with the Construction Code identified in the Repair/Replacement Plan, with the following exceptions:

(1) Base metal repairs on Class 3 items are not required to be volumetrically examined when the Construction Code does not require that full-penetration butt welds in the same location be volumetrically examined.

(2) When welding or brazing is performed in accordance with IWA-4600 or IWA-4700, the examination requirements of IWA-4600 or IWA-4700, respectively, shall be met in lieu of examinations required by the Construction Code or Section III.

(b) Except as required by (a)(2) above, when (a) above requires surface or volumetric examinations to be performed on pressure-retaining installation (but not fabrication) welds or welds made for correction of flaws or defects, the Owner may authorize use of the personnel qualifications, methods, techniques, and acceptance criteria of Section XI, in lieu of those of the Construction Code, provided the following requirements are met:

(1) The surface examination methods shall be limited to those permitted by the Construction Code.

(2) If the Construction Code requires radiographic examination, the Owner may instead authorize use of ultrasonic examination in accordance with IWA-4521.

(3) All other examination requirements of the Construction Code, including surface area requirements and timing of examinations, shall be met.

(4) The weld or braze material deposited as part of the repair/replacement activity shall meet the preservice acceptance standards of Section XI. If Section XI does not provide preservice acceptance standards, the acceptance criteria of the Construction Code or Section III shall be met.

(5) Acceptability of remaining flaws that existed prior to the repair/replacement activity shall be established using the provisions of Article IWA-3000.

(c) These examinations may be performed concurrently with the preservice inspections required by IWA-4530.

IWA-4521 Ultrasonic Examination Requirements

If permitted by IWA-4520(b), ultrasonic examination shall be performed using a procedure qualified in accordance with Mandatory Appendix VIII and the following requirements:

(a) Ultrasonic examination shall not be applied to weld joints that include austenitic castings, austenitic welds with single-side access, or piping with structural austenitic weld inlay.

(b) Ultrasonic examination shall include 100% of the weld volume plus 1/2 T for Class 1 vessel welds, or 3/4 in. (13 mm) for all other welds, on each side of the weld volume. A supplemental straight beam examination shall also be used to identify laminations that could limit angle beam examinations.

(c) A written procedure that identifies the ranges of essential variables of VIII-2100(d) shall be followed. The procedure, and any subsequent essential variable changes outside the qualified ranges, shall be demonstrated on a qualification block or specimen that includes both surface and subsurface flaws. The examination volume above shall be included in a supplemental performance demonstration.

(d) The qualification blocks shall be fabricated from material of the same material specification, product form, and material heat treatment condition as one of the materials joined. Alternatively, for piping, the qualification block shall be of a material of similar chemical composition, tensile properties, and metallurgical structure as the material being welded.

(1) The surface condition of the qualification block shall approximate the roughest surface condition for which the examination procedure is applicable.

(2) If two or more base material thicknesses are involved, the qualification block thickness shall be of a size sufficient to contain the entire examination path.

(3) For austenitic materials, the qualification block configuration shall contain a weld representative of the joint to be examined, including the same welding process.

(4) A supplemental performance demonstration using a previously qualified procedure shall be conducted through use of a blind test with appropriate specimens that contain three different construction-type flaws (e.g., slag, lack of fusion, incomplete penetration) distributed throughout the thickness of the specimens, unless such flaws were included in the Mandatory Appendix VIII qualification.

IWA-4530 Preservice Inspection

When portions of items requiring preservice or inservice inspection are affected by repair/replacement activities, or for items being fabricated or installed, including welded or brazed joints made for fabrication or installation of items, preservice inspections shall be performed in accordance with IWB-2200, IWC-2200, IWD-2200, IWE-2200, IWF-2200, or IWL-2200 prior to return of the system to service. The preservice inspection may be performed either prior to or following the pressure test required by IWA-4540.

IWA-4540 Pressure Testing of Classes 1, 2, and 3 Items

(a) Unless exempted by (b), repair/replacement activities performed by welding or brazing on a pressure-retaining boundary shall include a hydrostatic or system leakage test in accordance with Article IWA-5000, prior to, or as part of, returning to service. Only brazed joints and welds made in the course of a repair/replacement activity require pressurization and VT-2 visual examination during the test.
ERRATA TO 2002 ADDENDA

ASME BPVC.XI-2015

(b) The following are exempt from any pressure test:
(1) cladding
(2) heat exchanger tube plugging and sleeving
(3) welding or brazing that does not penetrate through the pressure boundary
(4) flange seating surface when less than half the flange axial thickness is removed and replaced
(5) components or connections NPS 1 (DN 25) and smaller
(6) tube-to-tubesheet welds when such welds are made on the cladding
(7) seal welds non-pressure-
(8) welded or brazed joints between retaining items and the pressure-retaining portion of the components
(9) valve discs or seats

(c) Replacement components and appurtenances shall be pressure tested in accordance with the Construction Code selected for use in accordance with IWA-4221.

(d) Braided joints and welds in replacement parts and plugging subassemblies, fabricated by the Repair/Replacement Organization, or fabricated in accordance with the Construction Code without a hydrostatic pressure test, shall be tested as required by (a).

IWA-4550 CLASS MC AND METALLIC PORTIONS OF CLASS CC CONTAINMENTS

Items subjected to repair/replacement activities shall be tested in accordance with Article IWE-5000.

IWA-4600 ALTERNATIVE WELDING METHODS

(a) When welding under water, the alternative requirements of IWA-4660 may be used in lieu of the welding requirements of the Construction Code or Section III.

(b) When postweld heat treatment is not to be performed, the following provisions may be used.

(1) The welding methods of IWA-4620, IWA-4630, IWA-4640, or IWA-4670 may be used in lieu of the welding and nondestructive examination requirements of the Construction Code or Section III, provided the requirements of IWA-4610 are met. Existing temper bead Welding Procedure Specifications and Procedure Qualification Records made in accordance with IWA-4610 and IWA-4620, IWA-4630, or IWA-4640 from the 1989 Edition or later editions or addenda may still be used.

(2) For welding of Class MC metal containments and their integral attachments and metallic liners of Class CC containments and their integral attachments, the provisions of IWA-4620 may be used, provided the requirements of IWA-4610 are met. Existing temper bead Welding Procedure Specifications and Procedure Qualification Records made in accordance with IWA-4610 and IWA-4620 from the 1989 Edition or later editions or addenda may still be used. Alternatively, the provisions of IWA-4650 may be used.

IWA-4610 GENERAL REQUIREMENTS FOR TEMPER BEAD WELDING

(a) The area to be welded shall be preheated and maintained as specified in IWA-4620, IWA-4630, IWA-4640, or IWA-4670, as applicable. Except as permitted by IWA-4672(c), thermocouples and recording instruments shall be used to monitor the process temperatures. Their attachment and removal shall be in accordance with Section III.

(b) The welding procedure and the welders or welding operators shall be qualified in accordance with Section IX and the additional requirements of this Subarticle.

(1) Procedure Qualification

(a) The test assembly material for the welding procedure qualification test shall be of the same P-Number and Group Number, including a postweld heat treatment that is at least equivalent to the time and temperature already applied to the material being welded.

(b) Consideration shall be given to the effects of welding in a pressurized environment. If they exist, they shall be bounded in the test assembly within the limits of Table IWA-4662.1-1.

(c) Consideration shall be given to the effects of irradiation on the properties of material, including weld material for applications in the core belt line region of the reactor vessel. Special material requirements in the Design Specification shall also apply to the test assembly materials for these applications.

(d) If qualifying ambient temperature temper bead procedures of IWA-4670, the maximum interpass temperature for the first three layers of the procedure qualification test assembly shall be 150°F (66°C).

(e) Temper bead welding procedures used for welding similar materials in IWA-4620, dissimilar materials in IWA-4630, or cladding in IWA-4640 shall be qualified in accordance with Section IX, QW-290, using the following procedure qualification impact testing requirements:

(1) The test assembly base materials for the welding procedure qualification shall meet the impact test requirements of the Construction Code and Owner’s Requirements. If such requirements are not in the Construction Code and Owner’s Requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material at or below the lowest service temperature of the item to be repaired. The base metal Charpy V-notch specimens shall be taken from approximately the same depth as the HAZ specimens and should be aligned in the same manner as the HAZ specimens. The location and orientation of the test specimens shall be as specified in (3) below but shall

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Figure IWC-2500-3
Nozzle-to-Vessel Welds

Exam. surface A - B

1/2 in. (13 mm)

1/2 in. (13 mm)

Exam. surface A - B

1/2 in. (13 mm)

1/2 in. (13 mm)

arc length

GENERAL NOTES:
(a) 1/2 in. = 13 mm
(b) Nozzle sizes over NPS 4 (DN 100); vessel thickness \( \leq \frac{3}{4} \) in. (13 mm).
ARTICLE IWE-5000  
SYSTEM PRESSURE TESTS

IWE-5200  SYSTEM TEST REQUIREMENTS

IWE-5210  GENERAL

The requirements of Article IWA-5000 are not applicable to Class MC or Class CC components.

IWE-5220  TESTS FOLLOWING REPAIR/REPLACEMENT ACTIVITIES

IWE-5221  General

(a) Except as noted in IWE-5224, a pneumatic leakage test shall be performed in accordance with IWE-5223 following repair/replacement activities performed by welding or brazing, prior to returning the component to service.

(b) The following are exempt from the requirements of this Article:

(1) attachments (e.g., as defined in NE-1132) and non-pressure-retaining items

(2) welding or brazing on pressure-retaining portions of components, when the remaining wall thickness after metal removal is at least 90% of the minimum design wall thickness

IWE-5222  Personnel Qualification

Personnel performing tests in accordance with IWE-5223.4(a) and IWE-5224 shall meet the qualification requirements of Section V, Article 1, or IWA-2300.

IWE-5223  Pneumatic Leakage Test

IWE-5223.1  Pressure. The pneumatic leakage test shall be conducted at a pressure between 0.95P_a and 1.10P_a, except when otherwise limited by plant technical specifications, where P_a is the design basis accident pressure.

IWE-5223.2  Boundaries. The test boundary may be limited to brazed joints and welds affected by the repair/replacement activity.

IWE-5223.3  Test Medium and Temperature.

(a) The test medium shall be nonflammable.

(b) The test may be conducted with the vessel partially filled with water, provided the vessel stresses resulting from the test do not exceed the limits of the Construction Code.

(c) The test shall be conducted at a temperature that will preclude brittle fracture of the component.

IWE-5223.4  Examination. During the pneumatic leakage test, the leak tightness of brazed joints and welds affected by the repair/replacement activity shall be verified by performing one of the following:

(a) a bubble test — direct pressure technique in accordance with Section V, Article 10, Mandatory Appendix I, or any other Section V, Article 10 leak test that can be performed in conjunction with the pneumatic leakage test

(b) a Type A, B, or C Test, as applicable, in accordance with 10CFR50, Appendix J

IWE-5223.5  Leakage. The test area is acceptable if the acceptance standards of Section V, Article 10 are met or if the measured leakage is less than can be detected by the bubble test-direct pressure technique.

IWE-5224  Bubble Test — Vacuum Box Technique

(a) As an alternative to the requirements of IWE-5223, a bubble test - vacuum box technique may be performed following repair/replacement activities performed by welding or brazing on the following:

(1) metallic shell and penetration liners of Class CC components

(2) nonstructural pressure-retaining metallic liners of Class MC components embedded in, or backed by, concrete

(b) The bubble test shall be performed in accordance with Section V, Article 10, Mandatory Appendix II at a partial vacuum of at least 5 psi (35 kPa) below atmospheric pressure.

(c) Only brazed joints and welds made in the course of the repair/replacement activity require testing.

IWE-5240  VISUAL EXAMINATION

The visual examination requirements of IWE-2200(c) shall be met.

IWE-5250  CORRECTIVE ACTION

If the leakage test requirements of IWE-5220 cannot be satisfied, the source of leakage shall be located and the area shall be examined to the extent necessary to establish the requirements for corrective action. Repair/replacement activities shall be performed in accordance with the requirements of Article IWA-4000. Leakage testing shall be reperformed as required by IWE-5220, prior to returning the component to service.
IWE-5200 SYSTEM TEST
REQUIREMENTS

IWE-5210 GENERAL

The requirements of IWA-5000 are not applicable
to Class MC or Class CC components.

IWE-5220 TESTS FOLLOWING REPAIR/
REPLACEMENT ACTIVITIES

IWE-5221 Leakage Test

Except as noted in IWE-5222, repair/replacement
activities performed on the pressure retaining boundary
of Class MC or Class CC components shall be
subjected to a pneumatic leakage test in accordance
with the provisions of Title 10, Part 50 of the Code of
Federal Regulations, Appendix J, Paragraph IV.A.

IWE-5222 Deferral of Leakage Tests

Leakage tests for the following minor repair/
replacement activities performed on the pressure
retaining boundary may be deferred until the next
scheduled leakage test, provided nondestructive
examination is performed in accordance with the Repair
/Replacement Program and Plan:

(a) welds of attachments to the surface of the
pressure retaining boundary;
(b) weld cavities, the depth of which does not
penetrate the required design wall by more than 10%;
and
(c) welds attaching penetrations that are NPS 1
(DN25) or smaller.

IWE-5221 General

(a) Except as noted in IWE-5224, a pneumatic
leakage test shall be performed in accordance with IWE-
5223 following repair/replacement activities performed
by welding or brazing, prior to returning the component
to service.
(b) The following are exempt from the requirements
of this Article:

(1) attachments (e.g., as defined in NB-1132)
and non-pressure-retaining items
(2) welding or brazing on pressure-retaining
portions of components, when the remaining wall
thickness after metal removal is at least 90% of the
minimum design wall thickness.

IWE-5222 Personnel Qualification

Personnel performing examinations or tests in
accordance with IWE-5222.1, and IWE-5224 shall meet
the qualification requirements of Section V, Article 1 of
IWA-2300.

IWE-5223 Pneumatic Leakage Test

IWE-5223.1 Pressure. The pneumatic leakage

test shall be conducted at a pressure between 0.96 \( P_a \)
and 1.0 \( P_a \), except when otherwise limited by plant

IWE-5223.2 Boundaries. The test boundary may
be limited to brazed joints and welds affected by the
repair/replacement activity.

IWE-5223.3 Test Medium and Temperature

(a) The test medium shall be nonflammable.
(b) The test may be conducted with the vessel
partially filled with water, provided the vessel stresses
resulting from the test do not exceed the limits of the
Construction Code.
(c) The test shall be conducted at a temperature that
will preclude brittle fracture of the component.
IWE-5240 VISUAL EXAMINATION

The visual examination requirements of IWE-2200(c) shall be met.

IWE-5250 CORRECTIVE ACTION

If the leakage test requirements of IWE-5240 cannot be satisfied, the source of leakage shall be located and the area shall be examined to the extent necessary to establish the requirements for corrective action. Repair/replacement activities shall be performed in accordance with the requirements of IWA-4000. Leakage testing shall be reperformed as required by IWE-5220, prior to returning the component to service.
ARTICLE IWL-5000
SYSTEM PRESSURE TESTS

IWL-5100 SCOPE

This Article provides requirements for pressure testing concrete containments following repair/replacement activities.

IWL-5200 SYSTEM TEST REQUIREMENTS

IWL-5210 GENERAL

A containment pressure test shall be performed following repair/replacement activities unless
(a) the repair/replacement activity consists of only the exchange of post-tensioning tendons, tendon anchorage hardware, shims, or
(b) an evaluation is performed demonstrating that the containment satisfies the requirements of the Construction Code and the Owner's Requirements prior to and during the performance of the repair/replacement activity. This evaluation shall be reviewed by the Responsible Engineer.

IWL-5220 TEST PRESSURE

The pressure test shall be conducted at the design basis accident pressure, \( P_o \).

IWL-5230 LEAKAGE TEST

A leakage test shall be conducted as required by Article IWE-5000.

IWL-5250 TEST PROCEDURE AND EXAMINATIONS

The Responsible Engineer shall review the pressure test procedure and shall authorize performance of the pressure test. The surface of all containment concrete placed during repair/replacement activities shall be examined in accordance with IWL-2310(b) prior to start of pressurization, at test pressure, and following completion of depressurization. Extended surface examinations, additional examinations during pressurization, other examinations, and measurements of structural response to pressure shall be conducted as specified by the Responsible Engineer.

IWL-5260 CORRECTIVE ACTION

If the surface examinations of IWL-5250 cannot satisfy the requirements specified by the Responsible Engineer, the area shall be examined to establish requirements for corrective action. Repair/replacement activities shall be performed in accordance with Article IWL-4000, and pressure testing shall be repeated in accordance with IWL-5200, prior to returning the containment to service.

IWL-5300 REPORT

A pressure test report shall be prepared under the direction of the Responsible Engineer. The report shall describe pressure test procedures, summarize examination results, and state whether or not the repair/replacement activity is acceptable. If the repair/replacement activity is not acceptable, the report shall specify corrective measures.
IWL-4220 CONCRETE

(b) The affected area shall be visually examined to assure proper 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 sufficient to warrant 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.

IWL-5210 GENERAL

A containment pressure test shall be performed following repair/replacement activities unless

(a) the repair/replacement activity involves only the exchange of post-tensioning tendons, tendon anchorage hardware, shims; or

IWL-5210 GENERAL

A containment pressure test shall be performed following repair/replacement activities unless

(a) the repair/replacement activity consists of only the exchange of post-tensioning tendons, tendon anchorage hardware, shims; or

November 11, 2008, NOTE: this item was reviewed again and Passed WG Containment Unanimously 6-0-0-1
November 12, 2008, NOTE: this item was reviewed and Passed SGWCS 20-0-0-0 with minor revisions, reflected herein.
2 PROCEDURE

(a) The geometry of the metal loss region must be characterized in accordance with C.3.3.

(b) The length of the evaluation period over which the analytical evaluation remains established.

(c) The rate of metal loss on both the inside and outside surfaces of the pipeline item during the evaluation period shall be determined in accordance with C.3.1. The rate of metal loss analysis shall consider the relevant mechanisms, such as general corrosion or wastage, and local corrosion such as pitting. The analysis shall project the metal loss region to the end of the evaluation period.

(d) Validation of predicted rate of metal loss shall meet the requirements of C.3.2.

(e) If multiple metal loss regions are detected, the interaction and combined area of metal loss in a given pipe section shall be accounted for in the analytical evaluation. Concurrent metal loss at the same location on both the inside and outside surfaces, as applicable, in a given pipe section shall be accounted for in the analytical evaluation.

(f) The projected metal loss region at the end of the evaluation period shall be analytically evaluated using the acceptance standards C.4. One of two levels of analytical evaluation of the metal loss region shall be used, as follows.

(1) Level 1 analytical evaluation of C.5 requires that the piping item meets the design requirements.

(2) Level 2 analytical evaluation of C.6 is based on use of engineering equations to demonstrate that requirements based on internal pressure loading, soil and surcharge loads, bending moments, axial forces, and transverse forces are met.

(g) Subsequent examination of the metal loss region shall be performed no later than the end of the evaluation period. If examinations reveal the metal loss does not meet the acceptance criteria of this Case, a repair/replacement activity shall be performed. A re-evaluation or repair/replacement activity shall be performed for operation beyond the end of the evaluation period.

(h) Examination or repair/replacement activity of the affected piping item shall be performed no later than when the metal loss region is projected to no longer meet the acceptance criteria of C.4.
"%" instead of "5"

"<" needed

CASE (continued)
N-806-1

Table A-1
Modulus of Soil Reaction, \( E' \)

<table>
<thead>
<tr>
<th>Classification of Pipe Embedment</th>
<th>E' Degree of Compaction of Pipe Embedment, psi (MPa) [Note (4)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dumped</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Dumped</td>
<td>50 (0.3)</td>
</tr>
<tr>
<td>Clays and silts with any combination of sand plus gravel that is less than 30%, CL, ML</td>
<td>150 (1.1)</td>
</tr>
<tr>
<td>Sandy or gravelly silts and clays with any combination of sand plus gravel that is more than 50%, CL, ML, Sands and gravels with 13% or more fines GC, GM, SM</td>
<td>200 (1.4)</td>
</tr>
<tr>
<td>Crushed rock with less than 25% passing 3/8 in. (10 mm) sieve and less than 12% fines [Note (5)]</td>
<td>1,000 (7)</td>
</tr>
<tr>
<td>Controlled Low Strength Material (CLSM) [Note (7)]</td>
<td>3,000 (21)</td>
</tr>
</tbody>
</table>

GENERAL NOTES:
(a) Values only valid for pipe cover of 50 ft (15 m) or less.
(b) The \( E' \) values shown are only valid when used with a prism load as defined by eq. (A-6).
(c) Only applicable when the trench walls are as stiff or stiffer than the embedment soil beside the pipe.

CL = inorganic clays of low to medium plasticity
GC = clayey gravels, poorly-grained gravel-sand-clay mixtures
GM = silty gravels, poorly-grained gravel-sand mixtures
GW = gravelly sand, gravel-sand mixtures, little or no fines
GM = well-grained, gravelly sand, gravel-sand mixtures, little or no fines
ML = inorganic silts and very fine sand, or silty clay fine sands
SC = clayey sands, poorly-grained sand-clay mixtures
SM = silty sands, poorly-grained sand-silt mixtures
SG = poorly-grained sands, gravelly sands, little or no fines
SW = well-grained sands, gravelly sands, little or no fines

NOTES:
(1) Unified Soil Classification based on ASTM D2487 or ASTM D2488.
(2) Soil Classification of Embedment also applies to dual symbol or borderline soils beginning with the symbol shown in column.
(3) Fines are soil particles that pass a No. 200 (75 \( \mu m \)) sieve (clays and silts).
(4) P denotes standard Proctor density (ASTM D698 or AASHO T-99). BD denotes relative density (ASTM D4253 or ASTM D4254).
(5) Does not apply to SP soils containing more than 50% fine sand (passing No. 40 sieve). These soils shall be treated as ML soil for the purposes of this Table.
(6) All faces of crushed rock shall be fractured.
(7) Degree of compaction of pipe embedment is not applicable to CLSM. Use of \( E' \) for CLSM is permitted in this case only if the entire pipe circumference is embedded in CLSM.

Table A-2
Bedding Constant, \( K \)

<table>
<thead>
<tr>
<th>Total Bedding Angle, deg</th>
<th>Bedding Constant, ( K )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.110</td>
</tr>
<tr>
<td>20</td>
<td>0.106</td>
</tr>
<tr>
<td>45</td>
<td>0.105</td>
</tr>
<tr>
<td>60</td>
<td>0.102</td>
</tr>
<tr>
<td>90</td>
<td>0.096</td>
</tr>
<tr>
<td>120</td>
<td>0.090</td>
</tr>
</tbody>
</table>

GENERAL NOTE: Total bedding angle is illustrated in Figure A-4.
manufacturing tolerances or accuracy of the thickness measurements, generic historical data may be used to predict the rate of metal loss when justified. Prediction of the rate of metal loss shall take into account (b)-(6), as applicable.

(2) Internal Corrosion. The predicted rate of metal loss on the inside surface of the piping item shall include both general corrosion and local corrosion, as applicable. Mitigation of future metal loss, such as improved surface condition or water treatment, may be credited in the prediction of metal loss rate, when justified. The requirements of one or more of (a), (b), (c), or (d) shall be met. The same method need not be used for both general and local corrosion.

(a) The rate of metal loss may be determined using measurements from the current examination of the metal loss region, and from one or more previous examinations of the same metal loss region.

(b) The rate of metal loss may be determined, using repeat measurements at two or more times, at another location in a piping item, which may be above ground, provided the following are the same for both the metal loss region under analytical evaluation and the other location, as applicable:

(1) piping material
(2) lining material, age, and condition
(3) type of joint that is under analytical evaluation
(4) fluid and fluid additives, such as water treatment
(5) oxygen content of the fluid
(6) type of flow conditions, such as stagnant, continuous, intermittent, or dead leg conditions, including dead leg orientation; a dead leg is a section of pipe with no flow connected to a pipe with flow

Differences between temperatures and flow rates of the piping item containing the metal loss region under analytical evaluation and the piping system containing the other location of measured metal loss shall be taken into account.

(c) The rate of metal loss may be determined using repeat measurements of corrosion coupons or probes at two or more times, provided the following are taken into account, as applicable:

(1) any difference between exposure times of the piping item and the coupon or probe
(2) any differences between corrosion susceptibility of the piping item base metal and the joint
(3) potential for loss of lining protection
(4) if repeat measurements of metal loss in accordance with (a), (b), or (c) are not available, or if calculation of the rate of metal loss from repeat measurements is not practical due to uncertainties related to pipe manufacturing tolerances or accuracy of the thickness measurements, generic historical data may be used to predict the rate of metal loss when justified. Prediction of the rate of metal loss shall take into account (b)-(1) through (b)-(6), as applicable, and temperatures and flow rates of the piping item containing the metal loss region under analytical evaluation. The projected future metal loss during the evaluation period, \( \Delta N_{\text{eval}} \), shall be calculated as follows:

\[
\Delta N_{\text{eval}} = \left( F_{\text{gen}, \text{i.p.}} R_{\text{gen}, \text{i.d.}} + F_{\text{loc}, \text{i.d.}} R_{\text{loc}, \text{i.d.}} \right) \left( F_{\text{gen}, \text{o.d.}} R_{\text{gen}, \text{o.d.}} + F_{\text{loc}, \text{o.d.}} R_{\text{loc}, \text{o.d.}} \right) \frac{t_{\text{eval}}}{100}
\]

where

\( F_{\text{gen}, \text{i.p.}} \) = factor to account for uncertainty in predicted rate of metal loss due to general corrosion on the inside surface, dimensionless
\( F_{\text{gen}, \text{o.d.}} \) = factor to account for uncertainty in predicted rate of metal loss due to general corrosion on the outside surface, dimensionless
\( F_{\text{loc}, \text{i.d.}} \) = factor to account for uncertainty in predicted rate of metal loss due to local corrosion on the inside surface, dimensionless
\( F_{\text{loc}, \text{o.d.}} \) = factor to account for uncertainty in predicted rate of metal loss due to local corrosion on the outside surface, dimensionless

\( R_{\text{gen}, \text{i.p.}} \) = predicted rate of metal loss on the inside surface due to general corrosion during the evaluation period, in./yr (mm/yr)
\( R_{\text{gen}, \text{o.d.}} \) = predicted rate of metal loss on the outside surface due to general corrosion during the evaluation period, in./yr (mm/yr)
\( R_{\text{loc}, \text{i.d.}} \) = predicted rate of metal loss on the inside surface due to local corrosion during the evaluation period, in./yr (mm/yr)
\( R_{\text{loc}, \text{o.d.}} \) = predicted rate of metal loss on the outside surface due to local corrosion during the evaluation period, in./yr (mm/yr)

\( F_{\text{eval}} \) = predicted rate of metal loss during the evaluation period on the internal surface, in./yr (mm/yr)

\( \Delta t_{\text{eval}} \) = project future metal loss during the evaluation period, in. (mm)

\( t_{\text{eval}} \) = length of the evaluation period, yr

In eq. (1), the term \( F_{\text{loc}, \text{i.d.}} R_{\text{loc}, \text{i.d.}} \) shall be included only at locations where there is local corrosion on the inside surface, and the term \( F_{\text{loc}, \text{o.d.}} R_{\text{loc}, \text{o.d.}} \) shall be included only at locations where there is local corrosion on the outside surface.
### Table 1

Values of Allowable Wall Thickness and Length of Local Metal Loss Region of Figure 5

<table>
<thead>
<tr>
<th>$L_m(t)/\left(R t_{\text{min}}\right)^{1/2}$</th>
<th>$\varepsilon_{\text{local}}/\varepsilon_{\text{min}}$ of Curve 1 if $L_m(t) \leq (R t_{\text{min}})^{1/2}$</th>
<th>$\varepsilon_{\text{local}}/\varepsilon_{\text{min}}$ of Curve 2 if $L_m(t) &gt; (R t_{\text{min}})^{1/2}$</th>
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</tbody>
</table>

9 (N-806-1)
CASE (continued)

**N-806-1**

\[ h_w = \text{height of water table above top of piping item, in. (mm)} \]

\[ I_{xx} = \text{moment of inertia of the area of the local metal loss region, } A, \text{ about the local axis that is parallel to the } x'x' \text{ axis and intersects the centroid of the local metal loss region, at the end of the evaluation period, in.}^2 \text{ (mm}^4) \]

\[ I_{w1} = \text{projected minimum moment of inertia of the cross-section of the piping item containing the metal loss region about the neutral axis, considering all orientations of the cross-section of the neutral axis, in.}^2 \text{ (mm}^4) \]

\[ I_{pwr} = \text{through-wall bending moment of inertia of the piping item per unit length at the end of the evaluation period, in.}^2 \text{ (mm}^4) \]

\[ I_{w} = \text{moment of inertia of the cross-section of the piping item about the } x'x' \text{ axis at the end of the evaluation period and as calculated in the absence of the local metal loss region, in.}^2 \text{ (mm}^4) \]

\[ K = \text{bedding constant, as given in Table A-2, or may be obtained from AWWA M 11, dimensionless} \]

\[ L = \text{maximum extent of local metal loss region with wall thickness less than } t_{ww}, \text{ at the end of the evaluation period, in. (mm)} \]

\[ L_{w} = \text{maximum extent of local metal loss region with wall thickness less than } t_{w}, \text{ at the end of the evaluation period, in. (mm)} \]

\[ L_{w(a)} = \text{maximum axial extent of local metal loss region with wall thickness less than } t_{w}, \text{ at the end of the evaluation period, in. (mm)} \]

\[ L_{w(a),max} = \text{maximum of the axial extents of wall thickness less than } t_{w}, \text{ at the end of the evaluation period, in. (mm)} \]

\[ L_{w(a),max} = \text{maximum axial extent of local metal loss region with wall thickness less than } t_{w}, \text{ at the end of the evaluation period, in. (mm)} \]

\[ L_{w(a),min} = \text{minimum axial extent of local metal loss region with wall thickness less than } t_{w}, \text{ at the end of the evaluation period, in. (mm)} \]

\[ N = \text{number of point measurements of wall thickness in the metal loss region, dimensionless} \]

\[ P_{cr} = \text{critical buckling pressure for the piping item, psi (MPa)} \]

\[ P_0 = \text{Design Pressure, psi (MPa)} \]

\[ P_{gw} = \text{hydrostatic pressure around the piping item due to groundwater, psi (MPa)} \]

\[ P_{neg} = \text{negative internal pressure, where the numerical value is negative, psi (MPa)} \]

\[ P_{mil} = \text{pressure at the top of the piping item due to weight of the trench fill, psi (MPa)} \]

\[ P_{ss} = \text{pressure at the top of the piping item due to soil and surface loads, psi (MPa)} \]

\[ P_{ss'} = \text{total external pressure plus negative internal pressure, psi (MPa)} \]

\[ P_{ext} = \text{pressure at the top of the piping item due to surface loads, psi (MPa)} \]

\[ Q = \text{parameter used in the calculation of the length over which the wall thickness is averaged, dimensionless} \]

\[ R = \text{pipe mean radius at the end of the evaluation period, in. (mm)} \]

\[ R_w = \text{outside radius of the local metal loss region at the end of the evaluation period, in. (mm)} \]

\[ R_t = \text{radius of the elbow or bend to the elbow or bend centerline, in. (mm)} \]

\[ R_{gen,i,d} = \text{predicted rate of metal loss on the inside surface due to general corrosion during the evaluation period, in./yr (mm/yr)} \]

\[ R_{ext,i,o} = \text{predicted rate of metal loss on the outside surface due to general corrosion during the evaluation period, in./yr (mm/yr)} \]

\[ R_{loc,i,d} = \text{predicted rate of metal loss on the inside surface due to local corrosion during the evaluation period, in./yr (mm/yr)} \]

\[ R_{loc,o,d} = \text{predicted rate of metal loss on the outside surface due to local corrosion during the evaluation period, in./yr (mm/yr)} \]

\[ R_{ad,0.5} = \text{mean radius of the piping item based on outer radius and } t_{w}, \text{ in. (mm)} \]

\[ R_{ad} = \text{outside radius of the piping item adjacent to the metal loss region, in. (mm)} \]

\[ R_w = \text{buoyancy factor, dimensionless} \]

\[ S = \text{allowable stress for Class 2 and 3 components, at the Design Temperature, psi (MPa)} \]

\[ S = \text{length of the metal loss region in the longitudinal direction, in. (mm)} \]

\[ S_{loc} = \text{allowable stress at the design temperature or the temperature consistent with the loading under consideration, psi (MPa)} \]

\[ S_{loc} = \text{specified ultimate tensile strength of the material at the temperature consistent with the loading under consideration, psi (MPa)} \]

\[ S_{loc} = \text{specified yield strength of the material at the temperature consistent with the loading under consideration, psi (MPa)} \]

\[ S_{loc} = \text{pressure-based minimum allowable local wall thickness of the local metal loss region, in. (mm)} \]

\[ t_{aluc} = \text{a value of } t_{aluc} \text{ for protection against pressure blowout of a local metal loss region with limited axial and circumferential extent, in. (mm)} \]

\[ t_{aluc} = \text{a value of } t_{aluc} \text{ for area reinforcement of a local metal loss region with limited axial and circumferential extent, in. (mm)} \]

\[ t_{loc} = \text{current wall thickness of the metal loss region, in. (mm)} \]
CASES OF ASME BOILER AND PRESSURE VESSEL CODE

Case N-806-1
Analytical Evaluation of Metal Loss in Class 2 and 3 Metallic Piping Buried in a Back-Filled Trench
Section XI, Division 1

Inquiry: What methods may be used to evaluate Class 2 and 3 metallic piping items (e.g., pipe and fittings) buried in a back-filled trench with metal loss on the inside or outside surfaces?

Reply: It is the opinion of the Committee that the following methods may be used to evaluate Class 2 and 3 metallic piping items buried in a back-filled trench with metal loss on the inside or outside surfaces.

1 SCOPE

(a) These requirements apply to Section III, B31.1, and B31.7 metallic piping classified by the Owner as Class 2 or 3 and buried in a back-filled trench. The provisions of this Case do not apply to the following:
   (1) cast iron piping items
   (2) leakage through a piping item or piping joint
   (3) a cracked piping item or piping joint

(b) The provisions of this Case apply to Class 2 and 3 piping for which the maximum normal operating temperature does not exceed 200°F (93°C).

(c) The rate of metal loss on both the inside and outside surfaces of the piping item during the evaluation period shall be determined in accordance with 3.1. The rate of metal loss analysis shall consider the relevant mechanisms, such as general corrosion or wastage, and local corrosion such as pitting. The analysis shall project the metal loss region to the end of the evaluation period.

(d) Validation of predicted rate of metal loss shall meet the requirements of 3.2.

(e) If multiple metal loss regions are detected, the interaction and combined area of metal loss in a given pipe section shall be accounted for in the analytical evaluation. Concurrent metal loss at the same location on both the inside and outside surfaces, as applicable, in a given pipe section shall be accounted for in the analytical evaluation.

(f) The projected metal loss region at the end of the evaluation period shall be analytically evaluated using the acceptance standards of 4. One of two levels of analytical evaluation of the metal loss region shall be used, as follows.

(1) Level 1 analytical evaluation of 5 requires that the piping item meets the design requirements.

(2) Level 2 analytical evaluation of 6 is based on use of engineering equations to demonstrate that requirements based on internal pressure loading, soil and surcharge loads, bending moments, axial forces, and transverse forces are met.

(g) Subsequent examination of the metal loss region shall be performed no later than the end of the evaluation period. If examinations reveal that the metal loss does not meet the acceptance criteria of this Case, a repair/replacement activity shall be performed. A re-evaluation or repair/replacement activity shall be performed for operation beyond the end of the evaluation period.

(h) Examination or repair/replacement activity of the affected piping item shall be performed no later than when the metal loss region is projected to no longer meet the acceptance criteria of 4.

3 CHARACTERIZATION OF METAL LOSS

3.1 Current and Projected Future Wall Thickness

(a) Current wall thickness of the metal loss region, \( t_c \), shall be characterized by volumetric thickness measurement or by physical measurement. The condition of the full pipe circumference shall be assessed and the metal loss region shall be examined inspected to characterize the extent of degradation. The examination techniques used to characterize the metal loss shall be applicable to
(e) The projected future metal loss during the evaluation period, \( \Delta s_{\text{ml}} \), shall be calculated as follows:

\[
\Delta s_{\text{ml}} = (F_{\text{ml}, \text{IP}, R_{\text{ml}, \text{IP}}} + F_{\text{ml}, \text{IP}, D, R_{\text{ml}, \text{IP}}} + F_{\text{ct}, \text{IP}, D, R_{\text{ct}, \text{IP}}}) t_{\text{ev}} \quad (4)
\]

\[
\Delta s_{\text{ml}} = (F_{\text{ct}, \text{IP}, R_{\text{ct}, \text{IP}}} + F_{\text{ct}, \text{IP}, D, \text{inc}}) t_{\text{ev}} + F_{\text{ct}, \text{IP}, D, \text{inc}} R_{\text{ct}, \text{IP}} \quad (1)
\]

where

- \( F_{\text{gen}, \text{IP}} = \) factor to account for uncertainty in predicted rate of metal loss due to general corrosion on the inside surface, dimensionless
- \( F_{\text{gen}, \text{IP}} = \) factor to account for uncertainty in predicted rate of metal loss due to general corrosion on the outside surface, dimensionless
- \( F_{\text{loc}, \text{IP}} = \) factor to account for uncertainty in predicted rate of metal loss due to local corrosion on the inside surface, dimensionless
- \( F_{\text{loc}, \text{IP}} = \) factor to account for uncertainty in predicted rate of metal loss due to local corrosion on the outside surface, dimensionless
- \( R_{\text{gen}, \text{IP}} = \) predicted rate of metal loss on the inside surface due to general corrosion during the evaluation period, in./yr (mm/yr)
- \( R_{\text{gen}, \text{IP}} = \) predicted rate of metal loss on the outside surface due to general corrosion during the evaluation period, in./yr (mm/yr)
- \( R_{\text{loc}, \text{IP}} = \) predicted rate of metal loss on the inside surface due to local corrosion during the evaluation period, in./yr (mm/yr)
- \( R_{\text{loc}, \text{IP}} = \) predicted rate of metal loss on the outside surface due to local corrosion during the evaluation period, in./yr (mm/yr)
- \( F_{\text{ml}, \text{IP}, D, R_{\text{ml}, \text{IP}}} = \) factor to account for uncertainty in predicted rate of metal loss on the internal surface, dimensionless
- \( F_{\text{ml}, \text{IP}, D, R_{\text{ml}, \text{IP}}} = \) factor to account for uncertainty in predicted rate of metal loss on the external surface, dimensionless
- \( R_{\text{ml}, \text{IP}} = \) predicted rate of metal loss during the evaluation period on the internal surface, in./yr (mm/yr)
- \( R_{\text{ml}, \text{IP}} = \) predicted rate of metal loss during the evaluation period on the external surface, in./yr (mm/yr)
- \( \Delta s_{\text{ml}} = \) projected future metal loss during the evaluation period, in. (mm)
- \( t_{\text{ev}} = \) length of the evaluation period, yr

In eq. (1), the term \( F_{\text{loc}, \text{IP}, R_{\text{loc}, \text{IP}}} \) shall be included only at locations where there is local corrosion on the inside surface, and the term \( F_{\text{loc}, \text{IP}, R_{\text{loc}, \text{IP}}} \) shall be included only at locations where there is local corrosion on the outside surface.

Determination of predicted rates of metal loss and factors to account for uncertainties in predicted metal loss shall be the responsibility of the Owner.

(d) The projected distribution of wall thickness of the metal loss region at the end of the evaluation period, \( t_p \), shall be determined. The projected wall thickness of the metal loss region may have a different value at any given location within the metal loss region.

\[
t_p = t_c - \Delta s_{\text{ml}} \quad (2)
\]

where

- \( t_c = \) current wall thickness of the metal loss region, in. (mm)
- \( t_p = \) projected wall thickness of the metal loss region at the end of the evaluation period, in. (mm)

The minimum value of \( t_p \) anywhere in the metal loss region is \( t_{\text{min}} \).

(e) The projected wall thickness of the material surrounding the metal loss region at the end of the evaluation period, \( t_{\text{pipe}} \), shall be determined.

(f) If there is evidence that the rate of metal loss is greater than projected, the metal loss rate evaluation shall be updated. The metal loss rate evaluation may also be updated if the rate of metal loss is less than projected.

### 3.2 Validation of Predicted Rate of Metal Loss

The time interval, \( \tau_{\text{math}} \), from the start of the evaluation period, for the wall thickness of the metal loss region under analytical evaluation to reach the minimum allowable wall thickness in accordance with the acceptance criteria of this Case shall be determined. Subsequent validation of the predicted rate of metal loss shall be performed in accordance with one of 3.2(a), 3.2(b), or 3.2(c) for external corrosion, and in accordance with one of 3.2(a), 3.2(b), or 3.2(d) for internal corrosion.

(a) The rate of metal loss may be validated by subsequent examination of the metal loss region no later than the lesser of 0.5 \( \tau_{\text{math}} \) or \( \tau_{\text{ev}} \) from the start of the evaluation period. The predicted rate of metal loss for the metal loss region under analytical evaluation is validated if the measured rate of metal loss is less than or equal to the predicted rate.

(b) The rate of metal loss may be validated by repeat measurements at another location in a piping item that has a predicted metal loss rate greater than or equal to the rate of the metal loss region under analytical evaluation, as determined in accordance with items (i) through (vi) of 3.1(c)(1)(a) for external corrosion, and items (i) through (vi) of 3.1(c)(2) for internal corrosion, at two or more times that are no later than the lesser of 0.5 \( \tau_{\text{math}} \) or \( \tau_{\text{ev}} \) from the start of the evaluation period. Measurements obtained prior to the start of the evaluation period may be used. At least one measurement shall be performed during a time interval that is the lesser of 0.5 \( \tau_{\text{math}} \) or \( \tau_{\text{ev}} \) from the start of the evaluation period. The predicted rate of metal loss for the metal loss region under analytical evaluation is validated if the measured rate of metal loss at the other location is less than or equal to the predicted rate.

(c) For metal loss due to external corrosion, the rate of metal loss may be validated using repeat measurements of corrosion coupons, linear polarization probes, or electrical resistance probes, at two or more times that are no later than the lesser of 0.5 \( \tau_{\text{math}} \) or \( \tau_{\text{ev}} \) from the start of the evaluation period.
### TABLE 1
VALUES OF ALLOWABLE WALL THICKNESS AND LENGTH
OF LOCAL METAL LOSS REGION OF FIGURE 5

<table>
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<tr>
<th>( \frac{L_{min}}{R_{min}} )</th>
<th>( \frac{L_{max}}{R_{min}} ) of Curve 1 for ( L_{max} \leq \left( \frac{R_{min}}{L_{min}} \right)^{1/2} )</th>
<th>( \frac{L_{max}}{R_{min}} ) of Curve 2 for ( L_{max} &gt; \left( \frac{R_{min}}{L_{min}} \right)^{1/2} )</th>
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</tr>
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<td>0.874</td>
<td>0.956</td>
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<td>0.964</td>
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<tr>
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<td>0.990</td>
</tr>
<tr>
<td>8.00</td>
<td>1.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Note to Editor: New Table 1.
\[ X = \text{surface width of the area over which the surface load is uniformly spread as normalized by the burial depth of the piping item, dimensionless} \]
\[ Y = \text{distance between the neutral axis of the cross-section of the piping item containing the metal loss region at the end of the evaluation period, } x - x, \text{ and the axis } x-x, \text{ in. (mm)} \]
\[ Y_{LX} = \text{distance between the centroid of the metal loss region and the } x-x \text{ axis at the end of the evaluation period, in. (mm)} \]
\[ \Delta y = \text{out-of-round deflection of the cross-section of the piping item causing ovality, in. (mm)} \]
\[ Y = \text{surface length of the area over which the surface load is uniformly spread as normalized by the burial depth of the piping item, dimensionless} \]
\[ Z = \text{parameter dependent on surface width and length of the area over which the surface load is uniformly spread as normalized by the burial depth of the piping item, dimensionless} \]
\[ Z_s = \text{surface area over which the surface load is uniformly spread as normalized by the square of burial depth of the piping item, dimensionless} \]
\[ Z_{min} = \text{minimum section modulus of the cross-section of the piping item containing the metal loss region, including consideration of the shift of the neutral axis of the cross-section containing the metal loss region, in.}^2 \text{ (mm}^2) \]
\[ \alpha = \text{parameter used to calculate the Coefficient of Variation (COV) of the wall thickness measurements, in.}^2 \text{ (mm}^2) \]
\[ \phi = \text{angle from the extrados of the elbow or bend to the boundary of the local metal loss region that is closest to the intrados, as measured in the pipe circumferential cross-section, see Figure 3, radians} \]
\[ \Phi_H = \text{hoop stiffness parameter, dimensionless} \]
\[ \gamma_s = \text{unit weight of dry soil or trench fill, lb/in.}^3 \text{ (N/mm}^3) \]
\[ \gamma_w = \text{unit weight of water above the top of the piping item, lb/in.}^3 \text{ (N/mm}^3) \]
\[ \Theta = \text{one-half of the circumferential angular extent of the metal loss region, radians} \]
\[ \eta = \text{wall thickness ratio used in the calculation of the length over which the wall thickness is averaged} \]
\[ \sigma_{max} = \text{through-wall bending stress due to ovalization of the piping item, psi (MPa)} \]
\[ \tau_{ev} = \text{length of the evaluation period, yr} \]
\[ \Omega = \text{ovality of the piping item cross-section, dimensionless} \]
\[ \Omega_{max} = \text{maximum allowable ovality of the piping item cross-section, dimensionless} \]

Note to Editor: New nomenclature is given below.

\[ F_{gas,lo} = \text{factor to account for uncertainty in predicted rate of metal loss due to general corrosion on the inside surface, dimensionless} \]
\[ F_{gas,ow} = \text{factor to account for uncertainty in predicted rate of metal loss due to general corrosion on the outside surface, dimensionless} \]
\[ F_{loc,lo} = \text{factor to account for uncertainty in predicted rate of metal loss due to local corrosion on the inside surface, dimensionless} \]
\[ F_{loc,ow} = \text{factor to account for uncertainty in predicted rate of metal loss due to local corrosion on the outside surface, dimensionless} \]

\[ R_{gas,lo} = \text{predicted rate of metal loss on the inside surface due to general corrosion during the evaluation period, in./yr (mm/yr)} \]
\[ R_{gas,ow} = \text{predicted rate of metal loss on the outside surface due to general corrosion during the evaluation period, in./yr (mm/yr)} \]
\[ R_{loc,lo} = \text{predicted rate of metal loss on the inside surface due to local corrosion during the evaluation period, in./yr (mm/yr)} \]
\[ R_{loc,ow} = \text{predicted rate of metal loss on the outside surface due to local corrosion during the evaluation period, in./yr (mm/yr)} \]

\[ \Delta t_{eval} = \text{time interval, from the start of the evaluation period, for the wall thickness of the metal loss region under analytical evaluation to reach the minimum allowable wall thickness, in accordance with the acceptance criteria of this Case} \]
TABLE A-1

MODULUS OF SOIL REACTION, E'

<table>
<thead>
<tr>
<th>Classification of Pipe Embedment(1,2,3)</th>
<th>E' for Degree of Compaction of Pipe Embedment(4), psi (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dumped</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Clays and silts with any combination of sand plus gravel that is less than 30%, CL, ML</td>
<td>50 (0.3)</td>
</tr>
<tr>
<td>Sandy or gravelly silts and clays with any combination of sand plus gravel that is more than 30%, CL, ML</td>
<td>150 (1.1)</td>
</tr>
<tr>
<td>Sands and gravels with 13% or more fines GC, GM, SC, SM</td>
<td>200 (1.4)</td>
</tr>
<tr>
<td>Sands and gravels with 12% or less fines GW, GP, SW, SP (Note 5)</td>
<td>1,000 (7)</td>
</tr>
<tr>
<td>Crushed rock with less than 25% passing 3/8 in. (10 mm) sieve and less than 12% fines (Note 6)</td>
<td>3,000 (21)</td>
</tr>
<tr>
<td>Controlled Low Strength Material (CLSM) (Note 7)</td>
<td></td>
</tr>
</tbody>
</table>

GENERAL NOTES:
(a) Values only valid for pipe cover of 50 ft (15 m) or less.
(b) The E' values shown are only valid when used with a prism load as defined by eq. (A-6).
(c) Only applicable when the trench walls are as stiff or stiffer than the embedment soil beside the pipe.

NOTES:
(1) Unified Soil Classification based on ASTM D 2487 or ASTM D 2488.
(2) "Soil Classification of Embedment" also applies to dual symbol or borderline soils beginning with the symbol shown in column.
(3) Fines are soil particles that pass a No. 200 (75 micrometer) sieve (clays and silts).
(4) CL denotes inorganic clays of low to medium plasticity.
(5) GC denotes clayey gravels, poorly-graded gravel-sand-clay mixtures.
(6) GM denotes silty gravels, poorly-graded gravel-sand-silt mixtures.
(7) GP denotes poorly-graded gravels, gravel-sand mixtures; little or no fines.
(8) GW denotes well-graded gravels, gravel-sand mixtures; little or no fines.
(9) ML denotes inorganic silts and very fine sand, or silty or clayey fine sands.
(10) SC denotes clayey sands, poorly-graded sand-clay mixtures.
(11) SM denotes silty sands, poorly-graded sand-silt mixtures.
(12) SP denotes poorly-graded sands, gravelly sands, little or no fines.
(13) SW denotes well-graded sands, gravelly sands, little or no fines.
(14) P denotes standard Proctor density (ASTM D 698 or AASHTO T-99).
(15) BD denotes Relative Density (ASTM D 4253 or ASTM D 4254).
(16) Does not apply to SP soils containing more than 50% fine sand (passing No 40 sieve). These soils shall be treated as ML soil for the purposes of this table.
(17) All faces of "Crushed Rock" shall be fractured.
(18) Degree of compaction of pipe embedment is not applicable to CLSM.
(19) Use of E' for CLSM is permitted in this Case only if the entire pipe circumference is embedded in CLSM.
### TABLE A-2
**BEDDING CONSTANT, K**

<table>
<thead>
<tr>
<th>Total Bedding Angle(^{(1)}) (deg.)</th>
<th>Bedding Constant, K</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.110</td>
</tr>
<tr>
<td>30</td>
<td>0.108</td>
</tr>
<tr>
<td>45</td>
<td>0.105</td>
</tr>
<tr>
<td>60</td>
<td>0.102</td>
</tr>
<tr>
<td>90</td>
<td>0.096</td>
</tr>
<tr>
<td>120</td>
<td>0.090</td>
</tr>
</tbody>
</table>

**Note:**
(1) Total bedding angle is illustrated in Figure A-4.

---

### Figure A-4  Illustration of Total Bedding Angle

[Diagram showing ground surface, total bedding angle, haunching, and bedding layers]
### Table IWE-2500-1 (E-A)
**Examination Category E-A, Containment Surfaces**

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Parts Examined</th>
<th>Examination Requirements/ Fig. No. [Note (1)]</th>
<th>Examination Method</th>
<th>Acceptance Standard</th>
<th>Extent and Frequency of Examination</th>
<th>Deferral of Inspection to End of Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1.10</td>
<td>Containment Vessel Pressure-Retaining Boundary [Note (1)]</td>
<td>IWE-2310</td>
<td>General visual</td>
<td>IWE-3510</td>
<td>100% During each Inspection Period</td>
<td>100% During each Inspection Period</td>
</tr>
<tr>
<td>E1.11</td>
<td>Accessible Surface Areas</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E1.12</td>
<td>Wetted Surfaces of Submerged Areas</td>
<td>IWE-2310</td>
<td>VT-3</td>
<td>IWE-3510</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>E1.20</td>
<td>BWR Vent System Accessible Surface Areas</td>
<td>IWE-2310</td>
<td>VT-3</td>
<td>IWE-3510</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>E1.30</td>
<td>Moisture Barriers [Note (4)]</td>
<td>IWE-2310, Figure IWE-2500-1</td>
<td>General visual</td>
<td>IWE-3510</td>
<td>100% During each Inspection Period</td>
<td>100% During each Inspection Period</td>
</tr>
</tbody>
</table>

**NOTES:**

1. Examination shall include all accessible interior and exterior surfaces of Class MC components, parts, and appurtenances, and metallic shell and penetration liners of Class CC components. The following items shall be examined:
   
   (a) integral attachments and structures that are parts of reinforcing structure, such as stiffening rings, manhole frames, and reinforcement around openings.
   
   (b) surfaces of attachment welds between structural attachments and the pressure-retaining boundary or reinforcing structure, except for nonstructural or temporary attachments as defined in NE-4435 and minor permanent attachments as defined in CC-4543A.
   
   (c) surfaces of containment structural and pressure boundary welds, including longitudinal welds (Category A), circumferential welds (Category B), flange welds (Category C), and nozzle-to-shell welds (Category D) as defined in NE-3351 for Class MC and CC-3040 for Class CC; and surfaces of Fixed Head and Bellows Seal Circumferential Welds joined to the Penetration.
   
   (d) pressure-retaining bolted connections, including bolts, studs, nuts, bushings, washers, and threads in base material and flange ligaments between fastener holes. Bolted connections need not be disassembled for performance of examinations.
   
2. Examinations may be performed at any time during the interval, provided successive examinations are performed no less frequently than every third period.
3. Includes flow channeling devices within containment vessels.
4. Examination shall include moisture barrier materials intended to prevent intrusion of moisture against inaccessible areas of the pressure-retaining metal containment shell or liner at concrete-to-metal interfaces and at metal-to-metal interfaces which are not seal-welded. Containment moisture barrier materials include caulking, flashing, and other sealants used for this application.
## Table IWE-2500-1 (E-C)
### Examination Category E-C, Containment Surfaces Requiring Augmented Examination

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Parts Examined</th>
<th>Examination Requirements/ Figure No.</th>
<th>Examination Method</th>
<th>Acceptance Standard</th>
<th>Extent and Frequency of Examination</th>
<th>Deferral of Inspection to End of Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>E4.10</td>
<td>Containment Surface Areas [Note (1)]</td>
<td>IWE-2310, IWE-2500(b)(1)</td>
<td>VT-1</td>
<td>IWE-3520</td>
<td>100% of surface areas identified by IWE-1242 [Note (1)] during each inspection period</td>
<td>Not permissible</td>
</tr>
<tr>
<td>E4.11</td>
<td>Visible Surfaces</td>
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<td></td>
<td>100% of surface areas identified by IWE-1242 [Note (1)] during each inspection period</td>
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<tr>
<td>E4.12</td>
<td>Surface Area Grid Minimum Wall Thickness Locations</td>
<td>IWE-2500(b)(2), (b)(3), (b)(4)</td>
<td>Ultrasonic thickness</td>
<td>IWE-3520</td>
<td>100% of minimum wall thickness locations during each inspection period established in accordance with IWE-2500(b)(3) and (b)(4)</td>
<td>Not permissible</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100% of minimum wall thickness locations during each inspection period established in accordance with IWE-2500(b)(3) and (b)(4)</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:**
(1) Containment surface areas requiring augmented examination are those identified in IWE-1240.