gas release. As a first step in the analysis, all potential release pathways to the environment were identified for the present chlorine gas system. A satellite PRA model was then developed to screen out those paths that did not lead to a significant release of gas. (Most of these pathways were of greater concern to the plant personnel safety impact model.) Results from the model led to the subsequent formation of two release categories based on the amount of chlorine that would escape to the environment. The release categories and their associated pathways are described below.

A catastrophic release of chlorine caused by gross failure of the railroad tank car is estimated to occur with a frequency of roughly 1.9×10^{-5}/yr. Such a catastrophic failure can result from any of the following:

- Spontaneous tank car rupture (considering two tank cars

present 50% of the time) at 1.5×10^{-5}/yr.

- Gross tank car failure due to shunting accidents at a rate of 4×10^{-7} per car-mile of travel based on railway experience. Millstone receives two full tank cars each year and the length of the railroad spur over which they travel within the site is 0.64 miles. Hence the predicted frequency of shunting accident occurrence is roughly 5×10^{-7}/yr.

- Gross rupture of the railroad tank car due to an earthquake overturning it. It is estimated that a 0.65g earthquake which occurs at the Millstone site with a frequency of 2×10^{-6}/yr would be required before gross rupture could take place. Because two cars are onsite 50% of the time, the total frequency of gross car rupture due to earthquakes is 3×10^{-6}/yr.

An intermediate continuous release of chlorine is caused by premature opening of the tank car overpressure relief valve and is estimated to occur with a frequency of 1.8×10^{-3}/yr. The failure rate for premature opening of a relief valve is 2×10^{-6}/hr. However, railroad tank cars are subject to a thorough inspection program and consequently it seems reasonable to assume a failure rate of 2×10^{-7}/hr. Using this assumption, the frequency of premature opening is roughly 1.8×10^{-3}/yr.

After estimating the frequencies for the two release categories, it was necessary to determine the associated concentrations of chlorine gas that would be present at the Millstone site boundary. A computer model designed to estimate chlorine concentrations in the event of a 25% puff release of the stored volume, with the balance being vaporized and released over time, was used. The model estimates a concentration of 5000mg/m^3 at the site boundary, following a catastrophic chlorine release from the tank car due to its gross rupture. This value is over 100 times the chlorine toxicity limit and approximately 4 times the lowest lethal concentration for man.

Using the model for the intermediate continuous release which is caused by premature relief valve opening, the site boundary concentrations are predicted to be 1,100 mg/m^3. This value is still over 24 times the chlorine toxicity limit and 85% of the lowest lethal concentration for humans.

In order to calculate the number of individuals that would be exposed to the two types of releases, the effective offsite population within 2km was estimated. The calculation was based on site specific data for the probability of wind direction and the number of people living offsite. Results of the calculation yield an effective offsite population of 100 persons.

The following assumptions were made in calculating the number of persons affected by the two type os releases and in converting the resultant effects to Man-Rems equivalent exposure.

- o Following a catastrophic release from the chlorine tank car, it was assumed that persons living at the site boundary would be exposed to chlorine concentrations in excess of 100 times the toxicity limit (i.e. four times lethal dose). Persons living at the edge of the 2km radius were assumed to be exposed to 27 times the toxicity limit (i.e. lethal dose). Thus, it was concluded that all 100 persons would suffer severe long term health effects or possibly death.

- o The intermediate continuous release produces approximately 1/4 the concentration of chlorine that the catastrophic release does. Accordingly, it was assumed that only 25 individuals would suffer severe long term health effects due to chlorine exposure.

- o It was assumed that each severe health effect, experienced by a member of the offsite population, is the equivalent of a radiation induced latent cancer. Accordingly, a value of 10^4 Man-Rems was assigned to each severe health effect.

Results

Based on the analysis, the following results were obtained if it is assumed that the chlorine tank cars are used for chlorination for the rest of the life of the plant:

- A catastrophic release of chlorine is equivalent to 475 Man-Rems of equivalent exposure. This is based on a catastrophic release rate of 1.9×10^{-5}/yr.

- An intermediate continuous release of chlorine is equivalent to 1.13×10^{4} Man-Rems of equivalent exposure. This is based on a release frequency of 1.8×10^{-3}/yr.

The effects of a chlorine induced core melt accident on the other hand are found to be insignificant. Assuming the more probable chlorine release frequency and multiplying it by the probability of core melt given chlorine release (i.e., 5.124×10^{-4}) the resultant probability of a core melt would be 9.22×10^{-7}/yr. Assuming a TE1 Plant Damage State this would result in an exposure of 34.5 Man-Rems.

In view of these considerations, the dominant source of public risk is the chance of an intermediate continuous release of chlorine gas from the tank car. The public safety impact of removing this potential risk would be ranked 10+ on a scale of 10, although the score could actually be higher due to uncertainties in the analysis.