UNITED STATES
NUCLEAR REGULATORY COMMISSION
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ENCLOSURE 2

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

REACTOR AND TURBINE BUILDINGS

FOR BLAST LOAD FROM THE HYDROGEN

WATER CHEMISTRY FACILITY

NORTHERN STATES POWER COMPANY

MONTICELLO NUCLEAR GENERATING PLANT

DOCKET NO. 50-263

Introduction

Every hydrogen storage system is potentially a safety hazard because of postulated rupture of storage tanks. When a storage tank ruptures, explosion or high blast may cause damage to the surrounding structures. In the report entitled "Evaluation of Steel-Sided Portion of Reactor and Turbine Buildings for Blast Load from the Hydrogen Water Chemistry Facility, Northern States Power Company, Monticello Nuclear Generating Plant" (references and 1 and 2), Bechtel Power Corporation studied the potential damage to the steel-sided top floors of the Turbine and Reactor Buildings in the event of a worst case hypothetical detonation of the system's hydrogen storage tank. It is the purpose of this report to evaluate the method of analysis and the structural integrity of the Reactor and Turbine Buildings of the Monticello Nuclear Generating Plant subjected to the blast load from the hydrogen water chemistry facility.

Discussion

The safety of a structure subjected to a blast loading depends mainly on two general considerations: the nature of the explosion traveling through a distance from its source to the structure, and the capacity of structure to resist blast loadings.

(A) The Explosion

The effects of explosions that are of concern in analyzing structure response to blasts are incident or reflected pressure (overpressure), dynamic (drag) pressure, blast induced ground motion, and blast-generated missiles. Regulatory Guide 1.91 (ref. 3) states that overpressure effects are controlling while other effects are of much less significance. Since the separation distance from the hydrogen storage tank to the Turbine and Reactor Buildings is more than 1,200 ft., it is sufficient to just consider the effects of the blast pressure due to its reflection off the ground. The primary result of a hydrogen explosion is the formation of a shock wave composed of a high-pressure shock front which expands radially outward from the center of the detonation. The intensity of the pressure decays as a function of distance and time. U.S. Army Technical Manual TM5-1300 (ref. 4) provides a procedure to calculate the blast magnitude and duration and has been accepted by Regulatory Guide 1.91.

The magnitude of the blast is based on a TNT equivalence for hydrogen. Following the EPRI Guidelines (ref. 5) for permanent BWR hydrogen water chemistry installation,

1000 standard cubic feet (SCF) hydrogen = 27.1 lbs. TNT
1 gallon liquid hydrogen = 1.37 lbs. TNT

The facility holds 60,000 SCF of gaseous hydrogen and 9,000 gallons of liquid hydrogen; the equivalent TNT weights are 1060 lbs. and 12,300 lbs. respectively.

(B) Method of Analysis

The blast shock wave is an impulse load with a short duration of about 1/10 second. An elastic analysis using dynamic load factors (DLF) is used to determine the behavior of the structure when impacted by the blast. The DLF is based on the blast load treated as a triangular load pulse and dependent on the ratio of the load duration to the natural period of the structure.

The period of the overall structure is determined by a free vibration analysis using a three-dimensional finite element model. Separate frequency analyses are performed for the different walls and roof panels. When the dynamic characteristics of the wall/roof panels are considered together with the structural framing, the resulting dynamic load factors will be reduced since the individual component flexibilities are combined in series.

Two structures, the Reactor Building and the Turbine Building, are taken into consideration. The model of the Reactor Building consists of a steel truss, a concrete base represented by a stick model, and the soil supporting the building. For the Turbine Building analysis, the structural steel framing frequency obtained from the reactor enclosure building analysis was used instead of performing a separate analysis for the Turbine Building because of their similarities.

The loading combination is in accordance with Regulatory Guide 1.91 (ref. 3) with the assumption that thermal load and pipe reaction during normal operation or shutdown are negligible.

(C) Acceptance Criteria

The steel frame of both Reactor and Turbine Buildings is fabricated from ASTM A36 steel with a minimum yield strength of 36,000 psi. The structures are designed to UBC criteria but assured against collapse due to extreme seismic conditions. Steel members and connections are generally checked in accordance with AISC Specifications (ref. 6)

The structures may undergo inelastic deformations as a consequence of the blast load. The calculated ductility of the individual structural elements must be such that they will be capable of absorbing the blast loads and prevent collapses of the structures. A set of allowable ductility factors are established in the report. Structural members are acceptable when the calculated ductility is less than the allowable value.

Findings

1. Characteristics of the hydrogen explosion with regard to the time of rise, decay, propagation of blast wave and impulse-peak overpressure relationships are assumed to be very similar to those of a TNT explosion so that the effect of the hydrogen explosion can be projected by TNT weight equivalence. This practice has been used and verified by EPRI and is therefore acceptable.

2. The blast is categorized as an "unconfined surface-burst load" with the shock wave amplified due to ground reflections. The procedure provided by Army publication TM5-1300 (ref. 4) to calculate the blast magnitude and duration has been accepted by Regulatory Guide 1.91.

3. The dynamic load factor (DLF) method is used to assess the dynamic response and behavior of the structures. When the wall/roof panels are coupled with the structural framing, the lower frequency (or higher period) results in a smaller DLF and the calculated DLFs of the building plus decking/siding and purlins/girts are always less than 1. Therefore dynamic amplification is not a problem here.

4. The capacity of connections, joints and anchor bolts was evaluated for the forces and reactions consistent with the peak positive pressure. Since the negative pressures are smaller than the positive, the connection capacity is quite adequate to encounter the adverse effect of negative pressures. The structure is not analyzed for the damage by missiles because no sizable objects generated by the blast are expected to travel through a distance of more than 1200 ft.

5. The ductility of steel members is in general in accordance with the requirements of Appendix A to Standard Review Plan Section 3.5.3 (ref. except that in case of compression members the allowable ductibility ratio (μ = 4.0 for $l/r \leq 30$) used by the licensee is higher than that of the S.R.P (μ=1.3). However, since all columns of the Reactor Building will remain elastic for blast loads and most critical columns of the Turbine Building are calculated to have a required ductility of about 1.1 for compression and 4.0 for flexure, no problem of ductility is anticipated. Structure members are acceptable when the calculated ductility is less than the allowable value.

6. As per staff's request, the licensee has examined the buckling strength of long columns and the problem of anchor bolts. The effects of loads applied to the full length of the Turbine Building column were evaluated. The contribution of the axial load to the total required ductility ratio is less than 10 percent. The capacity of the anchor bolts were found to be adequate for the loads applied to the full length of the Turbine Building columns.

Conclusion

Based on the findings described above, we conclude that the methods of calculating the design dynamic pressure load on the structures in the event of a worst case hypothetical detonation of a hydrogen storage tank are reasonable and acceptable. The steel-sided top floors of the Reactor and Turbine Buildings are capable of withstanding such blast loads without impairing the structural integrity of these structures.

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REFERENCES

1. "Evaluation of Steel-Sided Portion of Reactor and Turbine Buildings for Blast Load from the Hydrogen Water Chemistry facility. Northern States Power Company. Monticello Nuclear Generating Plant." Revision 1, January 1988. Bechtel Power Corporation.

2. "Letter from D. Musolf of NSP to NRC dated December 28, 1988, transmitting response to questions from the NRC staff on the subject.

3. US NRC Regulatory Guide 1.91, "Evaluation of Explosions Postulated to Occur on Transportation Routes near Nuclear Power Plants". Revision 1, February 1978.

4. "Structures to Resist the Effects of Accidental Explosions", Department of the Army Technical Manual TM5-1300, June 1969.

5. EPRI "Guidelines for Permanent BWR Hydrogen Water Chemistry Installation," 1987 Revision.

6. AISC Manual of Steel Construction, Eighth Edition, American Institute of Steel Construction, Inc.

7. USNRC Standard Review Plan Section 3.5.3. Appendix A "Permissible Ductility Ratio for Overall Damage Prediction" July 1981.