material is consumed. The test sample for ESW shall be removed from the weld metal of the mechanical properties test coupon. Where a chemical analysis is required for a welding material which does not have a mechanical properties test requirement, a chemical analysis test coupon shall be prepared as required by WC-2431.1(c), except that heat treatment of the coupon is not required and the weld coupon thickness requirements of WC-2431.1(c) do not apply.

(d) The alternate method provided in (b) above for the preparation of samples for chemical analysis of welding material to be used for corrosion resistant overlay cladding shall require a test weld made in accordance with the essential variables of the welding procedure specification that will be followed when the welding material is consumed. The test weld shall be made in conformance with the requirements of Section IX, QW-214. The removal of chemical analysis samples shall conform to QW-453 for the minimum thickness for which the Welding Procedure Specification is qualified.

WC-2432.2 Requirements for Chemical Analysis.
The chemical elements to be determined, the composition requirements of the weld metal, and the recording of results of the chemical analysis shall be in accordance with (a), (b), and (c) below.

(a) Welding material of ferrous alloy A-No. 8 (Section IX, Table QW-442) shall be analyzed for the elements listed in Table WC-2432.2-1 and for any other elements specified either in the welding material specification referenced by the Welding Procedure Specification or in the Welding Procedure Specification.

(b) The chemical composition of the weld metal or filler metal shall conform to the welding material specification for elements having specified percentage composition limits. Where the Welding Procedure Specification contains a modification of the composition limits of SFA or other referenced welding material specifications, or provides limits for additional elements, these composition limits of the Welding Procedure Specification shall apply for acceptability.

(c) The results of the chemical analysis shall be reported in accordance with NCA-3862.1. Elements listed in Table WC-2432.2-1 but not specified in the welding material specification or Welding Procedure Specification shall be reported for information only.

WC-2433 Delta Ferrite Determination

A determination of delta ferrite shall be performed on A-No. 8 weld material (Section IX, Table QW-442) backing filler metal (consumable inserts; bare electrode, rod, or wire filler metal; or weld metal, except that delta ferrite determinations are not required for SFA-5.4 Type 16-8-2 or A-No. 8 weld filler metal to be used for weld metal cladding.

WC-2433.1 Method. Delta ferrite determinations of welding material, including consumable insert material, shall be made using a magnetic measuring instrument and weld deposits made in accordance with (b) below. Alternatively, the delta ferrite determinations for welding materials may be performed by the use of the chemical analysis of WC-2432 in conjunction with Figure WC-2433.1-1.

(a) Calibration of magnetic instruments shall conform to AWS A 4.2.

(b) The weld deposit for magnetic delta ferrite determination shall be made in accordance with WC-2432.1(c).

(c) A minimum of six ferrite readings shall be taken on the surface of the weld deposit. The readings obtained shall be averaged to a single Ferrite Number.

WC-2433.2 Acceptance Standards. The minimum acceptable delta ferrite shall be 5FN (Ferrite Number). The results of the delta ferrite determination shall be included in the Certified Material Test Report of WC-2130 or WC-4120.

WC-2440 STORAGE AND HANDLING OF WELDING MATERIAL

Suitable storage and handling of electrodes, flux, and other welding materials shall be maintained. Precautions shall be taken to minimize absorption of moisture by fluxes and cored, fabricated, and coated electrodes.

WC-2500 EXAMINATION AND REPAIR OF CONTAINMENT MATERIAL

WC-2510 CONTAINMENT MATERIAL

Containment material shall be examined and repaired in accordance with the material specification and as otherwise required by this subarticle.

WC-2530 EXAMINATION AND REPAIR OF PLATE

WC-2531 Required Examination

Plates shall be examined in accordance with the requirements of the material specification. In addition, for ferritic steels, the containment shell in the area of the closure welds made, after loading the containment (Figure WC-4265) shall be examined by the ultrasonic method in accordance with WC-2532.
\[ t = \text{nominal thickness of part penetrated} \]
\[ t_c = 0.7 t_n \text{ or } \frac{3}{4} \text{ in. (6 mm)}, \text{ whichever is less} \]
\[ t_n = \text{nominal thickness of penetrating part} \]

(4) The corners of the end of each connection extending less than \( \sqrt{d_{c1}} \) beyond the inner surface of the part penetrated shall be rounded to a radius of one-half the thickness \( t_n \) of the connection or \( \frac{3}{4} \text{ in. (19 mm)}, \text{ whichever is smaller.} \)

(d) Fittings With Internal Threads. Internally threaded fittings shall be limited to NPS 2 (DN 50). Internally threaded fittings shall be attached by means of full penetration groove welds meeting the fabrication requirements of WC-4266(d) and shall be capable of being examined in accordance with WC-5245. The minimum dimensions and geometrical requirements of Figure WC-4266(d)-1 shall be met, where

\[ t_c = 0.7 \ t_n \text{ or } \frac{3}{4} \text{ in. (6 mm)}, \text{ whichever is less} \]
\[ t_n = \text{nominal thickness of neck} \]

(e) Attachment of Nozzles Using Partial Penetration Welds. Partial penetration welds shall meet the fabrication requirements of WC-4266(e) and shall be capable of being examined in accordance with WC-5245. They shall be used only for attachments such as instrumentation openings and inspection openings, which are subjected to essentially no external mechanical loadings and on which there will be no thermal stresses greater than those on the containment itself. Such attachments shall satisfy the requirements of WC-3231(g).

**WC-3254 Structural Attachment Welds**

Welds for structural attachments shall meet the requirements of WC-4432.

**WC-3255 Welding Grooves**

The dimensions and shape of the edges to be joined shall be such as to permit complete fusion and complete joint penetration, except as otherwise permitted in WC-3252.4 or WC-3262.

**WC-3259 Design Requirements for Nozzle Attachment Welds and Other Connections**

The minimum design requirements for nozzle attachment welds and other connections are set forth in (a) and (b) below.

(a) Permitted Types of Nozzles and Other Connections. Nozzles and other connections may be any of the types for which rules are given in this subarticle, provided the requirements of (1) through (5) below are met.

1. Nozzles shall meet requirements regarding location.
2. The attachment weld shall meet the requirements of WC-3252.4.
3. The requirements of WC-3230 shall be met.

4. Type No. 1 full penetration joints shall be used when the openings are in shells 2\( \frac{3}{8} \text{ in. (64 mm)} \) or more in thickness.

5. The welded joints shall be examined by the methods stipulated in WC-5240.

(b) Attachments. Typical attachments are shown in Figure WC-4433-2. The minimum dimensions in this figure are as follows:

\[ a \geq \frac{t}{4} \]
\[ b \geq \frac{t}{2} \]
\[ c \geq t \]

where

\[ c = \text{minimum thickness of weld metal from the root to the face of the weld} \]
\[ t = \text{thickness of attached member} \]

**WC-3260 SPECIAL CONTAINMENT REQUIREMENTS**

**WC-3261 Category A or B Joints Between Sections of Unequal Thickness**

In general, a tapered transition section as shown in Figure WC-3261-1, shall be provided at joints of Categories A and B between sections that differ in thickness by more than one-fourth the thickness of the thinner section. The transition section may be formed by any process that will provide a uniform taper. An ellipsoidal or hemispherical head that has a greater thickness than a cylinder of the same inside diameter may be machined to the outside diameter of the cylinder, provided the remaining thickness is at least as great as that required for a shell of the same diameter. A uniform taper is not required for flanged hubs. The adequacy of the transition shall be evaluated by stress analysis. Stress intensity limitations are given in Section III Appendices, Mandatory Appendix XIII. The requirements of this paragraph do not apply to flanged hubs.

**WC-3262 Category C Full and Partial Penetration Closure Welds in Containments**

**WC-3262.1** Welds in the end closures using a single cover plate [Figure WC-4265 sketch (a)] and made after the containment is loaded may be full or partial penetration and shall be examined in accordance with Table WC-3262-1 either by magnetic particle or liquid penetrant method. The allowable stress intensity values of Section II, Part D, Subpart 1, Tables 2A, 2B, and 4 shall be reduced by the stress reduction factor provided in Table WC-3262-1. The welds shall be tested in accordance with WC-6720.
WC-3262.2 For welds in the end closures using two cover plates [Figure WC-4265, sketch (b)] and made after the containment is loaded, the following apply:

(a) The inner cover plate weld shall use a design stress reduction factor of 0.9. The root and final layers shall be examined by the liquid penetrant or magnetic particle method in accordance with Article WC-5000, and shall be tested in accordance with WC-6720.

(b) The outer cover plate weld shall use the stress reduction factors of Table WC-3262-1 and shall be examined to the requirements of Table WC-3262-1.

WC-3262.3 Vent and drain cover plate welds may be full penetration welds examined in accordance with WC-5250 partial penetration welds using the examination and stress reduction factors of Table WC-3262-1.

WC-3262.4 For partial penetration closure welds, a fatigue strength reduction factor of not less than 4.0 shall be used when fatigue analysis is required.

WC-3700 STRAIN-BASED ACCEPTANCE CRITERIA

The strain-based acceptance criteria are applicable only to the metallic portions of storage containments subject to energy-limited dynamic events. It is not the intent of this subarticle to permit significant regions or major portions of the containment to experience strains at or near the limits of these strain-based acceptance criteria without consideration of the overall component deformation. These strain-based acceptance criteria are established to address the regions of the containment that experience high strains due to the effects of direct impacts. Deformation limits, if any, provided in the Design Specification shall be satisfied.

Section III Appendices, Nonmandatory Appendix FF provides the strain-based acceptance criteria.
**WC-4265 Category C Weld Joints**

Category C weld joints shall be as described in subparagraphs (a) through (d) below.

(a) **Full Penetration Butt Joints.** Category C welds shall be Type No. 1 or Type No. 2 butt joints.

(b) **Full Penetration Corner Joints.** Welds in full penetration corner joints shall be groove welds extending completely through at least one of the parts being joined and shall be fully fused to each part. Typical details for type No. 1 and No. 2 full penetration corner joints are shown in Figure WC-4265-1.

(c) **Partial Penetration Closure Joints.** Partial penetration joints are acceptable for flat head closure welds (per WC-3262). Typical details are shown in Figure WC-4265-2.

(d) **Flat Heads With Hubs.**

(1) Hubs for butt welding to the adjacent shell, head, or other containment parts, as shown in Figure WC-4265-3, for flat heads, shall not be machined from flat plate. The hubs shall be forged in such a manner as to provide in the hub the full minimum tensile strength and elongation specified for the material in the direction parallel to the axis of the containment vessel. Proof of this shall be furnished by a tension test specimen (subsize, if necessary) taken in this direction and as close to the hubs as is practical. One test specimen may represent a group of forgings, provided they are of the same nominal dimensions, from the same heat material and the same heat treatment lot, and forged in the same manner. The minimum height of the hub shall be the lesser of 1\(\frac{1}{2}\) times the thickness of the containment part to which it is welded or \(\frac{3}{4}\) in. (19 mm), but need not be greater than 2 in. (50 mm).

(2) Hubbed flanges shall not be machined from flat plate.

**WC-4266 Category D Weld Joints**

Category D and similar weld joints shall be welded using one of the details of (a) through (e) below.

(a) **Butt-Welded Attachments.** Nozzles shall be attached by Type No. 1 butt welds through either the containment or the nozzle wall as shown in Figure WC-4266(a)-1.

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**Figure WC-4265-1**

Acceptable Full Penetration Weld Details for Category C Joints

![Diagram of Acceptable Full Penetration Weld Details for Category C Joints](image)

**Type No. 1 Corner Welded Joints**

![Diagram of Type No. 1 Corner Welded Joints](image)

**Type No. 2 Corner Welded Joints**

![Diagram of Type No. 2 Corner Welded Joints](image)

**GENERAL NOTE:** For definitions of nomenclature, see WC-3252.3.
(a) Single Closure Weld Detail

(b) Double Closure Weld Detail

**Figure WC-4265-2**
Typical Partial Penetration Weld Detail for Category C Flat Head Closure Joints

- **WC-4267 Types of Attachment Welds**
  - Structural attachments shall be attached to containment by continuous or intermittent welds.

- **WC-4300 WELDING QUALIFICATIONS**

- **WC-4310 GENERAL REQUIREMENTS**

- **WC-4311 Types of Processes Permitted**
  - Only those welding processes which are capable of producing welds in accordance with the welding procedure qualification requirements of Section IX and this Subsection may be used for welding containments or attachments thereto. Any process used shall be such that the records required by WC-4320 can be prepared, except that records for stud welds shall be traceable to the welders and welding operators and not necessarily to each specific weld.

- **WC-4311.1 Stud Welding Restrictions.** Stud welding is acceptable only for nonstructural and temporary attachments (WC-4435). Studs shall be limited to 1 in. (25 mm) maximum length for round studs and an equivalent cross-sectional area for studs of other shapes when welding in the flat position and 3/4 in. (19 mm) diameter for all other welding positions. Postweld heat treatment shall comply with WC-4600, except that time at temperature need not exceed 72 hr regardless of base material thickness. Welding procedure and performance qualification shall comply with the requirements of Section IX.

- **WC-4311.2 Capacitor Discharge Welding.** Capacitor discharge welding may be used for welding temporary attachments and permanent nonstructural attachments provided:
  - (a) temporary attachments are removed in accordance with the provisions of WC-4435(b);
  - (b) the energy output for permanent nonstructural attachments such as strain gages and thermocouples is limited to 125 W-sec and the minimum thickness of the material to which the attachment is made is greater than 0.09 in. (2 mm); and
  - (c) a Welding Procedure Specification is prepared describing the capacitor discharge equipment, the combination of materials to be joined, and the technique of application; qualification of the welding procedure is not required.
Figure WC-4265-3
Typical Flat Heads

GENERAL NOTE: For definition of nomenclature, see WC-3225.