UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

January 8, 1986

Docket No. 50-410

Mr. B. G. Hooten
Executive Director of Nuclear Operations
Niagara Mohawk Power Corporation
300 Erie Boulevard West
Syracuse, New York 13202

Dear Mr. Hooten:

Subject: Structural Adequacy of the Nine Mile Point, Unit 2 Downcomer Design

On December 20, 1985, the NRC staff met with members of your staff to discuss the Nine Mile Point, Unit 2 (NMP-2) downcomer design. A summary of that meeting is included as Enclosure 1.

In addition a draft SER is enclosed (Enclosure 2) which evaluates the NMP-2 downcomer design. As indicated in the draft SER and during our meeting on December 20, 1985, there are a number of concerns with the analysis performed on the NMP-2 downcomers. Also, as discussed during the above referenced meeting, the unbraced downcomer design may not fully comply with the FSAR commitments to certain industry design codes and staff acceptance criteria. Specifically:

1. In the FSAR you committed to use the guidance and criteria provided in a staff-approved topical report (NEDO-21985 by General Electric). The downcomer analysis has failed to demonstrate that the unbraced design is in compliance with the criteria specified. In an attempt to demonstrate compliance through an option provided in the staff topical report evaluation, the analysis used methodology and acceptance criteria that in the staff's view are inconsistent with commonly accepted practice.

2. The methodology in the downcomer analysis for combining loads appears to be inconsistent with the guidance provided in NUREG-0484 Rev. 1. If this method for combining loads is deemed unacceptable, the downcomer design would not meet the design limits, in some cases, by a substantial margin.

3. Although the deformations under various load combinations were not given, these deformations may be large enough to undermine the validity of the linear elastic hypothesis of the structural behavior because;

    -- excessive ovalization can drastically reduce the load carrying capability; and

-- invalid hypothesis of linear-elastic behavior can undermine the basis for accepting SRSS load combination methodology.

At the meeting your staff indicated that they would be prepared to respond to the concerns listed in the enclosed meeting summary by January 15, 1986. The NRC staff will review those responses when they are submitted.

Sincerely,

Robert M. Bernero

Robert Bernero, Director
Division of BWR Licensing

DESIGNATED ORIGINAL

Certified By

Mr. B. G. Hooten
Niagara Mohawk Power Corporation

Nine Mile Point Nuclear Station
Unit 2

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ENCLOSURE 1

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

Docket No. 50-410

APPLICANT: Niagara Mohawk Power Corporation

FACILITY: Nine Mile Point Nuclear Station, Unit 2

SUBJECT: SUMMARY OF MEETING HELD DECEMBER 20, 1985, TO DISCUSS THE DESIGN OF THE DOWNCOMERS FOR NINE MILE POINT NUCLEAR STATION, UNIT 2

On December 20, 1985, the NRC staff met with representatives of Niagara Mohawk Power Corporation (NMPC) and their consultants, Stone and Webster Engineering Corporation (SWEC), to discuss the adequacy of the design of the downcomers at Nine Mile Point Nuclear Station, Unit 2 (NMP-2).

Mr. Robert Bernero opened the meeting stating that it was unfortunate timing to be discussing an issue of this potential effect so close to the scheduled fuel load for NMP-2.

The downcomer issue was then divided into two parts. The first part related to the Submerged Structure Loads on the downcomers and the assumptions made in developing the SRV loads. Enclosure 1 contains a handout provided by the applicant on the "SRV Submerged Structure Load." Agreement was reached on the load methodology used to determine the submerged structure loads if they were applied to rigid downcomers. There remained however a concern that loads, which had been considered as secondary loads in NUREG-0487 and NUREG-0808 (e.g. pool swell sloshing) and, therefore, were considered negligible for the stiff, laterally-supported downcomers, might be more significant when applied to the downcomers without lateral supports, which, consequently, have a lower natural frequency.

The second part of the discussion on downcomers was related to the structural adequacy of the downcomers. Enclosure 2 contains the applicant's handout on "Buckling and the Functional Capability of Downcomers."

In the analysis performed by SWEC for the adequacy of the downcomers, it was noted that using ASME Code Equations with modified stress intensity factors and additional limits for deformation control for the functional capability analysis of the downcomers would yield unacceptable results. This is the accepted method of analysis from NEDO-21985, September 1978. SWEC then elected to perform a dynamic stability analysis. This is another option identified by the NRC staff in their safety evaluation of NEDO-21985 (ref. February 27, 1981, letter Tedesco to Sherwood). After reviewing the dynamic stability analysis performed by SWEC for the downcomers, the NRC staff stated that the analysis performed was actually a static analysis. The NRC staff further stated that, in its response to question 210.53 requesting details of design considerations of piping in the suppression pool, the applicant did not indicate that the alternate method of performing a dynamic stability analysis had been used.

The NRC staff expressed concern about the possibility of a buckling failure in the downcomers near the supports. Such a failure would allow steam to bypass the suppression pool in a LOCA event. SWEC stated that the buckling load is small. The NRC staff, however, was concerned that the frequency content was not considered and the low natural frequency of the downcomers (1 to 2 Hz) is in the range of the frequency content of the loads.

A number of ASME Code equations were used in the downcomer analysis. The NRC staff expressed concern that some of these equations may have been used inappropriately since Limit Load Theory is used as a basis for some of these equations. Limit Load Theory does not apply for piping with a D/t ratio of greater than 50. The D/t ratio for the downcomers is 64.

The square-root-sum-of-the-squares (SRSS) method of combining loads has been accepted by the NRC staff when used appropriately for loads which can be shown to act independently (ref. NUREG-0484, Rev. 1). The NRC staff, however, questioned the way the SRSS method was applied in the downcomers analysis. For example the following combination was used,

$$[(SSEI^2 + SSES^2 + SRV(ONE)^2 + SRV(I)^2 + CO(LAT)^2 + CO(I)^2]^{\frac{1}{2}}$$

instead of

$$[(SSEI + SSES)^2 + (SRV(ONE) + SRV(I))^2 + (CO(LAT) + CO(I))^2]^{\frac{1}{2}}$$

Where	SSEI	=	inertia effect from SSE
	SSES	=	sloshing effect from SSE
	SRV(ONE)	=	response from activation of one SRV
	SRV(I)	=	inertia effect from activation of one SRV
	CO(LAT)	=	response from LOCA condensation oscillation resulting from lateral load from adjacent downcomers
	CO(I)	=	inertia effect of LOCA condensation oscillation

Mr. Robert Bernero, NRC Director of the Division of BWR Licensing, stated that the applicant had two options: reanalysis or a mechanical fix. Mr. Bernero indicated that the NRC would be open to a review of new material if the applicant desired to submit more information, but that the staff did not foresee that new analytical data were likely to make the current downcomer design acceptable. Mr. Bernero also indicated that resubmittal of material already discussed would not be viewed as new information.

The applicant indicated that they wanted to continue reviewing the existing design. The NRC staff, therefore, requested that the applicant respond to the following concerns.

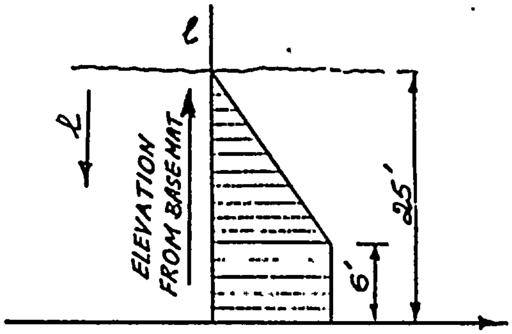
1. The downcomer analysis should be formally submitted.

Enclosure 1

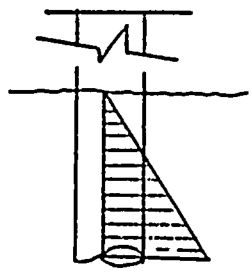
NMP2 DOWNCOMERS SAFETY RELIEF VALVE SUBMERGED STRUCTURE LOAD

KWU METHODOLOGY

Based on Wall Pressure Profile (NUREG 0802)



Differential Pressure Across the Downcomer is Calculated from Empirically Determined Multiplier



$$\Delta P = 0.75\ Pw$$

$$= 0.75 * PKKB * H(l)$$

0.75 is the product of 2 factors, an empirically determined 0.5 differential pressure factor and a 1.5 transferring factor from KKB to MK II.

SRV LOAD ON DOWNCOMER

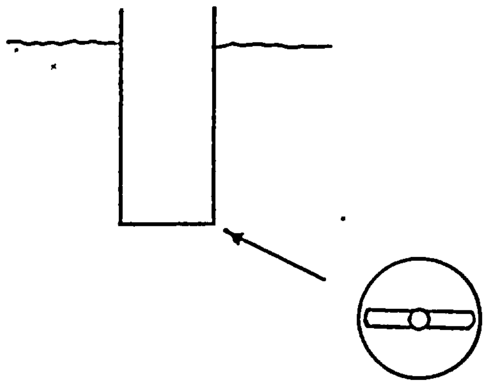
$$= F = \Delta P *_{//} A$$

$$= \int_{l=0} \Delta P * D * dl$$

Specified differential pressure conservatively bounds the differential pressure predicted from potential flow theory (1/r Law)

The differential pressure factor 0.5 has been verified against inplant test data KKB, KTG, and Caorso.

DFFR METHODOLOGY (NUREG 0487)



Rayleigh Bubble Formulation

Bubble Located at the center of the Quencher device.

Bubble Radius = Radius of the Quencher

Bubble Pressure = 1/4 Ramshead Bubble Pressure

Shoreham Application

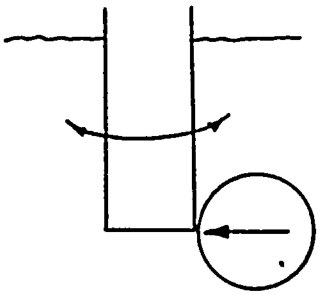
Same as above except using 1.5 PKKB as bubble pressure.

NMP2 SRV SUBMERGED STRUCTURE LOAD METHODOLOGY

Hybrid DFFR/KWU Methodology

Coupled Fluid - Structure System Approach

Source Terms:



$P_B = P_W$

Bubble Pressure equivalent to Shoreham

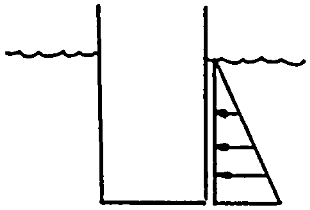
Bubble Radius same as Shoreham

Flow field calculated from Rayleigh Bubble with a negative image to satisfy the pool surface boundary condition (conservative compared to Shoreham)

Interference effect of adjacent structures on the acceleration drag coefficent comply with NUREG 0487 Supplement 1

1.1 Asymmetric Factor applied comply with NUREG 0487

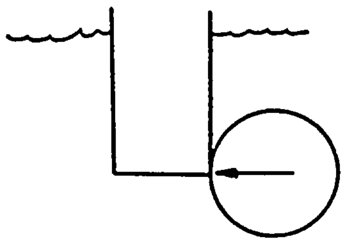
VERIFICATION OF THE FORCING FUNCTION METHODOLOGIES FOR RIGID STRUCTURE



KWU Multiplier Method

Apply KWU differential pressure load on downcomer

$$0.75\, P_{KKB} * H(\ell)$$



NMP2 Procedure Without Coupled Fluid Structure Interaction

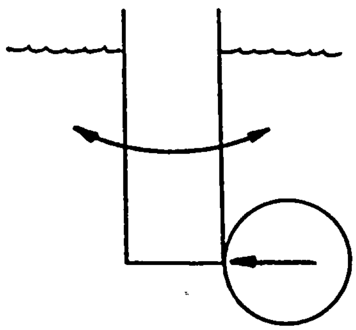
Touching bubble at downcomer tip

Bubble Pressure = Wall Pressure

$$P_B = P_{KKB} * H(\ell)$$

The downcomer responses are within 1% of each other.

NMP2 APPLICATION



Downcomer is flexible, this motion must be considered.

Fluid structure coupling flow field is needed to calculate the relative motion of the downcomer with the fluid.

Fluid structure coupling method is standard textbook practice, Ref. R.D. Blevins "Flow Induced Vibrations," Van Nostraud, Reinhold, 1977.

Enclosure 2

BUCKLING AND FUNCTIONAL CAPABILITY OF DOWNCOMERS

Determine the ultimate buckling moment of the downcomer and establish that collapse by buckling will not occur from the postulated dynamic loadings.

Determine the effects of ovalization caused by the dynamic loads and demonstrate that the reduction in area is within acceptable limits.

CALCULATION OF ULTIMATE BUCKLING MOMENT

Ultimate buckling moment is obtained from an expression which considers critical strain (i.e. strain at the point of instability), and geometric and material properties of the pipe. The basis of calculating the ultimate moment involves expressing the critical strain in terms of the thickness and radius of the pipe, obtaining a relationship between rotation and strain at instability, describing a non-linear stress-strain relationship for the material and integrating stress over a cross-section to determine the bending moment. This basis is documented in literature and substantiated by testing.

Moment from the worst dynamic loading combination is calculated at the downcomer fixed end.

The ultimate buckling moment is 40% higher than the maximum moment calculated from the postulated dynamic loading combinations, thus buckling is not expected to occur.

CONSIDERATION OF OVALIZATION EFFECTS

Assume that moment causes the initially round pipe to become elliptical in shape.

Determine principal axes of the ellipse using the strain energy method (or the principle of least work).

The reduction in the area of cross-section is determined to be about 1%, which is within the acceptance criteria.

ENCLOSURE 3

LIST OF ATTENDEES

NAME	ORGANIZATION
Mary F. Haughey	NRC-Licensing Project Manager
Y. C. (Renee) Li	NRC-BWR-EB
E. G. Adensam	NRC-BWR-PD#3
Divakar Bhargava	Stone & Webster Eng. Corp.
Chen P. Tan	NRC-BWR-EB
Nick Rapagnani	SWEC-Lead Engineer
R. M. Bernero	NRC-DBL
B. D. Liaw	NRC-DBL-EB
Donald L. Hill	NMPC Licensing
Alan W. Chan	Stone & Webster-Division Manager
Mark A. Durka	SWEC-Assistant Project Engineer
David Terao	NRC-DPL-B
Farouk Eltawila	NRC-RIB-DSRO
Jack Kudrick	NRC-DBL-PSB
Jerry Hulman	NRC-DBL-PSB
Gus Lainas	NRC-DBL
R. Wayne Houston	NRC-DBL
Peter Antony-Spies	KWU
L. P. Prunotto	NMPC-Struct. Engineering
C. V. Mangan	NMPC-VP
A. F. Zallnick	NMPC-Mgr. Licensing
E. R. Klein	NMPC-NMP2-Project Manager Design
R. A. Cushman	NMPC-Licensing
D. E. Vandeputte	SWEC-Licensing
T. L. Wang	SWEC

DRAFT
SAFETY EVALUATION REPORT
NINE MILE POINT UNIT 2 DOWNCOMER DESIGN

Introduction

The downcomer design at NMP-2 is unique in that it does not provide lateral supports at the free ends of downcomers; i.e., at the bottom, the downcomers are free to move in a plane perpendicular to the downcomers. All other domestic Mark II plants have employed a bracing system to tie all downcomers together at the bottom to prevent free movement of an individual downcomer pipe. The downcomers are made of 304 stainless steel (SA 312 - 304) pipes, 24 inches in diameter, and 30 to 45 feet in length, and 3/8 inch in thickness. These pipes are designed to ASME Code rules for Class 2 piping, in accordance with staff criteria on load combinations specified in SRP Section 3.9.3. and in NUREG-0484 Rev. 1, "Methodology for Combining Dynamic Responses."

Subsequent to reviewing the applicant's responses to staff concerns submitted in September 1985, the NRC staff, during a conference call, requested a copy of the detailed design report on the downcomers. After a preliminary review of the design calculations, a tentative staff conclusion was reached that the design may not be adequate. After a conference call failed to resolve all of the reviewers' questions, a meeting with the applicant and its A/E consultant was held on December 20, 1985, in Bethesda, Maryland to discuss the detailed analysis. This SER presents the specific areas of concerns that remain to be resolved for the NMP-2 downcomers.

Methodology of Design Analysis

The design of the downcomers at NMP-2 is very "soft", i.e., the fundamental mode natural frequency is 1.0 to 2.0 Hz (cycle per second). The diameter-to-thickness ratio (D/t) is 64; this exceeds the value of 50 that is generally viewed as the upper limit of the applicability of design procedures for nuclear piping specified in the ASME Boiler and Pressure Vessel Code (hereinafter referred to as the Code). In a "soft" structure, the deformation is expected to be large; this can invalidate the basic assumptions for performing a linear-elastic structural system analysis. Although there are no clear definitions of "large" deformations (e.g., excessive ovalization and flexure) in the theory, the range of uncertainties in the analysis is expected to become larger and results of the analyses become less reliable as deformation increases.

The staff believes that the Code-specified procedures are based on analytical solutions to a class of problems in the theory of elasticity, modified by results of experimental tests. The majority of the tests were conducted for piping with D/t ratio less than 50.

Load Combinations

In Section 6A.2.2.5 of the applicant's Design Assessment Report for Hydrodynamic Loads it is indicated that for all mechanical systems, components, and supports,

the structural responses to dynamic loads such as LOCA, SRV and OBE/SSE are combined by the square-root-of-the-sum-of-the-squares (SRSS) method, while responses due to similar dynamic loads for applicable seismic Category I structures are combined by the absolute-sum method (e.g., SRP Section 3.8.2 Steel Containment). Even though the downcomers are part of the pressure-suppression system, they have been designed as a mechanical piping system, which the staff has accepted. The staff also accepted the SRSS method for combining the responses of the above-mentioned dynamic loads in the design analysis of the downcomers.

The staff position on the combinations of dynamic responses by the SRSS method are given in NUREG-0484, Rev. 1 as follows:

> "In applying SRSS methodology, the responses should be calculated on a linear elastic basis and time-phase relationship among functions to be combined should be random. Functions which are not independent such as those that result from the same dynamic initiating event should not be combined by SRSS methodology. In those cases for which the independence of the function cannot be established (e.g., annulus pressurization and jet impingement or reaction loading which result from a postulated LOCA), absolute summation of responses or the use of time-phased responses is required."

- In the NMP-2 downcomer design, the SRSS method of combining the dynamic loads has been carried out, for instance, as follows:

$$[SSEI^2 + SSES^2 + SRV^2 + SRV\ (I)^2 + CO\ (LAT)^2 + CO(I)^2\ ]^{\frac{1}{2}}$$

Instead of the following expression which would seem to conform to the criteria more appropriately:

$$[(SSEI + SSES)^2 + \{\ SRV + SRV\ (I)\ \}^2 + \{CO\ (LAT) + CO\ (I)\}^2]^{\frac{1}{2}}$$

Where SSEI ∿ inertia effect due to SSE

SSES ∿ sloshing effect due to SSE

SRV ∿ response due to activation of SRVs

SRV (I) ∿ inertia effect due to activation of one SRV

CO (LAT) ∿ response due to LOCA condensation oscillation resulting from lateral load from adjacent downcomers

CO (I) ∿ inertia effect of LOCA condensation oscillation

Therefore, the SRSS method for response combinations in NMP-2 does not appear to conform with the staff position provided in NUREG-0484 Rev. 1, because the applicant has not demonstrated the independence of function or time-phased relationships of responses. If the stresses are combined in accordance with NUREG-0484, Rev. 1, the resultant stresses in a number of loading cases are likely to exceed the design limits specified in the Code.

Functional Capability

In response to a staff concern on the functional capability of essential piping systems for NMP-2, the applicant made a commitment in their FSAR, as amended, that all essential ASME Code Class 1, 2 and 3 piping systems would be designed to meet the functional capability criteria provided in the topical report (NEDO-21985) submitted to the staff by General Electric. Based on this commitment, the staff stated in the SER Section 3.9.3.1 that "... for those piping systems identified as essential that are subjected to loads in excess of Service Level B limits, their functional capability has been evaluated in accordance with the criteria provided in the GE Topical Report, NEDO-21985, "Functional Capability Criteria for Essential Mark II Piping," dated September 1978, which the staff has previously reviewed and approved."

In the detailed design report for the NMP-2 downcomer recently submitted, the applicant indicated that the design of the NMP-2 downcomers failed to meet the functional capability criteria presented in the NEDO-21985. The applicant then elected to perform a detailed dynamic stability analysis, which is an option provided in the staff evaluation of the topical report dated February 27, 1981. In their topical report evaluation, the staff stated that to provide assurance of functional capability, three options are available:

(1) Perform a detailed dynamic stability analysis. The analysis may extend beyond the elastic range if necessary.

(2) Conduct dynamic stability testing of various piping configurations under simulated design loads.

(3) Utilize existing ASME Code equations with modified stress indices or stress intensification factors, and additional stress limits for deformation control.

It is noted that the staff did not provide guidance nor acceptance criteria for the dynamic stability analysis.

In an attempt to demonstrate the functional capability of downcomer piping through the first option, the applicant calculated the applied bending moment due to the stress responses for faulted condition, combined by the aforementioned methodology. The bending moment is then compared with the calculated ultimate moment (for general buckling) by Stone & Webster internal procedure using an ASME publication by T. L. Gerber to determine the mode of "failure". The calculated ultimate moment is shown to be about 1.4 times the applied moment.

Based on the review of the analysis provided in the NMP-2 downcomer design report, the staff determines that the applicant has not adequately demonstrated the functional capability of the downcomers for the following reasons:

- The analysis presented in the downcomer design report is a general stability (buckling) analysis due to an equivalent static load, not a dynamic stability analysis.

- The analysis presented in the downcomer design report referred to an ASME publication, "Plastic Deformation of Piping Due to Pipe-whip Loading," by T. L. Gerber. The referenced ASME publication used test data for pipes with a D/t ratio from 8 to 34. Furthermore, it showed that for pipes with a D/t ratio greater than 25, the mode of collapse appears to change to local buckling. Based on these results, the effects of local buckling for the NMP-2 downcomer with a D/t ratio of 64 would most likely be dominant, rather than the cases of general buckling, and may drastically reduce the load carrying capability of the downcomer. Therefore, the results presented in the referenced publication are not directly applicable to the NMP-2 downcomer analysis.

Fatigue Analysis

The applicant performed a fatigue analysis in accordance with ASME Code Class 1 fatigue rules. The staff reviewed the results of that analysis which indicated the cumulative damage of the anticipated stresses were acceptable. However, in the review of the detailed downcomer design report, the applicant performed a fatigue analysis in accordance with a method contained in a draft report written by a Subcommittee on SRSS/LCAC of the Mark II Owners Group, entitled "Mark II Generic Techniques for Fatigue Evaluation of the SRVDL's and Downcomers in the Wetwell." This method has not been reviewed and evaluated in detail by the staff. From the specified range of frequencies of interest; i.e., f_j = 3.5 to 50 Hz, it appears that the method is applicable to more rigid piping systems, not to the NMP-2 downcomers, because the dominant mode natural

frequency of an individual downcomer is less than 3.5 Hz. If the fundamental mode is excited, the most significant fatigue damage may incur from the low cycle/high stress oscillations. Thus, the cumulative damage of the anticipated stresses may be greater than that indicated by the applicant. Therefore, a definitive conclusion on the adequacy of the fatigue design cannot be reached at this time. Further clarification or analysis will be needed by the applicant in order to demonstrate the adequacy of the fatigue design of the NMP-2 downcomers.

Load Application

In the resolution of USI A-8, "Mark II Containment Pool Dynamic Loads," the staff, with the assistance of their consultants, evaluated and approved, in NUREG-0487 and NUREG-0808, the bases for concluding that certain loads were secondary in nature and, therefore, were negligible (Two of the eight secondary loads identified in NUREG-0487, for example, were water sloshing during and after the pool swell and seismic sloshing.) These conclusions were based on the results of single-cell, full scale tests of pool swell and steam condensation phenomena from a LOCA. The dynamic characteristics of downcomers were not considered in the modelling, and the single downcomer in the test chamber was supported laterally.

The application of the loads provided in the Mark II Owners Group's Load Definition Report was reviewed and approved for Mark II plants. In applying the specified loads to NMP-2 with unbraced downcomers, the applicant has not evaluated whether the bases for neglecting some of the secondary loads are

still valid; i.e., the applicant has not evaluated the potential for the flexible downcomers to resonate with these dynamic loads.

Summary

The concerns described above were discussed with the applicant and their consultant in the December 20, 1985, meeting. The applicant is expected to evaluate these concerns and to determine whether or not these concerns can be resolved in a satisfactory manner.