MANDATORY APPENDIX 9
JACKETED VESSELS

9-1 SCOPE

(a) The rules in Mandatory Appendix 9 cover minimum requirements for the design, fabrication, and inspection of the jacketed portion of a pressure vessel. The jacketed portion of the vessel is defined as the inner and outer walls, the closure devices, and all other penetrations or parts within the jacket which are subjected to pressure stresses. Parts such as nozzle closure members and stiffening or stay rings are included.

(b) All other Parts of this Division shall apply unless otherwise stated in this Appendix.

(c) Where the internal design pressure is 15 psi (100 kPa) or less, and any combination of pressures and vacuum in the vessel and jacket will produce a total external pressure greater than 15 psi (100 kPa) on the inner vessel wall, then the entire jacket shall be interpreted as within the scope of this part.

(d) For the purpose of this Appendix, jackets are assumed to be integral pressure chambers, attached to a vessel for one or more purposes such as:

1. to heat the vessel and its contents;
2. to cool the vessel and its contents;
3. to provide a sealed insulation chamber for the vessel.

(e) As stated in U-2(g), this Division does not contain rules to cover all details of design and construction. These rules are therefore established to cover most common jacket types, but are not intended to limit configurations to those illustrated or otherwise described herein.

(f) Half-pipe jackets are not within the scope of this Appendix.

9-2 TYPES OF JACKETED VESSELS

This Appendix shall apply to jacketed vessels having jackets which cover the shell or heads as illustrated in Figure 9-2 and partial jackets as illustrated in Figure 9-7. Jackets, as shown in Figure 9-2, shall be continuous circumferentially for Types 1, 2, 4, or 5 shown and shall be circular in cross section for Type 3. The use of any combination of the types shown is permitted on any one vessel, provided the individual requirements for each are met. Nozzles or other openings in Type 1, 2, 4, or 5 jackets that also penetrate the vessel shell or head shall be designed in accordance with UG-37(d)(2). Dimpled jackets are not covered in this Appendix (see UW-19).

9-3 MATERIALS

Materials used in the fabrication of jackets shall be in accordance with Subsection A.

9-4 DESIGN OF JACKET SHELLS AND JACKET HEADS

Design shall comply with the applicable requirements of Subsection A except where otherwise provided for in this Appendix.

(a) Shell and head thickness shall be determined by the appropriate formula given in Subsection A. In consideration of the loadings given in UG-22, particular attention to the effects of local internal and external loads and expansion differentials at design temperatures shall be given. Where vessel supports are attached to the jacket, consideration shall be given to the transfer of the supported load of the inner vessel and contents.

(b) The requirements for inspection openings as prescribed in UG-46 shall apply to jackets except that the maximum size of opening need not exceed 2 in. (50 mm) pipe size (DN 50) for all diameter vessels.

(c) The use of impingement plates or baffles at the jacket inlet connection to reduce erosion of the inner wall shall be considered for media where vapors are condensed, i.e., steam.

(d) Jacketed vessels may be designed utilizing braced and stayed surfaces as given in UG-47, provided the jacket wall in addition to meeting the requirements of UG-47(a) also meets the applicable requirements of UG-27(c) and UG-27(d) and UG-32. This paragraph is not intended to apply to dimpled jackets. (See UW-19.)

9-5 DESIGN OF CLOSURE MEMBER OF JACKET TO VESSEL

(a) This paragraph gives rules for the design of closure members shown herein. Closures of geometries other than those illustrated may be used if the strength requirements of UG-101 are met.

(b) Symbols used in Figures 9-5 and 9-6 are as follows:

\[ a, b, c, Y, Z \]

\[ a, b, c, Y, Z = \text{minimum weld dimensions for attachment of closure member to inner vessel measured as shown in Figures 9-5 and 9-6} \]
(g-5), and (g-6), may be used on any of the types of jacketed vessels shown in Figure 9-2 where the attachment welds in accordance with Figure 9-5 sketch (i-1) or (i-2). This construction is limited to jackets where \( t_f \) does not exceed \( \frac{5}{8} \) in. (16 mm).

(7) Closures shown in Figure 9-5 sketch (h) used on Type 3 jacketed vessels shown in Figure 9-2 shall have attachment welds in accordance with Figure 9-5 sketch (i-1) or (i-2). This construction is limited to jackets where \( t_f \) does not exceed \( \frac{5}{8} \) in. (16 mm).

(8) Closures for conical or toriconical jackets shown in Figure 9-5 sketches (k) and (l) shall comply with the requirements for Type 2 jacketed vessels shown in Figure 9-2.

(d) Any radial welds in closure members shall be butt-welded joints penetrating through the full thickness of the member and shall be ground flush where attachment welds are to be made.

(e) Where the inner vessel must meet the requirements of UG-2, the attachment welds of the jacket to the inner vessel need not be welded for their full thickness nor radiographed. These attachment welds shall be postweld heat treated where required by UG-2 except as may be exempted by the notes to Tables UCS-56-1 through UCS-56-11. The remainder of the jacket need not comply with UG-2 when the inner vessel alone is subjected to the service restrictions. The diameter limitations of UG-12 and UG-13 do not apply to the jacket attachment welds.

(4) For designs Figure 9-6 sketches (e-1) and (e-2), the thickness required of the closure member attached to the inner vessel \( t_{rc1} \) shall be calculated as a shell under external pressure per UG-28. The required thickness of the flexible member \( t_{rc2} \) shall be determined from one of the following expressions:

\[
t_{rc2} = \frac{Pr}{SE - 0.6P}
\]

(when no tubular section exists between jacket and torus)

\[
t_{rc2} = \frac{PR_p}{SE - 0.6P}
\]

(when tubular section exists between jacket and torus)

where

- \( E = \) weld efficiency from Table UW-12 for circumferential weld in the torus for equation using \( r \), or for any weld in opening closure member for equation using \( R_p \) radius of penetration

(5) The minimum thickness \( t_{rc} \) for design (f) shall be calculated as a shell of radius \( R_p \) under external pressure per UG-28.

(6) Designs (b), (c), (d), and (e) of Figure 9-6 provide for some flexibility and are designed on a similar basis to that of expansion joints under the conditions of U-2(g) in combination with UG-22 and UG-23. Only pressure membrane loading is considered in establishing the minimum thickness of the penetration closure member, and it is not the intent that the combination of direct localized and secondary bending stress need be held to the Code-tabulated allowable stress values. It is recognized by UG-23(c) that high localized and secondary bending stresses may exist in Code vessels.

(e) All radial welds in opening sealer membranes shall be butt-welded joints penetrating through the full thickness of the member.

(f) Closure member welds shall be circular, elliptical, or obround in shape where possible. Rectangular member welds are permissible, provided that corners are rounded to a suitable radius.

9-7 DESIGN OF PARTIAL JACKETS

For jacket penetrations shown in Figure 9-6, sketch (a), design of openings shall be in accordance with the rules given in UG-36 through UG-45. However, when applying these rules, the limits of reinforcement for the vessel opening and jacket opening shall not overlap. For all other jacket penetrations shown in Figure 9-6, design of openings through the jacket space shall be in accordance with UG-2(g).

(1) Stayed partial jackets shall be designed and constructed in accordance with UG-47. Closure members shall conform to 9-5. The nozzle wall shall comply with the requirements of UG-28. The nozzle external design pressure \( P \) (of UG-28) shall be taken as the jacket internal design pressure \( P \) (of Appendix 9-5) plus the external design pressure of the main vessel, if applicable. The total length \( L \) (of UG-28) shall be taken as the jacket space \( j \) (of Appendix 9-5).
4.11 DESIGN RULES FOR JACKETED VESSELS

4.11.1 SCOPE

4.11.1.1 The minimum requirements for the design of the jacketed portion of a pressure vessel shall conform to the requirements given in 4.11. The jacketed portion of the vessel is defined as the inner and outer walls, the closure devices and all other penetration or parts within the jacket that are subjected to pressure stress. Parts such as nozzle closure members and stay rings are included in this definition. For the purposes of this section, jackets are assumed to be integral pressure chambers, attached to a vessel for one or more purposes, such as:

(a) To heat the vessel and its contents,
(b) To cool the vessel and its contents, or
(c) To provide a sealed insulation chamber for the vessel.

4.11.1.2 4.11 applies only to jacketed vessels having jackets over the shell or heads as illustrated in Figure 4.11.1, partial jackets as illustrated in Figure 4.11.2, and half-pipe jackets as illustrated in Figure 4.11.3.

4.11.1.3 The jacketed vessels shown in Figure 4.11.1 are categorized as five types shown below. For these types of vessels, the jackets shall be continuous circumferentially for Type 1, 2, 4, or 5 and shall be circular in cross section for Type 3. The use of any combination of the types shown is permitted on a single vessel, provided the individual requirements for each are met. Nozzles or other openings in Type 1, 2, 4, or 5 jackets that also penetrate the vessel shell or head shall be designed in accordance with 4.5. 4.11 does not cover dimpled or embossed jackets.

(a) Type 1 - Jacket of any length confined entirely to the cylindrical shell
(b) Type 2 - Jacket covering a portion of the cylindrical shell and one head
(c) Type 3 - Jacket covering a portion of one head
(d) Type 4 - Jacket with addition of stay or equalizer rings to the cylindrical shell portion to reduce the effective length
(e) Type 5 - Jacket covering the cylindrical shell and any portion of either head.

4.11.1.4 4.11 does not contain rules to cover all details of design and construction. Jacket types defined in 4.11.1.3 subject to general loading conditions (i.e., thermal gradients) or jacket types of different configurations subject to general loading conditions shall be designed using Part 5.

4.11.1.5 If the internal pressure is 100 kPa (15 psi) or less, and any combination of pressures and vacuum in the vessel and jacket will produce a total pressure greater than 100 kPa (15 psi) on the inner vessel wall, then the entire jacket is within the scope of 4.11.

4.11.2 DESIGN OF JACKETED SHELLS AND JACKETED HEADS

4.11.2.1 Shell and head thickness shall be determined using 4.3 and 4.4 as applicable. In consideration of the loadings given in 4.1, particular attention shall be given to the effects of local internal and external pressure loads and differential thermal expansion (see 4.11.1.4). Where vessel supports are attached to the jacket, consideration shall be given to the transfer of the supported load of the inner vessel and contents.

4.11.2.2 The requirements for inspection openings in jackets shall be in accordance with 4.5.16 except that the maximum size of inspection openings in the jacketed portion of the vessel need not exceed DN 50 (NPS 2) pipe for all diameter vessels.

4.11.2.3 The use of impingement plates or baffles at the jacket inlet connection to reduce erosion of the inner wall shall be considered for media where vapors are condensed (i.e., steam).

4.11.2.4 Flat plate regions of jacketed vessels may be designed as braced and stayed surfaces using the rules of 4.9.

4.11.3 DESIGN OF CLOSURE MEMBER OF JACKET TO VESSEL

4.11.3.1 The design of jacket closure members shall be in accordance with Table 4.11.1 and the additional requirements of 4.11.1.3. Alternative geometries to those illustrated may be used in accordance with 4.11.1.4.

4.11.3.2 Any radial welds in closure members shall be butt-welded joints penetrating through the full thickness of the member and shall be ground flush where attachment welds are to be made.

4.11.3.3 Partial penetration and fillet welds are permitted when both of the following requirements are satisfied.

(a) The material of construction satisfies the following equation.

\[
\frac{S_t}{S_w} \leq 0.625
\]  

(b) The component is not in cyclic service, i.e., a fatigue analysis is not required in accordance with 4.1.1.4.
4.11.3.4 Closures for any type of stay-bolted jacket may be designed in accordance with the requirements of Type 1 jackets shown in Figure 4.11.1, provided the entire jacket is stay-bolted to compensate for pressure end forces.

4.11.4 DESIGN OF PENETRATIONS THROUGH JACKETS

4.11.4.1 The design of openings through the jacket space shall be in accordance with the rules given in 4.5. Reinforcement of the opening in the jacket shall not be required for penetrations of the type shown in Table 4.11.2 since the opening is stayed by virtue of the nozzle or neck of the closure member.

4.11.4.2 Jacket penetration closure member designs shown in Table 4.11.2 shall conform to the following requirements stipulated in this table and the following provisions. Alternative geometries to those illustrated may be used if the design is based on Part 5.

(a) The jacket penetration closure member minimum thickness considers only pressure membrane loading. Axial pressure loadings and secondary loadings given in 4.1 shall be considered in the design.

(b) The design Details 2, 3, 4, 5 and 6 shown in Table 4.11.2 provide some flexibility. Only pressure membrane loading is considered in establishing the minimum thickness of the penetration closure member. If the localized stresses at the penetration detail need to be established, the methodology in Part 5 shall be used.

(c) All radial welds in opening sealer membranes shall be butt-welded joints that penetrate through the full thickness of the member.

(d) Closure member welds shall be circular, elliptical, or obround in shape where possible. Rectangular member welds are permissible, provided that corners are rounded to a suitable radius.

(e) The requirements of 4.11.3.3 shall be satisfied.

4.11.5 DESIGN OF PARTIAL JACKETS

4.11.5.1 Partial jackets include jackets that encompass less than the full circumference of the vessel. Some variations are shown in Figure 4.11.2.

4.11.5.2 The rules for construction of jacketed vessels in the preceding paragraphs also apply to partial jackets, with the following exceptions.

(a) Stayed partial jackets shall be designed and constructed in accordance with 4.9 with closures designed in accordance with 4.11.3.

(b) Partial jackets that, by virtue of their service or configuration, do not lend themselves to staybolt construction may be fabricated by other means, provided they are designed using Part 5.

4.11.6 DESIGN OF HALF-PIPE JACKETS

4.11.6.1 The rules in this section are applicable for the design of half-pipe jackets constructed of NPS 2, 3 or 4 pipes and subjected to internal pressure loading (see Figure 4.11.3). Configurations that do not satisfy the rules in 4.11.6.1 may be designed in accordance with Part 5.

4.11.6.2 The fillet weld attaching the half-pipe jacket to the vessel shall have a throat thickness not less than the smaller of the jacket or shell thickness. Consideration should be given to the selection of the half-pipe jacket pitch needed to provide welder access. In addition, the requirements of 4.11.3.3 shall be satisfied.

4.11.6.3 The minimum required thickness of a half pipe jacket is given by the following equation. For a design to be acceptable, the additional condition that \( P_j \leq P_{jpm} \) where \( P_{jpm} \) is given by eq. (4.11.3) must also be satisfied.

\[
\frac{t_{rp}}{0.85\delta_j - 0.6P_j} = \frac{P_{f_p}}{0.85\delta_j - 0.6P_j} \quad (4.11.2)
\]

4.11.6.4 The maximum permissible pressure in the half-pipe jacket, \( P_{jpm} \), shall be determined using the following equation.

\[
P_{jpm} = \frac{P_p}{K_p} \quad (4.11.3)
\]

where
Table 4.11.2 Design of Jacket Penetration Details

<table>
<thead>
<tr>
<th>Detail</th>
<th>Requirements</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>This closure details shall only be used when the requirements of 4.11.3.3 are satisfied. The nozzle wall may be used as the closure member where the jacket is welded to the nozzle. ( a = 2t_j \text{ min} ) and ( b = t_j \text{ min} )</td>
<td><img src="" alt="Diagram 1" /></td>
</tr>
<tr>
<td>2</td>
<td>This closure details shall only be used when the requirements of 4.11.3.3 are satisfied. The minimum required thickness, ( t_{rc} ), for the geometries shall be calculated as a shell under external pressure in accordance with 4.4. ( a = 2t_j \text{ min} ) and ( b = t_j \text{ min} ). Attachment A shall be made using details in Table 4.2.6.</td>
<td><img src="" alt="Diagram 2" /></td>
</tr>
<tr>
<td>3</td>
<td>This closure details shall only be used when the requirements of 4.11.3.3 are satisfied. The minimum required thickness, ( t_{rc} ), shall be equal to ( t_j ). Attachment A shall be made using details in Table 4.2.6.</td>
<td><img src="" alt="Diagram 3" /></td>
</tr>
</tbody>
</table>

The nozzle wall shall comply with the requirements of 4.4. The external design pressure \( P \) (of 4.4) shall be taken as the design pressure of the jacket chamber \( P_j \) (of 4.11) plus the external design pressure of the main vessel, if applicable. The unsupported length \( L \) (of 4.4) shall be taken as the jacket space \( j \) (of 4.11).