(c) It is recommended that when the flange and adjacent shell region are stressed by the full intended bolt or stud preload and by pressure not exceeding 20% of the preoperational system hydrostatic test pressure, minimum metal temperature in the stressed region should be at least the initial $RT_{NDT}$ temperature for the material in the stressed regions plus any effects of irradiation at the stressed regions.

(d) Thermal stresses shall be considered as secondary except as provided in NB-3213.13(b). The $K_f$ of G-2214.3(b) is recommended for the evaluation of thermal stress.

13 G-2223 Toughness Requirements for Nozzles

(a) A defect shall be postulated at the corner of the nozzle and cylindrical shell. The postulated defect is defined as circular in shape, with a depth equal to one-fourth of the length of a path oriented 45 deg to the nozzle flow axis that extends from the center point on the surface of the nozzle inner corner to the outside surface of the RPV wall (1/4-thickness), as shown in Figure G-2223-1. A smaller defect size may be postulated, appropriately considering the combined effects of internal pressure, external loading, thermal stresses, and flaw shape. Postulated defect sizes other than 1/4-thickness shall be no smaller than the applicable in-service inspection acceptance standards in Table IWB-3410-1 and compatible with examination detection capabilities demonstrated in accordance with IWA-2230 or other appropriate standards.

(b) The sources of stresses that may be significant for consideration in the corner region of a nozzle are those due to internal pressure loading, external nozzle attachment loading, and thermal loading. For Level A and Level B service conditions, the following shall be satisfied for the postulated defect:

$$2K_{IP} + K_{IT} \leq K_T$$  \hspace{1cm} (3)

where $K_{IP}$ and $K_{IT}$ are stress intensity factors due to internal pressure plus external loading and thermal loading, respectively.

(c) The stress intensity factor from internal pressure loading for a nozzle corner crack may be calculated using the equation\(^{58}\)

$$K_{IP} = F(a/r_n)\sigma_{th}\sqrt{a}$$  \hspace{1cm} (4)

where

$$F(a/r_n) = 2.4582 - 5.4782(a/r_n) + 9.6492(a/r_n)^2 - 8.80(a/r_n)^3 + 3.1446(a/r_n)^4$$

and

- $a$ = crack depth, determined in accordance with (a)
- $r_c$ = nozzle corner radius
- $r_f$ = actual inner radius of nozzle
- $r_n$ = apparent radius of nozzle $= r_f + 0.29r_c$
- $\sigma_{th}$ = shell hoop stress

Alternately, the method of (d) may be used to calculate stress intensity factor due to internal pressure.

(d) The stress intensity factor for any arbitrary stress distribution through the nozzle corner cross-section may be determined by curve fitting the stress distribution as a function of the distance into the cross-section, $x$, from the nozzle inner corner to a third order polynomial of the form.

$$\sigma = A_0 + A_1(x/a) + A_2(x/a)^2 + A_3(x/a)^3$$  \hspace{1cm} (5)

The stress intensity factor may be calculated using the following:

$$K_f = \sigma \sqrt{a} \left[ 0.723A_0 + 0.551\left(\frac{2a}{\pi}\right)A_1 + 0.462\left(\frac{a^2}{2}\right)A_2 + 0.408\left(\frac{4a^3}{3\pi}\right)A_3 \right]$$  \hspace{1cm} (6)

where $K_f$ is the stress intensity factor. The stress intensity factors resulting from each loading type may be superimposed. This method may be used for external loading, thermal loading, and for internal pressure loading when the stress distribution through the nozzle throat section is available.

(e) Fracture toughness analysis to demonstrate protection against nonductile failure is not required for portions of nozzles and appurtenances having a thickness of 2.5 in. (63 mm) or less, provided the lowest service temperature is not lower than $RT_{NDT}$ plus 60°F (33°C).
ARTICLE IWA-3000
STANDARDS FOR EXAMINATION EVALUATION

IWA-3100 EVALUATION

(a) Evaluation shall be made of flaws detected during an inspection examination as required by IWB-3000 for Class 1 pressure retaining components, IWC-3000 for Class 2 pressure retaining components, IWD-3000 for Class 3 pressure retaining components, IWE-3000 for Class 3MC pressure retaining components, or IWF-3000 for component supports.

(b) If acceptance standards for a particular component, Examination Category, or examination method are not specified in this Division, flaws that exceed the acceptance standards for materials and welds specified in the Section III Edition applicable to the construction of the component shall be evaluated to determine disposition. Such disposition shall be subject to review by the regulatory and enforcement authorities having jurisdiction at the plant site.

IWA-3200 SIGNIFICANT DIGITS FOR LIMITING VALUES

(a) All observed or calculated values of dimensions of component thickness and of flaws detected by nondestructive examinations to be used for comparison with the evaluation standards of IWB-3000, IWC-3000, IWD-3000, or IWE-3000, whether obtained as decimals or converted from fractions, shall be expressed to the nearest 0.1 in. (2 mm) for values 1 in. (25 mm) and greater, and to the nearest 0.05 in. (1.5 mm) for values less than 1 in. (25 mm). Rounding-off of values shall be performed in accordance with the Rounding-off Method of ASTM Recommended Practice E29.

(b) Interpolation of percentage values for acceptance standards, as required for intermediate flaw aspect ratios in the tables of allowable flaw standards, shall be rounded to the nearest 0.1%.

(c) Interpolation of decimal or fractional dimensions specified in the tables of allowable flaw standards shall be rounded to the nearest 0.1 in. (2 mm) or $\frac{1}{16}$ in. (2 mm), respectively.

IWA-3300 FLAW CHARACTERIZATION

(a) Flaws detected by the preservice and in-service examinations shall be sized by the bounding rectangle or square for the purpose of description and dimensioning. The dimensions of a flaw shall be determined by the size of a rectangle or square that fully contains the area of the flaw.

(1) The length $l$ of the rectangle or one side of the square shall be drawn parallel to the inside pressure retaining surface of the component.

(2) The depth of the rectangle or one side of the square shall be drawn normal to the inside pressure retaining surface of the component and shall be denoted as $a$ for a surface flaw and $2a$ for a subsurface flaw.

(3) The aspect ratio of a flaw shall be defined by $a/l$. The flaw aspect ratio shall not exceed 0.5. (see Figure IWA-3320-1, Flaw #3, as an example.)

(b) Flaws shall be characterized in accordance with IWA-3310 through IWA-3390, as applicable. If multiple flaws exist, each flaw shall be evaluated for its interaction with each adjacent flaw on an individual flaw basis, using the original flaw dimensions. First, the proximity of each flaw to the surface shall be determined. Any individual subsurface flaw that is determined to satisfy the criteria for surface interaction ($S < 0.4d_s$) shall be reclassified as a surface flaw. Next, the proximity of any flaw to adjacent flaws shall be evaluated. If two or more flaws are combined by the proximity rules using the original dimensions of each individual flaw, it is not required to consider further interactions based on the dimensions of the combined flaw with other flaws.

(c) The clad thickness dimension may be taken from the manufacturer's drawings.

(d) Flaws detected by the in-service examinations (IWB-2500) of steam generator tubing (Examination Category B-Q) shall be described as a percentage of wall thickness. The depth is the maximum radial dimension of the flaw. The wall thickness $t$ is the nominal wall thickness, and the tube radius $r$ is the mean radius as given by the specification to which the tubes were purchased. These flaws shall be compared with the standards of IWB-3521.

IWA-3310 SURFACE PLANAR FLAWS

(a) A continuous indication shall be considered as a surface planar flaw if the detected area of the flaw is oriented primarily in any single plane, other than parallel to the surface of the component, and any portion of the flaw penetrates a surface of the component, as shown in Figure IWA-3310-1.

(b) A subsurface indication shall be considered a surface flaw if any portion of the flaw is less than $0.4d_s$ from the surface of the component nearest the flaw. If the
ARTICLE IWA-3000
STANDARDS FOR EXAMINATION EVALUATION

The dimensions of a flaw shall be determined by the size of a rectangle or square that fully contains the area of the flaw.

(1) The length \( l \) of the rectangle or one side of the square shall be drawn parallel to the inside pressure retaining surface of the component.

(2) The depth of the rectangle or one side of the square shall be drawn normal to the inside pressure retaining surface of the component and shall be denoted as \( a \) for a surface flaw and \( 2a \) for a subsurface flaw.

(3) The aspect ratio of a flaw shall be defined by \( a/l \). The flaw aspect ratio shall not exceed 0.5. (see Fig. IWA-3320-1, Flaw #3, as an example.)

(b) Flaws shall be characterized in accordance with IWA-3310 through IWA-3390, as applicable. If multiple flaws exist, each flaw shall be evaluated for its interaction with each adjacent flaw on an individual flaw basis, using the original flaw dimensions. First, the proximity of each flaw to the surface shall be determined. Any individual subsurface flaw that is determined to satisfy the criteria for surface interaction \((S < 0.4d_i)\) shall be reclassified as a surface flaw. Next, the proximity of any individual flaw to adjacent flaws shall be evaluated. If two flaws are combined by the proximity rules, it is not required to consider further interactions of the combined flaw with other individual or combined flaws.

(c) The clad thickness dimension may be taken from the manufacturer’s drawings.

(d) Flaws detected by the in-service examinations (IWB-2500) of steam generator tubing (Examination Category B-Q) shall be described as a percentage of wall thickness. The depth is the maximum radial dimension of the flaw. The wall thickness \( t \) is the nominal wall thickness, and the tube radius \( r \) is the mean radius as given by the specification for which the tubes were purchased. These flaws shall be compared with the standards of IWB-3521.

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(a) A continuous indication shall be considered as a surface planar flaw if the detected area of the flaw is oriented primarily in any single plane, other than parallel to the surface of the component and any portion of the flaw penetrates a surface of the component, as shown in Fig. IWA-3310-1.

(b) A subsurface indication shall be considered a surface flaw if any portion of the flaw is less than 0.4\( d \) from the surface of the component nearest the flaw. If the
examinations. Training shall include requirements for in-service and preservice examinations and reporting
criteria for the following:
- (a) concrete (applicable conditions such as those
described in ACI-201.1 should be included)
- (b) reinforcing steel
- (c) post-tensioning system items (e.g., wires, strands, anchorage hardware, corrosion protection
medium, and free water) [for plants with post-tensioning
systems only]
- (3) training proficiency shall be demonstrated by
administering a qualification examination consisting of
the following:
- (a) a written examination covering Section XI, Subsection IWL requirements and plant-specific
procedure requirements for visual examination, containing at
least 15 questions in each of the following:
  - (1) concrete and reinforcing steel;
  - (2) post-tensioning system components (i.e.,
wires, strands, anchorage hardware, corrosion protection
medium, and free water) [for plants with post-tensioning
systems only].
- (b) a practical examination using test specimens
with flaws or indications to be detected by the following
visual examination techniques:
  - (1) general and detailed visual examination of
concrete
  - (2) detailed visual examination of reinforcing
steel
  - (3) detailed visual examination of post-
tensioning system components (i.e., wires, strands, and
anchorage hardware) [for plants with post-tensioning
systems only]
- (c) passing grades for visual examinations shall
be as follows:
  - (1) an average combined grade of 80% for
written and practical examinations, and
  - (2) a minimum grade of 70% for each written
and practical examination
- (d) individuals failing to attain the required
passing grades shall receive additional training as deter-
mined by the Responsible Engineer before reexamination.
The written reexamination questions shall be selected at
random from a bank of questions containing at least twice
the number of examination questions, or the written
examination shall contain at least 50% different or
recorded questions. The practical reexamination test shall
contain at least 50% different test specimens or shall
contain specimens with at least 50% different flaws or
indications from those used during the most recent
practical examination that was not passed by the can-
didate. No individual shall be reexamined more than twice
within any consecutive 12 month period.
- (4) training proficiency shall be demonstrated by
administering subsequent examinations at a frequency
not exceeding 5 years
- (5) the vision test requirements of IWA-2321

(b) The preceding qualification requirements shall be
described in the Employer's written practice.

IWL-2330 RESPONSIBLE ENGINEER

The Responsible Engineer shall be a Registered Profes-
sional Engineer experienced in evaluating the condition of
structural concrete. The Responsible Engineer shall have
knowledge of the design and Construction Codes and
other criteria used in design and construction of concrete
containments in nuclear power plants.
The Responsible Engineer shall be responsible for the
following:
- (a) development of plans and procedures for examina-
tion of concrete surfaces
- (b) approval, instruction, and training of personnel
performing general and detailed visual examination
- (c) evaluation of examination results
- (d) preparation or review of Repair/Replacement Plans
and procedures
- (e) review of procedures for pressure tests following
repair/replacement activities
- (f) submittal of a report to the Owner documenting
results of examinations, repair/replacement activities, and
pressure tests

IWL-2400 INSERVICE INSPECTION
SCHEDULE

IWL-2410 CONCRETE

(a) Concrete shall be examined in accordance with IWL-2510 at 1, 3, and 5 years following the
completion of the containment Structural Integrity Test
CC-6000 and every 5 years thereafter.
(b) The 1-, 3-, and 5-year examinations shall commence
not more than 6 months prior to the specified dates and
shall be completed not more than 6 months after such
dates. If plant operating conditions are such that examina-
tion of portions of the concrete cannot be completed
within this stated time interval, examination of those
portions may be deferred until the next regularly
scheduled plant outage.
(c) The 10-year and subsequent examinations shall
commence not more than 1 year prior to the specified
dates and shall be completed not more than 1 year after
such dates. If plant operating conditions are such that
examination of portions of the concrete cannot be completed
within this stated time interval, examination of those
portions may be deferred until the next regularly
scheduled plant outage.
(d) Concrete surface areas affected by a repair/replacement
activity shall be examined in accordance with the
requirements of IWL-2510 at 1 year (±3 months) follow-
ing completion of repair/replacement activity. If plant
operating conditions are such that examination of portions
ARTICLE IWL-4000
REPAIR/REPLACEMENT ACTIVITIES

IWL-4100 GENERAL

The requirements of IWA-4000 are applicable except as follows.
(a) The requirements of IWA-4320, IWA-4340, and IWA-4700 are not applicable.
(b) The requirements of IWA-4224, IWA-4225, and IWA-4226 are applicable only to reinforcing steel, metallic load bearing items of the post-tensioning system, and welding materials.
(c) The requirements of IWA-4400 are applicable only to bearing plates.

IWL-4110 SCOPE

(a) This Article provides requirements for repair/replacement activities on concrete containments.
(b) The following are exempt from the requirements of the Article:
   (1) anchorage end caps, including installation fasteners and seals or gaskets;
   (2) sealants or coatings;
   (3) removal, replacement, or addition of corrosion protection medium;
   (4) activities affecting concrete, provided
      (a) the affected concrete is external to the outermost layer of reinforcing steel and does not provide anchorage-bearing plate support;
      (b) the activities are not required to correct a condition unacceptable for continued service; and
      (c) the activities have been approved by the Responsible Engineer.

IWL-4200 REPAIR/REPLACEMENT PLAN

IWL-4210 RESPONSIBLE ENGINEER

The Repair/Replacement Plan shall be developed under the direction of a Responsible Engineer (IWL-2300).

IWL-4220 CONCRETE

(a) The Repair/Replacement Plan shall document conditions indicative of damage or degradation, such as described in ACI 201.1R and ACI 349.3R, on surfaces requiring a repair/replacement activity and shall specify requirements for removal of defective material.
(b) The affected area shall be visually examined to assure specified surface preparation of concrete and reinforcing steel prior to placement of concrete.
(c) When removal of defective material exposes reinforcing steel, the reinforcing steel shall receive a detailed visual examination as defined in IWL-2310(b). Reinforcing steel is acceptable when the Responsible Engineer determines that there is no evidence of damage or degradation requiring further evaluation or repair. When required, reinforcing steel shall be repaired in accordance with IWL-4230. Repair/replacement activities on exposed-end anchors of the post-tensioning system shall be in accordance with IWL-4240.
(d) New material shall be chemically, mechanically, and physically compatible with existing concrete.
(e) When detensioning of prestressing tendons is required for the repair/replacement activity on the concrete surface adjacent to the tendon, the Repair/Replacement Plan shall require the following:
   (1) selection of new material to minimize stress and strain incompatibilities between new material and existing concrete;
   (2) procedures for application of new material;
   (3) procedures for detensioning and retensioning of prestressing tendons.
(f) The Repair/Replacement Plan shall specify requirements for in-process sampling and testing of new material.

IWL-4230 REINFORCING STEEL

Damaged reinforcing steel shall be corrected by any method permitted in the original Construction Code or in Section III, Division 2, with or without removal of the damaged reinforcing steel.
Proposed IWL Commentary Revision Addressing BC05-140 (WG/C-L 03-04.1)

The requirements for a VT-3C examination have been replaced with a "general visual examination," and the requirements for a VT-1C examination have been replaced with a "detailed visual examination." The general visual examination of a concrete surface is performed to indicate the general condition of the containment. In order to assist in the performance of a general visual examination to identify the types of concrete deterioration and distress that can occur, reference is made to ACI 201.1R. Contained in ACI 201.1R is a checklist for making a survey of the condition of concrete, and photographs and descriptions of various distress manifestations.

The Working Group - Containment has proposed changing IWL-2310(a) to include reference to ACI 349.3R. ACI 349.3R provides additional information on various degradation mechanisms that can impact the performance of containments. For example, differential settlement, and degradation of mild steel reinforcement and post-tensioning systems is described. It is the committee's intent that the only applicable sections of ACI 349.3R are those that relate to degradation mechanisms. Information contained in ACI 349.3R on evaluation procedures and acceptance criteria were developed for nuclear power plant concrete structures other than containments; however, this information can be of assistance in resolution of the significance of observed areas of concrete deterioration and distress. As part of the proposed change to IWL-2310(a), the text "defined" is to be changed to "described" because it is felt that information contained in ACI 201.1R and 349.3R provides more of a description of the potential forms of deterioration and distress than a strict definition. (See WG/C-L #00-03, SGWCS #01-06, ISI #02-09, MC/BC #BC02-2384 for more detailed information).

The purpose of the general visual examination is to detect signs of deterioration. A detailed visual examination is then performed to determine the magnitude and extent of the deterioration. Alternative lighting and resolution requirements have been added to Subsection IWL to be used in lieu of the requirements of IWA-2000. It was determined that the lighting and resolution requirements contained in IWA-2000 (referenced in earlier versions of Subsection IWL), which were developed for use in Class 1, 2, and 3 examinations, are not suitable in many instances for use in performing containment examinations. For example, the requirements of IWA-2000 are used to detect flaws in piping. Containment concrete deterioration such as spalling and discoloration can be detected with less resolution and lighting. Because of the diversity in containment conditions with regard to resolution and lighting needs, the ASME has given the Registered Professional Engineer (discussed below under IWL-2330) the authority to determine these program requirements.

2. Interpretation #XI-3-98-31, File #IN98-004 clarifies that the Responsible Engineer (IWL-2304) is responsible for approval, instruction, and training of concrete examination personnel. This interpretation clarified that this responsibility does not reside with the Level III Instructor required by IWL-2310 (ANSI/ASME CP-189), unless this individual also happens to be the Responsible Engineer.

3. WG/C-L #00-03, SGWCS #01-06, ISI #02-09, MC/BC #BC02-2384. Working Group - Containment agenda for 9/10/02 meeting indicate that this action has been approved. Publication expected in 2003 Addenda.

4. VT-1C and VT-3C examination requirements were removed from IWL-2310 in the 1997 Addenda.

Date Revised: 02/08/06
Case N-739-1
Alternative Qualification Requirements for Personnel Performing Class CC Concrete and Post-Tensioning System Visual Examinations
Section XI, Division 1

Inquiry: What alternative to the requirements of IWL-2310 may be used for qualification of personnel performing Class CC concrete and post-tensioning system visual examinations?

Reply: It is the opinion of the Committee that the following alternative to the requirements of IWL-2310 may be used for qualification of personnel performing Class CC concrete and post-tensioning system visual examinations:

(a) Personnel performing general or detailed visual examinations (1995 Edition with the 1997 Addenda through the 2004 Edition with the 2006 Addenda) or VT-3C, VT-1C, or Limited VT-1 (i.e., wires, strands, anchorage hardware, and reinforcing steel) visual examinations (1992 Edition with the 1995 Edition with the 1996 Addenda) shall be approved by the Responsible Engineer and shall be qualified by satisfying the following requirements:

(1) at least 10 hr plant experience, such as that gained by plant personnel involved in inspection, maintenance, or repair/replacement activities in each of the following:
   (a) structural concrete and reinforcing steel
   (b) post-tensioning system components (for plants with post-tensioning systems only)

(2) at least 4 hr of training in Section XI, Subsection IWL requirements and at least 2 hr of training in plant-specific procedures for IWL visual examinations. Training shall include requirements for in-service and preservice examinations and reporting criteria for the following:
   (a) concrete (applicable conditions such as those described in ACI 201.1R should be included)
   (b) reinforcing steel 201.1R
   (c) post-tensioning system items (e.g., wires, strands, anchorage hardware, corrosion protection medium, and free water) [for plants with post-tensioning systems only]

(3) training proficiency shall be demonstrated by administering a qualification examination consisting of the following:
   (a) A written examination covering Section XI, Subsection IWL, requirements and plant-specific procedure requirements for visual examinations, containing at least 15 questions in each of the following:
      (i) concrete and reinforcing steel
      (ii) post-tensioning system components (i.e., wires, strands, anchorage hardware, corrosion protection medium, and free water) [for plants with post-tensioning systems only]
   (b) A practical examination using test specimens with flaws or indications to be detected by the following visual examination techniques:
      (iii) detailed visual examination (1995 Edition with the 1997 Addenda through the 2004 Edition with the 2006 Addenda) or VT-1 visual examination (1992 Edition with the 1995 Edition with the 1996 Addenda) of post-tensioning system components (i.e., wires, stands, and anchorage hardware) [for plants with post-tensioning systems only]
   (c) Passing grades for examinations shall be as follows:
      (i) an average combined grade of 80% for written and practical examinations
      (ii) a minimum grade of 70% for each written and practical examination
      (d) Individuals failing to attain the required passing grades shall receive additional training as determined by the Responsible Engineer before reexamination. The written reexamination questions shall be selected at random from a bank of questions containing at least twice the
When evaluating reducers, the large and small ends shall be evaluated separately. For the large end, \( t_{p, \text{min}} \) shall be determined from all locations for the large end and conical section. For the small end, \( t_{p, \text{min}} \) for the entire reducer shall be used.

(c) Detailed stress analysis may be conducted based on the complete set of measurements around the thinned cross-section of the piping item. The nominal longitudinal pressure stress, \( S_p \), shall be determined by

\[
S_p = \frac{P A_l}{A_p}
\]

(1) To evaluate piping at a branch connection beyond the limits of reinforcement, it shall be assumed that the entire region within limits of reinforcement is at thickness \( t_{\text{min}} \) for the unreinforced pipe section, with the outside surface at the pipe nominal outside radius. If excess reinforcement is available within the limits of reinforcement, the excess metal area may be included in \( A_p \).

(2) When evaluating the longitudinal pressure stress in the central cone of a reducer, the stress shall be determined based on the local radius at the cross section and the local \( t_p \) at and adjacent to the cross section of interest, except that the resulting stress shall be multiplied by a factor of 1/cos\( \theta \).

(d) When using Code Editions and Addenda that require use of stress indices, the nominal longitudinal stress determined in accordance with (b) and (c) shall be doubled.

### 3623.3 Nominal Longitudinal Bending Stresses

(a) Thinning of the piping item cross-sectional area might result in bending stresses different from those of the piping stress analysis of record. The nominal longitudinal bending stress, \( S_b \), for the various loading conditions and load combinations shall be determined by

\[
S_b = \frac{M_b + P A_p \delta}{Z_{\text{min}}}
\]

(b) For simplified analysis, the piping item section modulus may be based on a uniformly thinned section with thickness \( t_{p, \text{min}} \). When evaluating reducers, the large and small ends shall be evaluated separately. For the large
### Stress Categories and Limits of Stress Intensity for Annealing Evaluation

<table>
<thead>
<tr>
<th>Stress Category</th>
<th>General Membrane</th>
<th>Local Membrane</th>
<th>Bending</th>
<th>Expansion</th>
<th>Membrane Plus Bending</th>
<th>Peak and Fatigue</th>
<th>Evaluation not required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Average primary stress across solid section. Excludes effects of discontinuities and concentrations. Produced by mechanical loads.</td>
<td>Average stress across any solid section. Considers effects of discontinuities but not concentrations. Produced by mechanical loads.</td>
<td>Component of primary stress proportional to distance from centroid of solid section. Excludes effects of discontinuities and concentrations. Produced by mechanical loads. [Note (1)]</td>
<td>Stresses which result from the constraint of free end displacement. Considers effects of discontinuities but not local stress concentration (not applicable to vessels).</td>
<td>Self-equilibrating stress necessary to satisfy continuity of structure. Occurs at structural discontinuities. Can be caused by mechanical loads or differential thermal expansion. Excluded local stress concentrations.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Combination of stress components and allowable limits of stress intensities

- $P_n$
- $S_m$
- $P_t$
- $P_b$
- $P_e$
- $Q$
- $F$

### General Notes:
(a) The value of $S_m$ shall be determined from Table 1 using the concurrent temperature at the point being evaluated.
(b) The structural strength of the cladding may be neglected.
(c) When other items are attached to the reactor vessel in the high temperature region ($T > 700°F$), these items shall be evaluated for their effect on the pressure boundary.

### Notes:
1. Bending component of primary stress for piping shall be the stress proportional to the distance from centroid of pipe cross section.
2. The symbols $P_n$, $P_t$, $P_b$, $P_e$, $Q$, and $F$ do not represent single quantities, but sets of six quantities representing the six stress components $P_n$, $P_t$, $P_b$, $P_e$, $Q$, and $F$.
3. The stresses in category $Q$ are those parts of the total stress that are produced by thermal gradients, structural discontinuities, etc., and they do not include primary stresses that may also exist at the same point. However, it should be noted that a detailed stress analysis frequently gives the combination of primary and secondary stresses directly, and, when appropriate, the calculated value represents the total of $P_n + P_b + Q$, and not $Q$ alone.
4. The special stress limits of NB-3227.5, Nozzle Piping Transition, for stresses resulting from the annular activity, shall be met, except that the $3S_m$ limit applies to the maximum value of the stress intensity rather than the range.
5. The $3S_m$ limit applies to the maximum value of the stress intensity rather than the range.
Table WB-3217-1
Classification of Stress Intensity in Containments for Some Typical Cases (Cont'd)

NOTES (CONT'D):
(3) If an end connection of two concentric shells is relatively weak, the differential thermal expansion of the shells may lead to the formation of a plastic hinge in the connection and could cause excessive deformation or failure. The end connection shall be evaluated for such a condition treating the bending stresses as $P_b$.
(4) The special stress limits of WB-3227 shall also be met.
(5) Consideration shall also be given to the possibility of wrinkling and excessive deformation in containments with a large diameter-thickness ratio.
(6) Consider possibility of thermal stress ratchet.
(7) Equivalent linear stress is defined as the linear stress distribution that has the same net bending moment as the actual stress distribution.

Figure WB-3221-1
Stress Categories and Limits of Stress Intensity for Design Loadings

<table>
<thead>
<tr>
<th>Stress Category</th>
<th>General Membrane</th>
<th>Local Membrane</th>
<th>Bending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol [Note (1)]</td>
<td>$P_m$</td>
<td>$P_L$</td>
<td>$P_b$</td>
</tr>
</tbody>
</table>

Combination of stress components and allowable limits of stress intensities.

Legend: 〇 = Allowable value  □ = Calculated value

Note: (1) The symbols $P_m$, $P_L$, and $P_b$ do not represent single quantities, but rather sets of six quantities representing the six stress components $\sigma_r$, $\sigma_\theta$, $\tau_{rs}$, $\tau_{r\theta}$, and $\tau_{rs}$. 

Correction was done in 2013 edition