Docket No.: 50-423

DEC 18 1985

Mr. John Opeka
Senior Vice President
Northeast Utilities
P. O. Box 270
Hartford, Connecticut 06141

Dear Mr. Opeka:

In September 1981 the Director of the Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission (NRC) requested that Northeast Utilities (NU) perform a design-specific risk study for Millstone 3, a high population density site. In August 1983 NU submitted the Millstone 3 Probabilistic Safety Study (PSS) which estimated the core damage frequency and risk from internal and external events. The NRC staff has recently completed its review of the PSS in the form of a draft risk evaluation report (RER) submitted to NU for comment on October 17, 1985. The staff's review of your report considered current understanding of pump behavior and diesel generator availability and led to identification of station blackout (loss of all offsite and onsite AC power) as the most dominant contributor to core damage frequency from internal events. Concern for station blackout has been further highlighted by the recent loss of offsite power event caused by Hurricane Gloria. The staff review considered four measures, two of which would result in significant reduction in the likelihood of core melt. A discussion of these measures and the supporting cost benefit analyses are provided in the enclosure.

Accordingly, in order to determine whether or not the Millstone 3 license should be modified, suspended, or revoked in order to reduce the apparant large contribution to risk due to station black out, pursuant to 10 CFR 50.54(f), you are requested to furnish under oath or affirmation, in writing no later than 30 days from the date of this letter, your evaluation regarding the staff's analysis and conclusions.

Sincerely,
Original Signed by
H. R. Denton
Harold R. Denton, Director
Office of Nuclear Reactor Regulation

Enclosure:
Regulatory Analysis for Reduction of Station Blackout Core Damage Frequency at Millstone 3

cc: See next page

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ENCLOSURE 1

Regulatory Analysis: Reduction of Station Blackout Core Damage Frequency At Millstone 3

Statement of Problem

The term "station blackout" refers to the complete loss of alternating current (AC) electric power to the essential and nonessential buses in a nuclear power plant. Station blackout therefore involves the loss of offsite power concurrent with the failure of the onsite emergency AC power system. Because many safety systems required for reactor core decay heat removal and containment heat removal are dependent on AC power, the consequences of station blackout could be severe.

The staff in its review of the Millstone 3 Probabilistic Safety Study (PSS) finds that the Millstone 3 emergency power system, while meeting all our regulatory requirements, has a near minimum design. There are two emergency diesel generators at Millstone 3 with no diversity, electrical cross-ties, or additional emergency power sources as are found at plants such as Indian Point and Zion, other high population density sites.

Station blackout leading to a reactor coolant pump (RCP) seal LOCA is the largest contributor in the Draft Millstone 3 Risk Evaluation Report (RER) to mean core damage frequency (staff estimates about 1x10-4 per year). The staff estimates that station blackout contributes 50% of the core damage frequency due to internal events.

Station blackout is estimated by the staff in the RER to contribute about 30% of the societal dose due to internal events. Depending on the assumptions made (e.g., conditional probability of H_2 burn, offsite power recovery rate, de-inerting due to condensation), the estimated mean dose per reactor-year from station blackout out to 50 miles from the plant can range from about 2 to 60 person-rem. (The staff's central estimate out to 50 miles is about 7 person-rem per reactor-year). Out to 150 miles from the plant, the mean annual dose can range from about 8 to 200 person-rem. (The staff's central estimate out to 150 miles is about 26 person-rem per reactor year.) While ordinarily CRAC calculations out to only 50 miles would be used in a backfit analysis value-impact assessment, New York City, its suburbs, and other densely populated areas lie beyond 50 miles but within 150 miles. This is significant because staff CRAC calculations estimate that downwind whole-body doses of 5 rem or more are quite possible for individuals living more than 50 miles from the site (based on long-term overpressure failure of containment).

The staff is pursuing generic resolution of the issues related to station blackout (USI A-44) and reactor coolant pump seal failure (GI-23).

Uncertainties

There are uncertainties related to the assumptions, equipment failure rates, omissions, modeling, human error, and other areas involved in estimating core damage frequency and risk due to station blackout. Some of these areas appear to be biased towards increasing or decreasing core damage frequency and risk. This section discusses both biases and uncertainties.

Some areas with associated uncertainty appear to be biased such that we believe the results given by their mean values may result in a conservative estimate:

° One of the most important uncertainties in the estimation of station blackout core damage frequency and risk is the RCP seal leak rate. The assumed average leak rate per pump for RCP seal LOCAs, once seal cooling is lost for some time following station blackout, will determine the time to core uncovery and core melt. Our analysis assumed a 300 gpm per pump leak rate (same as used in the Indian Point Probabilistic Safety Study) starting 30 minutes after loss of cooling. Increasing the assumed leak rate would not change our core damage or risk results. A 50 gpm per pump leak rate would uncover the core about 4 hours after the leak began. If the leak rate could be dropped to 10 gpm per pump or or less, it would take over 20 hours to uncover the core assuming no inventory makeup is possible. Generic Issue 23 is seeking resolution of RCP seal failure.

  The Westinghouse owners group on RCP seal failure has committed (no date determined) to replace the current O-ring seals with seals of a composition more suited to withstand the conditions they would experience during a station blackout (i.e., high temperature and pressure). Reactor coolant pump O-ring failure is believed to be a significant contributor to catastrophic RCP seal failure during a station blackout.

° The staff's analysis does not take full credit for fission product agglomeration that can accelerate the gravitational settling that will occur in containment and will continue to remove fission products from the containment atmosphere. This difference is a "new source term perception" based on NAUA which has been benchmarked against experiments. This is an important bias because it may reduce by an order of magnitude the estimated releases on containment failure due to long term overpressure.

° The staff analysis assumes that depletion of the DC safety related batteries under station blackout conditions leads to rapid core melt since the operator will be without any instrumentation and control power for valves, relays, etc. The estimated core damage frequency is not sensitive to the time at which core damage occurs following battery depletion.

Some areas with associated uncertainty appear to lead to higher core damage frequency and risk estimates:

° Frequency of loss of offsite power events of long duration is likely underestimated.

- Loss of room cooling (which itself can cause station blackout) is not included in the station blackout core damage frequency or risk results. We performed a scoping analysis which estimated the potential mean core damage frequency contribution from room cooling to be greater than 1x10-4 per year. The analysis did not consider operator recovery and assumed that switchgear failed if room cooling was lost for two hours. These may be very conservative assumptions.

- The following areas would tend to increase core damage frequency and risk for station blackout and could turn out to be the most important uncertainties. They are not readily quantifiable: design and construction errors, omissions in the analysis, and sabotage.

- The staff has estimated that early containment failure modes such as direct heating will have negligible effect on risk. If a 10% conditional probability of early failure were assumed, the risk estimates would be increased by about an order of magnitude.

Sensitivity Analysis

For station blackout events not caused by an earthquake, the staff in the RER first evaluated a base case where, if de-inerting of the containment occurred due to natural condensation, the containment was estimated to fail 10% of the time; if deinerting was due to spray recovery six or more hours after vessel failure, the containment was estimated to fail 50% of the time; and if AC power was unavailable for as long as 24 hours, power was always assumed to be restored at 24 hours. Battery depletion time was assumed to be 3 hours. This case resulted in an estimated mean annual risk of two person-rem within 50 miles of the plant and eight person-rem within 150 miles of the plant.

In the first variation, the battery depletion time following station blackout was assumed to be three hours; containment failure due to H_2 burns following natural condensation was neglected; if deinerting was due to spray recovery six or more hours after vessel failure, the containment was estimated to fail 50% of the time; and if offsite/onsite power was unavailable for as long as 48 hours, power was always assumed restored at 48 hours. For the first variation, the estimated mean annual risk was seven person-rem within 50 miles of the plant and 26 person-rem within 150 miles of the plant. The staff considers this their central estimate of mean annual risk from non-earthquake induced station blackouts.

The second variation was the same as the base case, but all H_2 burns (natural condensation or spray de-inerting) were assumed to fail containment. For the second variation, and more conservative case, the estimated mean annual risk was 16 person-rem within 50 miles of the plant and 70 person-rem within 150 miles of the plant.

For the third variation (the most conservative case), a station blackout lasting six hours after vessel failure was assumed to always cause a hydrogen burn which failed containment. This resulted in an estimated mean annual risk of 59 person-rem within 50 miles of the plant and 200 person-rem within 150 miles of the plant.

Objectives

The general objective of proposing the following possible fixes is to reduce the impact of severe accidents associated with station blackout by reducing the station blackout contribution to total core melt frequency and risk.

Alternatives

The following approaches were considered as alternatives to meet the objective of reducing station blackout induced (non-earthquake events) core damage frequency and risk.

(i) Add a diverse gas turbine generator (which can charge an emergency battery) and an enclosure capable of withstanding winds of 150 mph. Add a self-cooling, high head, low volume electric pump (powered by the gas turbine generator) to supply coolant to the RCP seals.

(ii) Add a redundant emergency diesel generator (which can charge an emergency battery) and an enclosure capable of withstanding very high winds (e.g., 150 mph). Add a self-cooling, high head, low volume electric pump (powered by the added diesel generator) to supply coolant to the RCP seals.

(iii) Upgrade emergency battery, instrument air, and auxiliary feedwater supply capacity to last at least eight hours following station blackout.

(iv) Add a steam-driven turbine generator to charge emergency batteries and power an added electric pump (self cooled) to supply coolant to the RCP seals.

(v) Take no action and await resolution of USI A-44 and Generic Issue 23.

Table 1 displays the value-impact analysis for each of the potential fixes out to 150 miles. We have used 150 miles rather than 50 miles in the value-impact analysis for several reasons:

- Dense population areas lie beyond 50 miles but within 150 miles of the Millstone site.
- CRAC calculations for events which result in late failure of containment estimate that a significant fraction of the time whole-body doses will exceed 5 person-rem to individuals living more than 50 miles from the site.

° The vast majority of the total estimated mean annual dose to individuals (even calculated out to 2000 miles) occurs to individuals living between 50 to 150 miles from the site.

Table 3 provi'es a summary of benefits and costs. These include (1) public risk reduction due to avoided offsite releases associated with reduced accident frequencies; (2) increased occupational dose from implementation and from operation and maintenance activities, as well as reduced occupational exposure from cleanup and repair because of lower accident frequency; (3) costs to Northeast Utilities for implementation of modifications and operation and maintenance; (4) cost savings to Northeast Utilities from accident avoidance (onsite damage); and (5) NRC costs for review. Table 4 provides a comparison of monitized value and costs (including avoided onsite property damage).

Value and Impact of Alternatives

Alternative (i):

This alternative fix would require installation of a non-Seismic Category 1 gas turbine generator in an enclosure designed to withstand very high winds (e.g., 150 mph). The turbine generator would be capable of providing sufficient AC power to run an electric pump to cool RCP seals and charge an emergency battery. This alternative would also require installation of a non-Seismic Category 1, self-cooled, electric pump with high shutoff head and low volumetric capacity. The value from implementing this potential fix is a reduction in the estimated frequency of core melt due to station blackout and the associated risk of offsite radioactive releases. The impact is primarily on Northeast Utilities which would have to make the modifications. The major advantages of this fix are that it reduces the probability of RCP seal LOCA, of battery depletion, and of common cause failure of the emergency AC power system.

Value

Based on the staff estimates for Millstone 3 of expected core damage frequency and risk due to station blackout (details are given in the Draft Millstone 3 Risk Evaluation Report), we can estimate the range of incremental risk and core damage frequency reduction associated with this alternative. Core damage frequency reduction for Alternative (i) is based on the assumption that the gas turbine generator (a diverse emergency power supply) will have a reliability of at least 0.95 and therefore will reduce core damage frequency by about an order of magnitude.

In calculating "value", we have taken into account that not every core melt sequence leads to containment failure, and not every containment failure has the same estimated offsite consequences. The risk estimates used for this value-impact analysis are unique to the staff evaluation of Millstone 3. They differ from other plant specific and generic risk analyses in part because of plant and site features and in part because of assumptions used in the Millstone 3 review and this value-impact analysis.

Table 1 Value-Impact Assessment For Station Blackout-Related Plant Modifications (150 miles)

Potential Modifications	Estimated* Costs ($Million)	Incremental Reduction in Frequency of Core Melt per Reactor Year	Range**of Incremental Reduction in Exposure (person-rem per reactor year)	Estimated Average*** Cost Per Person-rem Averted Over 40 Year Life ($ per person-rem)
1. Add a non-Seismic Category 1 diverse gas turbine generator and enclosure. Add an electric pump for RCP seal cooling.	.7 to 1.2	8x10-5	7 to 190 (25)	630
2. Add a non-Seismic Category 1, emergency diesel and enclosure. Add an electric pump for RCP seal cooling.	.6 to .8	1.5x10-5	1 to 36 (5)	2900
3. Increase capability to cope with station blackout to 8 hours by increasing capacity of batteries, instrument air, and AFW supply	.3 to .5	1.1x10-5	1 to 27 (3)	1860

Table 1 Value-Impact Assessment For Station Blackout-Related Plant Modifications (150 miles)

Potential Modifications	Estimated* Costs ($Million)	Incremental Reduction in Frequency of Core Melt per Reactor Year	Range**of Incremental Reduction in Exposure (person-rem per reactor year)	Estimated Average*** Cost Per Person-rem Averted Over 40 Year Life ($ per person-rem)
4. Add a steam-driven turbine generator to charge batteries and power an added electric pump to cool RCP seals.	1.2 to 1.7	7x10-5	7 to 180 (23)	1005

* Costs developed from R. A. Clark, et al, Science and Engineering Associates, Inc., "Cost Analysis for Potential Modifications to Enhance the Ability of a Nuclear Plant to Endure Station Blackout," USNRC Report NUREG/CR-3840, July 1984.

** The range varies with the particular case assumed. The number in parenthesis is our central estimate out to 150 miles.

*** Based on geometric means of the cost and the person-rem averted.

Impact

The estimated cost to Northeast Utilities to implement this potential fix ranges from $0.7 million to $1.2 million based on costs given in R. A. Clark, et al, Science and Engineering Associates, Inc., "Cost Analysis for Potential Modifications to Enhance the Ability of a Nuclear Power Plant to Endure Station Blackout," p. A-19 USNRC NUREG/CR-3840, July 1984. The cost estimate includes hardware for a non-Seismic Category 1 gas turbine, a non-Seismic Category 1 electric pump (low flow, high head), and construction of an enclosure to house the gas turbine. The enclosure should be capable of withstanding very high winds (e.g., 150 mph). If installation of the turbine can be made inside an existing qualified structure, cost estimates would be lower. Table 1 lists the estimated range in costs for each potential fix.

Including averted plant damage costs can significantly affect the overall cost-benefit evaluation. The effect of the proposed action on averting plant damage and cleanup costs has been estimated by multiplying the reduction in accident frequency by the discounted onsite property costs. The following equations from "A Handbook for Value-Impact Assessment," USNRC Report NUREG/CR-3568, December 1983 were used to make this calculation:

$$V_{op} = FU$$

and

$$U = \frac{(Ce^{-rt_i})}{(mr^2)} [1 - e^{-r(t_f - t_i)}] (1 - e^{-rm})$$

where

V_{op} = value of avoided onsite property damage
F = reduction in accident frequency = 8×10^{-5}
U = present value of onsite property damage
C = cleanup, repair, and replacement costs = \$4.3 billion (\$2.5 billion for cleanup and repairs based on the assumed core melt being significantly worse than TMI-2 and \$1.8 billion for replacement power based on NUREG/CR-3568)
t_f = years remaining until end of plant life = 40
t_i = years before reactor begins operation = 0
r = discount rate = .10 (10%)
m = period of time over which damage costs are paid out (recovery period in years) = 10

The discounted present values are shown in Table 2. Table 4 compares costs and benefits including avoided onsite property damage.

Table 2 Discounted present value of avoided onsite property damage

	10% discount rate	5% discount rate
Cleanup, repair, and replacement power	$2.1 million	$4.7 million

Value-Impact Ratio

Table 3 provides a summary of the benefits and costs associated with the Alternative (i). These include: (1) public risk reduction due to avoided offsite releases associated with reduced accident frequencies; (2) increased occupational dose from implementation, and operation and maintenance activities, as well as reduced occupational exposure from cleanup and repair because of lower accident frequency; (3) costs to NU for implementation, and maintenance activities, as well as reduced occupational exposure from cleanup and repair because of lower accident frequency; (4) costs to NU for implementation of modifications, operation and maintenance, and increased reporting requirements; and (5) NRC costs for review of reports.

The estimated range of costs for NU to comply with Alternative (i) is \$0.7 to \$1.2 million based on NUREG/CR-3840. At a 10% discount rate, the present value of avoided cleanup, repair and replacement power is approximately \$2.1 million. Also, the public risk reduction over the 40 year life of the plant ranges from 280 to 7600 person-rem.

Alternative (i) is estimated to reduce the station blackout mean core damage frequency by 8x10-5 per year. The estimated incremental risk reduction for this alternative ranges from 7 to 190 person-rem per year depending on the scenario assumed. The estimated average cost per person-rem averted over the plant's 40 year lifetime is \$630 per person-rem (geometric mean). Our containment analysis conservatively treats fission product agglomeration and gravitational settling in containment.

If cost savings to Northeast Utilities from accident avoidance (cleanup and repair of onsite damages and replacment power) were included. the overall value-impact ratio would improve significantly. If this benefit were taken into account, the overall value-impact would show that estimated onsite savings are higher than estimated installation and operation costs.

Table 3 Value Impact Summary for Alternative (i) for Plant Lifetime

	Dose Reduction Range(person-rem)	Cost ($1,000)
Public Health	280 to 7600	
Occupational Exposure (Accidental)(1)	4	
Occupational Exposure (Routine)(2)	NA	
NU Implementation		700 to 1200
NU Operation (3)		35 to 60
NRC Implementation(4)		7
Total	284 to 7600 (150 miles)	742 to 1267

Value-Impact Ratio(5)	$ per Person-rem averted
The averaged sum of NRC and Northeast Utilities costs divided by public dose reduction	665(6)

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1 Based on an estimated occupational radiation dose of 40,000 person-rem for post-accident cleanup and repair activities, NRR Office Letter No. 16, Revision 2, "Regulatory Analysis Guidelines," October 3, 1984.

2 No significant increase in occupational exposure is expected from operation and maintenance or implementing the recommendations proposed in this resolution. Equipment additions and modifications contemplated do not require significant work in and around the reactor coolant system and therefore would not be expected to result in significant radiation exposure. NA = not affected.

3 Assumes 5% of installation costs for operation and maintenance. (From draft NUREG-1109).

4 Based on an estimated 120 person-hours for NRC review. (From draft NUREG-1109).

Table 3 Value Impact Summary for Alternative (i) continued

5 This does not take into account the additional benefit associated with avoided plant damage costs or replacement power costs resulting from reduced frequency of core melt. The cost for plant cleanup following a core melt accident is estimated to be $2.5 billion, and replacement power is estimated to cost about $1.8 billion based on NUREG/CR-3568. The estimated discounted present value of these avoided onsite costs is given in Table 2.

6 The estimate of $665 per person-rem is based on the geometric mean of the value divided by the geometric mean of the impact.

TABLE 4

Comparison of Values and Costs

Alternative	Value ($Million) Monitized** Averted Person-Rem ($1000/person-rem)	Discounted Averted Onsite Cost 5%	10%	Estimated Costs ($Million)*
1. Add a non-Seismic Category 1 diverse gas turbine generator and enclosure. Add an electric pump for RCP seal cooling.	1.0	4.7	2.1	0.7 to 1.2
2. Add a non-Seismic Category 1, emergency diesel and enclosure. Add an electric pump for RCP seal cooling.	0.2	0.9	0.4	0.6 to 0.8
3. Increase capability to cope with station blackout to 8 hours by increasing capacity of batteries, instrument air, and AFW supply.	0.1	0.6	0.3	0.3 to 0.5

Alternative	Value ($Million) Monitized** Averted Person-Rem ($1000/person-rem)	Discounted Averted Onsite Cost 5%	10%	Estimated Costs ($Million)*
4. Add a steam-driven turbine generator to charge batteries and power an added electric pump to cool RCP seals.	0.9	4.1	1.8	1.2 to 1.7

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* Costs developed from R. A. Clark, et al, Science and Engineering Associates, Inc., " Cost Analysis for Potential Modifications to Enhance the Ability of a Nuclear Plant to Endure Station Blackout," USNRC Report NUREG/CR-3840, July 1984.

** Central estimate

Alternative (ii)

This alternative fix would require similar modifications to those in Alternative (i) except that NU would install a non-Seismic Category 1 emergency diesel generator rather than a gas turbine generator. The major advantage is that the utility already is experienced in operating and maintaining diesel generators. The major disadvantage is that the extra diesel generator does little to reduce the chance of a common cause failure of all diesel generators. The estimated cost of Alternative (ii) ranges from 0.6 to 0.8 million dollars based on cost estimates given on p. A-15, USNRC NUREG/CR-3840. Alternative (ii) is estimated to reduce the station blackout core damage frequency by 1.5x10-5 per year based on the limiting common cause failure rate among 3 diesel generators. The estimated incremental risk reduction for this alternative ranges from 1 to 36 person-rem per year. The estimated average cost per person-rem averted over the plant's 40 year life is $2900 per person-rem.

Alternative (iii)

Another alternative considered by the staff would have NU upgrade the capacity of emergency DC bus batteries, instrument air system, and the water supply to the suction of the auxiliary feedwater pumps such that they would last at least eight hours following a station blackout. Along with this, emergency procedures and operator testing would be upgraded. The major advantages to these improvements are (1) the relative low cost and (2) if the frequency or magnitude of reactor coolant pump seal LOCAs is reduced, DC battery depletion appears to be the next largest contributor to station blackout induced core damage frequency. The major disadvantage to this alternative is that it does nothing to prevent or mitigate a reactor coolant pump seal LOCA. The estimated cost of Alternative (iii) ranges from 0.3 to 0.5 million dollars based on costs given in R. A. Clark et al, Science and Engineering Associates, Inc., "Cost Analysis for Potential Modifications to Enhance the Ability of a Nuclear Power Plant to Endure Station Blackout," pp A-5, C-2, and D-2, USNRC NUREG/CR-3840, July 1984. Based on staff analysis of the effect of extending battery capacity to 8 hours, Alternative (iii) is estimated to reduce station blackout core damage frequency by 1.1x10-5 per year. The estimated incremental risk reduction for this alternative ranges from 1 to 27 person-rem per year. The estimated average cost per person-rem averted over the plant's 40 year life is $1860 per person-rem.

Alternative (iv)

Another alternative would be to install a non-Seismic Category 1, AC-independent, steam-driven turbine generator to charge the emergency batteries and power an added, self-cooled, motor-driven pump capable of delivering 50 to 100 gpm to reactor coolant pump seals. This potential fix is similar to that instituted in France to help prevent core melt due to station blackout induced RCP seal failure and core melt due to emergency battery depletion. The major advantages to this alternative are that it helps reduce both frequency of station blackout and probability of emergency

battery depletion. The estimated cost of Alternative (iv) ranges from 1.2 million dollars to 1.7 million dollars based on costs given on p. B-6 of NUREG/CR-3840. Alternative (iv) is estimated to reduce station blackout core damage frequency by 7x10-5 per year based on an assumed reliability of 0.9 for the system. The estimated incremental risk reduction for this alternative ranges from 7 to 180 person-rem per year. The estimated average cost per person-rem averted over the plant's 40 year life is $1005 per person-rem.

Alternative (v)

This alternative would be to take no actions beyond those resulting from the proposed resolution of Unresolved Safety Issue A-44 And Generic Issue 23.

Mr. J. F. Opeka
Northeast Nuclear Energy Company

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