

**Wood Pipe.** Wood pipe is used where its availability and cost render it more advantageous than metal pipe. Under favorable conditions, certain woods, particularly California redwood, will last indefinitely. Materials used for wood-stave pipe include hemlock, spruce, yellow pine, Douglas fir, cypress, and redwood. The pipe

bands are made of steel, usually galvanized or coated to resist rust, and the ends held together in cast-iron shoes. The exterior of the pipe may be easily attacked by organic acids or plant growths, and it is subject to deterioration, particularly if alternately wet and dry. Wood pipe may be made of machine-banded logs or staves, or it may be held together by metal bands placed in the field. Machine-banded pipe is available in sizes up to 48 in. and is said to be water-tight at 280 lb. per square inch internal pressure. Wood-stave pipe is constructed in very large diameters but for

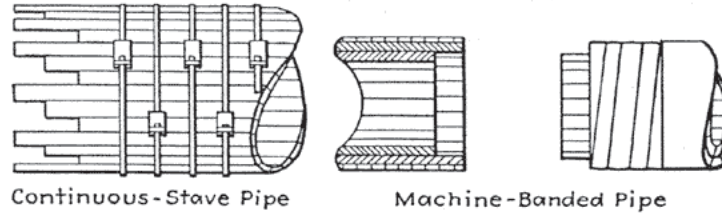


FIG. 39.—Wood pipe.

lower pressures than machine-banded pipe. The size of band and the spacing between them can be determined from the following formulas:

$$r = \frac{(R + t)e}{\pi f_t}$$

and

$$B = \frac{r^2 f_t \pi}{(pR + tw)}$$

in which  $r$  is the radius of the band in inches;  $R$  the internal radius of the pipe in inches;  $t$  the thickness of the stave in inches;  $e$  the crushing strength of the wood across the grain in pounds per square inch, usually taken at about 650;  $f_t$  the strength of the steel band in tension in pounds per square inch, usually taken between 15,000 and 20,000;  $p$  the internal pressure within the pipe in pounds per square inch;  $w$  the swelling strength of the wood in pounds per square inch, usually taken at about 100; and  $B$  the distance between the centers of the bands in inches.

**Stresses in Pipe.** Among the stresses which pipes must resist are bursting, temperature, bends, water hammer, and external compression. All but the last can be formulated. The bursting stress is

$$S = pR \tag{1}$$

in which  $S$  is the tension per unit length across a longitudinal joint,  $p$  the intensity of internal pressure, and  $R$  the inside radius of the pipe. The stress due to temperature is

$$S = ETC \tag{2}$$

in which  $S$  is the tension, or compression, per unit length on a transverse joint,  $E$  the modulus of elasticity of the material,  $T$  the change in temperature in degrees, and  $C$  the coefficient of expansion of the metal. The full stress is not developed unless the metal is held immovable. If the pipe can move, the amount of movement is

$$M = LCT \tag{2a}$$

in which  $M$  is the change in length of the pipe, if free to move,  $L$  the length of the pipe affected, and  $C$  the coefficient of expansion of the material. Where partial or complete movement is permitted, as by an expansion joint,

$$S = \frac{(M - M')E}{L} \tag{2b}$$

in which  $M'$  is the actual change in length permitted by the expansion joint, and the other nomenclature is unchanged.

The stress at a bend is

$$S = \frac{WAV^2}{g} + pA \quad (3)$$

in which  $S$  is the tension (total) on a transverse joint due to water flowing around a bend,  $W$  the unit weight of water,  $A$  the cross-sectional area of the pipe,  $V$  the linear velocity of flow of the water,  $p$  the intensity of internal pressure, and  $g$  the acceleration due to gravity. If a buttress is placed against the joint to hold the pipe in position, the thrust against the buttress is

$$P = 2A \left( \frac{WV^2}{g} + p \right) \sin \frac{\theta}{2} \quad (3a)$$

in which  $P$  is the total thrust,  $\theta$  the central angle subtended by the curve, and the remaining nomenclature as in Eq. (3).

An expression for the pressure due to water hammer is

$$P = \left[ \frac{t_1}{t_2} \right] \left[ \frac{4,700VW}{144g} \right] \sqrt{\frac{E}{E + 294,000 \frac{d}{t}}} \quad (4)$$

in which  $P$  is the excess pressure above normal in pounds per square inch,  $V$  the velocity of flow of water in feet per second,  $W$  the unit weight of the water in pounds per square inch,  $E$  the modulus of elasticity of the material of which the pipe is made,  $d$  the diameter of the pipe in inches,  $t$  the thickness of the shell of the pipe in inches,  $g$  the acceleration due to gravity in foot-second units,  $t_1$  the time in seconds for the pressure wave to pass from the point of stoppage to a point of relief of pressure and to return to the point of stoppage, and  $t_2$  the time in seconds required to stop the flow. The maximum value of  $t_1/t_2$  is unity. The magnitude of  $t_1$  can be found from knowledge of the length of the pipe affected by the water hammer and the solution of the expression

$$V' = 4,700 \sqrt{\frac{E}{E + 294,000 \frac{d}{t}}} \quad (4a)$$

in which  $V'$  is the velocity of travel of the pressure wave in the pipe in feet per second, and the other nomenclature is as in Eq. (4).

A method for determining the distribution and magnitude of external loading on buried pipes is given by Prof. Anson Marston in *Bulletin 31* of the Engineering Experiment Station, Iowa State College of Agriculture. The maximum intensity of stress on the extreme fiber of a pipe across a longitudinal joint is

$$S = \frac{MC}{I} + \frac{P}{2A}$$

in which  $M$  is the bending moment across the section,  $C$  the distance from the neutral axis to the extreme fiber of the section formed by a unit length of the pipe,  $I$  is moment of inertia of the area about its neutral axis,  $P$  the total vertical load on a unit length of the pipe, and  $A$  the area of the cross-section subjected to the stress.

**Materials for Service Pipes.** Materials for service pipes include galvanized iron, either unlined or lined with tin, lead, or cement; lead, either unlined or lined with tin; cast iron, yellow brass; admiralty mixture; and copper. Each of these is used with satisfaction in some fields, but not all are satisfactory in all locations.

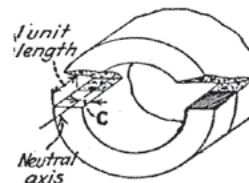


FIG. 40.

**Corrosion.** Corrosion of metal is attributed to an electrolytic action between different constituents of the metal or different materials in contact, to oxidation, or to attack by acids, alkalis, or corrosive salts. In electrolytic corrosion, a current is set up between two particles of different solution pressure, the material of higher pressure forming the anode which deteriorates by deposition on the cathode, which is the material of lower pressure. In the potential series of metals, zinc has a higher solution pressure than iron and, therefore, protects iron, but iron in contact with any other metal than zinc is corroded because of its higher solution pressure. The corrosion of metals by oxidation is the result of the combination of oxygen with the metal, forming rust which may act as a protective coating against further oxidation.

Corrosion can be avoided by the use of *pure* metals, *i.e.*, metals of homogeneous constituents; by the protection of metallic surfaces from external influences, particularly from oxygen; by avoiding contact between metals of different solution pressures; by treating water to remove corrosive substances; and through other expedients. Surface protection is provided by galvanizing or painting. The high solution pressure and the protective coating formed by zinc against deep penetration of oxygen serve as a satisfactory protection to ferrous metals. Painting is also satisfactory, but the quality is important, as lead paints may cause illness in the consumer, and paints containing phenol or certain other substances may impart undesirable tastes. Zinc paints are satisfactory.

#### QUALITY OF WATER

**Water Analysis.** Standard sanitary water analyses are classified as physical, bacteriological, chemical, microscopical, and mineral. The observations made in a physical analysis are color, odor (hot and cold), temperature, and turbidity. In a bacteriological analysis, only the total number of bacteria and the *B. coli* are determined. Among the various constituents and indicators determined in a chemical analysis are the following: nitrogen as free ammonia, albuminoid ammonia, nitrites, nitrates, and total nitrogen; oxygen consumed; chlorides; total, suspended, dissolved, volatile, and fixed solids, and possibly settleable solids; acidity or alkalinity and hydrogen-ion concentration (pH); and dissolved oxygen. Some routine determinations, less frequently made, include biochemical oxygen demand. Only sufficient of these determinations are made in an analysis to indicate the source and the quality of the water or to aid in the control of a purification or treatment plant.

A microscopical analysis is made to observe the minute organic life in water. Where such organisms are causing trouble, the analysis will be continued to identify the species present. A mineral analysis reports the mineral constituents of the water. Such analyses are not made in routine studies of the quality of the water. Methods of making most of these analyses are described in "Standard Methods of Water Analysis," published by the American Public Health Association.

**Significance of Constituents.** The presence and the intensity of concentration of any constituent in a water analysis do not always indicate the same thing in different samples, except in relation to the history of the sample and in relation to other constituents. In a study of the quality of a water supply from various sources, the chemical constituents are merely indicators to direct attention. Adverse reports on the potability of a water supply should not be based on the results of a chemical analysis alone. Confirmatory information must be obtained through a sanitary survey of the source or through the results of a bacteriological examination or a microscopical examination or all.

*Color* is reported numerically by matching a sample of the water with standard colored-glass disks or a platinum-cobalt solution.

*Turbidity* is measured by the depth at which a standard platinum wire disappears when immersed. It is a measure of the suspended and colloidal matter in the water.