January 13, 2003

MEMORANDUM TO: Geoffrey E. Grant, Director
Division of Reactor Projects
Region III

FROM: Ledyard B. Marsh, Acting Director /RA/
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

SUBJECT: DONALD C. COOK NUCLEAR PLANT, UNITS 1 AND 2 - RESPONSE TO TASK INTERFACE AGREEMENT (TIA 2001-15) REGARDING EVALUATION OF CONTAINMENT STRUCTURE CONFORMANCE TO DESIGN-BASIS REQUIREMENTS (TAC NOS. MB3603 AND MB3604)

By memorandum dated December 12, 2001, you requested that the Office of Nuclear Reactor Regulation (NRR) provide a technical assessment verifying that Donald C. Cook Nuclear Plant, Units 1 and 2 (D.C. Cook) containment structures meet design-basis requirements. Specifically, you requested that NRR review the licensee's transient mass distribution and structural calculations to determine that the licensee utilized appropriate methodologies, assumptions, and inputs in determining that containment structures comply with design-basis requirements.

The NRR staff performed a detailed review of the licensee's methods and calculations used to restore the original design and licensing margins to the containment structural components. In addition to the review of the licensee's materials at the NRR Headquarters Offices, the NRR staff performed a design audit at the licensee's office on January 8-10, 2002. The audit reviewed structural calculations and other documentation to verify conformance with the design and licensing basis requirements for various structural components within the containment structure.

At the request of Region III, the NRR staff worked with the licensee to resolve the above issues. By letter dated May 31, 2002, the NRR staff issued a request for additional information (RAI). By letters dated July 16 and August 23, 2002, the licensee responded to the RAI.

Details of the NRR's staff evaluation and response to the questions raised in the TIA are attached. Based on the results of the evaluation and audit, the NRR staff found, with the exception of the Upper Rector Cavity area (Control Rod Drive Missile Shield), the licensee has used acceptable methods and appropriate assumptions and design parameters to restore the original design and licensing basis margins of the containment structural components.

For the Control Rod Drive Missile Shield in the Upper Reactor Cavity, the licensee changed the original design and licensing basis limits to allow the use of yield strength values for steel rebar obtained from certified material test reports (CMTRs). The NRR staff does not, in principle, accept the use of material CMTR limits (e.g., yield strength) in lieu of nominal specified code properties. Therefore, for the Control Rod Drive Missel Shield, the NRR staff found that the licensee has not used an acceptable method to restore the original design and licensing basis margins. The NRR staff will follow-up with the licensee to resolve this item.

With respect to containment operability, the NRR staff continues to have reasonable assurance that the Control Rod Drive Missile Shield in the Upper Reactivity Cavity will perform its intended function, as previously evaluated by the NRR staff in memorandums to Region III dated November 17, 2000, (Accession No. ML003770041) for D.C. Cook Unit 1 June 9, 2000, (Accession No. ML003723695) for D.C. Cook Unit 2 operability determination.

Docket Nos. 50-315 and 50-316

Attachment: As stated

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Docket Nos. 50-315 and 50-316

Attachment: As stated

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NUCLEAR REACTOR REGULATION (NRR) STAFF ASSESSMENT RELATING TO

TASK INTERFACE AGREEMENT (TIA 2001-15)

EVALUATION OF DONALD C. COOK (D. C. COOK) CONTAINMENT STRUCTURE

CONFORMANCE TO DESIGN-BASIS REQUIREMENTS

1.0 INTRODUCTION

By memorandum dated December 12, 2001, Region III requested the Office of Nuclear Reactor Regulation (NRR) via Task Interface Agreement (TIA 2001-15) to review the licensee's Transient Mass Distribution (TMD) and structural calculations to verify that the Donald C. Cook Nuclear Plant, Units 1 and 2 (D.C. Cook) containment structures meet their design-basis and licensing basis requirements as contained in the licensee's updated final safety analysis report (UFSAR). The TIA requested the NRR staff to determine if the licensee utilized appropriate methodologies, assumptions, and input in concluding that containment structures comply with design-basis requirements. Specifically, Region III requested that NRR verify the following six attributes in the calculations:

1. Concrete strength utilized in structural calculations;

2. Reinforcing steel material strength used in structural calculations;

3. Unit 2 design input that licensee obtained subsequently to June 11, 2001, meeting is consistent or conservative with respect to the value utilized in the TMD and structural calculations;

4. If utilized, justification for the use of a dynamic increase factor (DIF) adequately justified by the licensee;

5. If utilized, acceptability for applying the yield line theory analysis in structural calculations.

6. The methodology and assumptions utilized by the licensee to perform TMD analysis and structural calculations were consistent with licensing basis code requirements.

The NRR staff performed a detailed review of the licensee's structural calculations and the TMD analysis. The NRR staff also performed a design audit at the licensee's office on January 8-10, 2002, to review structural calculations and other documentation to verify their conformance with the design-basis requirements for various concrete slabs and walls within the containment structure. A complete list of structural calculations and design documents, which were reviewed in response to TIA 2001-15, is in Section 8.0 of this evaluation.

ATTACHMENT

At the request of Region III, the NRR staff worked with the licensee to resolve the above issues identified in the NRR staff initial review. By letter dated May 31, 2002, the NRR staff issued a request for additional information (RAI). By letters dated July 16 and August 23, 2002, the licensee responded to the RAI.

2.0 BACKGROUND

During the period when D. C. Cook, Units 1 and 2, were in the extended shutdowns, the licensee discovered that certain containment structural components did not meet the current design and licensing basis standards as described in the UFSAR. As a result of this, the licensee prepared operability evaluations for the degraded structural components. Under the cognizance of the Inspection Manual Chapter 0350 panel, the operability of the Units 1 and 2 containment structures was evaluated by the NRR staff prior to restart of each unit from the extended outages. The NRR staff found that the containment structures were adequate for the restart of the units; however, some of the assumptions and design inputs to the calculations would not be acceptable for the long-term corrective action of returning the containment structures to their original design and licensing basis.

On June 28, 2000, the licensee submitted Licensee Event Report (LER) 316/2000-003-00, "Containment Internal Concrete Structures Do Not Meet Design Load Margins." The LER contained the following two commitments:

1. A review of containment internal structures will be performed prior to Unit 1 startup to determine the extent of condition, repairs to structural elements will be made where applicable, and critical calculations will be reconstituted or evaluations performed to document operability of the Unit 1 structures.

2. The final course and schedule for long-term corrective and preventive actions to restore and maintain the design pressure load factors for the internal containment concrete structural elements in both units will be determined prior to Unit 1 startup.

By letters dated October 15, 2000, May 9, 2001, and November 18, 2002, the licensee provided the status of corrective actions related to demonstrating that Units 1 and 2 containment structures would meet their design-basis requirements. On June 11, 2001, a public meeting was held at the Nuclear Regulatory Commission (NRC) Headquarters Offices, where the licensee stated that D. C. Cook containment structures were in compliance with the design and licensing basis. The licensee based this conclusion on new extensive TMD and structural calculations. The licensee stated that the methods used to reach this conclusion were consistent with licensed codes and methods; therefore, no licensing basis changes were needed. In addition, the licensee determined that no modifications were warranted since all design-basis requirements were met. The only actions remaining after the June 11, 2001, meeting, involved the validation by the licensee during the next refueling outage of Unit 2 containment parameters that were utilized in the TMD and structural calculations.

Since the June 11, 2001, meeting, the licensee has conducted walkdowns to confirm as-built Unit 2 containment parameters that were utilized in the TMD and structural calculations. The licensee stated that the results of the walkdown confirmed that the parameters utilized in the calculations were the same as, or conservative to, the values used in the original design and licensing calculations.

3.0 TMD ANALYSIS REEVALUATION EFFORT

3.1 Background

General Design Criterion 50 requires that the reactor containment structure and associated heat removal systems be designed so that the containment structure and its internal components can accommodate the calculated pressure and temperature conditions resulting from any loss-of-coolant accident (LOCA).

Standard Review Plan (SRP) (NUREG-0800), Section 6.2.1.1.B, “Ice Condenser Containments,” Section II, specifies that in meeting the requirements of GDC 50 regarding the integrity of containment internal structures, the containment subcompartment or control volume differential pressures should be calculated using the TMD computer code, without the augmented critical flow correlation. The TMD code should incorporate the heat transfer correlation developed from the 1974 full scale ice condenser tests, and should include the compressibility factor “Y” in the incompressible flow equation.

The licensee has performed subcompartment reevaluation for the containment internal structures and has used the above guidance even though D. C. Cook is not required to comply with the guidance of NUREG-0800.

SRP Section 6.2.1.3, “Mass and Energy Release Analysis for Postulated Loss-of-Coolant Accidents,” states that the analytical approach used to compute the mass and energy profile will be accepted if both the computer program and the volume noding of the piping system are similar to those of an approved emergency core cooling system analysis.

The D. C. Cook analyses examined as part of this review used the SATAN 4 computer code to calculate mass and energy release. This is consistent with the SRP guidance.

At the NRR staff’s request, the licensee supplied subcompartment analyses for several containment interior compartments of the containment, these analyses included:

- Westinghouse letter report AEP-01-056, Revision 0 (licensee report NED-2001-018-REP, Rev 0), dated May 2001.

- Westinghouse Calculation CN-CRA-99-94, Revision 0, “D. C. Cook Units 1 and 2 (AEP/AMP)- Evaluation of Input Changes to the TMD Fan/Accumulator Room Subcompartment Model.”

- Westinghouse Calculation CN-CRA-99-94, Revision 1, “D. C. Cook Units 1 and 2 (AEP/AMP)- Evaluation of Input Changes to the TMD Fan/Accumulator Room Subcompartment Model.”

- D. C. Cook Calculation SD-010426-001, “TMD Input for Revised Fan/Accumulator Room Nodalization.”

- D. C. Cook Calculation SD-001020-001, “Net Flow Areas for Accumulator Rooms for Westinghouse TMD Analysis.”

The licensee's subcompartment analysis calculations used the Westinghouse TMD Version 4 computer code described in Reference 1. In addition to the description of the model in this reference, the TMD Code also incorporates a compressibility model. The TMD computer code has been approved by the NRC for these calculations. This approval was provided specifically for D. C. Cook in the Atomic Energy Commission's Safety Evaluation Report (SER) dated September 10, 1973. TMD was also approved for more general use in a letter from D. B. Vassallo, USAEC, to Romano Salvatori, Westinghouse Electric Corporation, dated December 18, 1973. The conditions specified for the use of TMD include those quoted above from the NRC Standard Review Plan. The D. C. Cook calculations examined as part of this review are consistent with these conditions, as discussed in the evaluation section below.

Westinghouse letter report AEP-01-056, Rev. 0 (licensee report NED-2001-018-REP, Rev 0), dated May 2001, describes the use of TMD for the D. C. Cook fan/accumulator room subcompartment analyses. In particular, Section 3.3.1, "Computer Codes," and Section 3.3.2, "Key Computer Code Assumptions" list the major methods and assumptions of this analysis. These sections state that the guidance of Standard Review Plan, Sections 6.2.1.2, "Subcompartment Analysis," and 6.2.1.3, "Mass and Energy Release Analysis for postulated Loss-of-Coolant Accidents," was used for the D. C. Cook fan/accumulator room calculations.

3.2 Evaluation

The NRR staff review concentrated on calculations of the pressure difference across the walls of the D. C. Cook containment fan/accumulator rooms. The fan/accumulator room enclosures are designed for a guillotine break of the main steamline, with an inside pipe area of 4.27 ft^2, downstream of the steam line flow restrictor (AEP Report No. NED-2001-018-REP, Rev. 0).

Subcompartment analyses are subject to large uncertainties. It is, therefore, necessary to ensure that sufficient conservatism is included in the calculations to account for these uncertainties. Standard Review Plan (SRP), Section 6.2.1.2, "Subcompartment Analyses," and SRP, Section 6.2.1.3, "Mass and Energy Release Analysis for Postulated Loss-of-Coolant Accidents," contain recommendations to ensure conservatism.

The Westinghouse TMD Computer Program (Reference 1) is used for the D. C. Cook subcompartment analyses. TMD was initially approved by the AEC for D. C. Cook in an SE dated September 10, 1973. A generic acceptance by the NRC of the Westinghouse TMD computer code is documented in Reference 2. At a later date, the compressibility model was added to TMD. This model is described in Revision 17 to the UFSAR Chapter 14.3. It is a standard fluid mechanics model (see Reference 3) used to adjust incompressible flow for the effects of compressibility at high subsonic Mach numbers (> .90) due to changes in area. The compressibility factor reduces the mass flow from the compartment and therefore increases the pressure in the compartment and the pressure difference between compartments. Sensitivity studies in Calculation CN-CRA-99-94 Revision 0 demonstrate this effect. The use of this model is acceptable since it is recommended by SRP Section 6.2.1.2, based on standard fluid mechanics methods and its inclusion accounts for a real effect.

SRP 6.2.1.2, "Subcompartment Analysis," specifies that the initial atmospheric conditions within a subcompartment should be selected to maximize the resultant differential pressure. Calculation CN-CRA-99-94, Revision 0, describes sensitivity studies done to select the most conservative conditions. The SRP states that maximum temperature, minimum absolute pressure, and zero per cent humidity should be used for subcompartment pressure differential calculations unless other values are justified. The licensee's sensitivity studies showed minimum subcompartment temperature to be more conservative for subcompartment pressure differential calculations (e.g., Calculation CN-CRA-99-94 Revision 1 Table 1 and Table 3). The licensee used an initial humidity of 15 percent, rather than zero percent as specified in the SRP. An assumption of zero percent relative humidity is bounding. Fifteen percent is a more realistic minimum value. Humidity is not an important parameter for pressure differential calculations, and therefore, the difference between 0% and 15% is not significant for two reasons. First, minimizing the amount of vapor maximizes the amount of air. This produces a higher containment pressure when the air is heated. Second, an increase in the amount of air decreases the heat transfer to structures within the containment. However, for subcompartment analyses, because of the short time to peak pressure, the primary pressurization mechanism is compression of the subcompartment air due to the released steam, not heating of the air. Also, because of the short time to peak pressurization, heat transfer to the subcompartment walls is not significant for subcompartment pressurization and therefore the effect of relative humidity on heat transfer is not important. For these reasons, relative humidity has a small effect on subcompartment pressure.

No single-failures are assumed for these analyses since the pressure differentials of interest occur before actuation of any mitigating equipment (including the main steamline isolation) could occur.

AEP Report No. NED-2001-018-REP, Revision 0, points out that SATAN-4, used for the mass and energy input to the TMD analysis, does not model momentum flux. The calculation claims that this is conservative for a high velocity steam blowdown since it over predicts steam pressure (and enthalpy) near the break. The NRR staff concurs with this assumption.

The critical mass flow rate from the break subcompartment to adjacent compartments for air or a superheated mixture of air and steam is calculated from the standard equations for isentropic critical flow of a perfect gas. For two phase flow, the homogeneous equilibrium model is used. This model tends to underestimate the mass flow rate in comparison with data. This is conservative since more fluid is retained in the break subcompartment which increases the subcompartment pressure and the differential pressure with respect to adjoining subcompartment.

The TMD Report (Reference 1) discussed the use of an augmentation factor which brought the critical flow calculated with the homogeneous equilibrium model into agreement with test data by increasing (augmenting) the flow up to 20 percent. However, the AEC's SER on the TMD code (Reference 2) did not accept this augmentation factor. The AEC's September 10, 1973, SER on the D. C. Cook use of the TMD Code also specifies that the augmentation factor should not be used for licensing calculations. The licensee's new calculations do not use the augmentation factor.

The calculations assume 100 percent entrainment; that is, all of the water in the compartment with the break is carried over to the adjoining compartment(s). This is based on the assumption that a high level of turbulence in the break room and adjoining rooms entrains all liquid water injected or condensed. Additionally, with the relatively low pressures in the containment, it is assumed that there is no slip between the phases in the pathways. Increased liquid flow increases the fluid density and results in a greater pressure drop (and thus higher forces on the walls) compared to the case where the fluid drops out of the flow (zero percent entrainment). These assumptions are consistent with the SRP, Section 6.2.1.2.II.B.4.

TMD utilizes the temperature flash model for the break discharge into the containment. This model assumes that the incremental mass released during a time step flashes and the vapor and liquid are in thermal equilibrium. Use of the temperature flash model increases the calculated pressure over the actual pressure. However, for a steamline break, the increase is probably not significant.

The SRP 6.2.1.2.II.B.2 states that the subcompartment nodalization scheme should be chosen so that there is no substantial pressure gradient within a node. The licensee's calculations have divided the fan/accumulator room into five elements to achieve this. Licensee Calculation SD-010426-001, Revision 1, calculates the refined noding. Note 4 of Section 3.0, "Assumptions and Limitations," of this calculation states that bounding values of dimensions are used and defines the bounding values as those that minimize free volume or which minimize the flow path area. The licensee also pointed out the following conservatisms that are included in the analysis: (1) the critical subcompartment volumes are biased low, (2) the flow areas between volumes are biased low, and (3) the unrecoverable loss coefficients (K and fL/D) are biased high. The NRR staff reviewed the above issues and concurs with the licensee.

3.3 Conclusion

The subcompartment analysis of the D. C. Cook fan/accumulator compartment is consistent with the applicable NRC SRP guidance using a NRC-approved computer code consistent with the NRC SER for that code. The input has been biased in the conservative direction.

Therefore, based on the above, the NRR staff finds TMD subcompartment analyses used for D. C. Cook to be consistent with the SRP and conservative. See Section 5.3 for the NRR staff's discussion of specific questions raised in the TIA concerning the TMD Code and its use at D. C. Cook.

4.0 STRUCTURAL ANALYSIS

Based on a sampling review of the calculations and design documents, the NRR staff noted that, with the exception of the calculations for the Control Rod Drive Missile Shield (for details see Section 5 below), the licensee's calculation methodology and assumptions appear to be reasonable and consistent with the original licensing basis code requirements.

5.0 DESIGN-BASIS CALCULATION ATTRIBUTES VALIDATION

5.1 Attribute # 1 - Concrete strength utilized in structural calculation

The NRR staff reviewed Calculation No. SD-010516-001, Determination of 28-Day Design Strength of Containment Concrete from Test Sample Data. The NRC staff verified several 28-day compressive strength data points from Attachment 2 of the Calculation, Concrete Test Reports, were correctly used (averaged) in Attachment 1 of the Calculation. The NRR staff, checked several deviation squared data points and found minor differences attributed to round off by the licensee. The NRR staff determined that the round off was acceptable.

American Concrete Institute (ACI)-214-65, ACI-318-63, and ACI-301-66 are the Codes of record for reinforced concrete. ACI-318-63 states that the specified compressive strength of the concrete is to be based on cylinder tests at 28 days or earlier (Source of information: (Safety Screening/Safety Evaluation 2001-0074-00)).

ACI-318-63 states that the ultimate strength of the concrete is to be based on the 28-day strength, because the design is being performed prior to knowledge of the actual or as-built strength. ACI-318-63 also includes requirements to obtain actual 28-day strength test results. Concrete pour information has been obtained for the D.C. Cook containment structures as described in UFSAR Section 5.2.2.5 in accordance with ACI-214-65 (Design Input 3.2.9). This information is to be used to determine the actual 28-day as-built strength for the containment structure. The 28-day as-built strength is to be used to evaluate the design of the containment concrete structures (Source of information: ES-CIVIL-0432-QCN).

For containment structures, the 28-day compressive strength of concrete is determined in accordance with the statistical methodologies outlined in ACI 214-65. The values utilized for input are obtained from the construction pour cards which include the pour location, batch design, and compressive test results. This compressive strength value is utilized for determination of the design structural capacity utilizing the load combinations given in Section 5.2.2.3 of the UFSAR.

The licensee utilized as-built concrete strength of 4424 psi based on 28 days concrete cylinder strength. The NRR staff had reviewed the licensee's justification for the as-built concrete strength earlier during the review of the operability evaluation and considered the use of 28-days strength acceptable for the reconstituted design-basis calculations. However, in the computer analysis for fan-accumulator room walls (Calculation SD-010412-001, Rev. 1), the licensee used concrete strengths of 4468 psi for Unit 1, and 4424 psi for Unit 2. For the calculation of shear stress in fan-accumulator room walls, the licensee used concrete strength of 4450 psi for Unit 1, and 4478 psi for Unit 2 (calculation SD-01016-001). The licensee did not use a consistent value for concrete strength, f_c', in its reevaluation of the fan-accumulator room walls in Units 1 and 2. The concrete strength values used are higher than 4424 psi that the NRR staff has accepted earlier during its review of the operability determination.

The maximum concrete strength, f_c', used in the calculations is about 1 percent higher than the 4424 psi value. This difference is judged to have no tangible effect on the calculation of allowable wall shear stress since the ACI code allowable shear stress varies with the square root of the concrete strength, f_c'. The NRR staff finds the concrete strengths utilized in the containment structural analyses are acceptable.

5.2 Attribute # 2 - Reinforcing Steel Material Strength

5.2.1 Revision of Reinforcing Steel Yield Strength

During the audit, the NRR staff identified that only two containment structures, ice condenser end walls and the Control Rod Drive Missile Shield in the Upper Reactor Cavity have utilized certified mill test reports (CMTRs) to establish a reinforcing steel (rebar) yield strength for use for the reevaluation of affected concrete components. CMTRs are required from the supplier to certify that the rebar meets the code required minimum guaranteed 40 ksi design-basis yield strength. The licensee, in Section 5.5.3 of its engineering specification, ES-CIVIL-0432-QCN, Revision. 1, approved the use of tested rebar yield strength for the design-basis calculations and revised the UFSAR to reflect this change.

(a) Ice Condenser End Walls (Calculation SD-010307-003, Revision 1, page 81)

The licensee indicated in this calculation that, in order to qualify the design of ice condenser end walls for calculated TMD pressure, it was necessary to use test CMTR values for the rebar yield strength. The CMTRs for the rebar material in the ice condenser end walls are provided in Attachment to Calculation SD-010307-003, Revision 1. In an Attachment of the calculation, the licensee identified #11 size rebar marked “5319” as the critical bars for design evaluation. These rebar were fabricated from three different heats of steel. The critical rebar heats are identified as D-7051, C-2093, and C-32919. Typically, CMTRs for each heat contain only one test value of the rebar yield strength ignoring inherent statistical variability. The licensee used the yield strength of 47.7 ksi (19 percent higher than the design-basis yield strength of 40 ksi) that was reported for heat # C-32919.

The licensee’s reinforcing steel procurement specification No. DCC CE 107 QCS, Revision 3, dated March 26, 1969, was reviewed by the staff. The requirements in this specification are that (1) the buyer (licensee) shall be provided with CMTRs for each heat of steel by the supplier in accordance with American Society for Testing and Materials (ASTM) A-615-68 specification, and (2) in addition, the buyer will have independent tests performed to confirm compliance with ASTM A-615-68 for tensile, yield point, and percent elongation for each heat. For this confirmatory (“check”) test, the buyer required in the procurement specification that the rebar supplier furnish six specimens from each heat to the licensee’s job site testing laboratory at Bridgman, Michigan. The procurement specification states that the fabricator will be informed when the test results are known.

During the audit, the licensee provided certified test results as discussed above that were performed by Calumet Steel (the supplier) to certify that the rebar meets the minimum guaranteed yield strength of 40 ksi. However, documentation of the “check” tests performed by the licensee’s laboratory was not available.

The use of limited test data (total of three, one from each heat) although adequate for demonstrating that the rebar meets the original licensing basis minimum design strength of 40 ksi, is not justified to support a higher yield strength (47.7 ksi) in support of the revision to the licensing basis and, the NRR staff did not find the use of CMTR acceptable. By letter dated May 31, 2002, the NRR staff requested that the licensee provide additional information to support the use of CMTR in the calculation.

By letter dated August 23, 2002, the licensee stated that Calculation SD-010307-003, Revision 1, has been redone using only the nominal code rebar strength of 40ksi. The new calculation demonstrated that the ice condenser end walls meet the required capacity without reliance on as-built rebar strength. The NRR staff finds this acceptable and further finds that the licensee has restored the original design and licensing basis margins to the ice condenser end walls.

(b) Missile Shield (Calculation SD-010307-001, Rev.1, dated 6/26/01)

The licensee indicated that the maximum acceptable LOCA pressure would have to be reduced from 50 psi to 42.37 psi in order to qualify the missile shield with the as-built 40 ksi rebar installed. To meet the load combinations stated in the UFSAR, the licensee opted to use CMTR test value for the rebar yield strength to qualify the design of the missile shield for the calculated TMD pressure of 50 psi. The licensee used the rebar yield strength of 50.6 ksi that is 26 percent higher than the design-basis yield strength of 40 ksi. Based on the rebar test strength of 50.6 ksi, the licensee concluded that the capacity of the missile shield for LOCA pressure is 53.6 psi, which is greater than the calculated TMD pressure of 50 psi.

Attachment 6 to the Control Rod Drive Missile Shield calculation provides rebar yield strength test data. The Actual CMTRs are not provided; rather a summary of the yield strength from each heat is included in the attachment. The missile shield design utilized # 5, #8, and #11 size rebar. Each size rebar comes from a different heat of steel. For each heat, only one yield strength test value is provided. The licensee used rebar yield strength of 50.6 ksi to determine the moment capacity of the missile shield. The NRR staff's initial review does not consider the use of very limited test data to support higher yield strength values for the installed rebar to be an adequate justification for revising the licensing basis and, is therefore, unacceptable. By letter dated May 31, 2002, the NRR staff requested that the licensee provide additional information to support the use of CMTR in the calculation.

By letter dated July 16, 2002, the licensee provided additional information to support the use of CMTR yield strength value for rebar in the missile shield structural calculation. The justification is based on the ACI Code and ASTM specification. The following is a summary of the licensee's justification:

(i) The containment structure at D.C. Cook Nuclear Plant (CNP) was designed in accordance with ACI 318-63, "Building Code for Reinforced Concrete" as stated in the CNP UFSAR. In that code, yield strength is defined as the "Specified minimum yield strength or yield point of reinforcement in pounds per square inch. Yield strength or yield point shall be determined in tension according to applicable ASTM specifications." As documented in the UFSAR, the applicable ASTM specification is ASTM A615-68, "Standard Specification for Deformed Billet-Steel Bars for Concrete Reinforcement." In accordance with ASTM A615-68, an analysis of each heat of reinforcing steel was made by the manufacturer to determine chemical and mechanical properties. These analyses were performed on test ingots taken during the pouring of the heats. The yield point and tensile strength determined by these analyses were documented on the CMTR. For Grade 40 rebar, the yield point was verified to be a minimum of 40,000 psi and the tensile strength was verified to be a minimum of 70,000 psi. Therefore, the use of a rebar yield strength based on the minimum yield strength from CMTR test data is justified on the basis that ACI 318-63 allows the use of reinforcements passing a specified minimum yield point and meeting the requirements of ASTM A615-68. In addition, the licensee states that if the minimum yield point from the CMTR data indicates a higher yield strength, the definition of yield strength in ACI 318-63 also allows CMTR data to be used for adoption of a higher yield strength.

(ii) ACI 349-01, "Code Requirements for Nuclear Safety Related Concrete Structures," and ACI 318-99, "Building Code Requirements for Structural Concrete," both provide guidance on evaluation of existing structures. Chapter 20 in both codes provides guidance on strength evaluation of existing structures. Section 20.1 of both codes provides general instructions for strength evaluations. Sub-section 20.1.2 of both codes allows analytical evaluation when dimensions and material properties are adequately known. Sub-section 20.2.4 of both codes state, "If required, reinforcement or tendon strength shall be based on tensile tests of representative samples of the material in the structure in question." Therefore, current ACI guidance for evaluation of existing concrete structures consistently requires that reinforcement strength for existing structures be based on tensile tests of representative samples of the material in question.

With respect to the licensee's first justification, the NRR staff does not agree that either ACI 318 Code or ASTM A615 standard allow the use of a higher yield strength value for Grade 40 rebar based on CMTR values. The provisions in Section 8, "Tensile Requirements," of ASTM A615 standard are explicit in that, "The material, as represented by the test specimens, shall confirm to the requirements for tensile properties prescribed in Table 2." Table 2 of ASTM A615 standard identifies that the required yield strength values for Grade 40 and Grade 60 rebar are 40 ksi and 60 ksi, respectively. The intent of both ACI 318 Code and ASTM A615 standard is to confirm, rather than increase, the code required minimum guaranteed design basis yield strength.

With respect to the licensee's second justification, the NRR staff's position has been to review any tension testing data to resolve the issue if there is testing data that adequately justifies the increased yield strength of Grade 40 rebar at CNP. The licensee stated in its reconstituted engineering specification that the rebar yield strength based on the CMTRs can be used for the design-basis calculations. The licensee has also revised the UFSAR to reflect this change to the original design-basis criteria. The staff does not agree with the licensee's contention and UFSAR revision. As the staff discussed in Reference 1, CMTRs are required from the supplier to certify that the rebar meets the code required minimum guaranteed design-basis yield strength. Typically, CMTRs for each heat contain only one test value of yield strength within that heat. Therefore, inherent statistical variability (coefficient of variation) in the yield strength can not be accounted for. Furthermore, the licensee did not provide any testing data that was obtained from the tension tests performed on a rebar that has been used in the missile shield structure at CNP. Therefore, the licensee's use of a revised yield strength value of 50.6 ksi, which is about 26 percent higher than the code required minimum guaranteed design-basis yield strength of 40 ksi, for the missile shield structure is unacceptable.

5.2.2 <u>Discussion of Florida Power Crystal River Unit 3</u>

The licensee provided the following excerpts from the Crystal River UFSAR and the associated staff SER on an issue that the licensee considered relevant to the change to the UFSAR concerning the use of CMTR. The licensee, in its 50.59 evaluation, relied on these documents to justify the licensing basis change in the D.C. Cook UFSAR and the use of rebar test yield strength, that is as high as 26 percent greater than the minimum required design-basis strength of 40 ksi, in the reconstituted licensing basis calculations.

Excerpt from Crystal River Unit 3 UFSAR, (Revision 26, Chapter 5, Page 49 of 89, Section 5.2.6 on Interior Structures)

"The secondary shield wall is designed to15.0 psi differential pressure, in accordance with ACI 318-71. For 17.5 psi peak differential pressure as reported in Section 14.2.2.5.11, the stress in the rebar is approximately 40400 psi, which is slightly higher than the guaranteed minimum yield strength of the material specified (Grade 40). Based on 70,000 psi minimum ultimate strength of grade 40 rebar, in order to have rebar failure, the maximum differential pressure can be as high as 30.3 psi."

Excerpt from Crystal River 3 SER (UCR NO: 99-UFSAR-0850-03, Page 505)

"The secondary shield wall was designed for a differential pressure of 15 psi with capability to 17.5 psi taking the reinforcing steel to yield. The secondary shield wall was designed in accordance with ACI 318-71 which was consistent with using the latest available codes at the time of its design."

The NRR staff finds, the above excerpts do not set a precedent that the NRC has approved the use of CMTR test rebar yield strength for design-basis calculations. The SER essentially accepts the Crystal River licensee's justification and concurs with its assessment that the stress in the shield wall reinforcement is slightly above the rebar minimum yield stress of 40,400 psi by only 1 percent which was considered insignificant. These excerpts do not provide the basis for using test rebar yield strength as high as 26 percent greater than the guaranteed minimum design-basis yield strength that was used in the D.C. Cook's design-basis calculations. Furthermore, the Crystal River SER does not endorse an UFSAR design change that will allow the use of test rebar yield strength for all future design calculations.

Based on the above, the NRR staff finds in the calculations for the Control Rod Drive Missile Shield, the licensee has not provided adequate justification for the use of CMTRs values for rebar yield strength for the Control Rod Drive Missile Shield.

5.3 Attribute #3 - Unit 2 design input that licensee obtained subsequent to June 11, 2001, meeting are consistent or conservative with respect to the value utilized in the TMD and structural calculations.

In September 2001, the licensee surveyed the Unit 2 containment to obtain as-built measurements to be used in the TMD analysis and structural calculations. The licensee found that the measurements used in the calculations prior to the Unit 2 walk downs were conservative and the TMD calculations remain valid.

In February 2002, resident inspector staff provided field measurements of openings in the Reactor Cavity. The measurements were compared with the dimensions used by licensee as input dimensions for the TMD analysis. Based on the NRR staff review, the dimensions used by the licensee in the TMD analysis were larger than the dimensions taken by the Resident Inspector staff.

Cavity Access Window (East North East location in cavity head area):

Window area	=	28.875 square feet
Duct	=	7.3 square feet
cable tray	=	3.7 square feet
conn boxes(2)	=	1.0 square foot
cable	=	0.58 square feet
cable	=	0.1 square feet
Open area	=	16.2 square feet measured by the NRC resident staff

Licensee's value used in the TMD analysis = 29.1 square feet. The increase in opening size is based on the licensee's assumption that following a DBA duct work will be collapsed increasing the opening area the of window.

By letter dated May 31, 2002, the NRR staff requested that the licensee provide justification for increasing the actual measured opening between subcompartments following a DBA. By letter dated July 16, 2002, the licensee responded to the request for additional information. The licensee indicated that there were only 2 locations in the subcompartment analysis that the licensee took credit for the deformation of duct work passing through openings. Those areas are the Steam Generator Enclosures and the Upper Reactor Cavity.

The NRR staff reviewed the licensee's analysis for the duct deformation provided in the July 16, 2002, letter. The NRC staff questioned both the methodology for calculating the pressure to which the ducts may be subjected, and assumptions made in the method for calculating the capacity of the ducts.

The NRR staff reviewed the original design and licensing basis values for free volume of the subcompartments inside the containment and also the vent area between the subcompartments. During the licensing stage for D. C. Cook Unit 1 by letter date June 1, 1973, the NRR staff issued an RAI requesting the free volume and vent areas for each subcompartment inside of containment that would be used as input to the TMD analysis. By letter dated July 13, 1973, the licensee issued Amendment No. 45 to the final safety analysis report which provided the requested information. The NRR staff compared the licensee's response with the inputs for the new TMD analysis performed by the licensee in 2001. The NRR staff found that in each case the licensee used more conservative inputs to the 2001 TMD analysis than were used in the original design and licensing basis TMD analysis. Therefore, the NRR staff finds the input to the TMD analysis performed in 2001 were consistent and/or more conservative that the original design and licensing basis input valves.

5.4 Attribute # 4 - Justification of DIF

The licensee indicated that it did not use DIF in the structural calculations. The NRR staff's audit findings are consistent with the licensee's assertion.

5.5 Attribute # 5 - If utilized, did the licensee properly apply yield line theory analysis in structural calculations:

The licensee did not indicate, and the NRR staff did not identify during the sampling audit, the use of yield line theory analysis in the structural calculation of fan-accumulator room walls (SD-010412-001, Rev. 1). The NRR staff notes, however, that the use of yield line theory is technically acceptable if properly implemented and is also referenced in the design-basis documents.

5.6 Attribute # 6 - The methodology and assumptions utilized by the licensee to perform TMD analysis and structural calculations was consistent with licensing basis code requirements.

5.6.1 Structural Calculations

Based on a sampling review of the calculations and design documents, the NRR staff noted that, with the exception of the calculations for the Control Rod Drive Missile Shield, the licensee's calculation methodology and assumptions appear to be reasonable and consistent with the original design and licensing basis code requirements,

During the January 2002, audit, the NRR staff found that the analysis of the Units 1 and 2, fan-accumulator room walls, used a computer program, *SOLVIA,* that has not been reviewed by the NRR staff in other applications. By letter dated May 31, 2002, the NRR staff requested that the licensee provide detailed documentation for the validation of the use of the *SOLVIA* code. The licensee responded to the RAI by latter dated July 12, 2002.

In the response licensee stated that the SOLVIA program is a commercially-available finite element analysis software program for linear and nonlinear analysis of displacements, stresses, and temperatures under static or dynamic conditions. The program can be used to perform various analyses, including:

– Complex structural analyses, including elastic and plastic response, concrete cracking, inclusion of rebar in beam and shell elements.

– Vibration analyses for frequencies and mode shapes, general forcing functions, harmonic response, power flow with viscous or hysteretic damping.

– Earthquake analyses using response spectrum method, weighted damping, raw/design/envelope response spectra, and time integration of nonlinear response.

– Buckling and post-buckling analyses, including automatic load stepping, initial imperfections, and linearized buckling.

– Heat transfer analyses, including three dimensional conduction with convection/radiation surfaces in stationary/transient analyses.

As part of the SOLVIA validation, the NRR staff requested bench marking data to provide a comparison with a program which has been approved by the NRC staff. The licensee selected the ADINA computer program for comparison with the SOLVIA program. Similar to SOLVIA, ADINA provides a single-system program for comprehensive finite element analyses of structures, fluids, and fluid flows with structural interactions. The following documents indicate that the NRC has found the ADINA program to be acceptable:

– NUREG/CR-6651, "International Comparative Assessment Study of Pressurized Thermal Shock in Reactor Vessels," by Oak Ridge National Laboratory.

– Appendix A in the NRC SER for Amendment No. 48 to the LaSalle County Station Unit 2. In that appendix, the NRC indicated that the ADINA program was acceptable and noted that the program had been verified by the supplier and by the contracted engineering company under the company's quality assurance program.

Additionally, the ADINA program was used by the licensee for several structural calculations provided to the NRC prior to the restart of CNP Units I and 2 from their extended shutdowns in 1998 - 2000.

Based on NRC reviews of the ADINA applications described above, the licensee considers the ADINA program to be an NRC-approved program. As a result, the licensee has used the ADINA program as a benchmark for comparison with the SOLVIA program.

The staff found that the containment calculations performed for CNP used elements that are common between the ADINA and SOLVIA programs. These elements are addressed in the common verification problems, which yielded the same answers for both programs as shown in the licensee's July 16, 2002, letter. Specifically, the linear analyses in the CNP containment calculations used truss elements, solid elements, beam elements, and shell elements, which were validated using Verification Problems A13, A16, A17 and A20, respectively, as identified in the licensee's July 16, 2002, letter. The staff also found that the nonlinear analyses used the same concrete material nonlinear stress-strain and steel (re-bar) elastic-plastic stress-strain inputs in both the SOLVIA and ADINA programs in the common verification problem examples identical for both programs.

In addition, the licensee stated that the calculations using the SOLVIA program were performed by its contractor, Stevenson & Associates (S&A). S&A has performed various structural analyses for numerous nuclear plants and is an approved vendor in accordance with the CNP Quality Assurance program. The licensee stated that S&A has used the SOLVIA program since approximately 1995, and the program was validated and verified in accordance with S&A's quality assurance program, which meets the requirements of 10 CFR Part 50, Appendix B.

The NRR staff concurs with the licensee's contention that both the ADINA and SOLVIA computer programs contain comparable elements, have common verification problems, and produce similar results. Based on these similarities, the NRR staff concurs that the ADINA program provides an acceptable benchmark for comparison with the SOLVIA program, and that the SOLVIA program is acceptable for use in the analyses of the CNP containment structures.

The NRR staff concludes that the licensee has provided sufficient justification to determine its similarity with the computer program, ADINA, which has been accepted by the staff in various safety related applications. Therefore, the NRC staff finds the use of the SOLVIA program is acceptable.

5.6.2 TMD Analysis

Based on the review performed by the NRR staff, the TMD subcompartment analysis used by D. C. Cook is consistent with the applicable NRC SRP guidance using an NRC-approved computer code consistent with the NRC SER for that code. The input has been biased in the conservative direction. See Section 3.

6.0 CONCLUSION

Based on the above evaluation, the NRR staff finds that with the exception of the calculation concerning the Control Rod Drive Missile Shield, the licensee has used acceptable analyses, with conservation assumptions and input parameters to confirm the original design and licensing basis of the containment structural components. The NRR staff does not find the use of CMTR values for the steel rebar acceptable. The NRR staff finds that the Control Rod Drive Missile Shield is degraded, but adequate margin exist that following a DBA the Control Rod Drive Missile Shield will perform its intended function. NRR staff will attempt to resolve this issue with the licensee.

7.0 REFERENCES

1. Ice Condenser Containment Pressure Transient Analysis Methods, WCAP 8077, March 1973.

2. Letter from D.B. Vassallo, USNRC, to Mr. Romano Salvatori, Westinghouse Electric Company, December 18, 1973.

3. Fluid Mechanics, Victor L. Streeter and E. Benjamin Wylie, Seventh Edition, McGraw-Hill Book Company, 1979.

8.0 DOCUMENTS REVIEWED DURING EVALUATION OF TIA 2001-15

8.1 D.C. Cook Procedures Reviewed

PMP-2350-SES-001	10 CFR 50.59 Reviews
PMP-2350-SAR-001	UFSAR Update Process
PMP-7030-CAP-001	Corrective Action Program Process Flow
PMP-5043-CDI-001	Configuration Document Impacts
PMI-7300	UFSAR Revision Process
12-EHP-5040-DES-003	Calculations
12-EHP-5040-DES-020	Engineering Specifications
12-EHP-5043-EDC-001	Evaluation of Discrepant Conditions
12-EHP-5043-OAR-001	Owner's Acceptance Review

8.2 D.C. Cook SE Reviewed

2001-0074-00	Safety Screeening/SE Design Specification for the Evaluation of the Unit 1 & 2 Containment Structures

8.3 D.C. Cook Design Specification Reviewed

ES-CIVIL-0432-QCN, Rev. 1	Design Specification for the Evaluation of the Unit 1 & 2 Containment Structures

8.4 D.C. Cook FSAR Change Reviewed

UCR-99-UFSAR-1565	UFSAR Change Request

8.5 D.C. Cook Condition Report Reviewed

CR P-99-27607	Corrective Action Program Ice Condenser Ice Bed
CR 00328020	UFSAR Assessment timliness of corrective actions
CR P-99-26578	Numerous discrepancies in UFSAR figures
CR P-99-26797	Definition for current licensing basis
CR 00299056	Procedure EHP-7300-SAR-001 does not agree with PMP-7300-UFSAR-001
CR P-99-23044	Field Observations identified discrepancies

8.6 D.C. Cook Analyses Reviewed

NED-2001-005-REP	Pressurizer Enclosure Subcompartent Analysis, May 2001
NED-2001-004-REP	Loop Subcompartent Analysis, June 2001
NED-2001-018-REP	Fan/Accumulator Room Subcompartment Analysis, May 2001
NED-2001-013-REP	Reactor Cavity Subcompartment Analysis, May 2001
NED-2001-012-REP	Steam Generator Enclosure Subcompartment Analysis, May 2001
NED-2001-005-REP	Pressurizer Enclosure Subcompartment Analysis, June 2001
NED-2001-010-REP	Test Report for Reactor Reflective Insulation Crushing Experiments, May 2001
NED-2001-011-REP	The Response of Reflective Insulation and HVAC Ducting to Design-Basis Events

8.7 D.C. Cook Calculations Reviewed

SD-010516-001	Determination of 28-Day Design Strength of Containment Concrete from Test Sample Data
SD-001005-001	Net Flow Areas for Openings and Penetrations in the Primary Shield Wall of the Containment Building
SD-010501-003	Reactor Cavity Flowpath and Volume Data for TMD Analysis of D.C. Cook Units 1 & 2
SD-001020-001	Net Flow Areas for Accumulator Rooms for Westinghouse TMD Analysis
SD-010501-003	Reactor Cavity Flowpath and Volume Data for TMD Analysis of D.C. Cook Units 1 & 2
SD-990909-005	Beam and Slab Design, Elevation 612' (Containment Building)
SD-010411-001, Rev. 1, 8/1/01	Unit 1 Ice Condenser Slab at 640'
SD-010412-001, Rev. 1	Design-Basis Analysis of Unit 1 and Unit 2 Fan-accumulator room walls
SD-000713-001, Rev. 1, 8/2/01	Load and load combination
SD-010307-001	Design-Basis Analysis of Unit 1 and Unit 2 Reactor Cavity Missile Shield Blocks
SD-010307-003, Rev. 1, Page 81	Ice Condenser End Walls
SD-990909-002, Rev. 1	Unit 1 Ice condenser slab-concrete slab and beams detailed analysis
SD-990909-008	Unit 2 Ice Condenser Columns and Anchorage
SD-000314-003	Ice condenser slab - sub-floor steel frames
SD-000403-001	Ice condenser slab-supporting steel columns
SD-010426-001	TMD Input for Revised Fan/Accumulator Room Nodalization Disk Unit 2 Digital Photos of Unit 2 Walkdown

8.8 D.C. Cook PORC Meeting Summary Reviewed

PORC Meeting 01-3856	Design Specification for the Evaluation of the Safety Screening/Evaluation No. 2001-0074-00, Unit 1 & 2 Containment Structures Crystal River	Date: 03/12/01

Excerpt from Crystal River Unit 3 UFSAR, (Rev. 26, Chapter 5, Page 49 of 89, Section 5.2.6 on Interior Structures)

Excerpt from Crystal River Unit 3 SER (UCR NO: 99-UFSAR-0850-03, Page 505)