GPU Nuclear

SAFETY ANALYSIS

SA # 4550-3254-85-02

Rev. # 2

TITLE

SAFETY EVALUATION REPORT

FOR

REACTOR BUILDING SUMP CRITICALITY EVALUATION

JANUARY 1986

THREE MILE ISLAND

UNIT 2

Originator Paul J. Babel Date 1-17-86

CONCURRENCE

Lead Engineer/RTR [signature] Date 1/16/86 SRG [signature] Date 1/21/86

Cognizant Eng. Carl H. Nostenfeld Date 1/16/86 Rad Con MJ Slobodien for JE Hildebrand Date 1-16-86

APPROVAL

Mgr. Eng. Section [signature] Date 1/22/86 Site Ops Director WJ Marshall for S Levin Date 1/22/86

Mgr. Recovery Pgms. [signature] Date 1/22/86

TABLE OF CONTENTS

<u>REFERENCES</u>

1. GPUNC Letter 4410-82-L-007, B. K. Kanga to L. H. Barrett "Three Mile Island Nuclear Station, Unit No. 2 (TMI-2) Operating License DPR-73, Docket No. 50-320, Reactor Building Decontamination" September 23, 1982

2. GPUNC Safety Evaluation Report 4350-3887-83-1, "Safety Evaluation Report for the Polar Crane Load Test" February 1983.

3. B&W Document No. 77-1158426-00, "Three Mile Island - Unit 2, Evaluation of the Structural Integrity of the TMI-2 Reactor Vessel Lower Head", June 1985

4. GPUNC Calculation No. 4550-3223-85-03 by S. Bokharee, "Exposure Rate Due to the Fuel in S. L.", dated April 1, 1985

5. GPUNC Calculation No. 4550-3223-85-04 by C. H. Distenfeld, "Fuel Estimation in Surge Line", dated March 28, 1985

6. GPUNC Calculation No. 4550-3223-85-01 by C. H. Distenfeld, "Fuel Estimation in Pressurizer", dated April 8, 1985

7. GPUNC Calculation No. 4550-3223-85-09 by S. Bokharee, "Fuel in the Bottom of the Pressurizer", dated May 2, 1985

8. GEND-INF-060 by George O. Hayner, "TMI-2 H8A Core Debris Sample Examination Final Report", May 1985

9. GPUNC Calculation No. 4550-3233-85-27 by P. J. Babel, "RB Basement Floor Fuel Debris", dated April 24, 1985

10. GEND-042 by C.V. McIsaac and D.G. Keefer, "TMI-2 Reactor Building Source Term Measurements: Surfaces and Basement Water and Sediment," October 1984.

11. Technical Plan for Ex-RCS Criticality Safety, TPO/TMI-132, TMI-2 Technical Planning Department, November 1985.

12. GPUNC letter 4418-84-L-0154, F. R. Standerfer to B. J. Snyder, "Three Mile Island Nuclear Station, Unit 2 (TMI-2) Operating License No. DPR-73, Docket No. 50-320, Technical Specification Change Request No. 46", dated November 6, 1984

13. M. Rogovin, "Three Mile Island, A Report to the Commissioners and to the Public", Nuclear Regulatory Commission Special Inquiry Group

14. GPUNC Memo No. 4240-85-0427, K. J. Hoffstetter to G. R. Eidam, "Analyses of Reactor Building Basement Sludge Samples" 12/5/85

REACTOR BUILDING SUMP CRITICALITY EVALUATION

SAFETY EVALUATION REPORT

1.0 Introduction

Measurements and samples for the presence of reactor fuel in the reactor building (RB) basement have been made in areas of the RB basement where the majority of fuel would have been deposited during the TMI-2 accident. Based on these measurements, samples and related calculations, this Safety Evaluation Report (SER) demonstrates that the possibility of a criticality event occurring in the RB basement or sump due to the introduction of non-borated water is sufficiently unlikely as to not constitute undue risk to the health and safety of workers and the public. Therefore, the use of non-borated water for RB decontamination purposes is acceptable.

After the TMI-2 reactor accident, it was postulated that a significant amount of fuel in the form of fines could have been transported from the reactor core through reactor coolant system (RCS) leakage to the RB basement (Reference 1). To prevent a potential criticality event, procedures were established that prohibited introducing water into the RB that was borated to less than 1700 ppm (Reference 2). The value of 1700 ppm was selected because mass balance calculations have shown that this boron concentration was the lowest concentration experienced in the basement at any time after the accident and there was no evidence of criticality.

The purpose of this evaluation is to show that all the available evidence substantiates the fact that insufficient fuel is available in the RB basement or sump to create a criticality potential. Consequently, the use of non-borated water for decontamination purposes is acceptable.

2.0 Description of Analysis Methods and Evaluation

The methods used to evaluate the criticality potential in the RB basement and sump are as follows:

1. Transport Analysis:
   a) The potential fuel transport paths from the reactor core to the RB.
2. Samples:
   a) Sample results applicable to the RCS or other samples during the time period when fuel fines may have been transported from the RCS.
   b) Analysis of RB basement and sump samples to substantiate the belief that insufficient fuel is available to create a criticality.
3. Radiation Measurements:
   a) Gamma ray spectrometry measurements of the RCS piping and components, and the RB basement to provide an estimate of fuel material in the basement.

2.1 Transport Analysis

Two potential pathways for fuel to enter the RB basement have been considered. The pathways are a breach in the reactor vessel lower head and from the reactor coolant drain tank (RCDT) rupture disc.

The first of these potential pathways, the structural integrity of the reactor vessel lower head, was evaluated (Reference 3). This evaluation shows that it is highly unlikely that there was a failure of the reactor vessel lower head or incore instrument tubes penetrating the lower head. It is therefore concluded that reactor fuel did not enter the RB basement via this path.

Two pathways existed for the transport of fuel fines from the reactor core to the RCDT: a) RCS pump leakage and/or b) through the pressurizer and the PORV. The most likely time for the formation of fuel fines was when the cladding and fuel were thermally quenched as the core was reflooded when reactor coolant pump (RCP) RC-P-2B was started at 0654:46, March 28, 1979, (see Table 1). In the event that positive coolant flow had been established immediately after reflood in the reactor vessel, one of the flow paths for fuel fines would have been through the RCP seals. Although heavy fuel particles could be suspended in the high velocity flow stream through the pump, the velocity on the inlet side of the seal is very low and significant settling of fuel fines would have occurred in the pump upper housing. However, the RCP seal leakage rate was insignificant relative to PORV leakage during the period that the PORV was open.

Based on the above analysis the only significant pathway for reactor fuel to reach the RB basement is from the reactor vessel through the pressurizer surge line to the pressurizer, through the pilot operated relief valve (PORV) and its relief piping to the RCDT, and finally through the RCDT rupture disc to the RB basement.

The PORV is part of the relief piping complex from the top of the pressurizer to the RCDT. This valve was open at various times during the accident. The pressurizer is relatively isolated from the normal RCS flow path. It is a vertical cylinder (84" I.D. x 42' 8-5/8" high) with an internal surge-diffuser and internal heating elements that would effectively interrupt and inhibit mass flow through it. The pressurizer is connected to the RCS by a 10 in. diameter surge line. If the pressurizer and surge line were full of water, suspended fuel fines could have been transported through.

2.2 Sample and Measurement Analysis

Gamma ray spectrometry measurements of the pressurizer surge line and the bottom head of the pressurizer indicate the presence of reactor fuel because of the detection of the characteristic 2.1857 MeV gamma ray peak for Ce-144/Pr-144. The calculated amount of reactor fuel in these components is based on gamma spectrometry measurements and a Ce-144/reactor fuel ratio of 1540 μCi/gm at the time the measurements were made. The amount of reactor fuel in the pressurizer surge line has been calculated to be about 0.1 - 0.2 kg (References 4, 5). The amount of reactor fuel in the pressurizer has been calculated to be approximately 11 - 25 kg (References 6, 7).

A TV camera was lowered into the RCDT. Observations indicate that little material was present in the bottom of the tank. The depth of material has been estimated as less than 1.0 in. and perhaps as little as 0.1 in. at the bottom of the horizontal cylindrical tank. This equates to between 15 and 170 kg of material in the tank, assuming an average density of 4 gm/cc

(Reference 8). Analysis of material extracted from the tank shows that a 9 mg sample contains less than 0.5 mg of uranium; or 0.055 mg/mg of sludge. Assuming uniform mixing in the sludge, this would indicate that between 1 and 10 kg of fuel may be in the RCDT.

The RCDT vent pipe discharges outside the RCDT room into the RB basement in the vicinity of the open stairwell. At the time of the quenching of the core due to RC pump operation, analyses of potential flows into and out of the RB indicate that there should have been at least two to three in. of water covering the 282'-6" elevation basement floor with the RB sump full of water. One cm of water depth in the basement is equivalent to 9070 liters over a floor area of 9.07×10^2 m^2 of floor. At this time, the RB sump pumps were not in operation and consequently no known mechanism is available for establishing flow across the basement floor. The effect of this reservoir would have been to cause fuel fines, which may have been discharged from the RCDT, to settle in the vicinity of the discharge from the RCDT because currents were not available to carry them elsewhere. Therefore, it is expected that the majority of fuel discharged from the RCDT would be found within approximately 3m of the RCDT discharge.

Gamma ray spectrometry measurements of the basement floor at the RCDT discharge point have been made. These measurements confirm the presence of fuel obtained in the form of physical samples from the basement near the open stairwell, which is near the RCDT vent discharge. The basement floor area in the vicinity of the RCDT vent discharge is approximately $46.5m^2$. This is equivalent to a disc 7.6m in diameter. If the fuel is assumed to be uniformly

distributed over this area, the amount of fuel is calculated to be about 0.9 kg or about 18.8 gm/m^2 (Reference 9). If it is conservatively assumed that this amount of fuel is uniformly distributed over the entire basement floor, the maximum amount of fuel present is calculated to be about 18 kg.

The assumption of a uniform distribution of fuel at the value given above is conservative for two reasons. First, as previously stated, the fuel would have most likely settled in the vicinity of the RCDT discharge because there is no mechanism to transport the fuel elsewhere. Second, samples taken from the basement indicate that the samples taken in the vicinity of the RCDT discharge represent the highest concentration of fuel. Table II provides a summary of all the solid samples taken in the basement (Reference 10, 14). This table shows that the concentration of fuel in the vicinity of the RCDT discharge, measured by sampling and calculations based on the gamma ray spectrometry measurements, may be one order of magnitude higher than samples taken at other locations in the RB basement. Most fuel concentrations are lower than the concentrations in the vicinity of the RCDT discharge.

Two areas of the RB basement remain unsampled; the area within the D-rings and the area under the reactor pressure vessel. No significant basis exists to expect the unsampled areas to contain a greater fuel concentration than the RCDT discharge area. Thus, the use of the fuel concentration of the RCDT discharge area as a conservative limit for the entire RB basement is justified.

As previously stated, the amount of fuel in the 46.5 m^2 vicinity of the RCDT discharge is about 0.9 kg as determined by gamma ray spectrometry. Because

the basement fuel concentrations for other locations are a small fraction of the fuel sampled in the vicinity of the RCDT discharge, it is estimated that the maximum amount of fuel in the basement is less than 2 kg.

Based on the following analytical techniques:

1. gamma ray spectrometry measurements in the basement and outside the pressurizer, and
2. measurements of fuel in samples from the basement floor and the RCDT,

the fuel present in the RB basement could vary between 2 kg to 18 kg.

The critical mass of UO_2 with three wt % U^{235} and 0.4 inch maximum pellet diameter in unborated water is 93 kg (Reference 11). To ensure that no criticality would occur, a conservative limit was established in which the minimum critical mass is considered to be 75% of 93 kg. Thus, the conservative critical mass is approximately 70 kg. Based on a comparison of the conservative minimum critical mass of 70 kg and the amount of fuel present in the RB basement which could vary between 2 kg to 18 kg, it is concluded that insufficient fuel was released from the RCDT to the RB basement to achieve a critical mass.

3.0 Accident Analysis

The purpose of this Safety Evaluation Report is to show that non-borated water may be safely used for decontamination. This non-borated water will

eventually accumulate in the RB basement and sump. This presents safety concerns in two areas. The first safety concern is criticality from the fuel on the RB basement floor. Section 2.0 of this SER has shown that there was insufficient fuel released to the RB basement floor to achieve a critical mass. Therefore non-borated water may be used without a danger of a criticality. The second safety concern is that non-borated water will represent a potential diluent for the boron concentration in the RCS should it become necessary to recirculate the sump water into the RCS due to an RCS leak. This concern has been evaluated. Technical Specification Change Request No. 46 demonstrated that sufficient properly borated water exists in the borated water storage tank (BWST) to permit an accumulation of approximately 70,000 gallons of unborated water in the RB basement and still assure returning 4350 ppm borated water to the RCS (Reference 12). Therefore, it is concluded that sufficient borated water exists to successfully provide properly borated water to the core to maintain subcriticality should a leak be experienced.

4.0 10 CFR 50.59 Evaluation

The use of non-borated water for building decontamination will not significantly affect the methods or procedures relating to decontamination within the RB. Based on the evaluations submitted in this Safety Evaluation Report, it is concluded that using non-borated water for building decontamination will not result in sump criticality nor present any undue risk to the health and safety of the workers or public.

Paragraph 50.59 of 10 CFR 50 permits the holder of an operating license to make changes to the facility or perform a test or experiment, provided the change, test, or experiment is determined not to be an unreviewed safety question and does not involve a modification of the plant technical specifications.

A proposed change involves an unreviewed safety question if:

a) The possibility of occurrence or the consequences of an accident or malfunction of equipment important to safety previously evaluated in the safety analysis report may be increased; or

b) The possibility for an accident or malfunction of a different type than any evaluated previously in the safety analysis report may be created; or

c) The margin of safety, as defined in the basis for any technical specification, is reduced.

The planned activities will not increase the probability of occurrence or the consequences of an accident or malfunction of equipment important to safety previously evaluated. This is based on the amount of reactor fuel in the RB basement being a small fraction of that required for a critical mass as described in Section 3.0. Therefore, there is no need for the use of borated water. In addition, the use of unborated water will not increase the probability of an accident based on the work being performed in accordance with approved procedures, and the measures to be taken for the prevention of an RCS boron dilution event. In addition, no potential for a core disturbance exists due to the use of non-borated water for RB decontamination.

TABLE 1 (Continued)

TIME	EVENT DESCRIPTION[13]
1139:34	Press block valve (RC-V2) opened
1315:00	Press block valve (RC-V2) was shut
1321:05	Press block valve (RC-V2) opened
1330:37	Press block valve (RC-V2) was shut
1349:35	Press block valve (RC-V2) opened and then shut it when 28 psig pressure spike was noted in R3
1401:35	Press block valve (RC-V2) opened
1512:37	Press block valve (RC-V2) was shut
1635:06	Press block valve (RC-V2) opened
1643:37	Press block valve (RC-V2) was shut
1652:37	Press block valve (RC-V2) opened
1715:37	Press block valve (RC-V2) was shut
2235:00	Reactor Coolant Letdown flow was lost

TABLE II

SAMPLE LOCATION	PENETRATION 401		COVERED HATCH	OPEN STAIRWELL	OPEN STAIRWELL		COVERED HATCH	SW QUAD
SAMPLE DATE	08/28/79	11/15/79	05/14/81	09/24/81	06/23/82		01/11/83	
ANALYSES BY	ORNL		INEL		ORNL	WHEDL		
SAMPLE SIZE (ML)	30	1050	110	120	18	27.5	45	55
TOTAL SOLIDS (GM)	0.0762	0.333	0.108	0.0246	0.3894	0.7186	0.002	0.499
FUEL (U) IN SOLIDS (MG/GM)	0.043	0.32	4.0	0.39	2.97	3.9	2.2	3.0
FUEL IN SOLIDS (GM)	3.3(-6)	1.1(-4)	4.3(-4)	9.6(-6)	1.2(-3)	2.8(-3)	4.4(-6)	1.5(-3)
FUEL CONCENTRATION (GM/ML)	1.1(-7)	1.0(-7)	3.9(-6)	8.0(-8)	6.4(-5)	1.0(-4)	9.8(-8)	2.7(-5)

SAMPLE LOCATION	SUMP PUMP	GAMMA SPECTROMETER	IMPINGEMENT AREA		
SAMPLE DATE	08/22/83	05/24/85	09/24/85		
ANALYSES BY	INEL	GPUNC	GPUNC		
SAMPLE SIZE (ML)	200	-	75	163	10
TOTAL SOLIDS (GM)	0.0718	-	0.025	0.022	0.071
FUEL (U) IN SOLIDS (MG/GM)	0.18	-	2.5	2.5	0.28
FUEL IN SOLIDS (GM)	1.3(-5)	-	6.3(-5)	5.5(-5)	2.0(-5)
FUEL CONCENTRATION (GM/ML)	6.4(-8)	1.2(-3)*	8.4(-7)	3.4(-7)	2(-6)

*calculated value

The use of non-borated water for decontamination will not create the possibility of an accident than any of that previously evaluated. This is based on the amount of reactor fuel being a small fraction of that required for a critical mass.

The use of borated water to prevent RB basement or sump criticality is not included in the basis for any technical specification. The margin of safety is not reduced because the amount of reactor fuel is a small fraction of a critical mass. In addition, the tasks included in this SER will not reduce the margin of safety as given in Technical Specification Change Request No. 46. This is based on operating the systems and equipment covered by the technical specification in accordance with approved procedures. Also, the releases of radioactivity to the environment are unaffected by this change.

Therefore, it is concluded that the use of non-borated water for building decontamination does not involve any unreviewed safety questions as defined in 10 CFR Part 50, Paragraph 50.59.

5.0 Conclusion

Based on the safety evaluations considered for the use of non-borated decontamination water, the activities may be accomplished without presenting undue risk to the health and safety of the workers or public.

TABLE 1

TIME	EVENT DESCRIPTION[13]
0400:41	RC-R2 (PORV) opened at setpoint of 2255 psig and RCDT pressure began increasing.
0400:52	PORV should have shut: (closure setpoint at 2205)
0402:03	RCDT temperature at normal (85°F)
0403:52	RCDT Relief Valve (WDL-R1)
0404:03	RCDT hi temp alarm received (128°F)
0408:06	RB sump pump (WDL-P-2A) started on high RB sump level - pump discharges 140 gpm; lined up to AB sump tank which was about full and had a ruptured disc.
0410:56	RB sump pump (WDL-P-2B) started
0411:25	RB sump hi level alarm was received; setpoint is 4.65 feet from bottom of RB sump
0415:28	RCDT rupture diaphragm (WDL-U-26) burst at 192 psig. Discharge is to RB and caused RB pressure to start increasing
0438:47	Auxiliary operator stopped RB sump pump (WDL-P-2A) to prevent overflow of MWHT
0438:48	Aux. operator stopped RB sump pump (WDL-P-2B) to prevent overflow of MWHT (one pump had operated for 28 minutes; the other 21 minutes and had transferred 8260 gallons to Auxiliary Building)
0619:37	Pressurizer block valve shut stopping discharge to RCDT
0654:46	Operator started RC-P-2B an RCS flowrate of 10^7 pounds/hr was experienced for about 5 seconds
0713:05	Pressurizer block valve opened to reduce RCS pressure; discharge line hi temp alarm was received (248°F)
0730:37	Press block valve (RC-V2) was shut
0740:36	Press block valve (RC-V2) opened
0918:37	Press block valve (RC-V2) was shut
0943:46	Press block valve (RC-V2) opened and was cycled
0944:04	RC-R2 discharge line hi temp alarm received