June 27, 2006

MEMORANDUM TO: Dwight D. Chamberlain, Director
Division of Reactor Safety
Region IV

FROM: Cornelius F. Holden, Deputy Director **/RA/**
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

SUBJECT: FINAL RESPONSE TO TASK INTERFACE AGREEMENT - TIA 2005-08, EVALUATION OF PROTECTION AGAINST TORNADOES AT COOPER NUCLEAR STATION (TAC NO. MC8236)

During an inspection at Cooper Nuclear Station (CNS), inspectors questioned the ability of the heating, ventilation, and air-conditioning (HVAC) system and other components located in the Emergency Diesel Generator (EDG) building to withstand the effects of a tornado. Specifically, the inspectors questioned whether changes in pressure, and differential pressures inside the EDG building resulting from a tornado passing over the EDG building could adversely affect systems and components inside the building. The Region IV staff performed a bounding risk assessment to determine the safety significance of the postulated event. Assuming a loss of offsite power concurrent with a failure of both EDGs resulting from an F-4 tornado striking the site, the delta core damage frequency was estimated at 1.54E-5 making this a potential Yellow issue. Region IV raised three specific questions in the TIA with respect to CNS's application of the requirements in the design of its EDG ventilation system:

(1) Under their current licensing basis, must the licensee be able to demonstrate (by test or analysis) that systems and components inside Class I structures will survive the effects of a design-basis tornado passing in close proximity to the plant (i.e., rapid depressurization and repressurization)? If so, and no analyses or tests exist, would this represent operation outside the design basis?

(2) Do the rapid depressurization and repressurization effects of a tornado present a challenge to the safe operation of the CNS facility?

(3) If there is a challenge to the safe operation of the facility, but it is not recognized in the current licensing basis, does the Office of Nuclear Reactor Regulation (NRR) consider that a backfit is warranted?

As you are aware, since the TIA was initially sent to NRR on August 26, 2005, the licensee changed its approach for evaluating the tornado pressure effects on systems and components inside the EDG building. NRR and Region IV met with the licensee on May 5, 2006, to discuss the licensee's revised approach to address the tornado design concerns.

By memo dated May 25, 2006 (Agencywide Documents Access and Management System accession number ML061380681 (non-publicly available)), NRR issued its draft response to TIA 2005-08. Region IV did not have comments on the draft response. Enclosed is the final response to TIA 2005-08.

If you have any questions on this matter or the enclosed staff's assessment, please contact the NRR Cooper Nuclear Station project manager, Brian Benney, at (301) 415-3764 or bjb@nrc.gov.

Docket No. 50-298

Enclosure:
As stated

cc w/encl: D. Starkey, OE
M. Ross-Lee, ADRO/IOEB
C. Jackson, ADRA/PGCB

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STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

FOR TASK INTERFACE AGREEMENT (TIA) 2005-08

EVALUATION OF PROTECTION AGAINST TORNADOES AT COOPER NUCLEAR STATION

NEBRASKA PUBLIC POWER DISTRICT

COOPER NUCLEAR STATION

DOCKET NO. 50-298

1.0 INTRODUCTION

As a result of questions arising from a Safety System Design and Performance Capability (SSD&PC) inspection performed at the Cooper Nuclear Station (CNS), the staff in Region IV requested technical support from the Office of Nuclear Reactor Regulation (NRR) to review the regulatory requirements and licensing basis for tornado design at CNS. The concerns were initially identified when regional inspectors questioned the ability of the safety-related heating, ventilation, and air-conditioning (HVAC) system and other auxiliary components located in the Emergency Diesel Generator (EDG) building to withstand the effects of a tornado. Specifically, the inspectors questioned whether changes in pressure and the resulting differential pressures caused by a tornado passing directly over the EDG building could adversely affect systems and components inside the EDG building. The Region IV staff performed a bounding risk assessment to determine the safety significance of the postulated event. Assuming a loss of offsite power concurrent with a failure of both stand-by emergency diesel generators resulting from an F-4 tornado striking the site, the delta core damage frequency was estimated at 1.54E-5 making this a potential Yellow issue. Region IV raised three specific questions in the TIA with respect to CNS's application of the requirements in the design of its EDG building ventilation system:

(1) Under their current licensing basis, must the licensee be able to demonstrate (by test or analysis) that systems and components inside Class I structures will survive the effects of a design-basis tornado passing in close proximity to the plant (i.e., rapid depressurization and repressurization)? If so, and no analyses or tests exist, would this represent operation outside the design basis?

(2) Do the rapid depressurization and repressurization effects of a tornado present a challenge to the safe operation of the CNS facility?

(3) If there is a challenge to the safe operation of the facility, but it is not recognized in the current licensing basis, does NRR consider that a backfit is warranted?

2.0 REGULATORY REQUIREMENTS

In 1967, the Atomic Energy Commission (AEC) issued a proposed Appendix A to Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, "General Design Criteria (GDC) for Nuclear Power Plant Construction Permits,[1]" for comment. The purpose of the proposed GDC was to provide guidelines to applicants in developing principal design criteria to be included in applications for construction permits (32 FR 10213). As stated in the staff requirement memorandum (SRM) on SECY-92-223 dated September 18, 1992, the Commission unanimously agreed that the GDC would not be applied to plants with construction permits issued prior to May 21, 1971. The CNS's construction permit was issued on June 4, 1968. In addition, the SRM stated that the proposed GDC were not new requirements, but were promulgated to more clearly articulate the licensing requirements and practice in effect at that time. Appendix F to CNS's Updated Safety Analysis Report (USAR) documents how the facility's design and construction had been performed in accordance with these proposed GDCs. For each GDC, the CNS applicant provided statements describing how it conformed to the proposed GDC, and these statements form part of CNS's licensing basis. The AEC accepted CNS's conformance with the proposed GDC during the proceedings for a construction permit.

In order to establish the tornado-design requirements and licensing basis for CNS, the NRR staff reviewed the regulatory requirements and written commitments including CNS's USAR to determine the extent to which the licensee is required and has committed to design safety-related structures, systems, and components (SSCs) to withstand additional loads resulting from natural phenomena hazards including tornadoes. As noted above, the proposed GDCs are not regulatory requirements for CNS, but, rather, the conforming statements from part of the facility's licensing basis. The applicable proposed GDC that addresses tornado design is proposed GDC 2, "Performance Standards." Proposed GDC 2 states:

> *Criterion 2—Performance Standards (Category A).* Those systems and components of reactor facilities which are essential to the prevention of accidents which could affect the public health and safety or to mitigation of their consequences shall be designed, fabricated, and erected to performance standards that will enable the facility to withstand, without loss of the capability to protect the public, the additional forces that might be imposed by natural phenomena such as earthquakes, tornadoes, flooding conditions, winds, ice, and other local site effects. The design bases so established shall reflect:
> (a) Appropriate consideration of the most severe of these natural phenomena that have been recorded for the site and the surrounding area and (b) an appropriate margin for withstanding forces greater than those recorded to reflect uncertainties about the historical data and their suitability as a basis for design.

For proposed GDC 2, the licensee's conforming statements provide, in part, that conformance to the structural loading criteria presented in Appendix C to the CNS USAR insures that those SSCs affected by this proposed GDC are designed and built to withstand the forces that might be imposed by the occurrence of various natural phenomena including tornado loadings. The scope of Appendix C of the USAR includes the loads, loading combinations, and allowable

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[1] The proposed GDC are also referred to as "draft GDC."

stress limits that are to be applied to Class I structures and components as defined in USAR, Section XII-2.1.1. Appendix C to the CNS USAR contains definitive criteria for consideration of tornado loadings in the design of concrete and steel structures. However, USAR, Appendix C, does not provide definitive criteria for the design of systems and components specifically for tornado loadings[2]; nor does Appendix C to the USAR specifically address the design of safety-related HVAC ductwork and associated components.

The NRR staff reviewed whether the design of HVAC ductwork was addressed in the CNS USAR as part of the structural design. It should be noted that "structural design" as defined in USAR, Section XII-2.0, includes the design of the two classes of "structures" and "equipment" for which the structural design requirements were applicable as stated in USAR, Section XII-2.1.1. As described in USAR, Section XII-2.1.2.3, Class I equipment includes the stand-by diesel generator system and auxiliaries. USAR, Section XII-2.3, discusses the loading considerations for Class I structures including tornado loads. Appendix C refers to the USAR, Section XII-2.3.3.2, for several aspects of tornado loadings (including differential pressure effects) for which the structures are to be designed. USAR, Section XII-2.3.3.2, states that Class I structures were designed to a pressure drop of 3 pounds per square inch (psi) occurring over a 3-second time interval. USAR, Section XII-2.3.3.2, also provides definitive criteria for the design of structures for other tornado wind and tornado-generated missile loadings. However, the CNS USAR does not provide definitive criteria describing how tornado loadings were considered in the design of Class I equipment. The CNS USAR only describes how tornado effects were evaluated for certain equipment and non-building structures (e.g., cranes, doors, refueling pool water, and blow-out panels as described in USAR, Sections XII-2.3.3.2.3 and XII-2.3.3.2.4). The CNS USAR does not describe specifically how tornado loadings were considered for the stand-by diesel generator system and auxiliaries.

The NRR staff reviewed the CNS USAR as it addressed protection of systems and components inside buildings with openings to the outside environment and their ability to withstand tornado pressure drop effects. The staff's review finds that the CNS USAR does not specifically discuss the design of systems and components in buildings with openings to the outside environment to withstand the additional loads generated as a result of their exposure to tornado-generated pressure gradients. The CNS USAR sections in which the structural loading criteria in Appendix C were applied indicate that these criteria were applied to building structures and not to systems and components unless specifically described.

3.0 SAFETY SIGNIFICANCE

To address the Region IV inspectors' questions about the impact of tornado pressurization loads on the HVAC components in the EDG building, the licensee performed an analysis to demonstrate that the HVAC ductwork in the EDG building would withstand the loads induced by

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[2] It should be noted that the licensee has reasonably implemented the accepted practice of enclosing safety-related systems and components inside building structures that are designed to resist tornado loads and isolate the enclosed systems and components from the effects of tornadoes. As such, these closed building structures (i.e., not open to the outside environment) provide the necessary protection for enclosed safety-related systems and components from the effects of tornadoes, and the design of enclosed safety-related systems and components does not need to further account for these effects.

pressure changes resulting from a tornado. Based on its review of the analysis documentation, the NRR staff concludes that the rapid depressurization and repressurization effects caused by a tornado will not result in structural failure of the ventilation ducting and components to the extent that it would cause a loss of cooling to components in the EDG building.

The staff is assessing the applicability of the CNS concerns to other nuclear facilities in order to establish the safety and risk significance of the issue and determine the extent to which this issue should be pursued on a generic basis. Our specific responses to the TIA questions are provided in the following section.

4.0 SPECIFIC RESPONSES TO TIA QUESTIONS

Question 1: Under their current licensing basis, must the licensee be able to demonstrate (by test or analysis) that systems and components inside Class I structures will survive the effects of a design-basis tornado passing in close proximity to the plant (i.e., rapid depressurization and repressurization)? If so, and no analyses or tests exist, would this represent operation outside design basis?

Answer: No. In its construction permit application for CNS, the licensee provided conforming statements in Appendix F to the USAR that described how the CNS design and construction satisfied the 1967 proposed GDC. These conforming statements to the 1967 proposed GDCs establish the licensing basis for the plant (except where specific commitments have been made to the 1971 GDCs as described in the USAR). Because the GDCs are not regulatory requirements for CNS, the licensee is not required to design its SSCs for tornado loadings. Rather, the design of SSCs at CNS for tornado loadings is a licensing commitment as described in the conforming statement.

Specifically, the conforming statement in Appendix F of the USAR states, in part, "Conformance to the structural loading criteria presented in Appendix C insures that those structures, systems, and components (SSCs) affected by this design criterion are designed and built to withstand the forces imposed by the occurrence of the various natural phenomena mentioned in the criterion, and this presents no risk to the health and safety of the public." As stated, the conforming statement appears to provide that systems and components (as well as structures) were designed to the structural loading criteria in Appendix C when affected by tornado loadings. However, as discussed above, the USAR, Appendix C, does not explicitly address the design of components for tornado loadings. Furthermore, the CNS USAR does not address the design of HVAC ductwork in the EDG building for tornado pressure-drop loads.

The NRR staff, therefore, concludes that under the CNS licensing basis, the licensee is not required to demonstrate that systems and components inside Class I buildings are capable of surviving the effects of a design-basis tornado passing in proximity to the plant (except for those Class I equipment specifically described in USAR, Sections XII-2.3.3.2.3 and XII-2.3.3.2.4).

Question 2: Do the rapid depressurization and repressurization effects of a tornado present a challenge to safe operation of the CNS?

Answer: No. The licensee has performed differential pressure analyses and structural analyses of critical H&V duct components in the EDG room under tornado conditions to provide reasonable assurance of the structural integrity of these components under design tornado conditions. The licensee reported the results of these analyses in CNS Calculation NEDC 05-021, Revision 2, dated April 24, 2006.

The differential pressure calculations in Calculation NEDC 05-021, Revision 2, are based on the assumption that the building is closed, except for an open exhaust backdraft damper in the H&V system used to cool the EDG room during EDG operation, that vents to the atmosphere. The intake damper in the supply plenum of this system, downstream from the opening in the wall, is assumed closed. The internal structures in the EDG room are assumed to be subject to maximum atmospheric pressure change effects, at the center of the tornado. The atmospheric pressure during the passage of the tornado and the open supply plenum is assumed to decrease from 14.7 psia to 11.7 psia in 3 seconds, based on licensing basis requirement as stated in the USAR. The largest possible differential pressure across the intake damper is therefore 3 psi or 432 psf. If the EDG room were a fully closed structure, this would be the maximum outward pressure (pressure in the room greater than tornado atmospheric) on the intake damper, and also on the supply plenum. The purpose of the calculations was to show that, if the EDG room is vented through the H&V fan exhaust duct to the atmosphere, the maximum differential pressure demand across the intake damper and the ducts is much lower than the 3 psi difference.

The differential pressure calculations consist of venting analyses that account for depressurization of the EDG room by itself, depressurization of the EDG room and the vestibule, and re-pressurization of the EDG room. The input tornado parameters were stated in the USAR. The depressurization stage provided the worst conditions acting on the ducts. To provide assurance that the loads acting on the weakest parts of the ducts are reasonable and were calculated correctly, the staff evaluated the depressurization differential pressure calculation for the EDG room and concluded that the licensee used a reasonable methodology, in accordance with accepted fluid mechanics principles. (The methodology is similar to that shown in Bechtel report BC-TOP-3A, "Tornado and Extreme Wind Design Criteria for Nuclear Power Plants," Revision 3, August 1974.) The depressurization analysis of the EDG room and the vestibule, as well as the re-pressurization analysis, are similar, since the same methodology was used in these analyses.

The structural analyses of the most vulnerable duct components were based on a methodology described in a paper titled, "Evaluation of the Ultimate Pressure Capacity of Rectangular HVAC Ducts for Nuclear Power Plants," by B. W. Wedellsborg, published in the ASCE Proceedings of the Third Conference on Structural Engineering in Nuclear Facilities, Volume 2, dated 1984. (Publication in ASCE proceedings does not imply ASCE endorsement.) This paper describes a methodology developed at the Bechtel Corporation for determining the lower bound pressure capacity of HVAC duct panels and stiffeners in duct failure modes. The methodology is based on an approximate finite deformation analysis of thin plates, and limit analysis of beams and plates. HVAC ducts can fail by either buckling and crimping of the duct corners, or by plastic collapse of the transverse stiffening angle beams, if the external pressure is higher than the internal pressure. The capacity of the ducts is defined by the pressure that may cause incipient failure of the panels between two stiffeners or of a stiffener between two duct panels. Two analyses are therefore necessary to determine the actual duct capacity, and the lower pressure of these analyses determines the safe duct capacity.

The staff performed a detailed confirmatory evaluation of the pressure capacity equations of the duct panels and the stiffening beams. They are based on an approximate analysis of the large deformation of rectangular diaphragms with fixed support edges, subjected to a membrane state of stress under transverse pressure loading and bending moments that occur only along the edges. This is analogous to a mechanism postulated in plastic limit analysis of plates, except for the interaction of the membrane state and the bending state at the edges only. The stiffener beam analysis also includes some results from limit analysis of flat plates. The theory in the paper was correlated with test results that were obtained from actual Bechtel tests of HVAC ducts under negative internal pressure performed as part of Arkansas Nuclear One (ANO) Unit 1 and Limerick Units 1 and 2 licensing. This correlation showed that a minimum factor of safety of 1.23 is obtained for the duct panels if an allowable stress value of $0.9f_y$ is used in the sheet pressure calculation, where f_y is the yield stress of the material. Likewise, a minimum factor of safety of 1.10 is obtained for the stiffening beams if an allowable stress value of $0.9f_y$ is used in the stiffener collapse pressure calculation. These allowable stresses were recommended by the author for design purposes. Aside from certain misprints, the staff found this methodology, as described in the paper, acceptable for evaluation of the CNS EDG room duct capacities.

The licensee reviewed the as-built configurations and drawings of the ductwork and determined that the critical duct locations for evaluation were the duct from the air intake to the plenum of the H&V unit, located in the vestibule, and the duct immediately downstream from the exhaust side of the unit. For these components, the capacities were calculated as 0.44 psi and 0.29 psi, respectively, based on stiffener buckling calculations. During depressurization, the largest pressure differential in the vestibule was calculated as 0.83 psi. The capacity of the stiffeners in this duct, 0.44 psi, is thus exceeded and the stiffeners are determined to collapse. To account for this, the licensee assumed the absence of an intermediate stiffener in calculating the sheet capacity of the duct. The duct sheet was thus longer than the stiffener spacing. On this basis, the lowest sheet capacity was calculated as 1.25 psi, based on an allowable stress equal to f_y, which indicates that no duct edge crimping will occur, even with a missing stiffener. For the duct immediately downstream from the exhaust side of the H&V unit, the sheet capacity was calculated as 1.66 psi. However, the capacity of the duct is limited to 0.29 psi, the limiting pressure for a stiffener in this duct. The largest pressure differential on this duct during depressurization was determined as 0.28 psi, which is slightly smaller than the capacity of the duct stiffeners. (The licensee conservatively estimated the stiffener capacities, by using the stiffener elastic section modulus instead of the plastic section modulus, on which the derivation of stiffener capacity is based. On this basis, the use of f_y as the allowable stress is acceptable.)

From the re-pressurization analysis, the licensee determined the largest differential pressure, equal to 2.5 psi. The pressure in the ducts is assumed to follow the external pressure, which is higher than the EDG room pressure until equalization occurs. The ducts are therefore under positive pressure (internal pressure greater than external) during re-pressurization. The potentially vulnerable component was found to be the exhaust fan backdraft damper, with an estimated pressure differential capacity of 1.5 psi. This indicated that this damper would sustain damage if it were closed during the re-pressurization stage. On this basis, the licensee is considering removing this damper. The licensee indicated that, even with damper failure, the EDG room H&V system would still be able to perform its function after the tornado event had terminated.

Based on its review of the licensee's calculations, the staff finds the application of the methodology described in the paper published in the ASCE Proceedings acceptable, and concludes that the EDG room H&V system will most likely remain functional in the event of CNS being impacted by a tornado with the properties specified in the USAR. The acceptance of this methodology does not constitute a general endorsement of this methodology by the NRC staff.

Question 3: If there is a challenge to safe operation of the facility, but it is not recognized in the current licensing basis, does NRR consider that a backfit is warranted?

Answer: No. The NRR staff finds that an F-4 tornado passing directly over the EDG building and through the CNS site is unlikely to result in the loss of both the HVAC ducting and associated equipment, and does not challenge the safe operation of the CNS facility. Accordingly, no backfit is warranted. The staff plans to assess this issue on a generic basis and determine the safety and risk significance of the issue for other nuclear power plants that might not have adequately considered the tornado pressure-drop effects on safety-related systems and components inside building structures open to the outside environment.