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

March 18,1986

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: Review of Downcomer Supports for Nine Mile Point, Unit 2

Enclosure 1 contains a draft Safety Evaluation Report for the downcomer design for Nine Mile Point, Unit 2 and is being sent for your information. Enclosures 2 and 3 contain reports from NRC consultants on the downcomer issue and are also being provided for your information. The staff is presently reviewing your exemption request of February 18, 1986 and will report the results of that review at a later date.

Sincerely,

Mary F. Haughey, Project Manager
BWR Project Directorate No. 3
Division of BWR Licensing

Enclosure: As stated

Mr. B. G. Hooten
Niagara Mohawk Power Corporation

Nine Mile Point Nuclear Station
Unit 2

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ENCLOSURE 1

SAFETY EVALUATION REPORT

ON 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 the plane perpendicular to 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 3.9.2. and in NUREG-0484 Rev. 1, "Methodology for Combining Dynamic Responses."

Because of the uniqueness of the unbraced downcomer design and the concern over the potential loss of structural stability before reaching the design limits, the staff requested the detailed design report on the NMP-2 downcomers. Upon receipt of the report (Reference 1) that was formally submitted later on December 31, 1985, the staff performed a preliminary review of the design calculations and concluded that the design appeared inadequate, because the unbraced design did not meet some of the licensing criteria established by the staff and accepted by the applicant. As a result of the finding, a meeting was held in Bethesda, Maryland, on December 20, 1985. In the meeting the staff presented the specific concerns in various areas of the downcomer design analysis provided by the applicant in Reference 1. Subsequent to the December 20, 1985 meeting, a draft safety evaluation report was transmitted to the applicant by letter dated January 8, 1986 (Reference 2). On January 15, 1986, a meeting was again held in Bethesda, Maryland, between the staff and the applicant with the

presence of his consultants; Stone and Webster Engineering Corporation, General Electric Corporation, Stevenson and Associates, and Management Analysis Company. After reviewing the staff's concerns described in Reference 2, the applicant performed a reanalysis of the NMP-2 downcomers on the following bases:

- a time history analysis was made for the seismic loads;
- chugging loads were revised according to NUREG-0808;
- allowable stresses were revised based on the temperatures in the NMP-2 wetwell;
- damping values were revised;
- the method for combining loads was revised; and
- a rigorous ASME Class 1 fatigue reanalysis was completed that superseded the original one presented in Reference 1 in which the stress intensification factor was not properly considered.

The applicant has also indicated that snap back tests with deflections of 1.2- and 3- inches were performed to justify the higher damping factors used in the reanalysis. The details of the above reanalysis were provided on January 21, 1986 and subsequently submitted by letter dated January 23, 1986 (Reference 3).

On January 24, 1986, the staff met with it's consultants to discuss the adequacy of NMP-2 downcomer design in the context of the reanalysis submitted by the applicant in Reference 3. After a detailed discussion, the staff and the consultants concluded that: (1) the unbraced downcomer design at NMP-2 was marginal; (2) the design met the licensing criteria for upset and emergency conditions; and (3) the applicant had not adequately demonstrated the design adequacy for the faulted condition. These conclusions along with staff recommendations for the possible resolution

were furnished to the applicant by letter dated January 31, 1986. In the following the staff's specific concerns on the design adequacy of NMP-2 downcomers, and the recommendations for resolution, and their bases are discussed.

DESIGN PHILOSOPHY

The downcomers are essential elements of the suppression type containment system and, strictly speaking, are not a piping system. The downcomers channel the steam that can result from a loss-of-coolant-accident (LOCA), or other accidents, from the drywell into the suppression pool. In fulfilling this suppression function, the downcomers will be subjected to flow-induced and pool hydrodynamic loads in addition to other loads that are considered in the design of structures inside the containment. The flow-induced and pool hydrodynamic loads can both be influenced by the structural characteristics of the downcomers. These loads have been determined from model testing of a "rigid" downcomer. Therefore, the staff believes that the use of "rigid" downcomers would obviate the potential problems of resonance, buckling (loss of geometric stability), low cycle fatigue, and functional capability.

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.

Even though the applicant has demonstrated that the design meets the Code criteria, the applicant has not shown an adequate margin of safety to accommodate the uncertainties associated with the definition of the loading, material properties, imperfections in the geometrical configuration, method of analysis, etc., since some design conservatisms have been reduced in the reanalysis. Stevenson & Associates (Reference 4) observed that "...there may be no inherent margin in failure mechanism formation between multi-supported statically indeterminate piping systems and statically determinate simply supported or cantilever supported systems." The staff believes this observation is basically irrelevant because in installing a bracing system connecting adjacent downcomers, thus resulting in a highly redundant (statically indeterminate) space frame, the structural capability of the downcomers would be greatly enhanced. Reference 4 further alluded that a cantilevered downcomer could be visualized as a pendulum that would be stable under dead and transient loads. If the downcomers act as visualized in the LOCA case, their behavior would be unpredictable and the displacements could be so large to eventually lead to collapse or break, resulting in functional impairment of the downcomers. The applicant should demonstrate that this failure mechanism could not occur or design the downcomer to prevent it from occurring.

LOADS AND LOAD APPLICATIONS

In the resolution of USI A-8, "Mark II Containment Pool Dynamic Loads," the staff and its consultants evaluated and approved the bases for concluding that certain loads were secondary by virtue of their low magnitude and, therefore, were negligible. These secondary loads included water sloshing during and after the pool swell, seismic sloshing, fluid/structural interactions, etc. These conclusions were based on results of scale-model tests of pool swell, chugging phenomenon, and pool response to SRV discharges. The dynamic characteristics of downcomers were not considered in the modelling and, therefore, possible resonance effects were also not considered. Also the single downcomer in the test chamber was supported laterally. Therefore, the generic conclusion that these loads were secondary and negligible may not be applicable to NMP-2 unbraced downcomer design.

In a meeting held on December 20, 1985, the applicant was requested to assess the potential of secondary loads being amplified to become significant due to resonance. The applicant reviewed all secondary loads as identified in NUREG-0487 and -0808. In this new light, only two loads were found to be cyclic in nature and, therefore, are potentially susceptible to resonance effects; they are seismic sloshing and post pool swell loads. The annulus pool seismic sloshing frequency was estimated by the applicant to be 0.13 Hz, which is far from the downcomer resonance frequency of 1.55 Hz. Due to this wide separation, the applicant has concluded that resonance will not occur. The staff concurs with this conclusion.

With respect to post pool swell loads, the test data base was reviewed by the applicant. He concluded, and the staff concurs, that water fall back will not effectively excite the sloshing waves. Notwithstanding this conclusion, the applicant computed the frequencies of these waves if they were to occur to be between 0.29 Hz and 0.56 Hz. This range is well below the 1.94 Hz downcomer natural frequency in case of LOCA when the water column inside a downcomer would be displaced by steam. The staff agrees with the applicant that based on this analysis resonance will not occur. Therefore, the staff concludes that the applicant has adequately considered all secondary loads. Furthermore, it is noted that in its downcomer design analysis for chugging loads, the applicant utilized GE 800-Series in lieu of the GE 700-Series tests that had been used in earlier analyses. The applicant performed downcomer analyses considering both the GE 801 and GE 804 chugs. For the remaining 800-Series chugs, the applicant was able to demonstrate that the previous analyses using the 700-Series or the two 800-Series cases were bounding. Since the above approach conforms to the staff acceptance criteria, we find the revised design chugging loads acceptable.

LOAD COMBINATIONS

In Section 6A.2.2.5 of the 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. Even though the downcomers are part of the pressure-suppression system, they have been designed as mechanical piping system. As a result, the staff has 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 combination of dynamic responses by the SRSS method are given in NUREG-0484, Rev. 1.

In reviewing the load combination method as presented in Reference 1, the staff noted that the SRSS method for response combinations for the NMP-2 downcomers is not in conformance with staff position provided in NUREG-0484, Rev. 1. The applicant was requested to assess its load combination method in accordance with the staff position (Reference 2). In response to the staff concern, the applicant has revised its methodology for load combinations in accordance with the methodology described in NUREG-0484, Revision 1. This resolved the staff's concern on the load combinations.

FUNCTIONAL CAPABILITY

In response to an earlier 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 system 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 (Reference 1) for the NMP-2 downcomers previously 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. Based on the review of the analysis provided in Reference 1, the staff concluded that the applicant did not adequately demonstrate the functional capability of the downcomers, and conveyed its specific concerns to the applicant in Reference 2.

In response to the staff concern, the applicant reevaluated the functional capability of the NMP-2 downcomer (Reference 3 and 4). In this reevaluation, the applicant performed a finite element elasto-plastic shell analysis using the revised limiting loads for the faulted condition. The results were compared to criteria contained in NUREG-0261 on deflection, in NEDO-21985 on functional capability, and in NUREG-1061, Volume 2 on strain. Note that the strain criteria proposed in NUREG-1061, Volume 2 have not been accepted as a staff position. Furthermore, NUREG-1061, Volume 2 recommended that a factor of safety of 1.5 to 2.0 be applied for the design.

Based on the review of the information provided in References 3 and 4, the staff concludes that the applicant has not adequately demonstrated the design adequacy for the faulted conditions; i.e., the downcomer may lose geometrical stability before reaching the calculated stress levels for the faulted condition. The bases for this conclusion are as follows:

NUREG-0261 is based on a small displacement analysis that can not predict buckling. Accordingly, the comparison to the NUREG-0261 is not meaningful. NEDO-21985 was developed for piping systems. The NMP-2 unbraced downcomers are different from typical piping systems because of the following:

(1) Piping systems have two or more anchors; hence, a single plastic hinge will not lead to gross plastic displacements of the piping system.

(2) Piping systems usually have internal pressure. The stress criteria presented in the NEDO-21985 includes a pressure term of PD/4t. For piping with a large D/t, the pressure effect may be significant even for a relatively small internal pressure. It is noted that the applicant has not considered the effects due to internal pressure and dead weight of downcomers in making comparison to the NEDO-21985 stress criteria. If these two effects were included, the result of the comparison to NEDO-21985 criteria would have changed from being acceptable by a factor of 1.03 to being not acceptable.

Figure 2 of Reference 4 presents a comparison of the maximum calculated strain of 0.0059 at the limiting moment for NMP-2 downcomers to the strain criteria of $\varepsilon = 0.2$ (t/r), where t is the thickness and r is the nominal radius of a downcomer pipe, as suggested in NUREG-1061 (i.e., $\varepsilon = 0.00625$ at D/t = 64) as well as the test data from Reddy's paper (Reference 5). The validity of this comparison depends largely on the results presented in Reddy's paper. However, in reviewing the Reddy's paper, the staff notes that the paper has not clearly specified several key parameters relevant to material properties of the test specimens; e.g, actual wall thickness, out-of-roundness, type of material, etc. The staff believes that there are considerable uncertainties associated with these parameters that could invalidate their direct applicability to the NMP-2 downcomer design.

FATIGUE EVALUATION

In Reference 1, the applicant provided its fatigue evaluation of the NMP-2 downcomers. The staff's review of Reference 1 raises the concern that because the downcomers as designed have a fundamental mode natural frequency between 1 to 2 Hz, the most significant fatigue damage may incur from the low cycle/high stress oscillations. The applicant was requested to clarify its analysis to demonstrate the adequacy of the fatigue design of the NMP-2 downcomers.

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In response to the staff concern, the applicant provided a revised fatigue evaluation for the NMP-2 downcomers in Reference 3. The applicant stated that a rigorous ASME Class 1 fatigue reanalysis has been performed and the result satisfies ASME Class 1 requirement. The applicant also stated that this revised fatigue analysis is performed for the critical location of the downcomers; i.e., at the junction between the downcomers and the drywell floor, and all postulated loading events that can occur on a Mark II plant and can affect the downcomers are considered.

In reviewing the calculations provided in Reference 3, the staff noted the applicant's analysis method is not a straight forward application of the Code rules and in some areas of calculations the results were nonconservative as compared to the Code. However, in view of the substantial margin of the calculated cumulative usage factor (CUF) to the Code requirement; i.e., CUF = 0.182 which is significantly less than 1.0, the staff believes that the results provide a sufficient margin to assure the adequacy of the fatigue design of the NMP-2 downcomers.

CONCLUSIONS AND RECOMMENDATION

Based on its review of the information provided by the applicant in References 3 and 4, the staff concludes that the unbraced downcomer design at NMP-2 is marginal. The staff further concludes that the NMP-2 design meets the licensing criteria for upset and emergency conditions; however, the applicant has not adequately demonstrated the design adequacy for the faulted condition as discussed above. Specifically, the downcomers may lose geometrical stability before reaching the calculated stress levels for the faulted condition.

The staff recommends that the design adequacy with respect to the faulted condition be demonstrated; e.g., by out-of-plant testing which simulates the downcomer installation for NMP-2, or that hardware modifications be made to the downcomers.

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REFERENCES

1. Letter from C. V. Mangan to E. Adensam, dated December 31, 1985 regarding downcomer design for Nine Mile Point Nuclear Station, Unit 2.

2. Letter from R. Bernero to B. G. Hooten, "Structural Adequacy of the Nine Mile Point Unit 2 Downcomer Design", dated January 8, 1986.

3. Letter from C. V. Mangan to E. Adensam, dated January 23, 1986 regarding downcomer design for Nine Mile Point Nuclear Station, Unit 2.

4. Letter from C. V. Mangan to E. Adensam, dated January 24, 1986 regarding Stevenson & Associates final report on review of structural adequacy of BWR Mark II Downcomers for Nine Mile Point Unit 2 Nuclear Power Station.

5. Reddy, B. D., "An Experimental study of the plastic Buckling of Circular Cylinders in Pure Bending", Journal Solids Structures, Vol. 15 Perganmon Press Ltd. 1979.