TABLE 2. FLOW OF STEAM IN PIPES

$P$ = loss in pressure in pounds per square inch.
$D$ = inside diameter of pipe in inches.
$L$ = length of pipe in feet.
$d$ = weight of 1 cu ft of steam.
$W$ = pounds of steam per hour.

$$W = 5220 \sqrt{\frac{PdD^5}{\left(1 + \frac{3.6}{D}\right)L}}$$

$$P = 0.0000000367 \left(1 + \frac{3.6}{D}\right) \frac{W^2 L}{dD^5}$$

| Pressure Loss in Ounces | Col. 1 | Pipe Size | | Internal Area of Pipe Sq Inches | Col. 2 | Avg Steam Press. psig | Col. 3 | Length of Pipe in Feet | Col. 4 |
|---|---|---|---|---|---|---|---|---|---|
| | $5220\sqrt{\frac{P}{100}}$ | Nominal | Actual Internal Diameter | | $\sqrt{\frac{D^5}{1+\frac{3.6}{D}}}$ | | $\sqrt{d}$ | | $\sqrt{\frac{100}{L}}$ |
| 0.25 | 65.28 | 1 | 1.049 | 0.864 | 0.536 | −1.0[a] | 0.187 | 20 | 2.240 |
| 0.50 | 92.28 | 1¼ | 1.380 | 1.496 | 1.178 | −0.5[a] | 0.190 | 40 | 1.580 |
| 1.00 | 130.5 | 1½ | 1.610 | 2.036 | 1.828 | 0.0 | 0.193 | 60 | 1.290 |
| 2 | 184.6 | 2 | 2.067 | 3.356 | 3.710 | 0.3 | 0.195 | 80 | 1.120 |
| 3 | 226.0 | 2½ | 2.469 | 4.788 | 6.109 | 1.3 | 0.201 | 100 | 1.000 |
| 4 | 261.0 | 3 | 3.068 | 7.393 | 11.183 | 2.3 | 0.207 | 120 | 0.912 |
| 5 | 291.8 | 3½ | 3.548 | 9.887 | 16.705 | 5.3 | 0.223 | 140 | 0.841 |
| 6 | 319.7 | 4 | 4.026 | 12.730 | 23.631 | 10.3 | 0.248 | 160 | 0.793 |
| 7 | 345.3 | 4½ | 4.506 | 15.947 | 32.134 | 15.3 | 0.270 | 180 | 0.741 |
| 8 | 369.1 | 5 | 5.047 | 20.006 | 43.719 | 20.3 | 0.290 | 200 | 0.710 |
| 10 | 412.7 | 6 | 6.065 | 28.886 | 71.762 | 30.3 | 0.326 | 250 | 0.632 |
| 12 | 452.0 | 7 | 7.023 | 38.743 | 106.278 | 40.3 | 0.358 | 300 | 0.578 |
| 14 | 488.3 | 8 | 7.981 | 50.027 | 149.382 | 50.3 | 0.388 | 350 | 0.538 |
| 16 | 522.0 | 9 | 8.941 | 62.786 | 201.833 | 60.3 | 0.415 | 400 | 0.500 |
| 20 | 583.6 | 10 | 10.020 | 78.854 | 272.592 | 75.3 | 0.452 | 450 | 0.477 |
| 24 | 639.3 | 12 | 12.000 | 113.098 | 437.503 | 100.3 | 0.507 | 500 | 0.447 |
| 28 | 690.5 | 14 | 13.250 | 137.880 | 566.693 | 125.3 | 0.557 | 600 | 0.407 |
| 32 | 738.2 | 16 | 15.250 | 182.655 | 816.872 | 150.3 | 0.603 | 700 | 0.378 |
| 40 | 825.4 | | | | | 175.3 | 0.645 | 800 | 0.354 |
| 48 | 904.1 | | | | | 200.3 | 0.685 | 900 | 0.333 |
| 80 | 1167.2 | | | | | | | 1000 | 0.316 |
| 160 | 1650.7 | | | | | | | 1200 | 0.289 |
| 320 | 2334.5 | | | | | | | 1500 | 0.258 |
| 480 | 2859.1 | | | | | | | 2000 | 0.224 |

Column 1 × 2 × 3 × 4 = lb of steam per hour that will flow through a straight pipe for a given condition.

*Example 1:* 1 oz drop — 2 in. pipe — 1.3 lb press. — 100 ft equivalent length:

130.5 × 3.710 × 0.201 × 1 = 97.2 lb per hour.
97.2 × 4[b] = 388.8 sq ft equivalent radiation.

Table 2 does not allow for entrained water in low-pressure steam, condensation in covered pipe and roughness in commercial pipe as found in practice.

[a] Pounds per square inch gage = 2.04 in. Vacuum, Mercury Column.
[b] The factor 4 is the approximate equivalent in square feet of steam radiation of 1 lb of steam per hour.



has been established by Babcock in the formula given at the top of Table 2. In Columns 1, 2, 3, and 4 of this table, the numerical values of the factors for different pressure losses, pipe diameters, steam densities and lengths of pipe have been worked out in convenient form so that the steam flowing in any pipe may be calculated by multiplying together the proper factors in each column, as shown in the example at the bottom of the table.

## Pipe Sizes

The determination of pipe sizes for a given load in steam heating depends on the following principal factors:

1. The initial pressure and the total pressure drop which may be allowed between the source of supply and at the end of the return system.
2. The maximum velocity of steam allowable for quiet and dependable operation of the system, taking into consideration the direction of condensate flow.
3. The equivalent length of the run from the boiler or source of steam supply to the farthest heating unit.
4. The direction of flow of the condensate, whether against or with the steam.

## Initial Pressure and Pressure Drop

Theoretically, there are several factors to be considered such as initial pressure and pressure required at the end of the line, but it is most important that: (1) the total pressure drop does not exceed the initial gage pressure of the system, and in actual practice it should never exceed one-half of the initial gage pressure; (2) the pressure drop is not so great as to cause excessive velocities; (3) there is a constant initial pressure, except on systems specially designed for varying initial pressures, such as the sub-atmospheric, which normally operate under controlled partial vacua and orifice and vapor systems, which at times operate under such partial vacua as may be obtained due to the condition of the fire; and (4) the rise in water due to pressure drop does not exceed the difference in level, for gravity return systems, between the lowest point on the steam main, the heating units, or the dry-return, and the boiler water line.

All systems should be designed for a low initial pressure and a reasonably small pressure drop for two reasons: *first*, the present tendency in steam heating unmistakably points toward a constant lowering of pressures even to those below atmospheric; *second*, a system designed in this manner will operate under higher pressures without difficulty. When a system designed for a relatively high initial pressure and a relatively high pressure drop is operated at a lower pressure, it is likely to be noisy and have poor circulation.

The total pressure drop should never exceed one-half of the initial gage pressure when condensate is flowing in the same direction as the steam. Where the condensate must flow counter to the steam, the governing factor is the velocity permissible without interfering with the condensate flow. A.S.H.V.E. Research Laboratory experiments limit this to the capacities given in Table 3 for horizontal pipes at varying grades.

## Maximum Velocity

The capacity of a steam pipe in any part of a steam system depends upon the quantity of condensate present, the direction in which the condensate is flowing, and the pressure drop in the pipe. Where the quantity of condensate is limited and is flowing in the same direction as the steam, only the pressure drop need be considered. When the condensate must flow against the steam, even in limited quantity, the velocity of the steam must not exceed limits above which the disturbance between the steam and