ATTACHMENT I

GE/Teledyne Report TR-7377-1
"Justification for Use of Section III Subsection NE
Guidance in Evaluating the Oyster Creek Drywell"

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TECHNICAL REPORT TR-7377-1

JUSTIFICATION FOR USE OF SECTION III, SUBSECTION NE, GUIDANCE IN EVALUATING THE OYSTER CREEK DRYWELL

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1.0 SCOPE

The drywell of the Oyster Creek Containment was originally constructed to the requirements of Section VIII of the ASME Boiler and Pressure Vessel Code and applicable Code Cases, with a contract date of July 1, 1964. The Code requirements for nuclear containment vessels at that time were less detailed than at any subsequent date.

Is it proper to use the contents of a later Code, and specifically the requirements of Subsection NE of Section III, as guidance in present evaluations of the drywell?

2.0 CONCLUSIONS

It is proper to use the containment vessel requirements of the 1963 Edition or later editions or addenda of Section III as guidance in present evaluations of the Oyster Creek drywell for issues not explicitly considered in the rules applied to the initial construction or as amplification of those rules when the later requirements have equal or more conservatism requirements and all related requirements are met. As used by the Code, requirements are "related requirements" if the approval of one action was contingent on approval of a second action.

3.0 CODE STATEMENTS CONCERNING SUCH USAGE

The ASME Code permits the use of later editions and addenda. For example:

> Section III, NCA-1140(b), 1989 Edition, states that "Specific provisions within an Edition or Addenda later than those established in the Design Specifications may be used providing all related requirements are met."

Section XI, IWE-3122.4, the rules for acceptance by evaluation for metal containments, states that portions of later Editions of the Construction Code or Section III may be used.

4.0 RULES APPLIED TO INITIAL CONSTRUCTION

Burns and Roe Specification S-2299-4 required, in Section 2.1, that the containment vessel satisfy the following ASME requirements:

> Boiler and Pressure Vessel Code, Sections VIII and IX, latest edition, with all applicable addenda; Nuclear Code Case Interpretations 1270N5, 1271N, 1272N5 and other applicable case interpretations.

Because of the July 1, 1964 contract date, the latest applicable addenda was the Winter 1963 Addenda.

The specific Cases identified by Burns and Roe were:

1270N General Requirements for Nuclear Vessels

States that neither Sections I or VIII precisely covers nuclear vessels, states that the requirements of either Section may be used together with the contents of the applicable "N-Cases", and defines various types of vessels including containment vessels.

1271N Safety Devices

Permits containment vessels without such devices.

1272N Containment and Intermediate Containment Vessels

Defines special requirements with respect to welded joint types and radiography, stress relief, welded attachments, corrosion provisions, two-stage construction and allowable stresses.

One specific issue of interest here is the requirements on allowable stresses which go beyond the explicit requirements of Section VIII. The explicit requirements of Section VIII addressed only the minimum thickness of the vessel to resist, what we now term, the general membrane stresses which result from Design Pressure(s) and gravity, seismic, and wind loads. Case 1272N required that other types of loads and stresses be evaluated; including, those we now term, local membrane stresses and discontinuity stresses which result from gravity, seismic, pipe and wind loads, Design Pressure(s), normal operating pressures, pressure tests, and thermal gradients.

The other specific issue of interest is the requirements placed on materials, fabrication, examination and testing as they have evolved from those applied to the initial construction of the Oyster Creek drywell to the rules applied in the present reevaluation.

The evolution of the Code rules from the Nuclear Cases used in construction of the Oyster Creek drywell through the Summer 1977 Addenda to Section III is discussed in 5.0. This time period is pertinent because the present rules (1989 Edition with 1989 Addenda and Code Case N-284) contain only relative minor evolutions of the Summer 1977 Addenda, without basic changes affecting the issues presently being considered with regard to the Oyster Creek drywell except as discussed in Sections 7.0 and 8.0 of this document. Also, the design rules of the Summer 1977 Addenda were those implemented by the Mark I Program Plant Unique Analysis Application Guide, so have previously been applied to a reevaluation of the Oyster Creek containment.

The stress limits beyond those of Section VIII, including the transition from the Code Cases to Subsection NE are discussed in Section 6.0 of the present document. Section 7.0 of the present document discusses the history of the limitations on local membrane stress. Section 8.0 of the present document compares the materials, fabrication, examination and testing procedures applied to the construction of the Oyster Creek drywell with those of the Code rules at the time the drywell was constructed and with the rules of the present Code, including Case N 284.

5.0 EVOLUTION OF THE CODE REQUIREMENTS FOR CONTAINMENT VESSELS

5.1 Nuclear Cases to Initial Section III

The early development of the rules for nuclear vessels is discussed by E. O. Bergman ("The Basis and Content of a Nuclear Pressure Vessel Code," Preprint Paper No. 94, 1962 Nuclear Congress). Bergman starts with the appointment of a Task Group by the Code Committee in 1954 and discusses the development of the pre-Section III nuclear code cases, including those listed in 4.0 of this document, and of the original 1963 Edition of Section III.

The nuclear code cases required deviations from the rules of the existing Section I or Section VIII. A few deviations, such as those for safety devices, inspection openings, and gage glasses relaxed the existing requirements because of the special hazards associated with nuclear service. Others added requirements for new materials and new constructions. The majority of the deviations provided more restrictive requirements, including the stress limits which are discussed in Sections 6.0 and 7.0 of the present document.

The many revisions to certain of these cases reflect changes made to the cases to maintain consistency with the developing Section III, Nuclear Vessels, 1963. Bergman reviews the contents of this edition in his paper. With respect to the requirements for containment vessels, Bergman states:

The rules for containment vessels follows the requirement in present Case 1272N.

The "present case" was 1272N5, the revision applied to the Oyster Creek containment.

In preparing the 1963 Edition on the basis of Case 1272N5, some of the Case requirements were expressed in terms of the requirements of specific paragraphs in Section VIII and others were expressed in terms of the requirements for Class A vessels contained in Subsection A of Section III. An example of the later, as applied to the stress limits, is discussed in Section 6.0 of this document. However, there was no change in intent between Case 1272N5 and the 1963 Edition of Section III.

The statement by Bergman, or a comparison (as provided in this document for the aspects of specific interest) of Case 1272N5 and the contents of Subsection B of the 1963 Edition of Section III, confirm that the Code rules for the initial construction of the Oyster Creek drywell were the equivalent of those of the 1963 Edition of Section III. (Note that the Code, and this document, uses the word "construction" shorthand for all of the Code requirements: materials, design, fabrication, examination, testing, overpressure protection, and certification.) This conclusion is also supported by a comparison of the Oyster Creek and Nine Mile Point Unit 1 containments, although the initial construction Code for the latter was Section III because it was slightly later in time than was Oyster Creek.

5.2 1963 - 1977 Summer Addenda to Section III

The evolution of the Section III rules applicable to metal containments from the initial issuance of Section III through the 1977 Summer Addenda was examined by W. E. Cooper as a part of the Mark I containment program ("Mark I Containment Program Structural Acceptance Criteria, Containment System Design Rules and Classification, Task Number 3.1.1," General Electric Company Report NEDO-24522, April 1978).

There were a number of revisions during this time period, the more important of which may be summarized as follows:

Summer 1966 Addenda: Redesignated the material used in the Oyster Creek drywell as SA-516, Grade 70 rather than A-212, Grade B, Firebox Quality.

Winter 1967 Addenda: Revised the requirement in the event that the operating condition did not satisfy the fatigue exemption requirements to permit the local region to be evaluated to the fatigue evaluation for Class A vessels, rather than requiring the entire vessel to be upgraded to Class A. Added alternative requirements with respect to Categories C and D welded joints.

Summer 1969 Addenda: Improved the definition of jurisdictional boundaries, clarified the design rules without change in intent except for consideration of seismic conditions, and clarified the references to Section VIII. Differentiated between the stress limits applicable to the earthquake load for which the power system must remain operational or must regain its operating status (OBE) and that for which safe shutdown is required (SSE). The former was categorized as a normal operating condition and the latter as an emergency or as an upset condition depending upon whether or not the structure was integral. With respect to the Oyster Creek containment, the seismic condition considered is best described as twice the Design Basis Earthquake. Although this quantity is equivalent to today's SSE, the Oyster Creek seismic condition was, and still is, considered to be a normal operating condition in evaluating the drywell. Therefore, this revision is not applicable to the present drywell evaluation.

Since this was the first major rewrite of these rules, the Class MC vessels constructed to the rules of Section VIII with the nuclear cases or to Section III 1963 Edition through the Winter 1968 Addenda were essentially constructed to the same rules.

Winter 1970 Addenda: In anticipation of the major revision to Section III to appear in the 1971 Edition, introduced the designation change from Class B Vessels to Class MC Vessels, clarified the Scope for containment vessels, specifically identified the Section VIII paragraphs referenced, and described the technical changes between the 1968 Edition with addenda and the 1971 Edition. No such changes were identified for containment vessels.

1971 Edition: Implemented the Winter 1970 Addenda. Introduced the terms normal, upset, emergency, and faulted conditions in NE-3321, but stipulated that the containment function not be categorized as an emergency or faulted condition.

Summer 1972 Addenda: Deleted the operating condition categories introduced in NE-3321 of the 1971 Edition. Eliminated the need to reference other Section III Subsections and the contents of Section VIII by the development of a self-contained document including a cross-index between the applicable par[illegible]ns of the previous text and those of the addenda. One of the revisions to eliminate the need to refer to Subsection A was the addition of NE-3228 covering the application of plastic analysis. This copied NB-3228 except that the use of Plastic Analysis was restricted to the evaluation of local membrane stresses because NB-3222 was not copied into Subsection NE. The Winter 1973 Addenda to Subsection NE included NE-3222 and NE-3228 was revised to permit full application as was permitted for Class 1 vessels.

Identified 14 "essential differences" from the previous rules. With respect to the 14 essential differences: the first four redefined the definition of Design Pressure and the values of the allowable stresses in a manner consistent with the pre-Section III Code Cases; four added new stress tables, eliminating materials not being used for containments, and added additional materials; and, individual items changed the external pressure rules from those of Section VIII to those of Section III, eliminated formulas for special shapes, eliminated Section VIII paragraphs not applicable to containments, added repairs without PWHT, added special examinations for appurtenances, and added Appendix X. None of these are pertinent to the present issues with respect to the Oyster Creek drywell.

The impact of the change in external pressure design rules is included in Section 8.0 of the present document. Since Code Case N-284 is being applied to this reevaluation, rather than the design rules placed in NE-3000 by this addenda or subsequent changes to NE-3000 relative to external pressure design, the pertinent aspects of the changes which resulted from this Addenda are those which apply to forming tolerances.

<u>Winter 1972 Addenda</u>: Introduced special requirements for jet impingement and associated reactions in NE-3131.2.

<u>Winter 1973 Addenda</u>: Revised the postweld heat treatment requirements. Identified a number of editorial corrections. Included NB-3222 as a copy of NB-3222. Revised the requirements for plastic analysis in NE-3228 to be

identical to those in NB-3228. The requirements are identical to those in the 1989 Edition of Section III when subsequent paragraph renumbering is considered.

<u>1974 Edition</u>: Definition of the containment system was revised, but contained an anomaly which was corrected by the Winter 1974 Addenda. Clarified the stress limits applicable to jet impingement and associated reactions in NE-3131.2.

<u>Winter 1974 Addenda</u>: Modified the stress limits applicable to jet impingement and associated reactions in NE-3131.2.

<u>Winter 1975 Addenda</u>: The 1974 Edition anomaly was corrected by a complete rewrite of NE-1000.

<u>Summer 1976 Addenda</u>: Definition of local membrane stress revised, see Section 7.0 of this document.

<u>Summer 1977 Addenda</u>: Defined the various design parameters and Service Levels for containment in a manner consistent with the generally applicable definitions placed in NCA-2140 by the Winter 1976 addenda. Most importantly from the viewpoint of the present document, NE-3000, covering the design of Class MC vessels was revised to place emphasis on the "design by analysis" approach.

Specifically, NE-3131, General Requirements, was revised to make it clear that satisfaction of the Design by Analysis requirements of NE-3200 was the primary requirement, and that the Design by Rule requirements of NE-3300 only applied "in the absence of substantial mechanical loads or thermal loads other than pressure --- for those configurations which are explicitly treated in NE-3300."

It is the opinion of the writer that this revision did not change the requirements on containment design which had been applicable from the time Case 1272N5 was developed through the entire development of Section III to the date of this addenda. However, the revision did properly state the intended emphasis and, in conjunction with the added requirements with respect to Service Levels, provided a major clarification as to the intent of Section III.

5.3 Conclusion of Section 5.0

The original preparation of the 1963 Edition of Section III and the revisions made through the Summer 1972 Addenda were evolutionary, and did not change the basic considerations in containment design from those contained in Case 1272N5 except for the change in the forming tolerance rules which resulted from the change in external pressure rules from those of Section VIII to those applicable to Section III, Class 1 vessels, as discussed in Section 8.0 of the present document. The intent of the initial construction rules applied to the Oyster Creek containment was maintained. Rules were amplified and clarified, there were detailed changes in requirements without change in concept, and there were a number of changes (such as the distinction between OBE and SSE, added requirements with respect to jet impingement and associated reactions, and the definition of the various service levels) which addressed issues not applicable to the present evaluation of the Oyster Creek drywell.

This review of the general evolution of the Code requirements for containment vessels, when considered together with the more detailed review of the stress limits beyond those of Section VIII contained in Section 6.0 of this document and the even more detailed review of applicable issues included in Sections 7.0 and 8.0 of this document, indicates the appropriateness of applying the rules of Subsection NE to the present Oyster Creek evaluation.

6.0 STRESS LIMITS BEYOND THOSE OF SECTION VIII

6.1 Comparison of Case 1272N5 and 1963 Edition of Section III

Although the initial rules for construction were Section VIII plus the applicable nuclear code cases, the requirements of the cases applied when there was conflict with the requirements of Section VIII. The explicit Section VIII design requirements, those which consider the general membrane stress due primarily to Design Pressure and Design Temperature, were not revised by the case except that the basic allowable stress, S, was increased by 10% when the Design Pressure and Temperature are based on the maximum values which will be attained during the most severe credible incident. However, Case 1272N5 contained specific limits on combined general membrane, general bending, and local membrane stresses and on the sum of these quantities plus secondary stresses. Such limits were intended to provide specific guidance in response to the Section VIII, Par. U-2(c) requirement that:

> The Code does not contain rules to cover all details of design and construction. Where complete details are not given, it is intended that the manufacturer, subject to the approval of the authorized inspector, shall provide details of design and construction which will be as safe as those provided by the rules of this Code.

Although the terminology used in Case 1272N differed slightly from that adopted by Section III, the definitions clearly indicated the intent to be the same. The limits were also quite similar. The limit on combined general membrane, general bending, and local membrane stresses was stated as 1.5 times 1.1 S, which is, in present terminology, 1.5 S_{mc}. The limit on the sum of these quantities plus secondary stresses was stated as 3 S.

The consistency between the intent of these special limits in the Code Case and in Section III is even more obvious when the relevant contents of the 1963 Edition of Section III are considered. There, one of the provisions for permitting an allowable stress of 1.1 S is, in N-1310(f):

> The requirements of N-414.1, N-414.2, N-414.3, and N-414.4 of Subsection A are met for the stress values specified above.

The referenced N-400 paragraphs contain, respectively, the limits applicable to general primary membrane, local membrane, primary membrane (general or local) plus primary bending, and primary plus secondary stress intensities in Class A (now Class 1) vessels. However, the basic stress allowable for containment evaluations remained 1.1 S, not S_m.

Reference to the N-400 paragraphs for these requirements had the effect of amplifying the requirements of Case 1272N, in that alternative procedures were permitted for some of the stress limits. For example, N-417.5(b)(2) stated that:

> In lieu of satisfying the specific requirements of N-414.2 N-414.4, N-417.3, and N-417.4, at a specific location, the structural action is calculated on a plastic basis and the design shall be considered to be acceptable if shakedown occurs, as opposed to continuing deformation, and if the deformations which occur prior to shakedown do not exceed specified limits.

6.2 Subsequent Treatment of Limits

The subsequent treatment of these limits, until emphasis was placed on this "Design by Analysis" approach by the Summer 1977 Addenda, was reviewed in NEDO-24522 as follows:

> Prior to the Summer 1972 Addenda, the specific rules were not included in the containment vessel subsection, but

were referenced to the Class 1 (or A) rules. A symbol L1, L2, L3, or L4 is used herein for the purpose of identifying these requirements. For reference purposes, the following table identifies the pertinent paragraph references using the usual Code terminology as follows:

L1	P_M	General primary-membrane limit
L2	P_L	Local membrane limit
L3	$P_L + P_b$	Primary membrane plus bending limit
L4	$P_L + P_b + Q$	Primary-plus-secondary limit

Ed. or Add.		Applicable	Limit			
From	To	Class(es)	L1	L2	L3	L4
63E	71E	A & B	N-414.1	N-414.2	N-414.3	N-414.4
71E	S72A	1 & MC	NB-3221.1	NB-3221.2	NB-3221.3	NB-3222.2
S72A	74E	MC	NE-3221.1	NE-3221.2	NE-3221.3	NE-3222.2
74E	S77A	MC	NE-3221.1	NE-3221.2	NE-3221.3	NE-3222.2
S77A	Now	MC	NE-3221.1	NE-3221.2	NE-3221.3	NE-3221.4

Given a specific allowable value for the limit on L1, the numerical values on the other limits may be expressed as:

$$(L2) = (L3) = 1.5(L1)$$
$$(L4) = 3.0(L1)$$

Case 1733, effective November 3, 1975, modified the L3 limit applicable to pressure and mechanical loads plus the safe shutdown earthquake for structural members other than solid rectangular sections. This modification permitted use of limit analysis considerations in establishing the numerical coefficient used with the L3 limit. Both the Winter 1975 and Summer 1976 Addenda contained revisions to the definition of Local Primary-Membrane stresses in NE-3213.10, as discussed in 7.0 of this document.

The numerical value of the stress limit (L1) and the definition of the Design Pressure (Pd) when considering the containment function changed from time to time as follows, using S to designate the Section VIII allowable value and Pm to designate the maximum containment internal pressure under conditions for which the containment function is required:

Ed. or Add. From	To	Numerical Value (L1)
Case 1272N5		1.1 S with Pd = Pm
63E	W65A	1.1 S with Pd = Pm
W65A	S69A	S with Pd = 0.9 Pm
S69A	S72A	S with Pd = Pm, except Class 1 (or A) Sm value used with L4 in regions requiring fatigue evaluation
S72A	S77A	1.1 S with Pd = Pm
S77A	Present	Smc = 1.1 S with Pd = Pm

There has been some variability in these stress limits as Code changes have been made, but there has been no change in the required thickness which is dependent upon the ratio of Pd and the numerical value of (L1). The only significant change was in the Summer 1969 Addenda, which permitted use of the Class 1 (or A) Sm values with the L4 limit in regions where fatigue evaluation was required. Since the Sm value may be as large as 1.33 S, this change may be significant. It is justified on the grounds that the purpose of this limit is primarily to validate the elastic fatigue analysis.

The Summer 1977 Addenda to NE-3000 clarifies the preceding discussion by expressing the applicable limits in terms of the allowable stress intensity values S_{m1} and S_{mc} where:

S_{m1}	are the values of Table I-1.0
S_{mc}	are the values of Tables I-10.0, which are 1.1 S, where S is the Section VIII, Division 1 allowable value.

The Summer 1977 Addenda redirects the containment design effort to place emphasis on design by analysis procedures, is consistent with the overall Code revisions to clarify the use of Service Levels, and establishes various levels of design limits which are not specifically associated with the operating conditions.

It should also be noted that certain of the limits on primary and primary-plus-secondary stresses may be waived if plastic analysis techniques are applied. These alternative rules are provided in NE-3228 and may be summarized as follows:

If rules of listed paragraph are met:	The limits on the following are waived:
NE-3228.1	L2, L4
NE-3228.2	L2, L3
NE-3228.3	L4

Note that use of these rules may also affect the evaluation of other stress limits, including the fatigue limits.

6.3 Conclusion of Section 6.0

Stress limits beyond those of Section VIII have been provided throughout the time period of interest. Case 1272N5 contained explicit limits which addressed what are now termed general membrane stresses, local membrane stresses, primary bending stresses, and secondary stresses. These provisions were incorporated in the 1963, original, edition of Section III by reference to Class A (now Class 1) requirements. Additional provisions, such as that addressing fatigue, and alternative provisions, such as that permitting limit analysis, were thereby incorporated.

Subsequently, these provisions have been clarified and amplified without change in the basic considerations in containment design except for forming tolerances as discussed in Section 8.0 of the present document.

This review of the stress limits beyond those of Section VIII, when considered together with the general evolution of the Code requirements for containment vessels contained in Section 5.0 of this document and the even more detailed review of stress limit requirements included in Section 7.0 of this document, indicates the appropriateness of applying the rules of Subsection NE to the present Oyster Creek evaluation.

7.0 DEFINITION OF LOCAL MEMBRANE STRESS

7.1 Evolution of the Definition of Local Membrane Stress

Although the limit on the sum of the Primary (General or Local) Membrane plus Primary Bending Stress Intensity has remained a constant multiplier on the Primary Membrane Allowable Stress, at a value of 1.5, the definition of Primary Local Membrane Stress has varied with time. In particular, the size of a stressed region which may be considered as local has varied.

<u>Case 1272N5</u>: There was no size limitation given, the definition simply reflecting two examples, in the last footnote:

(2) Local membrane stresses in a shell produced by the external load and moment at a permanent support or nozzle neck.

(3) Local membrane stresses acting circumferentially at points of discontinuity, such as head-to-shell or nozzle-to-shell junctions.

<u>1963 Edition, N-412(j)</u>: A stressed region may be considered as local if it does not extend in the meridional direction more than 0.5 $\sqrt{(Rt)}$ and if it is not closer in the meridional direction than 2.5 $\sqrt{(Rt)}$ to another region where the limits of general primary membrane stress are exceeded, where R is the mean radius of the vessel and t is the wall thickness at the location where the general primary membrane stress limit is exceeded.

<u>Summer 1965 Addenda, N-412(j)</u>: A stressed region may be considered as local if the distance over which the stress intensity exceeds 1.1 S_m does not extend in the meridional direction more than 0.5 $\sqrt{(Rt)}$ and if it is not closer in the meridional direction than 2.5 $\sqrt{(Rt)}$ to another region where the limits of general primary membrane stress are exceeded, where R is the mean radius of the vessel and t

is the wall thickness at the location where the general primary membrane stress limit is exceeded.

Summer 1976 Addenda, NE-3213.10: A stressed region may be considered local if the distance over which the membrane stress intensity exceeds 1.1 S_m does not extend in the meridional direction more than 1.0 $\sqrt{(Rt)}$, where R is the minimum midsurface radius of curvature and t is the minimum thickness in the region considered. Regions of local primary stress intensity involving axisymmetric membrane stress distributions which exceed 1.1 S_m shall not be closer in the meridional direction than 2.5 $\sqrt{(Rt)}$, where R is defined as $(R_1 + R_2)/2$ and t is defined as $(t_1 + t_2)/2$, where t_1 and t_2 are the minimum thicknesses at each of the regions considered, and R_1 and R_2 are the minimum midsurface radii of curvature at these regions where the membrane stress intensity exceeds 1.1 S_m.

This is the definition in NE-3213.10 of the present Code, except that S_{mc} has replaced S_m.

7.2 Conclusion of Section 7.0

Since the definition in the Code Case applicable to the construction of the Oyster Creek containment had no dimensional limitations, use of the present definition is more restrictive than that used for initial construction and is proper for usage in the present Oyster Creek evaluation.

An important aspect in considering the use of the Subsection NE rules as guidance in the present evaluation is the definition of the base stress above which the stress is considered to be local. Neither Case 1272N nor the 1963 Edition or its Addenda defined this quantity. The Summer 1965 Addenda included such a definition, and defined the base stress as 1.1 S_m. (Since reference was still being made to Subsection A for the requirements which applied design by analysis concepts, the quotation is from that Subsection. The rules in Subsection B made it clear that the allowable value for S_m was to be taken as 1.1 S, where S is the Section VIII value of the allowable stress.) Currently, one would state the base stress as 1.1 S_{mc}.

There never has been a Code limit for the extent of the region in which the membrane stress exceeds 1.0 S_{mc} but is less than 1.1 S_{mc}. This 10% variation in allowable stress was provided because of the "beam on elastic foundation" effects of such local regions, the stress decays as one moves away from the thin region, but overshoots the general membrane stress value by a small amount as the effects vary with distance. It may be possible for one to argue that this provision is equivalent to a 10% increase in the allowable stress which can be taken advantage of in the original design to save material, but this argument is clearly contrary to the intent of the Code. However, given a design which satisfied the original Code intent, as the Oyster Creek drywell did as originally constructed, it is not a violation of the Code for the membrane stress to be between 1.0 S_{mc} and 1.1 S_{mc} over significant distances.

8.0 DISCUSSION OF MATERIALS, FABRICATION, AND EXAMINATION ISSUES

Attachment 1 of the present document is a copy of a report prepared by Chicago Bridge and Iron Nuclear (CBIN) describing the materials, fabrication, examination, and testing practices followed in the construction of the Oyster Creek drywell, including any changes in the CBI practices in the construction of the Mark I drywells constructed to Section III requirements.

In general, the contents of Attachment 1 support the conclusion of this document. Possible exceptions are discussed in the following subsections of this Section 8.0.

8.1 Material Requirements

The possible exception exists because the Code requirements with respect to impact testing when the Oyster Creek drywell was constructed, the requirements imposed by CBI on the construction of the Oyster Creek drywell, and the requirement imposed by the present Code differ. These differences are examined to establish that this possible exception is not significant to the conclusion of this document.

Code Case 1272N5(b)(1) required that plates not inside a heated enclosure be ordered to SA 300 and impact tested in accordance with UG-84 at or below the lowest metal service temperature (LST) - 30°F. UG 84, and SA-300, required that the impact testing be of the Charpy Keyhole or U-notch type (C_k) and indicate a 15 ft-lb minimum for the average of 3 specimens and have a minimum value of 10 ft-lb for the three specimens at or below the LST. In accordance with the Ralph M. Parsons Company, "Primary Containment Design Report", Section 1.2.4, the LST is 50°F but to provide an additional factor of safety, 30°F was used for the design basis. UG-84 did not substitute the Charpy V-Notch (C_v) test for the C_k test until the Summer 1969 Addenda, which required 15 ft-lb average and 12 ft-lb minimum, both for three specimens, at or below the LST.

The possible exception to nuclear requirements is that NE 1210 of the 1963 Edition of Section III required 20 ft-lb average and 15 ft-lb minimum, both for three specimens, using Charpy V-Notch (C_v) specimens and testing at or below LST - 30°F. The C_v test is retained by the 1989 Edition of Section III but, when impact testing of this material is not waived, the energy values required by Table NE-2332.1-2 for the thickest sphere material are 25 ft-lb average and 20 ft-lb minimum, both for three specimens, at or below the LST.

The Oyster Creek drywell was constructed of carbon-silicon steel plates ordered to SA-212, Gr. B, Firebox Quality meeting the requirements of SA-300. As indicated in 5.2 of the present document, the designation of this material was changed to SA-516, Gr. 70 by the Summer 1966

Addenda. By the material specifications, the material is normalized, fully killed and melted to fine grain melting practice. The drywell plate was impact tested, using the Charpy V-Notch specimen (C_V) at 0°F to 20 ft-lb minimum. The material specification and impact test complied with Code Case 1272N5 and with the 1963 Edition of Section III; and, if testing were required, with the minimum energy requirement of the 1989 Edition of Section III.

The possible exception is further resolved by showing that impact testing would not have been required if the present Subsection NE requirements were applied to the Oyster Creek drywell. The present NE 2121(c) permits material which is not impact tested to be used if it is normalized or quenched and tempered, fully killed, and melted to fine grain melting practice and the provisions of Table NE-2311(a)-1 are satisfied. That table exempts SA-516 Grade 70 in the normalized condition, from impact testing if the listed value of T_{NDT} (0°F) is lower than the LST by an amount established by the rules of Appendix R. By Appendix R, the permissible LST is defined as T_{NDT} + A. For thicknesses up to 2.5 inches A = 30°F. Therefore impact testing would not be required by the present Code rules unless the LST were less than 30°F, and the Oyster Creek drywell material would not require impact testing.

8.2 Forming Tolerances

Code Case N-284, the rules for buckling applied in the present evaluation, requires, in -1500, that the forming tolerance requirements of NE-4220 be satisfied. The possible exception exists because the requirements of NE-4220 were not in effect when the Oyster Creek drywell was constructed. The requirement imposed by Case N-284, the Code requirements at the time of construction, and the requirements imposed by CBI on the construction of the Oyster Creek drywell are examined to establish that this possible exception is not significant to the conclusion of this document.

The present (1989 Edition) NE-4220 imposes "roundness" requirements and "shape" requirements. These may be summarized as follows:

Roundness: the difference between the maximum and minimum inside diameters at any cross section shall not exceed 1% of the nominal diameter at the cross section under consideration. For the drywell, this would be an allowable difference of 8.4".

Shape: The maximum radial deviation from the true circular form shall not exceed the maximum permissible deviation 'e' over a specified arc length. The value of 'e' is determined from Fig. UG-80.1 as a function of the outside diameter divided by the radius (730) and the "length between stiffening rings" divided by the outside diameter. For spheres the "length between stiffening rings" is defined as one-half of the outside diameter, so that the second ratio is 0.5. The resulting point falls above the highest curve which permits e = t = 1.154". The arc length over which the measurement is to be made is defined as twice that determined from Fig. UG-29.2 as a function of the same ratios, so is 115" or 9.5'.

The Code rules in effect at the time of construction of the Oyster Creek drywell, the 1962 Edition of Section VIII with addenda through Winter 1963 and Code Case 1272N5 contained fabrication tolerances for cylinders and formed heads but not for spheres. Section III retained these provisions for containment vessels until, as was noted in 5.2 of this document, the Summer 1972 Addenda when the procedures required for Class A vessels were adopted for containment vessels. The essential changes from the previous Section VIII requirements were that spherical vessels were included and the rules previously applied to vessels subject to external pressure were also applied to vessels subject to internal pressure. This was implemented, in part, by defining the "length between stiffening rings" for spherical vessels as one-half of the outside diameter.

The NE-4220 requirements in the 1989 Edition of Section III are essentially identical to those of the Summer 1972 Addenda, the slight changes in the curve for 'e', which make the curve slightly less conservative, do not affect the value for the drywell.

The procedures actually applied by CBI in the construction of the Oyster Creek drywell are described in Attachment 1. The sequence of fabrication was forming of individual plates, making vertical welds to assemble the individual plates into rings, and making horizontal welds to join the rings. Since Case 1272N5 and Section VIII had no requirements applicable to this drywell, all dimensional checks made by CBI during construction of this drywell were made to assure that the completed vessel was within drawing tolerances and that the plates were formed to tolerances intended to assure that the vessel could be fabricated. Attachment 1 summarizes the procedures used and concludes that:

> The vessel as fabricated is made up of cylindrical plates which are considerably closer to the true curvature than that required by today's Code. The out-of-roundness is believed to also be compatible with today's Code, however, specific documented checks or procedures are not readily available.

This review indicates that the specific dimensional checks documented by CBI in fabrication of the Oyster Creek drywell were not sufficient to demonstrate satisfaction of the NE-4220 requirement on the deviation between maximum and minimum diameters or on the deviation from true spherical shape. However, the measurements made by CBI to assure fabricability provide reasonable assurance that the "shape" control was equal to or better than that required by NE-4220.

Based upon the buckling analysis performed by GE, the forming tolerance issue of most importance is that of local shape, the lower modes of buckling which are sensitive to gross out-of-roundness are not of interest. Also, since the buckling analysis performed by GE considered the eccentricity between the corroded and uncorroded regions in the shell, the provisions of NE-4221.4 are important. NE-4221.4 permits deviations from the specific tolerances stated in NE-4220 "provided the drawings are modified and reconciled with the Design Report and provided the modifications are certified by a Registered Professional Engineer in an addendum to the Stress Report." The evaluation performed by GE is consistent with this provision.

In summary, it is the opinion of TES that the matter of the forming tolerances applied in construction of the Oyster Creek drywell is not a valid basis for an exception to the conclusions expressed in Section 2.0 of this document.

8.3 Conclusion of Section 8.0

Based on the review conducted by CBIN, and included as Attachment 1, and the evaluation of possible exceptions contained in the other subsections of Section 8.0, the materials, fabrication, examination, and testing procedures applied in the construction of the Oyster Creek drywell are consistent with the Conclusion of this effort as stated in Section 2.0 of this document.

ATTACHMENT 1

FABRICATION, INSPECTION, NDE AND TESTING PRACTICES

FOLLOWED BY CBI

IN THE CONSTRUCTION OF THE OYSTER CREEK DRYWELL

Prepared by

CBI

I. General

The spherical plates were provided in accordance with ASME VIII, 1962 Edition, including the Summer 1964 Addendum and Code Cases 1270N-5 and 1272N-5. For purposes of comparisons, the requirements of the Code of Record will be contrasted with those of the 1989 Edition of ASME III, Subsection NE.

II. Fabrication Tolerances

The Code of Record, par. UG-80, provide guidelines for Permissible Out-of-roundness of cyclindrical shells subjected to a) Internal Pressure and b) External pressure. The rules for external pressure further define local deviations from a circular template. The code of record does no provide tolerances for spheres, neither gross out-of-roundness tolerances nor local deviations. Based on the lack of detailed requirements at that time, CBI most probably reverted to inhouse tolerance practices. These are based on CBI's interest in having spherical shell plates which will ensure efficient field fit-up and minimal field adjusting, including triming.

The following are excerpts from CBI's inhouse standards describing shop fabrication tolerances. (These were in effect in 1965, but not formally printed as a CBI Standard until 1970).

0.1 Scope: Gives desired limits on finished plate dimensions, curvature and bevels for dished spherical plates. Gives normal fabrication practices for forming, marking and burning dished spherical plates.

1.0 FABRICATION LIMITS

The following are within normal fabrication limits and should be achievable without spending an excessive amount of time and care with set-ups. If dimensions fall outside these limits, it does not mean the plate has to be discarded. It does mean consideration should be given to making compensation for the variance. It means the Construction and Engineering Departments must be advised of the variance.

1.1 Tolerances for Template

1.1.1 All arc dimensions: ± 1/32"

1.1.2 All diagonal dimensions: ± 1/16"

1.2 Dimensional Limits for Finished Plate

1.2.1 Burned edge from gage line if used: ± 1/32"

1.2.2 Arcs: Transverse ± 3/32"

Longitudinal ± 1/8"

Diagonal ± 1/8"

1.2.3 Land Location: ± 1/16"

1.2.4 Land Width: ±1/16"

1.2.5 Edge Bevels:

0.1 Scope: Gives desired limits on finished plate dimensions, curvature and bevels for dished spherical plates. Gives normal fabrication practices for forming, marking and burning dished spherical plates.

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The following are within normal fabrication limits and should be achievable without spending an excessive amount of time and care with set-ups. If dimensions fall outside these limits, it does not mean the plate has to be discarded. It does mean consideration should be given to making compensation for the variance. It means the Construction and Engineering Departments must be advised of the variance.

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1.2.1 Burned edge from gage line if used: ± 1/32"

1.2.2 Arcs: Transverse ± 3/32"

Longitudinal ± 1/8"

Diagonal ± 1/8"

1.2.3 Land Location: ± 1/16"

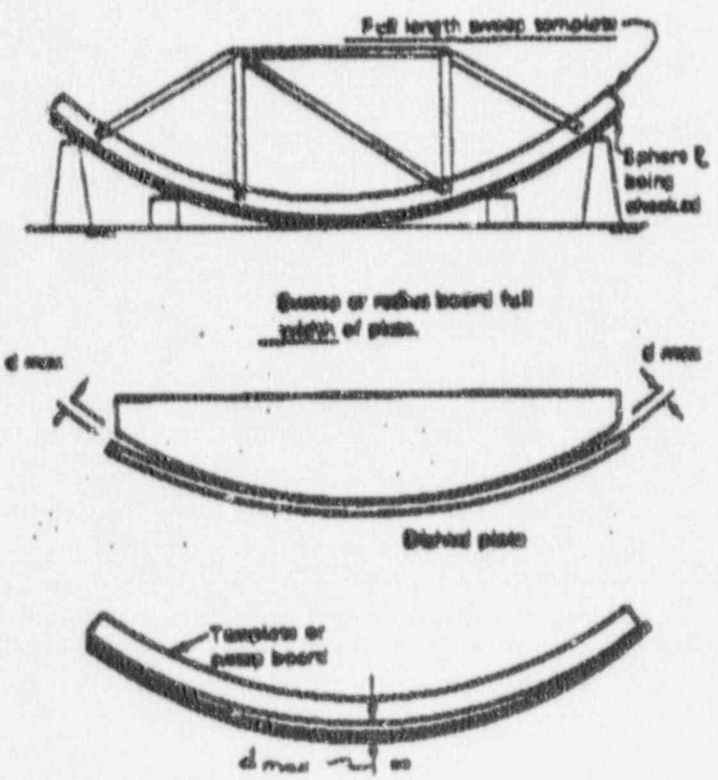
1.2.4 Land Width: ±1/16"

1.2.5 Edge Bevels: (+5° -5°)

1.3 Deviations From Sweep Board: All dimensions in Table 1.3a are measured from a full length sweep unless noted otherwise.

Table 1.3a Curvature Deviations

Sweep Location	Plate Thickness	d Max in. Fig 1.3b
ALONG LONGITUDINAL EDGE	Up To 3/4"	1/4"
	Over 3/4"	1/8"
ALONG TRANSVERSE EDGE	Up To 3/4"	1/8"
	Over 3/4"	3/32"
LONGITUDINAL THRU CENTER OF PLATE	Up To 3/4"	3/8"
	Over 3/4"	1/4"
TRANSVERSE THRU CENTER OF PLATE	Up To 3/4"	3/16"
	Over 3/4"	1/8"



For the 1.154" thick plate, the full length sweep type template would have been about 22 feet long and cut to a 35'-0 radius. The maximum permissible deviation, using inhouse standards was 1/4". This is equivalent to an e= 0.25/1.154 or 0.217.

Similarly, the full width template would have been about 9'-3" wide and also cut to a 35'-0 radius. The maximum permissible deviation, using inhouse standards was 1/8". This is equivalent to e = (0.125/1.154) = 0.108.

Now compare the above values to those now required by NE-4221 of ASME III, Div. 1, 1989 Edition. From NE-4221.2 (c) (3) for spheres L is one half of the outside diameter, Do in inches. In this case (840 + 2x1.154)/2 = (842.308")/2 = 421.154".

From Figure NE-4221-2-2; for L/D_o = .5 and Do/t = (842.308/1.154) = 730, template arc = .068 D_o

From NE - 4221.2 (a) 1.

2x arc length = chord = 2 x .068 x 842.308 = 114.55 inches or 9.54 ft.

The chord lengths actually used were about 22 ft and 9'-3" which are either about equal to or considerably greater than that now required.

The allowable eccentricity from Figure NE-4221.2-1 for L/o = .5 and Do/t = 730 is in the region above 1.0t. To be conservative, we will assume the maximum would be e = t = 1.154". (or 1.0t)

It is therefore obvious that the actual "as produced" tolerance which permitted a deviation of 1/8" over a 9'-3 wide template is considerably more demanding than that permitted by the 1989 version of ASME III which would permit a deviation of 1.154" over a 9.54 ft wide template.

The above fabrication tolerances are applicable to the shop only. The justification of these tolerances, which are about 1/8 of those permitted by Code lies in CBI's interest in providing plates to the field site which are so accurately formed as to preclude any possibility of requiring field adjustments. Economics dictated these shop tolerances.

Having established this shape accuracy and linear dimensions within ± 1/32" as shown in this report, the field fitup was achieved by matching adjacent seams and maintaining a constant weld gap throughout the entire length of the seam. This normally established the correct curvature across a weld joint. Checking of this curvature at each weld joint by use of a 9 feet or 10 foot sweep template was commonly done, but was not mandatory as far as we are able to determine at this time. Judicious field personnel interested in being assured that the closure plate would fit without readjustment of previously welded seemed to plan ahead by using these sweep templates as they progressed around the sphere.

As far as we can determine, there were no diametral checks recorded at the time the vessel was erected. None were required since the code did not address spheres. The roundness was established by having accurately formed individual plates, a correct total circumference and some checks of curvature across weld joints.

Conclusion: The vessel as fabricated is made up of spherical plates which are considerably closer to the true curvature then that required by today's code. The out-of-roundness is believed to also be compatible with today's code, however, specific documented checks or procedures are not readily avaialble.

III. Non Destructive Examinations

The project drawings called for the following NDE

1. All butt welds - 100% RT
2. All non-radiographable joints and fillet welds - 100% MT or PT (before and after pwht)
3. Solution film test all welds at 5 psi, and at design pressure

The 1989 Edition of ASME III, NE-5000 requires the same level of NDE. The technique and acceptance criteria is also essentially the same as the 1962 Edition of ASME VIII.

Code Case 1270N-5, par. 4 allowed embedment of the bottom prior to test.

IV. Welding

The past weld heat treatment, welding procedures, procedure qualification essential variables and individual welder qualifications are essentially the same in 1989 as they were in 1964, to the best of our knowledge.

V. Materials

The materials were ordered to the Charpy requirements of A300. These were 20 ft-lbs at 0 F, longitudinal Vee notch type tests. Although there are some subtleties in today's requirements, they are essentially the same as those provided.

Since the strain in the sphere plates is about .2%, the materials is exempt from cold forming qualifications and not buffer need be added per NE-4213.1 (d), of ASME III, 1989 Edition.

VI. Conclusions

The above information is based on CBI's efforts to determine what practices were in use at the time that the Oyster Creek Containment Vessel was constructed. The information is based on verbal discussions with many of ther personnel who were working in CBI's shops and construction sites at the time. The accuracy of the descriptions, with the exception of the exerpts from the the standards, are subject to the ability of those poled to remember what they did 25 years ago.

Based on all of the above, it appears that the essential ingredients of fabrication, NDE, inspection and testing practices used at the time that the vessel was built are compatible with those currently requires.

ATTACHMENT II

GE Reports Index No. 9-1 and 9-2
"An ASME Section VIII Evaluation of the Oyster Creek
Drywell Stress and Stability Analysis"