RIVETED JOINTS

A rivet is a short cylindrical bar with a head integral to it. The cylindrical portion of the rivet is called shank or body and lower portion of shank is known as tail, as shown in Fig. 9.1. The rivets are used to make permanent fastening between the plates such as in structural work, ship building, bridges, tanks and boiler shells. The riveted joints are widely used for joining light metals. The fastenings (i.e. joints) may be classified into the following two groups:

1. Permanent fastenings, and
2. Temporary or detachable fastenings.

Fig. 1. Rivet parts

The permanent fastenings are those fastenings which cannot be disassembled without destroying the connecting components. The examples of permanent fastenings in order of strength are soldered, brazed, welded and riveted joints.

The temporary or detachable fastenings are those fastenings which can be disassembled without destroying the connecting components. The examples of temporary fastenings are screwed, keys, cotters, pins and splined joints.

Methods of Riveting

The function of rivets in a joint is to make a connection that has strength and tightness. The strength is necessary to prevent failure of the joint. The tightness is necessary in order to contribute to strength and to prevent leakage as in a boiler or in a ship hull.

The plates are drilled together and then separated to remove any burrs or chips so as to have a tight flush joint between the plates. A cold rivet or a red hot rivet is introduced into the plates and the point (i.e. second head) is then formed. When a cold rivet is used, the process is known as cold riveting and when a hot rivet is used, the process is known as hot riveting. The riveting may be done by hand or by a riveting machine.
**Material of Rivets**

The material of the rivets must be **tough and ductile**. They are usually made of steel (low carbon steel or nickel steel), brass, aluminium or copper, but when strength and a fluid tight joint is the main consideration, then the steel rivets are used.

**Types of Rivet Heads**

1. Rivet heads for general purposes (below 12 mm diameter)

![Diagram of rivet heads](image)
3. Rivet heads for boiler work (from 12 mm to 48 mm diameter)

(a) Snap head.

(b) Ellipsoid head.

(c) Pan head (Type I).

(d) Pan head (Type II).

(e) Pan head with tapered neck.

(f) Conical head.

(g) Counter-sunk head.

(h) Round counter sunk head.

(i) Steeple head.

Fig. 4. Rivet heads for boiler work.
2. Rivet heads for general purposes (From 12 mm to 48 mm diameter)

![Rivet heads for general purposes](image)

The **snap heads** are usually employed for structural work and machine riveting. The **counter sunk** heads are mainly used for ship building where flat surfaces are necessary. The **conical heads** (also known as **conoidal heads**) are mainly used in case of hand hammering. The **pan heads** have maximum strength, but these are difficult to shape.

**Types of Riveted Joints**

Following are the two types of riveted joints, depending upon the way in which the plates are connected.

1. Lap joint, and 2. Butt joint.

**Lap Joint**

A lap joint is that in which **one plate overlaps the other** and the two plates are then riveted together.

**Butt Joint**

A butt joint is that in which the main plates are kept in alignment butting (i.e. **touching**) each other and a cover plate (i.e. strap) is placed either on one side or on both sides of the
main plates. The cover plate is then riveted together with the main plates. Butt joints are of the following two types:


In a **single strap butt joint**, the edges of the main plates butt against each other and only one cover plate is placed on one side of the main plates and then riveted together.

In a **double strap butt joint**, the edges of the main plates butt against each other and two cover plates are placed on both sides of the main plates and then riveted together.

In addition to the above, following are the types of riveted joints depending upon the number of rows of the rivets.


A **single riveted joint** is that in which there is a single row of rivets in a lap joint.

A **double riveted joint** is that in which there are two rows of rivets in a lap joint.

Similarly the joints may be **triple riveted** or **quadruple riveted**.

**Important Terms Used in Riveted Joints**

The following terms in connection with the riveted joints are important from the subject point of view:

1. **Pitch**. It is the distance from the **centre of one rivet to the centre of the next rivet** measured parallel to the seam. It is usually denoted by \( p \).
2. **Back pitch.** It is the perpendicular distance between the **centre lines of the successive rows.** It is usually denoted by \( p_b \).

3. **Diagonal pitch.** It is the distance between the **centres of the rivets in adjacent rows of zig-zag riveted joint.** It is usually denoted by \( p_d \).

4. **Margin or marginal pitch.** It is the distance between the **centres of the rivet hole to the nearest edge** of the plate. It is usually denoted by \( m \).

**Caulking and Fullering**

In order to **make the joints leak proof** or **fluid tight** in pressure vessels like steam boilers, air receivers and tanks etc. a process known as caulking is employed.

![Caulking and Fullering](image)

**Failures of a Riveted Joint**

A riveted joint may fail in the following ways:

1. **Tearing of the plate at an edge.** A joint may fail due to tearing of the plate at an edge as shown in Fig. 8. This can be avoided by keeping the margin, \( m = 1.5d \), where \( d \) is the diameter of the rivet hole.

![Tearing of the plate at an edge](image)

**Fig. 8. Tearing of the plate at an edge**

**Fig. 9. Tearing of the plate across the rows of rivets**
2. Tearing of the plate across a row of rivets. Due to the tensile stresses in the main plates, the main plate or cover plates may tear off across a row of rivets as shown in Fig. 9. The resistance offered by the plate against tearing is known as tearing resistance or tearing strength or tearing value of the plate.

Let

\[ p = \text{Pitch of the rivets}, \]
\[ d = \text{Diameter of the rivet hole}, \]
\[ t = \text{Thickness of the plate, and} \]
\[ \sigma_t = \text{Permissible tensile stress for the plate material.} \]

We know that tearing area per pitch length,

\[ A_t = (p - d) t \]

\[ \therefore \text{Tearing resistance or pull required to tear off the plate per pitch length,} \]
\[ P_t = A_t \cdot \sigma_t = (p - d) t \cdot \sigma_t \]

When the tearing resistance \( P_t \) is greater than the applied load \( P \) per pitch length, then this type of failure will not occur.

3. Shearing of the rivets. The plates which are connected by the rivets exert tensile stress on the rivets, and if the rivets are unable to resist the stress, they are sheared off as shown in Fig. 10. It may be noted that the rivets are in *single shear in a lap joint* and in a *single cover butt joint*, as shown in Fig. 9.10. But the rivets are in *double shear* in a *double cover butt joint* as shown in Fig. 9.11. The resistance offered by a rivet to be sheared off is known as shearing resistance or shearing strength or shearing value of the rivet.

![Fig. 10. Shearing of rivets](image)
Fig. 11. Shearing off a rivet in double cover butt joint

Let

\[ d = \text{Diameter of the rivet hole}, \]
\[ \tau = \text{Safe permissible shear stress for the rivet material, and} \]
\[ n = \text{Number of rivets per pitch length}. \]

We know that shearing area,

\[ A_s = \frac{\pi}{4} \times d^2 \quad \text{...(In single shear)} \]

\[ = 2 \times \frac{\pi}{4} \times d^2 \quad \text{...(Theoretically, in double shear)} \]

\[ = 1.875 \times \frac{\pi}{4} \times d^2 \quad \text{...(In double shear, according to Indian Boiler Regulations)} \]

\[ \therefore \text{Shearing resistance or pull required to shear off the rivet per pitch length,} \]
\[ P_s = n \times \frac{\pi}{4} \times d^2 \times \tau \quad \text{...(In single shear)} \]
\[ = n \times 2 \times \frac{\pi}{4} \times d^2 \times \tau \quad \text{...(Theoretically, in double shear)} \]
\[ = n \times 1.875 \times \frac{\pi}{4} \times d^2 \times \tau \quad \text{...(In double shear, according to Indian Boiler Regulations)} \]

When the shearing resistance \( P_s \) is greater than the applied load \( P \) per pitch length, then this type of failure will occur.

4. Crushing of the plate or rivets. Sometimes, the rivets do not shear off under the tensile stress, but are crushed as shown in Fig. 9.12. Due to this, the rivet hole becomes of an oval shape and hence the joint becomes loose. The failure of rivets in such a manner is also known as bearing failure. The area which resists this action is the projected area of the hole or rivet on diametral plane.

The resistance offered by a rivet to be crushed is known as crushing resistance or crushing strength or bearing value of the rivet.
The strength of a joint may be defined as the maximum force, which it can transmit, without causing it to fail. We have seen that $P_t$, $P_s$ and $P_c$ are the pulls required to tear off the plate, shearing off the rivet and crushing off the rivet.

If the joint is continuous as in case of boilers, the strength is calculated per pitch length. But if the joint is small, the strength is calculated for the whole length of the plate.
Efficiency of a Riveted Joint

The efficiency of a riveted joint is defined as the ratio of the strength of riveted joint to the strength of the un-riveted or solid plate. We have already discussed that strength of the riveted joint

\[
\text{Strength of the un-riveted or solid plate per pitch length, } P = p \times t \times \sigma_t
\]

\[\therefore \text{ Efficiency of the riveted joint, } \eta = \frac{\text{Least of } P_r, P_s, P_c}{p \times t \times \sigma_t} \]

where
- \(P_r\) = Pitch of the rivets,
- \(t\) = Thickness of the plate, and
- \(\sigma_t\) = Permissible tensile stress of the plate material.

Design of Boiler Joints

The boiler has a longitudinal joint as well as circumferential joint. The longitudinal joint is used to join the ends of the plate to get the required diameter of a boiler. For this purpose, a butt joint with two cover plates is used. The circumferential joint is used to get the required length of the boiler. For this purpose, a lap joint with one ring overlapping the other is used.

Assumptions in Designing Boiler Joints

The following assumptions are made while designing a joint for boilers:

1. The load on the joint is equally shared by all the rivets.
2. The tensile stress is equally distributed over the section of metal between the rivets.
3. The shearing stress in all the rivets is uniform.
4. The crushing stress is uniform.
5. There is no bending stress in the rivets.
6. The holes into which the rivets are driven do not weaken the member.
7. The rivet fills the hole after it is driven.
8. The friction between the surfaces of the plate is neglected.
Design of Longitudinal Butt Joint for a Boiler

1. **Thickness of boiler shell.** First of all, the thickness of the boiler shell is determined by using the thin cylindrical formula, i.e.

\[ t = \frac{P \cdot D}{2 \cdot \sigma_t \cdot \eta_l} + 1 \text{ mm as corrosion allowance} \]

where

- \( t \) = Thickness of the boiler shell,
- \( P \) = Steam pressure in boiler,
- \( D \) = Internal diameter of boiler shell,
- \( \sigma_t \) = Permissible tensile stress, and
- \( \eta_l \) = Efficiency of the longitudinal joint.

The following points may be noted:

(a) The thickness of the boiler shell should not be less than 7 mm.
(b) The efficiency of the joint may be taken from the following table.

**Table 1. Efficiencies of commercial boiler joints.**

<table>
<thead>
<tr>
<th>Lap joints</th>
<th>Efficiency (%)</th>
<th>*Maximum efficiency</th>
<th>Butt joints (Double strap)</th>
<th>Efficiency (%)</th>
<th>*Maximum efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single riveted</td>
<td>45 to 60</td>
<td>63.3</td>
<td>Single riveted</td>
<td>55 to 60</td>
<td>63.3</td>
</tr>
<tr>
<td>Double riveted</td>
<td>63 to 70</td>
<td>77.5</td>
<td>Double riveted</td>
<td>70 to 83</td>
<td>86.6</td>
</tr>
<tr>
<td>Triple riveted</td>
<td>72 to 80</td>
<td>86.6</td>
<td>Triple riveted (5 rivets per pitch with unequal width of straps)</td>
<td>80 to 90</td>
<td>95.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Quadruple riveted</td>
<td>85 to 94</td>
<td>98.1</td>
</tr>
</tbody>
</table>

**Table 2. Factor of safety for boiler joints.**

<table>
<thead>
<tr>
<th>Type of joint</th>
<th>Factor of safety</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Hand riveting</strong></td>
<td>Machine riveting</td>
</tr>
<tr>
<td>Lap joint</td>
<td>4.75</td>
<td>4.5</td>
</tr>
<tr>
<td>Single strap butt joint</td>
<td>4.75</td>
<td>4.5</td>
</tr>
<tr>
<td>Single riveted butt joint with two equal cover straps</td>
<td>4.75</td>
<td>4.5</td>
</tr>
<tr>
<td>Double riveted butt joint with two equal cover straps</td>
<td>4.25</td>
<td>4.0</td>
</tr>
</tbody>
</table>

2. **Diameter of rivets.** After finding out the thickness of the boiler shell (t), the diameter of the rivet hole (d) may be determined by using Unwin's empirical formula, i.e.

\[ d = 6 \sqrt{t} \quad (\text{when } t \text{ is greater than } 8 \text{ mm}) \]
But if the thickness of plate is less than 8 mm, then the diameter of the rivet hole may be calculated by equating the shearing resistance of the rivets to crushing resistance.

**Table 3. Size of rivet diameters for rivet hole**

<table>
<thead>
<tr>
<th>Basic size of rivet mm</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
<th>22</th>
<th>24</th>
<th>27</th>
<th>30</th>
<th>33</th>
<th>36</th>
<th>39</th>
<th>42</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rivet hole diameter (min) mm</td>
<td>13</td>
<td>15</td>
<td>17</td>
<td>19</td>
<td>21</td>
<td>23</td>
<td>25</td>
<td>28.5</td>
<td>31.5</td>
<td>34.5</td>
<td>37.5</td>
<td>41</td>
<td>44</td>
<td>50</td>
</tr>
</tbody>
</table>

3. **Pitch of rivets.** The pitch of the rivets is obtained by equating the tearing resistance of the plate to the shearing resistance of the rivets. It may noted that

(a) The pitch of the rivets should not be less than 2d, which is necessary for the formation of head.

(b) The maximum value of the pitch of rivets for a longitudinal joint of a boiler

\[ P_{\text{max}} = \frac{C \times t + 41.28}{1000} \text{ mm} \]

where

- \( t \) = Thickness of the shell plate in mm, and
- \( C \) = Constant.

**Table 5. Values of constant C.**

<table>
<thead>
<tr>
<th>Number of rivets per pitch length</th>
<th>Lap joint</th>
<th>Butt joint (single strap)</th>
<th>Butt joint (double strap)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.31</td>
<td>1.53</td>
<td>1.75</td>
</tr>
<tr>
<td>2</td>
<td>2.62</td>
<td>3.06</td>
<td>3.50</td>
</tr>
<tr>
<td>3</td>
<td>3.47</td>
<td>4.05</td>
<td>4.63</td>
</tr>
<tr>
<td>4</td>
<td>4.17</td>
<td>–</td>
<td>5.52</td>
</tr>
<tr>
<td>5</td>
<td>–</td>
<td>–</td>
<td>6.00</td>
</tr>
</tbody>
</table>

4. **Distance between the rows of rivets.** The distance between the rows of rivets is specified as follows:

(a) For equal number of rivets in more than one row for lap joint or butt joint, the distance between the rows of rivets (\( p_b \)) should not be less than

\[ 0.33 \times p + 0.67 \times d, \text{ for zig-zig riveting, and} \]
\[ 2 \times d, \text{ for chain riveting.} \]
(b) For joints in which the number of rivets in outer rows is half the number of rivets in inner rows and if the inner rows are chain riveted, the distance between the outer rows and the next rows should not be less than

\[ 0.33 \ p + 0.67 \ or \ 2 \ d, \] whichever is greater.

The distance between the rows in which there are full number of rivets shall not be less than 2d.

(c) For joints in which the number of rivets in outer rows is half the number of rivets in inner rows and if the inner rows are zig-zig riveted, the distance between the outer rows and the next rows shall not be less than \(0.2p + 1.15d\). The distance between the rows in which there are full number of rivets (zig-zag) shall not be less than \(0.165 \ p + 0.67d\).

5. **Thickness of butt strap.** The thicknesses for butt strap \((t_1)\) are as given below:

(a) The thickness of butt strap, in no case, shall be less than 10 mm.

(b) \(t_1 = 1.125t\), for ordinary (chain riveting) single butt strap.

\[
t_1 = 1.125 \ t \left( \frac{p - d}{p - 2d} \right), \text{ for single butt straps, every alternate rivet in outer rows being omitted.}
\]

\[
t_1 = 0.625 \ t, \text{ for double butt-straps of equal width having ordinary riveting (chain riveting).}
\]

\[
t_1 = 0.625 \ t \left( \frac{p - d}{p - 2d} \right), \text{ for double butt straps of equal width having every alternate rivet in the outer rows being omitted.}
\]

(c) For unequal width of butt straps, the thicknesses of butt strap are

\(t_1 = 0.75t\), for wide strap on the inside, and

\(t_2 = 0.625t\), for narrow strap on the outside.

6. **Margin.** The margin \((m)\) is taken as 1.5d.
Design of Circumferential Lap Joint for a Boiler

1. **Thickness of the shell and diameter of rivets.** The thickness of the boiler shell and the diameter of the rivet will be same as for longitudinal joint.

2. **Number of rivets.** Since it is a lap joint, therefore the rivets will be in single shear.

   \[ P_s = n \times \frac{\pi}{4} \times d^2 \times \tau \]

   where \( n = \) Total number of rivets.

   Knowing the inner diameter of the boiler shell (D), and the pressure of steam (P), the total shearing load acting on the circumferential joint,

   \[ W_s = \frac{\pi}{4} \times D^2 \times P \]

   From above equations,

   \[ n \times \frac{\pi}{4} \times d^2 \times \tau = \frac{\pi}{4} \times D^2 \times P \]

   \[ n = \left( \frac{D}{d} \right)^2 \frac{P}{\tau} \]

3. **Pitch of rivets.** If the efficiency of the longitudinal joint is known, then the efficiency of the circumferential joint may be obtained. It is generally taken as 50% of tearing efficiency in longitudinal joint, but if more than one circumferential joints is used, then it is 62% for the intermediate joints.

   Knowing the efficiency of the circumferential lap joint (\( \eta_c \)), the pitch of the rivets for the lap joint (\( p_1 \)) may be obtained by using the relation:

   \[ \eta_c = \frac{p_1 - d}{p_1} \]

4. **Number of rows.** The number of rows of rivets for the circumferential joint may be obtained from the following relation:

   \[ \text{Number of rows} = \frac{\text{Total number of rivets}}{\text{Number of rivets in one row}} \]

   and the number of rivets in one row

   \[ = \frac{\pi (D + t)}{P_1} \]

   where

   \[ D = \text{Inner diameter of shell.} \]
5. After finding out the number of rows, the type of the joint (i.e. Single riveted or double riveted, etc.) may be decided. Then the number of rivets in a row and pitch may be re-adjusted.

6. The distance between the rows of rivets (i.e. Back pitch) is calculated by using the relations as discussed in the previous.

7. After knowing the distance between the rows of rivets ($p_b$), the overlap of the plate may be fixed by using the relation,

$$\text{Overlap} = (\text{No. of rows of rivets} - 1) p_b + m$$

where $m = \text{Margin}$.

**Table 6. Recommended joints for pressure vessels.**

<table>
<thead>
<tr>
<th>Diameter of shell (metres)</th>
<th>Thickness of shell (mm)</th>
<th>Type of joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 to 1.8</td>
<td>6 to 13</td>
<td>Double riveted</td>
</tr>
<tr>
<td>0.9 to 2.1</td>
<td>13 to 25</td>
<td>Triple riveted</td>
</tr>
<tr>
<td>1.5 to 2.7</td>
<td>19 to 40</td>
<td>Quadruple riveted</td>
</tr>
</tbody>
</table>

**Riveted Joint for Structural Use–Joints of Uniform Strength (Lozenge Joint)**

Fig. 13. Riveted joint for structural use.
Let,

\[ b = \text{Width of the plate}, \]
\[ t = \text{Thickness of the plate}, \]
\[ d = \text{Diameter of the rivet hole}. \]

In designing a Lozenge joint, the following procedure is adopted.

1. **Diameter of rivet:** The diameter of the rivet hole is obtained by using Unwin's formula, i.e.

   \[ d = 6\sqrt{t} \]

   **Table 7. Sizes of rivets for general purposes.**

<table>
<thead>
<tr>
<th>Diameter of rivet hole (mm)</th>
<th>13.5</th>
<th>15.5</th>
<th>17.5</th>
<th>19.5</th>
<th>21.5</th>
<th>23.5</th>
<th>25.5</th>
<th>29</th>
<th>32</th>
<th>35</th>
<th>38</th>
<th>41</th>
<th>44</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of rivet (mm)</td>
<td>12</td>
<td>14</td>
<td>16</td>
<td>18</td>
<td>20</td>
<td>22</td>
<td>24</td>
<td>27</td>
<td>30</td>
<td>33</td>
<td>36</td>
<td>39</td>
<td>42</td>
<td>48</td>
</tr>
</tbody>
</table>

2. **Number of rivets**

   The number of rivets required for the joint may be obtained by the shearing or crushing resistance of the rivets.

   Let \( P_t = \text{Maximum pull acting on the joint}. \) This is the tearing resistance of the plate at the outer row which has only one rivet.

   \[ = (b - d)t \times \sigma_t \]

   and \( n = \text{Number of rivets}. \)

   Since the joint is double strap butt joint, therefore the rivets are in double shear. It is assumed that resistance of a rivet in double shear is 1.75 times than in single shear in order to allow for possible eccentricity of load and defective workmanship.

   \[ \therefore \text{Shearing resistance of one rivet,} \]

   \[ P_s = 1.75 \times \frac{\pi}{4} \times d^2 \times \tau \]

   and crushing resistance of one rivet,

   \[ P_c = d \times t \times \sigma_c \]

   \[ \therefore \text{Number of rivets required for the joint,} \]

   \[ n = \frac{P_t}{\text{Least of } P_s \text{ or } P_c} \]

3. From the number of rivets, the **number of rows and the number of rivets** in each row is decided.
4. **Thickness of the butt straps**
   The thickness of the butt strap, 
   \[ t_1 = 1.25t, \] for single cover strap 
   \[ = 0.75t, \] for double cover strap

5. **Efficiency of the joint**
   First of all, calculate the resistances along the sections 1-1, 2-2 and 3-3. 
   At section 1-1, there is only one rivet hole. 
   ∴ Resistance of the joint in tearing along 1-1, 
   \[ P_{t1} = (b - d)t \times \sigma_t \] 
   At section 2-2, there are two rivet holes. 
   ∴ Resistance of the joint in tearing along 2-2, 
   \[ P_{t2} = (b - 2d)t \times \sigma_t + \text{Strength of one rivet in front of section 2-2} \] 
   (This is due to the fact that for tearing off the plate at section 2-2, the rivet in front of section 2-2 i.e. at section 1-1 must first fracture). Similarly at section 3-3 there are three rivet holes. 
   ∴ Resistance of the joint in tearing along 3-3, 
   \[ P_{t3} = (b - 3d)t \times \sigma_t + \text{Strength of 3 rivets in front of section 3-3} \] 
   The least value of \( P_{t1}, P_{t2}, P_{t3}, P_s \) or \( P_c \) is the strength of the joint. 
   We know that the strength of unriveted plate, 
   \[ P = b \times t \times \sigma t \]
   ∴ Efficiency of the joint, 
   \[ \eta = \frac{\text{Least of } P_{t1}, P_{t2}, P_{t3}, P_s \text{ or } P_c}{P} \]

6. **The pitch of the rivets** is obtained by equating the strength of the joint in tension to the strength of the rivets in shear. The pitches allowed in structural joints are larger than those of pressure vessels.

**Table 8. Pitch of rivets for structural joints.**

<table>
<thead>
<tr>
<th>Thickness of plate (mm)</th>
<th>Diameter of rivet hole (mm)</th>
<th>Diameter of rivet (mm)</th>
<th>Pitch of rivet ( p = 3d + 5\text{mm} )</th>
<th>Marginal pitch (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>8.4</td>
<td>8</td>
<td>29</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>9.5</td>
<td>9</td>
<td>32</td>
<td>17</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>10</td>
<td>35</td>
<td>17</td>
</tr>
<tr>
<td>5–6</td>
<td>13</td>
<td>12</td>
<td>38</td>
<td>18</td>
</tr>
<tr>
<td>6–8</td>
<td>15</td>
<td>14</td>
<td>47</td>
<td>21</td>
</tr>
<tr>
<td>8–12</td>
<td>17</td>
<td>16</td>
<td>56</td>
<td>25</td>
</tr>
<tr>
<td>11–15</td>
<td>21</td>
<td>20</td>
<td>65</td>
<td>30</td>
</tr>
</tbody>
</table>

7. **The marginal pitch (m)** should not be less than 1.5d. 
8. **The distance between the rows** of rivets is 2.5d to 3d.