MANDATORY APPENDIX 2
RULES FOR BOLTED FLANGE CONNECTIONS WITH RING TYPE GASKETS

2-1 SCOPE

(a) The rules in Mandatory Appendix 2 apply specifically to the design of bolted flange connections with gaskets that are entirely within the circle enclosed by the bolt holes and with no contact outside this circle, and are to be used in conjunction with the applicable requirements in Subsections A, B, and C of this Division. The hub thickness of weld neck flanges designed to this Appendix shall also comply with the minimum thickness requirements in Subsection A of this Division. These rules are not to be used for the determination of the thickness of tubesheets integral with a bolting flange as illustrated in Figure UW-13.2 sketches (h) through (l) or Figure UW-13.3 sketch (c). Nonmandatory Appendix S provides discussion on Design Considerations for Bolted Flanged Connections.

These rules provide only for hydrostatic end loads and gasket seating. The flange design methods outlined in 2-4 through 2-8 are applicable to circular flanges under internal pressure. Modifications of these methods are outlined in 2-9 and 2-10 for the design of split and noncircular flanges. See 2-11 for flanges with ring type gaskets subject to external pressure, 2-12 for flanges with nut-stops, and 2-13 for reverse flanges. Rules for calculating rigidity factors for flanges are provided in 2-14. Recommendations for qualification of assembly procedures and assemblers are in 2-15. Proper allowance shall be made if connections are subject to external loads other than external pressure.

(b) The design of a flange involves the selection of the gasket (material, type, and dimensions), flange facing, bolting, hub proportions, flange width, and flange thickness. See Note in 2-5(c)(1). Flange dimensions shall be such that the stresses in the flange, calculated in accordance with 13-1, do not exceed the allowable flange stresses specified in 2-8. Except as provided for in 2-14(a), flanges designed to the rules of this Appendix shall also meet the rigidity requirements of 2-14. All calculations shall be made on dimensions in the corroded condition.

(c) It is recommended that bolted flange connections conforming to the standards listed in UG-44 be used for connections to external loads. These standards may be used for other bolted flange connections and dished covers within the limits of size in the standards and the pressure–temperature ratings permitted in UG-44. The ratings in these standards are based on the hub dimensions given or on the minimum specified thickness of flanged fittings of integral construction. Flanges fabricated from rings may be used in place of the hub flanges in these standards provided that their strength, calculated by the rules in this Appendix, is not less than that calculated for the corresponding size of hub flange.

(d) Except as otherwise provided in (c) above, bolted flange connections for unfired pressure vessels shall satisfy the requirements in this Appendix.

(e) The rules of this Appendix should not be construed to prohibit the use of other types of flanged connections, provided they are designed in accordance with good engineering practice and method of design is acceptable to the Inspector. Some examples of flanged connections which might fall in this category are as follows:

(1) flanged covers as shown in Figure 1-6;
(2) bolted flanges using full-face gaskets;
(3) flanges using means other than bolting to restrain the flange assembly against pressure and other applied loads.

2-2 MATERIALS

(a) Materials used in the construction of bolted flange connections shall comply with the requirements given in UG-4 through UG-14.

(b) Flanges made from ferritic steel and designed in accordance with this Appendix shall be full-annealed, normalized, normalized and tempered, or quenched and tempered when the thickness of the flange section exceeds 3 in. (75 mm).

(c) Material on which welding is to be performed shall be of good weldable quality. Satisfactory qualification of the welding procedure under Section IX is considered as proof. Welding shall not be performed on steel that has a carbon content greater than 0.35%. All welding on flange connections shall comply with the requirements for postweld heat treatment given in this Division.

(d) Fabricated flanges with hubs shall be in accordance with the following:

(1) Flanges with hubs may be machined from a hot-rolled billet, forged billet, or forged bar. The axis of the finished flange shall be parallel to the long axis of the original billet or bar, but these axes need not be concentric.
MANDATORY APPENDIX 2
RULES FOR BOLTED FLANGE CONNECTIONS WITH RING TYPE
GASKETS

GENERAL

2-1 SCOPE

(a) The rules in Mandatory Appendix 2 apply specifically to the design of bolted flange connections with gaskets that are entirely within the circle enclosed by the bolt holes and with no contact outside this circle, and are to be used in conjunction with the applicable requirements in Subsections A, B, and C of this Division. The hub thickness of weld neck flanges designed to this Appendix shall also comply with the minimum thickness requirements in Subsection A of this Division. These rules are not to be used for the determination of the thickness of supported or unsupported tubesheets integral with a bolting flange as illustrated in Figure UW-13.2 sketches (h) through (l) or Figure UW-13.3 sketch (c). Nonmandatory Appendix S provides discussion on Design Considerations for Bolted Flanged Connections.

These rules provide only for hydrostatic end loads and gasket seating. The flange design methods outlined in 2-4 through 2-8 are applicable to circular flanges under internal pressure. Modifications of these methods are outlined in 2-9 and 2-10 for the design of split and noncircular flanges. See 2-11 for flanges with ring type gaskets subject to external pressure, 2-12 for flanges with nut-stops, and 2-13 for reverse flanges. Rules for calculating rigidity factors for flanges are provided in 2-14. Recommendations for qualification of assembly procedures and assemblers are in 2-15. Proper allowance shall be made if connections are subject to external loads other than external pressure.

(b) The design of a flange involves the selection of the gasket (material, type, and dimensions), flange facing, bolting, hub proportions, flange width, and flange thickness. See Note in 2-5(c)(1). Flange dimensions shall be such that the stresses in the flange, calculated in accordance with 2-7, do not exceed the allowable flange stresses specified in 2-8. Except as provided for in 2-14(a), flanges designed to the rules of this Appendix shall also meet the rigidity requirements of 2-14. All calculations shall be made on dimensions in the corroded condition.

(c) It is recommended that bolted flange connections conforming to the standards listed in UG-44 be used for connections to external piping. These standards may be used for other bolted flange connections and dished covers within the limits of size in the standards and the pressure–temperature ratings permitted in UG-44. The ratings in these standards are based on the hub dimensions given or on the minimum specified thickness of flanged fittings of integral construction. Flanges fabricated from rings may be used in place of the hub flanges in these standards provided that their strength, calculated by the rules in this Appendix, is not less than that calculated for the corresponding size of hub flange.

(d) Except as otherwise provided in (c) above, bolted flange connections for unfired pressure vessels shall satisfy the requirements in this Appendix.

(e) The rules of this Appendix should not be construed to prohibit the use of other types of flanged connections provided they are designed in accordance with good engineering practice and method of design is acceptable to the Inspector. Some examples of flanged connections which might fall in this category are as follows:

(1) flanged covers as shown in Figure 1-6;
(2) bolted flanges using full-face gaskets;
(3) flanges using means other than bolting to restrain the flange assembly against pressure and other applied loads.

2-2 MATERIALS

(a) Materials used in the construction of bolted flange connections shall comply with the requirements given in UG-4 through UG-14.

(b) Flanges made from ferritic steel and designed in accordance with this Appendix shall be full-annealed, normalized, normalized and tempered, or quenched and tempered when the thickness of the flange section exceeds 3 in. (75 mm).

(c) Material on which welding is to be performed shall be proved of good weldable quality. Satisfactory qualification of the welding procedure under Section IX is considered as proof. Welding shall not be performed on steel that has a carbon content greater than 0.35%. All welding on flange connections shall comply with the requirements for postweld heat treatment given in this Division.

(d) Fabricated hubbed flanges shall be in accordance with the following:

(1) Hubbed flanges may be machined from a hot rolled or forged billet or forged bar. The axis of the finished flange shall be parallel to the long axis of the...
3.7.6.4 **Requirements for Nonferrous Nuts.** Nonferrous nuts shall meet the requirements in 3.7.5.3.

3.7.7 **MATERIALS FOR FERROUS AND NONFERROUS NUTS OF SPECIAL DESIGN**

Nuts of special design, such as wing nuts, may be made of any suitable wrought material permitted by this Division, and shall be either: hot or cold forged; or machined from hot-forged, hot-rolled, or cold-drawn bars.

3.8 **SUPPLEMENTAL REQUIREMENTS FOR CASTINGS**

3.8.1 **GENERAL**

3.8.1.1 Each casting shall be marked with the name, trademark, or other traceable identification of the manufacturer and the casting identification, including material designation. The casting manufacturer shall furnish certification that each casting conforms to all the applicable requirements in the casting specification and the requirements of this Division. The certification of castings shall also indicate the nature, location, and extent of any repairs.

3.8.1.2 All castings to be welded shall be of weldable grade.

3.8.2 **REQUIREMENTS FOR FERROUS CASTINGS**

3.8.2.1 **Centrifugal Steel Castings.** In addition to the minimum requirements of the material specification, all surfaces of centrifugal castings shall be machined after heat treatment to a finish not coarser than 6.35 \(\mu\)m (250 \(\mu\)in.) arithmetic average deviation.

3.8.2.2 **Nondestructive Examination of Ferrous Castings.**

(a) General – Castings shall be examined by radiographic, ultrasonic, magnetic particle and liquid penetrant methods examination as provided herein and shall meet the requirements of (a) through (d), inclusive. Radiographic examination, and when required ultrasonic examination, of castings shall be made after at least one austenitizing heat treatment, except austenitic castings not requiring heat treatment may have radiographic and ultrasonic examination performed at any stage of manufacture. Magnetic particle or liquid penetrant examinations shall be made after final heat treatment and after final machining of machined areas.

(b) Radiographic Examination – All parts of ferrous castings regardless of thickness shall be fully radiographed in accordance with the procedures of Section V, Article 2. The radiographs shall be compared to the appropriate Radiographic Standard listed below, and the maximum acceptable severity levels for imperfection shall be as follows:

1. For castings having radiographed thickness of less than 50 mm (2 in.), ASTM E446, Standard Reference Radiographs for Steel Castings up to 2 in. (50 mm) in Thickness, and with maximum severity levels as shown in Table 3.9.
2. For castings having radiographed thickness from 50 mm to 305 mm (2 in. to 12 in.), ASTM E186, Standard Reference Radiographs for Heavy-Walled [2 to 4\(\frac{1}{2}\) in. (50.8 to 114 mm)] Steel Castings, or ASTM E280, Standard Reference Radiographs for Heavy-Walled [4\(\frac{1}{2}\) to 12 in. (114 to 305 mm)] Steel Castings, as appropriate, and with maximum severity levels as shown in Table 3.10.

(c) Ultrasonic Examination – All parts of ferrous castings over 305 mm (12 in.) thick shall be examined by ultrasonic methods in accordance with the procedures of Section V, Article 4. Castings with imperfections shown by discontinuities whose reflections exceed the height equal to 20% of the normal back reflection, or which reduce the height of the back reflections by more than 30% during movement of the transducer 50 mm (2 in.) in any direction are unacceptable unless other methods of nondestructive testing, such as radiographic examination, demonstrate to the satisfaction of the vessel Manufacturer and the Inspector that the indications are acceptable or unless such imperfections are removed and the casting is repaired.

(d) Magnetic Particle Examination – Castings of ferromagnetic material shall be examined on all surfaces by a magnetic particle method in accordance with Part 7 of this Division. Castings with imperfections shown by Type I indications or by indications exceeding Degree I of Types II, III, IV, and V of ASTM E125, Reference Photographs for Magnetic Particle Indications on Ferrous Castings, are unacceptable unless the imperfections are removed and casting is repaired.

(e) Liquid Penetrant Examination – Castings of nonferromagnetic material shall be examined on all surfaces by a liquid penetrant method in accordance with Part 7 of this Division. Castings with cracks and linear imperfections exceeding the following limits are unacceptable:

1. Linear indications resulting in more than six indications in any 40 mm \(\times\) 150 mm (1\(\frac{1}{2}\) in. \(\times\) 6 in.) rectangle or 90 mm (3.5 in.) diameter circle with these taken in the most unfavorable location relative to the indications being evaluated.
except austenitic castings not requiring heat treatment may have radiographic and ultrasonic examination performed at any stage of manufacture. Magnetic particle or liquid penetrant examinations shall be made after final heat treatment and after final machining of machined areas.

(b) Radiographic Examination – All parts of ferrous castings regardless of thickness shall be fully radiographed in accordance with the procedures of Article 2 of Section V. The radiographs shall be compared to the appropriate Radiographic Standard listed below, and the maximum acceptable severity levels for imperfection shall be as follows:

(1) For castings having radiographed thickness of less than 50 mm (2 in.), E446, Standard Reference Radiographs For Steel Castings up to 50 mm (2 in.) in thickness, and with maximum severity levels as shown in Table 3.9.

(2) For castings having radiographed thickness from 50 mm to 305 mm (2 in. to 12 in.), E186, Standard Reference Radiographs for Heavy-Walled 50 mm to 115 mm (2 in. to 4.5 in.) Steel Castings or E 280, Standard Reference Radiographs for Heavy-Walled 115 mm to 305 mm (4.5 in. to 12 in.) Steel Castings, as appropriate, and with maximum severity levels as shown in Table 3.10.

(c) Ultrasonic Examination – All parts of ferrous castings over 305 mm (12 in.) thick shall be examined by ultrasonic methods in accordance with the procedures of Article 5 of Section V. Castings with imperfections shown by discontinuities whose reflections exceed the height equal to 20% of the normal back reflection, or which reduce the height of the back reflections by more than 30% during movement of the transducer 50 mm (2 in.) in any direction are unacceptable unless other methods of nondestructive testing, such as radiographic examination, demonstrate to the satisfaction of the vessel Manufacturer and the Inspector that the indications are acceptable or unless such imperfections are removed and the casting is repaired.

(d) Magnetic Particle Examination – Castings of magnetic material shall be examined on all surfaces by a magnetic particle method in accordance with Part 7 of this Division. Castings with imperfections shown by Type I indications or by indications exceeding Degree I of Types II, III, IV, and V of ASTM E125, Reference Photographs for Magnetic Particle Indications on Ferrous Castings, are unacceptable unless the imperfections are removed and casting is repaired.

(e) Liquid Penetrant Examination – Castings of nonmagnetic material shall be examined on all surfaces by a liquid penetrant method in accordance with Part 7 of this Division. Castings with cracks and linear imperfections exceeding the following limits are unacceptable:

(1) Linear indications resulting in more than six indications in any 40 mm x 150 mm (1 1/2 in. x 6 in.) rectangle or 90 mm (3.5 in.) diameter circle with these taken in the most unfavorable location relative to the indications being evaluated.

(2) Linear imperfections resulting in indications more than 6 mm (1/4 in.) in length for thicknesses up to 19 mm (3/4 in.), one third of the thickness in length for thicknesses from 19 mm (3/4 in.) to 57 mm (2.25 in.), and 19 mm (3/4 in.) in length for thicknesses over 57 mm (2.25 in.). Aligned acceptable imperfections separated from one another by a distance equal to the length of the longer imperfection are acceptable.

(3) All nonlinear imperfections which are indicated to have any dimension which exceeds 2.5 mm (0.0938 in.).

### 3.8.2.3 Repairing of Ferrous Castings.

(a) Castings with unacceptable imperfections may be repaired. Whenever an imperfection is removed and subsequent repair by welding is not required, the affected area shall be blended into the surrounding surface so as to avoid sharp notches, crevices, or corners.

(b) Repairing of Ferrous Castings by Welding – Castings having imperfections in excess of the maximum sizes permitted in 3.8.2.2 may be repaired by welding if the imperfections are removed and providing prior approval is obtained from the vessel Manufacturer. To ensure complete removal of such imperfections prior to making repairs the base metal shall be reexamined by either magnetic particle or liquid penetrant examination, if it is magnetic, or by liquid penetrant examination, if it is nonmagnetic.

(1) Requirements for Examining Repairs in Castings – All weld repairs of depth exceeding 10 mm (3/8 in.) or 20% of the section thickness, whichever is the lesser, shall be examined by radiography and by magnetic particle examination or liquid penetrant examination, if the material is magnetic, or by liquid penetrant examination, if it is nonmagnetic, in accordance with 3.8.2.2. Where the depth of the repairs is less than 20% of the section thickness or 25 mm (1 in.), whichever is the lesser, and where the repaired section cannot be radiographed effectively, the first layer of each 6 mm (1/4 in.) thickness of deposited weld metal and the finished weld surface shall be examined, as indicated previously by magnetic particle or liquid penetrant examination. The finished surface examination shall be made after any heat treating operations that are applied to the casting. Weld repairs resulting from ultrasonic examination shall be examined by ultrasonic methods.

(2) Postweld Heat Treatment of Repaired Castings – When repair welding is done after heat treatment of the casting, the casting shall be postweld heat treated after repair welding of the casting.
(b) Acceptable Category B welds are shown in Tables 4.2.4 and 4.2.5.
(c) Backing strips shall be removed from Type No. 2 butt joints unless access conditions prevent their removal. If a fatigue analysis of Type No. 2 butt joints with a backing strip in place is required, then a stress concentration factor of 2.0 for membrane stresses and of 2.5 for bending stress shall be applied.
(d) Transition joints between shell sections of unequal thickness shall meet the requirements of 4.2.5.2(c) and shall be in accordance with Table 4.2.4 and Table 4.2.5. An ellipsoidal head which 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.
(e) Transition joints between nozzle necks and attached piping of unequal thickness shall be in accordance with 4.2.5.10.
(f) When butt joints are required elsewhere in this Division for Category B, an angle joint connecting a transition in diameter to a cylinder shall be considered as meeting this requirement, provided the requirements of Type No. 1 butt joints are met. All requirements pertaining to the butt joint shall apply to the angle joint.

4.2.5.4 Category C Locations

(a) The joints of Category C may be any of the following types:
(1) Type No. 1 butt joints,
(2) Full penetration corner joints except as limited in 4.2.5.7.
(3) Fillet welded joints for the attachment of loose type flanges shown in Table 4.2.9, with the following limitations:
(-a) The materials of the flange and the part it is welded to are Type 1 Materials (see Table 4.2.3).
(-b) The minimum specified yield strength of both materials is less than 552 MPa (80 ksi).
(-c) The minimum elongation of both materials is 12% in 50 mm (2 in.) gauge length.
(-d) The thickness of the materials to which the flange is welded does not exceed 32 mm (1.25 in.).
(-e) The fillet weld dimensions satisfy the requirements shown in Table 4.2.9.
(-f) A fatigue-screening criterion shall be performed in accordance with 5.5.2 to determine if a fatigue analysis is required. If the results of this screening indicate that a fatigue analysis is required, then the analysis shall be performed in accordance with 5.5.2.
(-g) Loos type flanges that do not conform to ASME B16.5 are only permitted when both of the following requirements are satisfied.
(-1) The material of construction for the flange satisfies the following equation.
\[
\frac{5y_f}{S_y} \leq 0.625
\] (4.2.1)
(-2) The component is not in cyclic service, i.e., a fatigue analysis is not required in accordance with 4.1.1.4.

(b) Acceptable Category C welds are shown in the following tables.
(1) Table 4.2.4 - Some acceptable weld joints for shell seams.
(2) Table 4.2.6 - Some acceptable weld joints for unstayed flat heads, tubesheets without a bolting flange, and side plates of rectangular pressure vessels
(3) Table 4.2.7 - Some acceptable weld joints with butt weld hubs.
(4) Table 4.2.8 - Some acceptable weld joints for attachment of tubesheets with a bolting flange
(5) Table 4.2.9 - Some acceptable weld joints for flange attachments.

(c) Flat Heads, Lap Joint Stub Ends, and Tubesheets with Hubs for Butt Joints
(1) Hubs for butt welding to the adjacent shell, head, or other pressure parts such as tubesheets and flat heads as shown in Table 4.2.7 shall be forged or machined from flat plate. Forged 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 vessel. Proof of this shall be furnished by a tension test specimen (subsize, if necessary) taken in this direction and as close to the hub as practical. Hubs machined from flat plates should satisfy the requirements of 3.9.
(2) Flanges with hubs as shown in Table 4.2.9, Details 6, 7, and 8 shall not be machined from plate.

(d) Corner Joints - If shells, heads, or other pressure parts are welded to a forged or rolled plate to form a corner joint as shown in Table 4.2.6 and Table 4.2.8, then the welds shall meet the following requirements.
(1) On the cross section through the welded joint, the line between the weld metal and the forged or rolled plate being attached shall be projected on planes both parallel to and perpendicular to the surface of the plate being attached, in order to determine the dimensions a and b, respectively.
(2) The dimensional requirements on a and b shall meet the applicable requirements in Tables 4.2.6 and 4.2.8.
(3) Weld joint details that have a dimension through the joint that is less than the thickness of the shell, head, or other pressure part, or that provide attachment eccentric thereto are not permitted.
4.2.5.3 Category B Locations

(a) The joints of Category B may be any of the following types:
   (1) Type No. 1 butt joints,
   (2) Type No. 2 butt joints except as limited in paragraph 4.2.5.7,
   (3) Type No. 3 butt joints may only be used for shells having a thickness of 16 mm (0.625 in.) or less and a diameter of 610 mm (or 24 in.) and less.

(b) Acceptable Category B welds are shown in Tables 4.2.4 and 4.2.5.

(c) Backing strips shall be removed from Type No. 2 butt joints unless access conditions prevent their removal. If a fatigue analysis of Type No. 2 butt joints with a backing strip in place is required, then a stress concentration factor of 2.0 for membrane stresses and of 2.5 for bending stress shall be applied.

(d) Transition joints between shell sections of unequal thickness shall meet the requirements of paragraph 4.2.5.2(c) and shall be in accordance with Table 4.2.4 and Table 4.2.5. An ellipsoidal head which 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.

(e) Transition joints between nozzle necks and attached piping of unequal thickness shall be in accordance with paragraph 4.2.5.9 made using a tapered transition in accordance with Table 4.2.4, Details 7 and 8.

(f) When butt joints are required elsewhere in this Division for Category B, an angle joint connecting a transition in diameter to a cylinder shall be considered as meeting this requirement provided the requirements of Type No. 1 butt joints are met. All requirements pertaining to the butt joint shall apply to the angle joint.
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<td>7, 9, 10</td>
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<tr>
<td>E</td>
<td>Permanent attachments (Note 11)</td>
<td>MT or PT</td>
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Table 7.2
Nondestructive Examination (Cont'd)

Permitted Materials
All Materials in Annex 3-A

Weld Joint Efficiency
1.0 1.0 1.0 1.0 0.85 0.85
### FORM A-4 MANUFACTURER'S DATA REPORT SUPPLEMENTARY SHEET

**SHELL-AND-TUBE HEAT EXCHANGERS**

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 2

---

1. Manufactured and certified by

   (Name and address of manufacturer)

2. Manufactured for

   (Name and address of purchaser)

3. Location of installation

   (Name and address)

4. Type

   Horiz. or vert. tank

---

**FIXED TUBESHEET HEAT EXCHANGERS**

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<th>Name of Condition</th>
<th>Design/Operating Pressure Ranges</th>
<th>Design/Operating Metal Temperatures</th>
<th>Allowable Axial Differential Thermal Expansion Range</th>
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<td>Tube Side</td>
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<td></td>
<td>Min. (units) Max. (units)</td>
<td>Min. (units) Max. (units)</td>
<td>Min. (units) Max. (units)</td>
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**Data Report Item Number**

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Date

Co. Name

Manufacturer

Signed

Representative

Date

Signed

Authorized Inspector

Commissions

National Board Authorized Inspector

Commission number

---

(07/17)
### Table 2-D.3
Manufacturer's Data Report Forms (Cont'd)

**FORM A-4 MANUFACTURER'S DATA REPORT SUPPLEMENTARY SHEET**

**SHELL AND-TUBE HEAT EXCHANGERS**

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 2

---

1. **Manufactured and certified by**
   1. (Name and address of Manufacturer)

2. **Manufactured for**
   2. (Name and address of Purchaser)

3. **Location of installation**
   3. (Name and address)

4. **Type:**
   5. Horizontally, vertically, or sloped

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**FIXED TUBESHEET HEAT EXCHANGERS**

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<th>Design/Operating Metal Temperatures</th>
<th>Allowable Axial Differential Thermal Expansion Range</th>
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**Data Report Item Number**

| 48 |

**Remarks**

| 47 |

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**Date**

Co. Name: 43, 46

Signed: 43, 46

Manufacturer Representative

**Date**

Signed: 43, 46

Commissions: 43, 44, 46

Authorized Inspector

Nat'l. Board (incl. endorsements)

(07/15)