PINGP EVALUATION

NUMBER:	EC 15651	REV. 1	SHEET NO:	1 OF 14
TITLE:	MARGIN ASSESSMENT OF CONTAINMENT VESSEL AND CONCRETE STRUCTURES		DATE:	2/26/2010
			COMP. BY:	TRD

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1.0 Purpose and Summary Result

The purpose of this evaluation is to determine the minimum wall thickness of potentially corroded areas of the containment vessel and allowable concrete degradation that precludes a challenge to the functionality or structural integrity of the containment vessels and internal structures. The margin being estimated is the margin between the vessel and internals structures design condition and the level of degradation that presents a risk of failure. This action is the result of RCE 1160372 which included the action: "Perform a margin assessment of the containment vessel and containment structures to determine the minimum wall requirements of potentially corroded areas of the vessel and allowable concrete degradation including the area around the transfer tube." The action for the assessment was communicated to the NRC and ACRS (Advisory Committee on Reactor Safeguards) in presentations associated with License Renewal.

It should be noted there has been no significant degradation of either the containment vessel or containment structures detected to date. The acceptability of any actual indications would be dependent on the specific location and geometry of the degradation. As such, any detected degradation would need to be evaluated on a case by case basis to determine what, if any, corrective actions are required. This evaluation establishes a level of general degradation that could be tolerated without challenging the structural integrity or functionality of the vessel and interior structures under Design Basis Accident (DBA) and Design Basis Earthquake (DBE) conditions.

Results are summarized as follows:

Both the shell and bottom head could tolerate general corrosion of approximately 0.5 inch with no significant risk to functionality. The required thickness based on code design calculations assuming a stress 80% of the minimum yield strength is 0.95 inch as compared to an actual thickness of 1.5 inch. This result is conservative as the assumed stress is 20% below the minimum yield strength and less than half the minimum tensile strength of the vessel material. There is additional conservatism as the estimate does not consider the reinforcement of potentially corroded areas of the vessel shell by the interior concrete.

Review of USAR section 12 indicates significant margin in the design of the containment internal concrete structures. As noted in USAR section 12.2.4.1.5.2 which discusses Reactor Coolant System Compartments and Refueling Cavity: "The general structural model consists of a composite of the compartment walls, the adjoining biological shield, the attached floor systems and structures, and the refueling cavity pool. The analytical model is broken down into two distinct interacting models: (1) laminar horizontal frames analyzed by STRESS programs and (2) vertical structural elements analyzed to carry unbalanced load reactions to the base by the box girder action of the compartment walls. This latter model could more aptly be described as a modified folded plate structure. The local effect of forces are analyzed by considering loading conditions on simplified but conservative models limited to the immediate and closely adjoining areas of loading. The above described analysis results were later confirmed by an independent finite element method of analysis that indicated conservative margins in the results of the original analysis of the order of 30 percent and greater." The actual margin is likely significantly greater than the 30 percent cited in the USAR as some of the more significant loads considered were removed from the design basis as result of the elimination of large primary loop pipe rupture as the structural design basis (Leak-Before-Break). As discussed in USAR 12.2.4.1.5.1 loads considered in the design of the Reactor Coolant System Compartments and Refueling Cavity included:

- Jet impingement loads from pipe rupture
- Compartment internal pressure buildup that would occur during a LOCA
- Pipe rupture reaction loads
- Thermal loads from thermal gradients caused by a LOCA
- Residual construction loads from concrete shrinkage
- Refueling cavity pool water
- Seismic loads.

Under Leak-Before-Break (LBB) the loads associated with a LOCA are either eliminated or substantially reduced. The margin of 30% noted in the USAR can reasonably be extrapolated to include a 30% loss in cross sectional area of reinforcing steel.

The concrete behind the transfer tube was originally brought into question as it is one of the thinnest sections of concrete inside containment. As noted in the Dominion Report (EC14139) "The possible exception mentioned above that is considered to require further evaluation is the following. If degradation of concrete inside the liner should occur in the area around the transfer tube, it could represent a significant fraction of the wall. Accurately determining the concrete thickness in this area was not possible with the drawings available to DEI but, based on rough scaling, the thickness could reach a minimum of less than one foot, e.g. 10 inches. The estimated maximum degradation thickness of 0.31 inch would be about 3% or more, which might be significant depending on how highly loaded the concrete is in this area. It is recommended that this issue be resolved by further detailed evaluation." The containment concrete detail drawings (NF-38484-1) indicate the section of concrete behind the transfer tube to include a double matt of reinforcing steel. Review of the containment internals structures drawings also indicate no significant loading of this section of concrete. The dead weight of the concrete above this section is supported by a large concrete beam above the transfer tube. Any loading from the concrete above this section would result in only compressive stresses. A Design Basis Earthquake which assumes a lateral acceleration of 0.12g (USAR 12.2.1.3.5) would result in only minimal stress as the thin section behind the transfer tube is approximately only 10 feet high by 1 foot wide and tied to much heavier sections on all four sides. As a result, a 30% margin for the section of concrete around the transfer tube is a conservative estimate consistent with other containment internal structures.

2.0 Methodology

The evaluation is divided into three sections:

The first section establishes the minimum wall thickness of the vessel shell and bottom head that would result in a stress 80% of the minimum yield strength of the vessel material based on the original design (ASME VIII Div. 1 equations). The resultant reduced thickness is then used to perform a linear extrapolation of the localized thermal and dynamic stresses reported in the USAR. These extrapolated localized stresses are then compared to the tensile strength of the material with consideration to duration, material ductility and whether the stresses are primary or secondary to determine if these stresses present a challenge to structural integrity.

The second section estimates the design margin of containment interior structures that could potentially be exposed to refueling cavity leakage. Due to the complexity and indeterminate nature of the analysis that would be required, an independent stress analysis is outside the scope of this evaluation. The evaluation is instead based on the results and conclusions reported in the USAR.

The third section evaluates the area around the transfer tube to determine if this section of concrete is under any significant loading that could result in failure even with significant degradation. This evaluation is based on review of the construction details and engineering judgment. A simple analysis that assumes the concrete section around the transfer tube supports the weight of all the concrete directly above it is performed to provide a conservative estimate of the loading on this section.

3.0 Acceptance Criteria

There are no acceptance criteria as the purpose of the evaluation is to determine the level of degradation that could be tolerated without challenging the functionality or structural integrity of the containment vessel and internal concrete structures. As noted above, any detected degradation would need to be evaluated on a case by case basis to determine if there is a non-conformance and if any corrective action is required.

4.0 Assumptions and Inputs

4.1 The containment vessel shell and bottom head are 1.5 inch thick with a hemispherical top head 3/4 inch thick all of which is SA-516-70 steel. The vessel inside radius is 52 foot 6 inches with a 2:1 ellipsoidal bottom head. The vessel was designed per the rules of ASME VIII with a joint efficiency of 1. Validated by: Chicago Bridge and Iron Company "Certified Stress Report for Pioneer Service and Engineering Company (Containment Vessel) Prairie Island Nuclear Plant #1," Revision 1, dated February 2, 1970 [PI -7402-0365]. Also see drawing NF-38398-6 for vessel outline and general arrangement.

4.2 The minimum specified tensile strength of SA-516-70 is 70ksi with minimum yield strength of 38ksi. Validated by ASTM A 516/A 516M.

4.3 All other assumptions and inputs as noted in the evaluation.

5.0 Calculations

Evaluation of Containment Vessel

As noted in USAR 12.2.2.2 "The design, fabrication, inspection, and testing of the Reactor Containment Vessel complies with the requirements of the ASME Boiler and Pressure Vessel Code, Section II, Materials; Section III, Nuclear Vessels, Subsection B, "Requirements for Class B Vessels"; Section VIII, Unfired Pressure Vessels; and Section IX, Welding Qualifications Appendix IX. The Reactor Containment Vessel is a Class B vessel as defined in the ASME Boiler and Pressure Vessel Code, Section III, Nuclear Vessels N-132. Its design and construction meets all the requirements of state and local building codes. The Reactor Containment Vessel is code stamped for pressures of both 46 psig and 41.4 psig in accordance with Paragraph N-1500. The design internal pressure for the Reactor Containment Vessel is as specified in the provisions of the "Winter 1965 Addenda" to Section III of the ASME Boiler and Pressure Vessel Code. The design requirements for Class B vessels are contained in Paragraphs N-1311 through N-1314 of the addenda. Paragraph N-1312 states that the design internal pressure may differ from the maximum internal pressure but may not be less than 90 percent of the maximum containment internal pressure. A maximum internal pressure of 46 psig and a design internal pressure of 0.9 x 46 = 41.4 psig have been specified. The Reactor Containment Vessel has been pressure tested for acceptance of the Vessel, air locks, equipment door and all Vessel penetration nozzles in accordance with the rules of Section VIII, UG-100 and Section III, N-1314 (d). The maximum test pressure was 1.25 times the design internal pressure of 1.25 x 41.4 = 51.8 psig."

The first step of the evaluation is verification of appropriate containment pressure and temperature for the margin assessment. The original design pressure was specified as 41.4 psig with the recognition that design pressure must be at least 90% of the maximum pressure, resulting in a maximum allowable internal pressure of 46 psig (USAR 12.2.2.2). The maximum allowable internal pressure of 46 psig is consistent with peak pressures indicated in the USAR. A Main Steam Line Break (MSLB) results in a peak pressure of 45.9 psig (USAR Fig. 14.5-21). A DBA results in a peak pressure of 42.6 psig (USAR G.3.1). A peak containment temperature of 358.6 °F occurs approximately 130 seconds after a MSLB (USAR 14.5.5.5) with a peak containment temperature from a DBA of 268 °F. The design temperature of the containment vessel of 268 °F is appropriate due to the thermal mass of the containment vessel and the short duration of the peak temperatures. As shown in USAR Figure 14.5-24, the containment temperature drops to 260 °F approximately 280 seconds after a MSLB and continues to decline. In addition, temperatures below 650 °F do not reduce the allowable stress of the SA-516-70 vessel material (1986 ASME VIII Table USC-23). As a result, the pressure and temperature for this assessment will be 46 psig and 268 °F as specified in the Containment Vessel Stress Report.

The next step of the evaluation is to determine the required shell and bottom head thickness assuming an allowable stress 80% of the minimum yield strength. As noted on the National Agency for Finite Element Methods and Standards resources web page for pressure vessel stresses (http://www.nafems.org/resources/knowledgebase/012/) "Primary membrane stresses are not allowed to exceed yield otherwise there is the possibility of a catastrophic plastic collapse e.g. a burst under pressure." 80% of minimum yield is a reasonable limit as it provides 20% margin from the minimum yield strength. There is additional margin in that the actual yield strength is greater than the specified minimum. Further, any location of the shell potentially subject to degradation is covered on the inside radius with concrete including a double matt of reinforcing steel (drawings NF-38484-1 and NF-38498-8). The reinforced concrete would carry some of the stress of pressurization and insulate any corroded areas of the vessel from a rapid temperature change during a DBA or MSLB.

Minimum Containment Cylindrical Shell Thickness Based on 80% of Yield

The required shell thickness using the equation from the Stress Report is:

$$t = PR/(SE-.6P)$$

Where: P = pressure psig. (46 psig noted above)

R = inside radius in. (630 inch noted in assumptions)

S = allowable stress psi. (30.4ksi (80% of 38ksi noted in assumptions))

t = wall thickness in.

E = joint efficiency (1 from assumptions)

$$t = 46(630)/(30400(1)-.6(46))$$

$$t = 0.95 \text{ in.}$$

Minimum Containment Bottom Head Thickness Based on 80% of Yield

The design margin of the containment vessel of the bottom head can be estimated in a similar manner using the bottom head equation from the stress report:

$$t = PD/(2SE-.2P)$$

Where: P = pressure psig. (46 psig noted in assumptions)

D = inside diameter in. (1260 in. noted in assumptions)

S = allowable stress psi. (30.4ksi (80% of 38ksi noted in assumptions))

t = wall thickness

E = joint efficiency (1 from assumptions)

$$t = 46(1260)/((2)(30400)(1)-.2(46))$$

$$t = 0.95 \text{ in.}$$

The design thickness of the containment vessel shell and bottom head is 1.5 inch providing an estimated margin of 0.5 inch.

External pressure is not considered, as any area of the vessel that could potentially be corroded is lined with heavily reinforced concrete on the inside diameter. By engineering judgment, the interior concrete is more than adequate to resist the 0.8 psig external design pressure discussed in USAR 12.2.2.1.4.

Consideration of Seismic and Thermal Stresses

In addition to membrane stresses from internal pressure, the original design also considered dynamic and thermal stresses as reported in section 12 of the USAR. These stresses will be increased by 50% to account for a reduction in wall thickness from 1.5 to 1.0 inches. The stresses will then be compared to the yield strength or tensile strength as appropriate depending on whether they are primary or secondary stresses. As noted on the NAFEMS web site referenced above "Secondary stress can comfortably exceed yield but must be limited to ensure shakedown under cyclic load. Hence the range of secondary stress is limited to twice yield…" In this case, the minimum tensile strength (70 ksi) is used rather than twice yield (76 ksi) to add conservatism. There is additional conservatism in that the actual tensile strength of the vessel material is greater than the specified minimum.

Seismic loads are discussed in USAR section 12.2.2.1.5. The loads are generally minimal with the exception of where the bottom head enters the external concrete in the annulus. As stated in the USAR: "The lateral and vertical loads caused by earthquake are of such a minimal nature that the friction is neglected to simplify the analysis but conservative approximations of the bearing loads are considered." "The calculation of the vessel shears, membrane, and surface stresses is by the application of the Kalnin's program to shells. The most critical area of stress in the steel shell under these conditions occurs in the discontinuity zone at the line of the external embedment in the concrete. The calculated stresses and allowable stresses at this line are given in Table 12.2-16." The table shows the combined loads of DBA internal pressure and a simultaneous DBE to be 26990 psi. It should also be noted as stated in USAR section 12.2.1.5.2.1 "The probability of the simultaneous occurrence of the Design Basis Earthquake and a reactor coolant pipe double-severance is practically zero." As stated earlier, this load can be increased by 50% to account for reduced thickness which results in a stress of 40485 psi. The peak stress from a simultaneous MSLB and DBE would be somewhat higher as the peak pressure of a MSLB is 45.9 psig as compared to 41.4 psig referenced in the table. The stress component due to pressure (14,330 psi from the table) would be increased by approximately 11% adding an additional 1576 psi resulting in a peak stress of 42061 psi. This stress is above the minimum yield strength of the material of 38000 psi, suggesting the possibility of some localized deformation, but well below the tensile strength of the material. It should also be noted that the estimated peak stress of 42061 psi is below the maximum allowable stress intensity of 52.50 ksi for all stresses (USAR Table 12.2-22). It is expected that if deformation were to occur the material would strain-harden until the material strength reached the stress and/or the localized area would start to deform to a more spherical shape reducing the pressure stress. As observed by the fact that design thickness of the containment vessel hemispherical top head is only 3/4 inch as compared to the bottom head thickness of 1.5 inch, pressure stress in spherical shells is approximately one half the pressure stress in cylindrical and ellipsoidal shells. This tendency to become spherical is recognized in USAR section 12.2.2.5.1 "When the Reactor Containment Vessel is pressurized, in operational configuration, it exerts a pressure on the internal concrete in the knuckle region as the shell attempts to deform inward. Also, the vessel exerts a pressure on the concrete outside of the vessel where the elliptical head is tending to deform outward. These reactions on the concrete are due to the tendency of the elliptical head to become hemispherical in shape when pressurized." As discussed on the Engineer's Edge web site (http://www.engineersedge.com/material_science/work_strain_hardening.htm) "Work hardening is when a metal is strained beyond the yield point. An increasing stress is required to produce additional plastic deformation and the metal apparently becomes stronger and more difficult to deform." In addition, a DBE and peak pressure are both relatively short duration events with the worst case being a MSLB with a peak pressure duration of approximately 10 seconds (USAR Fig. 14.5-23). As such, a brief excursion somewhat over the yield strength, but well below the tensile strength, may result in some localized deformation and strain hardening of the material, but would not be a challenge to the vessel integrity or functionality.

The USAR does not discuss thermal stresses except to say "The steel shell in the knuckle region was designed for the combined pressure and temperature gradients present." (USAR 12.2.2.1.8). However, USAR tables 12.2-19 through 12.2-22 summarize both thermal stresses and combined stresses including temperature. Temperature stresses are minimal as summarized in table 12.2-19. As shown in table 12.2-22, the highest combination of all stresses including temperature with a DBE is 27860 psi. Assuming a 50% increase due to reduced thickness results in a stress of 41790 psi. Again, the highest stress is comparable to the minimum yield strength of the material suggesting the possibility of local deformation. However, the stress is well below the tensile strength of the material of 70000 psi.

The USAR discusses an area referred to as the "cold spot". This area is described in USAR section 12.2.2.5.3 as area 43.5 ft high and about 24 ft wide of the inside of the containment vessel covered by interior concrete in the vicinity of the transfer tube. As discussed in the USAR "The analysis discussed in this section was based on a containment pressure curve shown in USAR, Appendix G, Figure G.3-20 (originally FSAR, Figure 14.3.23). Subsequent containment pressure and temperature analyses (some performed prior to initial plant licensing - FSAR, Section 14C) showed that the peak temperature and pressure could occur much later than that predicted in Figure G.3-20. (Note that G.3-20 is strictly historical). The later occurrence of the peak temperature and pressure results in more heat being transferred to the containment shell; which increases the temperature difference between the heated shell and the "cold spot". However, the analysis of the stresses in the "cold spot" in this section was not updated to reflect the subsequent containment pressure and temperature analyses. An assessment was performed of the affect of the subsequent containment pressure and temperature curves (Appendix K, Figure K-18) and determined that the stresses due to the "cold spot" would not exceed the acceptance criteria (Reference 61)."

Although not specifically stated, there is an implication that a later peak pressure and temperature and associated increase the temperature difference between the heated shell and the cold spot would result in higher thermal stress. As stated in the USAR, "This increase does not occur in the portion of the shell protected by the internal concrete thus producing the "cold spot" which results in additional stresses in the steel shell. These stresses are classified as Thermal Stresses." There is also an implication that the amount of increase in thermal stress was not significant as the stresses reported in USAR Table 12.2-19 were not revised and are small (4.65 ksi maximum) compared to the stresses being considered. In addition, any stresses due to temperature gradient would be considered secondary stresses. As stated in the USAR "When the latter stresses are present, the allowable stress intensity is increased to 1.5Sm or 26,250 psi. When secondary stresses due to differential thermal expansion are included, the allowable stress intensity is increased to 3.0Sm or 52,500 psi." As discussed previously, secondary stresses are self limiting and can approach twice yield before significant risk of failure. Even if the thermal stress due to the increased temperature gradient were doubled the peak stresses would still be below the 52.5 ksi allowable and well below the minimum tensile strength of the material of 70ksi or twice yield of 76ksi.

Due to the short duration of the high stress (at most 10 seconds under a MSLB concurrent with a DBE) and that the thermal component of stress is secondary (the stress is relieved with plastic deformation), there is no challenge to the integrity or functionality of the containment vessel.

In summary, when all stresses are considered the containment vessel could tolerate approximately a 0.5 inch loss of the nominal 1.5 inch wall thickness without a significant challenge to integrity or functionality.

Evaluation of Containment Internal Structures

The purpose of this section is estimate the margin between the design of the containment internal concrete structures and the level of degradation that presents a risk of failure.

As discussed in USAR section 12.2.1.2 both the containment vessel and the internal structures were designed to meet applicable portions of several codes including:

- American Concrete Institute Codes; ACI 318-63, ACI 301-66, ACI 349-85 and other sections of the ACI Codes as applicable.
- American Welding Society Code D 1.0 "Standards for Arc and Gas Welding in Building Construction."
- International Conference of Building Officials "Uniform Building Code," 1967 Edition.
- Atomic Energy Commission publications TID 7024 "Nuclear Reactors and Earthquakes."

The internal containment structures consist of reinforced concrete walls and floors designed as Class I Structures (USAR 12.2.4.1) analyzed for the combination of dead, live, DBA and DBE loading (USAR 12.2.1.4) such that the reactor can be safely shutdown with no uncontrolled release of radioactivity (USAR 12.2.1.4.2). The areas of interest are the "Reactor Coolant System Compartments and Refueling Cavity" discussed in USAR section 12.2.4.1.5 as these are the areas that could potentially be affected by refueling cavity leakage. As discussed in USAR section 12.2.4.1.5.1:

"The vault compartment structure and refueling cavity are designed to carry the vertical and horizontal live and dead loads of adjacent floors and structures that are attached to it as well as its own live and dead loads and horizontal loads imposed on the compartment walls from the equipment components contained within and external to the compartments.

Also included in the design are: -

a. Jet Load

Jet impingement loads on compartment surfaces that are postulated to occur in the event of a pipe rupture.

b. Internal Pressure

Compartment internal pressure buildup that would occur during a LOCA blowdown. These loads are defined, Section 12.2.4.1.

c. Pipe Rupture Reaction Load

These are reaction forces on equipment and structures caused by a postulated pipe rupture.

d. Thermal Load

These are stress loads from thermal gradients through compartment walls that are caused by a LOCA.

e. Residual Construction Loads

These are internal residual construction stress loads resulting from the shrinkage of the various levels of construction pours of concrete.

f. Refueling Cavity Pool Water Loads

Vertical pool water load and lateral hydraulic water pressure loads from water in the refueling cavity pool. These loads are treated as live loads since they will only occur during reactor shut-down.

g. Seismic Loads

Seismic loads are determined from Reference 8 for the appropriate mass points under consideration."

As noted in USAR section 12.2.4.1 the loads associated with LOCA are either eliminated or substantially reduced due to Leak-Before-Break. "Section 4.6.2.3 discusses the basis for the elimination of large primary loop pipe rupture as a structural design basis. Based on the acceptance by the NRC, as documented in a Safety Evaluation Report (Reference 47) and as stated in NUREG-1061, Volume 3, pipe whip, pipe break reaction forces, jet impingement forces, and vessel cavity or subcompartment pressurization including asymmetric transient effects may be excluded for primary loop pipe rupture only. The original design included these dynamic effects, as described below, but should no longer be considered part of the plant design basis."

Even with inclusion of LOCA loads, the USAR indicates the internal structures of containment were conservatively designed with margins of 30% or more. USAR section 12.2.4.1.1.2 which discusses the steam generator compartments states: "Further, in regard to the reinforcing bars specified by code, minimum yield strength is 60,000 psi but it has a tested average strength of 70,000 psi. The margin of the compartment structural capability is indicated by the results for Load Combination 4c where, even for a hypothetical pressure differential load of 75 psi, the critical concrete stress is below both the specified and actual measured strength and the reinforcing steel stresses are below the specified and measured yield limits. Essentially no permanent deformation would be expected to occur. Initially only the compartment walls of Unit 2 were analyzed by a finite element analysis. In this case reinforcing provided was 40% more than the analysis required."

A similar statement is included in USAR section 12.2.4.1.5.2 which discusses the Reactor Coolant System Compartment and Refueling cavity which states: "The general structural model consists of a composite of the compartment walls, the adjoining biological shield, the attached floor systems and structures, and the refueling cavity pool. The analytical model is broken down into two distinct interacting models: (1) laminar horizontal frames analyzed by STRESS programs and (2) vertical structural elements analyzed to carry unbalanced load reactions to the base by the box girder action of the compartment walls. This latter model could more aptly be described as a modified folded plate structure. The local effect of forces are analyzed by considering loading conditions on simplified but conservative models limited to the immediate and closely adjoining areas of loading. The above described analysis results were later confirmed by an independent finite element method of analysis that indicated conservative margins in the results of the original analysis of the order of 30 percent and greater."

Review of peak stresses in the concrete and reinforcing steel of the internal containment structures reported in the USAR are consistent with the stated 30% or greater margin. USAR Table 12.2-38 shows the peak stresses in the concrete reinforcing steel during a "safe shut-down" event which includes operating + DBA + DBE loads as 32000 psi as compared to the minimum yield strength of the reinforcing steel of 60000 psi. It is recognized that peak stresses including pipe reaction loads and compartment differential pressure range up to 53200 psi. However, as stated earlier, LOCA loads no longer need to be considered. Even if LOCA loads are included, there is still a 30% margin between the 53200 psi peak stress and the tested average yield strength of the reinforcing steel of 70000 psi. The concrete design and actual compressive stress includes a similar margin. As stated in USAR section 12.2.4.1.1.2 which discusses the steam generator compartments "The stresses for the critical sections are summarized in Table 12.2-33. For Load Combination 4a the calculated stresses are below the stress limits. The assumed allowable concrete stress limit of 3400 psi is well below the actual measured 28-day compressive strength of 5000 psi."

In summary, the USAR supports an estimated design margin of 30% of both the concrete and steel reinforcing of containment internal structures. As the ability of a reinforcing bar to carry load is directly proportional to its cross sectional area, it is reasonable to conclude a 30% margin in cross sectional area of containment reinforcing steel.

Evaluation of Area Around Transfer Tube

The area around the transfer tube was called into question in the Dominion report which assessed the potential for degradation of the containment vessel and internal structures (EC14139). The report stated: "The possible exception mentioned above that is considered to require further evaluation is the following. If degradation of concrete inside the liner should occur in the area around the transfer tube, it could represent a significant fraction of the wall. Accurately determining the concrete thickness in this area was not possible with the drawings available to DEI but, based on rough scaling, the thickness could reach a minimum of less than one foot, e.g. 10 inches. The estimated maximum degradation thickness of 0.31 inch would be about 3% or more, which might be significant depending on how highly loaded the concrete is in this area. It is recommended that this issue be resolved by further detailed evaluation."

As shown in drawings NF-38484-1, NF-38484-4 and NF-38487-9, 10, 11, there is a thin section of concrete adjacent to the transfer tube with a minimum thickness of approximately 10 inches. This section is estimated to be 10 feet high and 1 foot wide, and is tied into adjacent thicker sections of concrete with a double matt of reinforcing steel. Review of the construction details of the area around the transfer tube indicates no significant loading with the possible exception of the weight of the concrete directly above this section. However, the concrete above this section is also supported by a 4 foot x 4 foot reinforced concrete beam which spans the approximate 4 foot width of the transfer pit. As such, the actual loading on the thinned section of concrete is minimized and purely compressive. Seismic stresses would also be minimal as the section is relatively small and tied into adjacent sections. A conservative estimate on the loading of this section can be made by assuming this section carries the weight of all the concrete directly above.

Per USAR section 12.2.2.1.1 the weight of concrete is 143 pound/cubic foot which is rounded up to 200 lb/cu-ft to account for reinforcing steel. The height of the concrete above the thin section is estimated at 31 feet resulting in a compressive stress of 43 psi (200 lb/cu-ft x 31 ft / 144 sq-in/sq-ft). The resultant stress is minimal compared to the compressive strength of the concrete of 5000 psi. As a result, the 30% margin estimated for containment structures can also be conservatively applied to the area around the transfer tube. As such, the 3% wall thickness degradation postulated in the Dominion report would not challenge the functionality or integrity of this section of concrete.

6.0 Conclusions

The estimated margin of the containment vessel is 0.5 inch as compared to the nominal shell thickness of 1.5 inch resulting in a margin of greater than 30%. The margin of containment internal concrete and reinforcing steel is 30% including the area near the transfer tube.

7.0 References

7.1 1986 ASME section VIII div. 1

7.2 USAR (as noted)

7.3 Containment Vessel Stress Report dated 2/2/1970

7.4 www.nafems.org (National Agency for Finite Element Methods and Standards)

7.5 www.engineersedge.com (Engineer's Edge Solutions by Design)

7.6 1991 ASTM standard A 516/A 516M

7.8 Drawings for concrete and rebar in area of transfer tube NF-38484-1, NF-38484-4 and NF-38487-9, 10, 11

8.0 Attachments

None

Prepared By: Tom Downing **Date:** 2/25/2010

Tech Review: [signature] **Date:** 2/25/10

Xcel Energy	**Design Review Comment Form**

Sheet 1 of 2

DOCUMENT NUMBER/ TITLE: EC 15651 MARGIN ASSESSMENT OF CONTAINMENT VESSELS AND INTERIOR CONCRETE STRUCTURES

REVISION: 0 DATE: 2/25/2010

ITEM #	REVIEWER'S COMMENTS	PREPARER'S RESOLUTION	REVIEWER'S DISPOSITION
1a.	Containment vessel evaluation The purpose section does not clearly state what margin is being evaluated. i.e. Is this the margin between actual measured plant condition and design condition, between design condition and regulatory required condition, between regulatory required condition and failure, or some combination of these margins?	Added sentence to more clearly state purpose as: "The margin being estimated is the margin between the vessel and internals structures design condition and the level of degradation that presents a risk of failure."	OK
1b.	No mention of the applicable code and year of design (ASME III?)	Added section from USAR that describes vessel code requirements.	OK
1c.	Section 4.1, provide sources for inputs. Drawing? Suggest also putting in full name of reference for the stress report similar to how it is referenced in the containment DBD.	Added containment outline drawing to section 4.1 and full name of stress report.	OK
1d.	Section 4.2, typo in material type.	Corrected.	OK
1e.	Somewhere should state that why external pressures are not considered,	Added discussion on why external pressure is not considered.	OK
1f.	It is not necessary to rely on the USAR statement that earthquake loads are minimal. You can take values from the stress report to show that they are minimal also.	May not be necessary, but provides adequate basis. No change.	OK
1g.	I am not convinced by your argument regarding the region of external embedment in the concrete. Here you state that it is acceptable to exceed the yield strength with a primary membrane stress of 40485 psi. This calculation used a 41 psig containment pressure. The MSLB results in containment pressure above 41 psig for more than 10 seconds. If it is really OK for primary stresses to exceed the yield stress during a MSLB, then we should be able to use a large value of "S" in the calculations. Perhaps an argument regarding how localized this stress	Added additional discussion on strain hardening and deformation to show the vessel would not fail due to stresses briefly exceeding the minimum yield strength.	OK.

ITEM #	REVIEWER'S COMMENTS	PREPARER'S RESOLUTION	REVIEWER'S DISPOSITION
	is would be more appealing (similar to the argument in the stress report where this stress also exceeds the design limit). But I don't understand the details on how the USAR values were determined.		
1h.	Typo top of page 8. "The USAR does not discuss thermal stresses except"	Corrected.	OK
1i.	In this same paragraph, it is not clear that this refers to the area where the interior concrete is in contact with the vessel wall at the area of the refueling cavity.	This paragraph along with other USAR discussions of high stress areas is referring to the "knuckle" area which is the short radius of the bottom ellipsoidal head near where the bottom head enters the annulus floor. The area is not near the refueling cavity.	Discussion was added under this paragraph which explained the differences between the paragraph discussion the embedment region (Knuckle) stresses and the cold spot stresses. – OK
1j.	In this paragraph, the USAR explains that 27860 psi is not the most limiting value. It states only that a new evaluation was not performed because the new MSLB results were judged to result in a value which remained below limits.	Added section that discusses potential increased thermal stress at cold spot due to peak temperature occurring later than originally calculated.	OK
1k.	In this paragraph, again, I am not convinced by your argument that a limited time of duration (10 seconds?) makes exceeding the minimum yield stress acceptable. How much of the stress is due to secondary stresses where a higher limit is applicable?	There is no suggestion that exceeding yield stress is acceptable. Only that a brief excursion above the yield strength, but well below the tensile strength would not result in failure due to strain hardening and local deformation. Also added discussion to account for the higher stress of a combination MSLB and DBE.	OK – Resolved by discussion
2a.	Containment Internal Concrete Structures Similar to 1.a, I believe that the purpose section should state what margin is being evaluated. Margin between actual and design, design and regulatory required, regulatory required and failure?	Added sentence to more clear state: "The purpose of this section is estimate the margin between the design of the containment internal concrete structures and the level of degradation that presents a risk of failure."	OK
2b.	Should state the code and dates (or maybe easier to reference sections of the USAR).	Added reference to USAR and listed some of the codes.	OK

ITEM #	REVIEWER'S COMMENTS	PREPARER'S RESOLUTION	REVIEWER'S DISPOSITION
2c.	Page 10, typo. Table 12.2.38. Transfer Tube	Corrected.	OK
3a.	Include drawings in the references section.	Added drawings to references.	OK
Reviewer: Lora Brenth Date: 2/25/10		Preparer: Tom Downing Date: 2/25/10	