307. Wood-stave Pipe.\(^1\)—Wood-stave pipes are of two types: continuous stave, as illustrated in Fig. 199, and machine-banded pipe, shown in Fig. 200. The pipes are made in all sizes up to about 20 ft. in diameter and for internal pressures up to 150 lb. per square inch, or higher.

Continuous stave pipe is usually manufactured in cradles at the point of installation. The staves are laid together in such a manner that the joints between the ends of the staves do not come at the same transverse section. The joints between the sides of the staves are planed radially. A copper or zinc plate is sometimes fitted between end joints to secure water-tightness, because of the slight longitudinal expansion of wood on swelling due to moisture. The staves are held in place by wire bands. The ends of the wires are held firmly in cast-iron shoes, such as are shown in Fig. 201, and the bands are drawn tightly by turning the nuts, also shown in the figure. Continuous stave pipe which is fabricated at the site of installation, can be made of one continuous length, and the flexibility of the wood is such that the pipe can be laid on curves with a minimum radius about fifty times the diameter of the pipe.

Machine-banded pipes are usually made in the factory, and are shipped to the site of installation. The staves are held together by spirally wound steel bands. The pipes are made in almost any length, up to 20 ft. Adjacent sections of pipes are joined by collars which are placed around the outside of the pipe or by
means of recessed or tenon joints, as shown in Fig. 200. The latter is suitable only for low pressures. The collars may be made of wood staves, cast iron, or steel. Where collars are used, it is necessary to leave an unbanded space at the end of each pipe over which the collar fits. The collars, when made of wood, are usually machine banded, and they should receive particular protection against rot, because they are not protected by the moisture in the pipe.

The backfilling of wood-stave pipe should be done with great care, particular attention being taken to tamp the backfill firmly under and around the pipe to the height of the horizontal diameter. Failure to do this results in high leakage or failure of the pipe, due to the weight of the backfill over the top of the pipe. Dry sand constitutes the best material for backfill next to the pipe. It must, however, be restrained. Loam and rich soil should not be placed in close proximity to wood pipe. If the pipe is not placed in a trench, it is supported by cradles at suitable intervals along the pipe.

The pipe should be slowly filled with water to allow the staves to swell and close leaks before the full water pressure is placed in the pipe. Large leaks might cause erosion of the backfill and endanger the safety of the pipe.

Fig. 201.—Cast-iron shoe for holding bands on wood-stave pipe.

Fig. 202.—Joint for machine-banded wood-stave pipe.
Connections to wood pipe are made by special iron castings which are fastened to the wood pipe in a manner similar to that shown in Fig. 203.

308. Design of Bands for Wood-stave Pipe.—In designing a wooden pipe made up of staves held together by metal bands, two factors are to be considered in the design of the bands: their diameter and the spacing between them. As these factors are dependent upon each other, one must be fixed before the other can be determined. It is customary to fix the diameter first, so as to develop the full crushing strength of the wood. Under such circumstances, the diameter of the band is independent of the internal bursting pressure. The distribution of stresses on a band around a wood-stave pipe is illustrated in Fig. 204. In this figure:

\[ 2S = (D + 2t)ae. \]

in which

\( S = \) the total stress in the band.
\( D = \) the internal diameter of the pipe.
\( t = \) the thickness of the wood stave.
\( e = \) the crushing strength of wood across the grain.
(Sometimes taken as about 650 lb. per square inch.)
\( a = \) width of the band in contact with the wood.
\( R = \) the internal radius of the pipe.
\( r = \) the radius of the band.
\( f_t = \) the strength of the steel in the band in tension. 
\( \) (Sometimes taken between 15,000 and 20,000 lb. per square inch.)

It is common practice to assume that \( a = r \) per unit length of the band.

Then:

\[
 r = \frac{(R + t)e}{\pi f_t}. 
\]  

\( 1 \)

The full strength of each band is \( S = \pi r^2 f_t \), and this must equal the total internal pressure between the bands. The internal pressure per unit length of pipe is:

\[
2pR + 2tW
\]

in which

\( p = \) the intensity of internal bursting pressure.
\( W = \) the swelling strength of wood. This is often assumed to be about 100 lb. per square inch.

Then if \( B \) represents the distance between bands, \( i.e., \) the pitch of the bands

\[
B(2pR + 2tW) = 2\pi r^2 f_t.
\]

Therefore,

\[
B = \frac{\pi r^2 f_t}{(pR + tW)}. 
\]

It is possible to determine the diameter and spacing of steel bands on wood-stave pipe by the use of formulas (1) and (2). The maximum spacing between bands is dependent upon the strength of the staves to resist bending and the allowable deflection. A spacing greater than 10 to 12 in. is unusual. The minimum limit of band spacing is fixed by the size of the band shoe and the possibility of turning up the nut.

The assumption that, for circular bands, the width of the contact surface is equal to the radius of the band, is approximate only. Actually, the smaller the band, the greater the relative area in contact. This is shown by Table 76.\(^1\) Circular or oval bands are preferable to flat bands, as the former expose rela-

Table 76.—Contact Area between Steel Band and Wood-stave Pipe

<table>
<thead>
<tr>
<th>Diameter of band, inches</th>
<th>Pressure, pounds per linear inch due to the crushing strength of the wood$^1$</th>
<th>Width of contact area in terms of the radius of the band on the basis that the crushing strength of wood is 650 lb. per square inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8</td>
<td>140</td>
<td>1.15</td>
</tr>
<tr>
<td>7/16</td>
<td>153</td>
<td>1.08</td>
</tr>
<tr>
<td>1/2</td>
<td>165</td>
<td>1.01</td>
</tr>
<tr>
<td>5/8</td>
<td>200</td>
<td>0.98</td>
</tr>
<tr>
<td>3/4</td>
<td>232</td>
<td>0.95</td>
</tr>
<tr>
<td>7/8</td>
<td>262</td>
<td>0.92</td>
</tr>
</tbody>
</table>


tively less surface to the atmosphere to be corroded and the condition of the bands can be more easily inspected. In general, the wood outlasts the bands, particularly if both are constantly wet.

309. Manufacture of Concrete Pipe.—Concrete pipe may be manufactured in place in the trench or in a manufacturing plant. For diameters up to 5 or 6 ft., precast pipe is less expensive and is of better quality than pipes cast in place. Precast concrete pipe may be manufactured by the use of an outer and an inner steel form, one type of which is shown in Fig. 205. The two forms are set on end in a cast-iron bottom ring of such design as to shape the end of the pipe properly. The reinforcing is held in place by holes or lugs in the bottom ring and by straps across the upper ends of the two forms. These straps serve also to keep the forms in place. The surfaces of the forms next to the concrete are sometimes greased before pouring concrete, to make the removal of the forms easier. Concrete is then rammed into the forms and around the reinforcing. The upper end of the pipe is made by ramming a properly shaped end piece into place when the forms are filled with concrete. The concrete is allowed to set for 8 to 24 hr., depending upon the temperature. It is then cured for 8 to 10 days, being kept moist and warm during the process of curing.

Concrete pipe is also made by a centrifugal process in which the outside mold is whirled about its axis, as the concrete is put