# HYDRAULIC HANDBOOK

**Fundamental Hydraulics and Data useful in the solution of pump application problems**

*Sixteenth Edition*

**Fairbanks Morse Pump**

A Member of Pentair Pump Group

**3601 FAIRBANKS AVENUE • KANSAS CITY, KANSAS 66106**

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# PREFACE

The Hydraulic Handbook is a publication of Fairbanks Morse Pump, A Member of Pentair Pump Group, compiled as an aid to the multitude of engineers who plan the installation of pumping machinery - and to plant managers and operators who are responsible for the efficient functioning of this machinery.

We have attempted to include enough of the fundamental principals of pumping to refresh the memories of those who work with pump applications at infrequent intervals. Also included are tables, data and general information which we hope will be of value to everyone who plans pumping equipment for public works, industry or agriculture.

Much of the material in the Hydraulic Handbook has been published previously and is reassembled in this single volume for your convenience. We sincerely appreciate permission to reprint - as generously granted by the Hydraulic Institute and others.

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# ACKNOWLEDGEMENTS

In compiling the "Hydraulic Handbook," we used pertinent data from many sources. We sincerely appreciate the courtesies extended and are happy to give credit as follows:

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"Domestic and Industrial Requirements" from "Willing Water #25", December 1953—*American Water Works Association,* New York, N.Y.

Illustrations of gauges—*United States Gauge Division of American Machine & Metals, Inc.* Sellersville, Pa.

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Chart "Vapor Pressure Versus Temperature For Motor and Natural Gasoline"—*Chicago Bridge & Iron Company,* Chicago, Ill.

Chart "Vapor Pressure Propane-Butane Mixture" — *Phillips Petroleum Company,* Bartlesville, Okla.

Table of the selection and horsepower rating of V-belt drives—*Dayton Rubber Manufacturing Co.,* Dayton, Ohio.

Text on Parallel and Series Operation—*De Laval Steam Turbine Company.* Trenton, New Jersey.

Tables of Cast Iron Pipe Dimensions—*Cast Iron Pipe Research Association,* Chicago, Illinois.

"Infiltration Rates of Soils"—*F. L. Duley and L. L. Kelly, S.C.S. Nebraska Experiment Station, Research Bulletin #12,* and "Peak Moisture Use for Common Irrigated Crops and Optimum Yields"—*A. W. McCullock, S.C.S. Reprinted from the Sprinkler Irrigation Handbook of the National Rain Bird Sales & Engineering Corp,* Azusa, Calif.

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# SECTION I—HYDRAULIC FUNDAMENTALS

I

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# SECTION I — HYDRAULIC FUNDAMENTALS

## HYDRAULICS

The science of hydraulics is the study of the behavior of liquids at rest and in motion. This handbook concerns itself only with information and data necessary to aid in the solution of problems involving the flow of liquids: viscous liquids, volatile liquids, slurries and in fact almost any of the rapidly growing number of liquids that can now be successfully handled by modern pumping machinery.

In a liquid at rest, the absolute pressure existing at any point consists of the weight of the liquid above the point, expressed in psi, plus the absolute pressure in psi exerted on the surface (atmospheric pressure in an open vessel). This pressure is equal in all directions and exerts itself perpendicularly to any surfaces in contact with the liquid. Pressures in a liquid can be thought of as being caused by a column of the liquid which, due to its weight, would exert a pressure equal to the pressure at the point in question. This column of the liquid, whether real or imaginary, is called the static head and is usually expressed in feet of the liquid.

Pressure and head are, therefore, different ways of expressing the same value. In the vernacular of the industry, when the term "pressure" is used it generally refers to units in psi, whereas "head" refers to feet of the liquid being pumped. These values are mutually convertible, one to the other, as follows:

$$\frac{\text{psi} \times 2.31}{\text{sg.}} = \text{Head in feet.}$$

Convenient tables for making this conversion for water will be found in Section III, Table 13 of this Handbook.

Pressure or heads are most commonly measured by means of a pressure gauge. The gauge measures the pressure above atmospheric pressure. Therefore, absolute pressure (psia) = gauge pressure (psig) plus barometric pressure (14.7 psi at sea level).

Since in most pumping problems differential pressures are used, gauge pressures as read and corrected are used without first converting to absolute pressure.

## LIQUIDS IN MOTION

Pumps are used to move liquids.

A consideration of the heads required to cause flow in a system and the definition of the terms used can best be understood by referring to the following drawings and text.

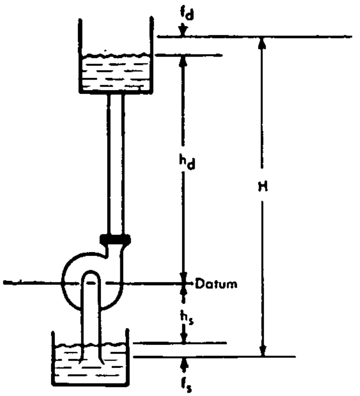



FIG. 1. Pump operating with suction lift. Suction bay level below center line of pump. Gauge reading at suction flange — vacuum.

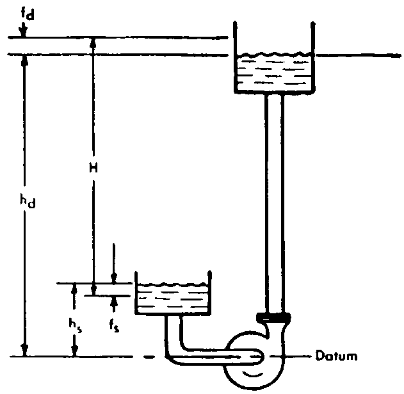



FIG. 2. Pump operating with suction head. Suction bay level above center line of pump. Gauge reading at suction flange — pressure.

For Figure 1—Pump under suction lift—

$$H = h_d + h_s + f_d + f_s + \frac{V_d^2}{2g}$$

For Figure 2—Pump under suction head—

$$H = h_d - h_s + f_d + f_s + \frac{V_d^2}{2g}$$

Where—

$H$ = Total head in feet (formerly known as total dynamic head) = the total head delivered by the pump when pumping the desired capacity. All heads are measured in feet of the liquid being pumped.

$h_d$ = Static discharge head in feet = vertical distance between the pump datum and the surface of the liquid in the discharge bay. The datum shall be taken at the centerline of the pump for horizontal and double suction vertical pumps or at the entrance eye of the first stage impeller for single suction vertical pumps.

$h_s$ = Static suction head or lift in feet = vertical distance from surface of water in suction bay to the pump datum. Notice in the equations above that this value is negative when operating under a suction head and positive when operating under a suction lift.

$f_d$ = Friction head in discharge in feet = the head required to overcome friction in the pipe, valves, fittings, turns, etc. in the discharge system.

$f_s$ = Friction head in suction in feet = the head required to overcome friction in the suction system.

$\frac{V_d^2}{2g}$ = The velocity head, in feet, at the discharge nozzle of the pump. Velocity head can be defined as the head required to cause the water to attain the velocity "$V$". It is velocity energy that is added to the liquid by the pump and since, in the illustrations Fig. 1 and 2, this velocity energy is lost at the sudden enlargement and never converted into pressure energy, it must be considered as part of the total head.

Since the velocity head in most installations will be less than two feet, on high head pumping installations it is a relatively small part of the total head. However, on low head pumping installations it is a significant part of the total head.

In pump testing, the total head is generally determined by gauge measurements. Since a gauge indicates the pressure energy only, the velocity head must always be calculated. The practice in testing horizontal centrifugal pumps differs from that used when testing vertical turbine or propeller pumps and is described in Chapter XI, Pump Testing.

For the various sizes of commercial pipe the velocity and velocity head are given for various capacities in the friction tables in Section II of this Handbook. When necessary to calculate the velocity head one of the following equations may be used:

$$\text{Velocity Head} = h_v \doteq \frac{V^2}{2g} = 0.0155V^2 = \frac{0.00259\ \text{Gpm}^2}{D^4}$$

$$= \frac{0.00127\ (\text{Bbl. per Hour})^2}{D^4}$$

The last two equations apply to circular piping having a diameter $D$ inches and the last equation to barrels of 42 gal. each.

## FLUID FLOW

Liquids are approximately incompressible—in fact, sufficiently so that no corrections need be made at low or medium pressures. However, at very high pressures there is a slight change in density that should be taken into consideration. Since liquids may be said to be incompressible there is always a definite relationship between the quantity of liquid flowing in a conduit and the velocity of flow. This relationship is expressed:

$$Q = AV \quad \text{or} \quad V = \frac{Q}{A}$$

$$\text{OR} \quad V = \frac{0.4085 \text{ Gpm}}{D^2} = \frac{0.2859 \text{ Bbl.}^{\oplus} \text{ per hour}}{D^2}$$

Where $Q$ = Capacity in cubic feet per second
$A$ = Area of conduit in square feet
$V$ = Velocity of flow in feet per second
$D$ = Diameter of circular conduit in inches
$\oplus$ = 42 gal. per barrel

## WATER HAMMER

Water hammer is a series of pressure pulsations, of varying magnitude, above and below the normal pressure of water in the pipe. The amplitude and periodicity depends on the velocity of water extinguished, as well as the size, length and material of the pipe line. Shock results from these pulsations when any liquid, traveling with a certain velocity, is stopped in a short period of time. The pressure increase, when flow is stopped, is independent of the working pressure of the system. For example: if water is flowing in a pipe at five feet per second and a valve is instantaneously closed, the pressure increase will be exactly the same whether the normal pressure in the pipe line is 100 psig or 1000 psig.

Water hammer is often, though not always, accompanied by a sound comparable to that heard when a pipe is struck by a hammer, hence the name. Intensity of sound is no measure of pressure magnitude because tests show that if 15%, or even less, of the shock pressure is removed by absorbers or arresters installed in the line the noise is eliminated, yet adequate relief from the effect of the water hammer is not necessarily obtained.

*Time of Valve Closure to Cause Maximum Water Hammer Pressure.* Joukovski, who was the first great investigator of the water hammer theory to be verified by test, published his paper in Moscow, Russia. It was translated and printed in the Journal of the American Water Works Association in 1904. In brief, he postulated that the maximum pressure, in any pipe line, occurs when the total discharge is stopped in a period of time, equal or less than the time, required for the induced pressure wave to travel from the point of valve closure to the inlet end of the line and return. This time he stated as:

$$t = \frac{2L}{a}$$

Where:

$t$ = time, in seconds, for pressure wave to travel the length of the pipe and return.
$L$ = length, in feet, of the pipe line.
$a$ = velocity, in feet per second, of pressure wave.

One form of the formula, developed to determine the velocity of the pressure wave, is

$$a = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{k} + \frac{d}{Ee}\right)}}$$

Where:

$a$ = velocity of pressure wave, fps.
$g$ = acceleration caused by gravity = 32.2 feet per sec. per sec.
$w$ = weight of one cu. ft. of water, lbs.
$d$ = inside diameter of pipe, in.
$e$ = thickness of pipe wall, in.
$k$ = bulk modulus of compressibility of water; approximately 300,000 psi.
$E$ = modulus of elasticity of pipe material, psi; for steel—approximately 30,000,000. For cast iron—approximately 15,000,000.

*Maximum Water Hammer Pressure.* The formula that evaluates the maximum pressure caused by water hammer is:

$$p = \frac{0.433\, a\, V}{g}$$

Where:

$p$ = maximum pressure, psig.
$a$ = velocity of pressure wave, fps.
$V$ = velocity of water stopped, fps.
$g$ = acceleration caused by gravity = 32.2 ft. per sec. per sec.
0.433 = a constant used to convert feet of head to psi.

Computations of the preceding formulae permit the layout of the accompanying chart, Fig. 3, which discloses the maximum water hammer pressure for various pipe sizes, thickness, and the velocity of water stopped. This chart is for water only, but recent investigations by the petroleum industry, disclosed that the shock pressure caused by any relatively incompressible liquid can be obtained by the correct substitution of the formula of the physical constants of the liquid; namely, those of weight per cu. ft. and bulk modulus of elasticity.

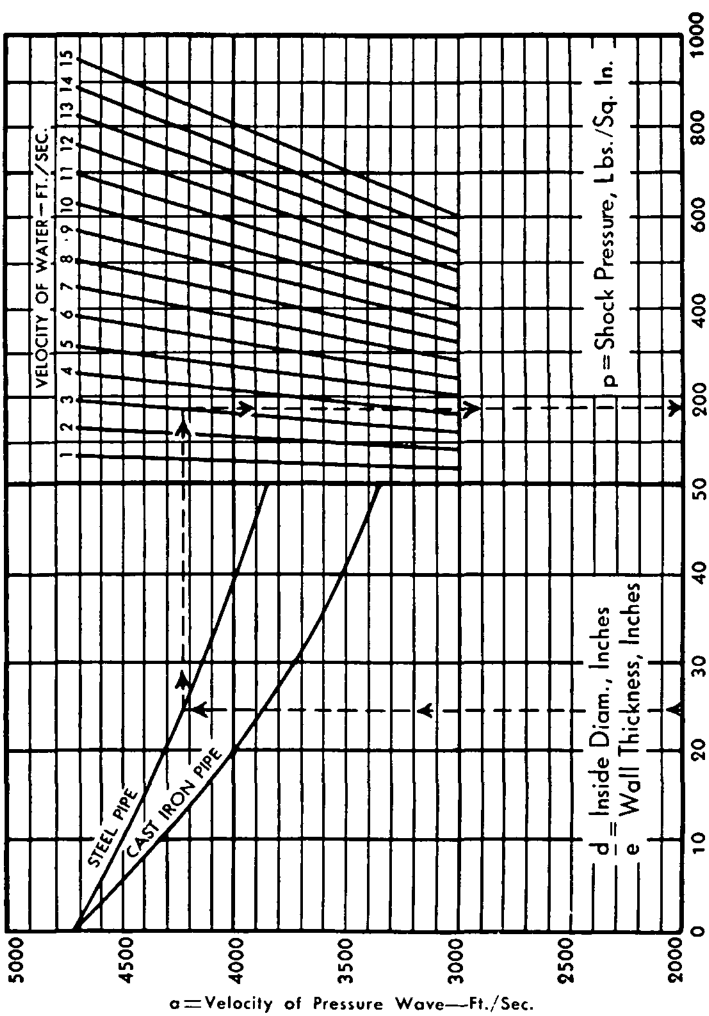



FIG. 3. Maximum shock pressure caused by water hammer (based on instantaneous closure of valves).

*Example:*

What is the maximum pressure caused by water hammer in an 8-inch steel pipe line (0.322-inches wall thickness) transporting water at a steady velocity of 3 fps?

*Procedure in Using Chart:*

Determine the ratio $\frac{d}{e} = \frac{\text{inside dia. of pipe, in.}}{\text{wall thickness of pipe, in.}} = \frac{7.981}{0.322} = 24.8.$

Enter the chart at $\frac{d}{e} = 24.8$ and project upward to the intersection with the line for steel pipe.

Note that the value of the velocity of the pressure wave, $a =$ 4225 fps.

Project horizontally to the right, to an intersection with the 3 fps. velocity line and then down to the base line, where shock pressure of 170 psi is obtained.

## SPECIFIC GRAVITY AND HEAD

The head developed by a centrifugal pump depends upon the peripheral velocity of the impeller. It is expressed thus:

$$H = \frac{u^2}{2g}$$

Where

$H$ = Total Head at zero capacity developed by the pump in feet of liquid

$u$ = Velocity at periphery of impeller in feet per second

Notice that the head developed by the pump is independent of the weight of the liquid pumped. Therefore in Fig. 4 the head $H$

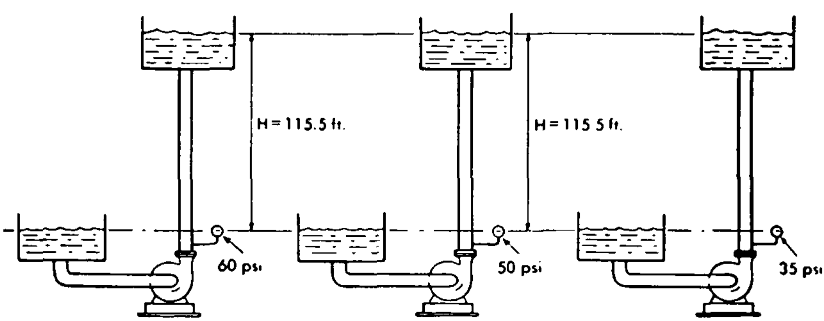



FIG. 4a. sg = 1.2 FIG. 4b. sg = 1.0 FIG. 4c. sg = 0.70

FIG. 4. Pressure—head relationship identical pumps handling liquids of differing specific gravities.

in feet would be the same whether the pump was handling water with a specific gravity of 1.0, gasoline with a sg. of 0.70, brine of a sg. of 1.2 or a fluid of any other specific gravity. The pressure reading on the gauge, however, would differ although the impeller diameter and speed is identical in each case.

$$\text{The gauge reading in psi} = \frac{H \times \text{sg.}}{2.31}$$

Refer to Fig. 5. All three of these pumps are delivering liquids at 50 psi. Because of the difference in specific gravity of the liquids each pump develops a different head in feet. Therefore, if the speed of all three pumps is the same, the pump in Fig. 5c must have the largest diameter impeller and that in Fig. 5a the smallest.

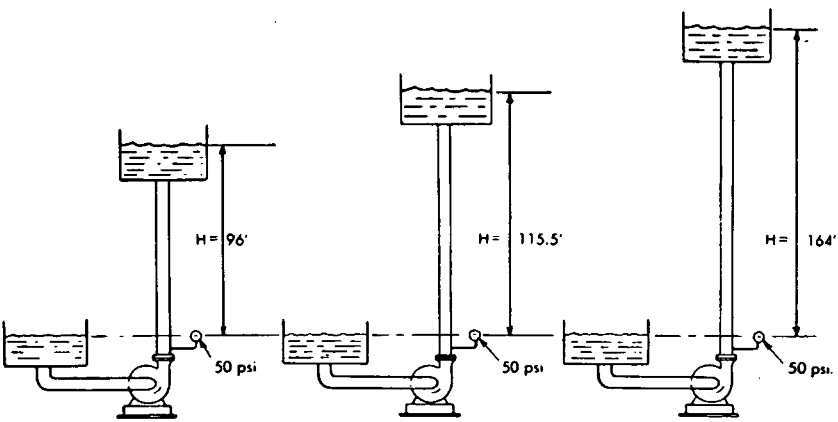



FIG. 5a. sg = 1.2 FIG. 5b. sg = 1.0 FIG. 5c. sg = 0.70

FIG. 5. Pressure—head relationship pumps delivering same pressure handling liquids of differing specific gravity.

Standard performance curves of pumps are generally plotted with total head in feet as ordinates against capacity in gpm as abscissae. Water is the liquid most often used in rating pumps. Since the head in feet developed by a centrifugal pump is independent of the specific gravity, if the head for a proposed application is figured in feet then the desired head and capacity can be read directly from the water curves without correction as long as the viscosity of the liquid is the same as that of water. The horsepower shown on the water curves will apply only to liquids with a specific gravity of 1.0. For other liquids multiply the water Hp by the specific gravity of the liquid being pumped.

## POWER, EFFICIENCY AND ENERGY

The Horse Power (Hp) required to drive a pump may be figured from the following formulae:

Liquid Hp or useful work done by the pumps =

$$\text{Whp} = \frac{\text{lbs. of liquid raised per min.} \times H \text{ in feet}}{33{,}000}$$

$$= \frac{\text{gpm} \times H\text{, ft.} \times \text{sg.}}{3960}$$

The Brake Horsepower required to drive the pump =

$$\text{Bhp} = \frac{\text{gpm} \times H\text{, ft.} \times \text{sg.}}{3960 \times \text{Pump Eff.}}$$

$$\text{Pump Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Whp}}{\text{Bhp}}$$

$$\text{Electrical Hp input to Motor} = \frac{\text{Bhp}}{\text{Motor Eff.}}$$

$$= \frac{\text{Gpm} \times H\text{, ft.} \times \text{sg.}}{3960 \times \text{Pump Eff.} \times \text{Motor Eff.}}$$

$$\text{Kw input to Motor} = \frac{\text{Bhp} \times 0.746}{\text{Motor Eff.}}$$

$$= \frac{\text{Gpm} \times H\text{, ft.} \times \text{sg.} \times 0.746}{3960 \times \text{Pump Eff.} \times \text{Motor Eff.}}$$

$$\text{Overall Eff.} = \text{Pump Eff.} \times \text{Motor Eff.}$$

$$\text{Kwh per 1000 gal. water pumped} = \frac{H\text{, ft.} \times 0.00315}{\text{Overall Eff.}}$$

$$\text{Kwh per 1000 gal. water pumped} = K \times H$$

Where $K$ = a constant depending upon the overall efficiency of the pumping unit obtained from Table 15 in Section III.

## SPECIFIC SPEED

Specific speed may be defined as that speed in revolutions per minute at which a given impeller would operate if reduced proportionately in size so as to deliver a capacity of 1 GPM against a total dynamic head of 1 foot. The visualization of this definition, however, has no practical value for specific speed is used to classify impellers as to their type or proportions, as shown in Fig. 6 and as a means of predicting other important pump characteristics, such as, the suction limitation of the pump.

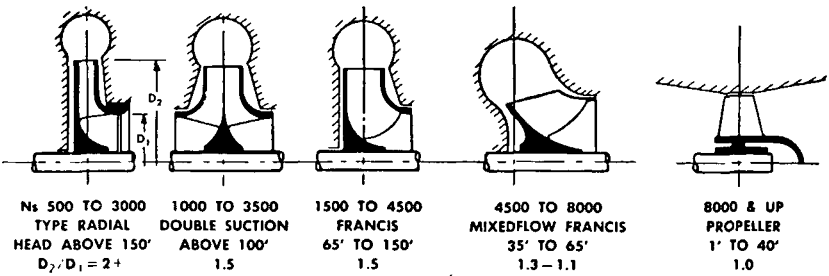



FIG. 6. Relation specific speeds, $N_s$, to pump proportions, $\frac{D_2}{D_1}$

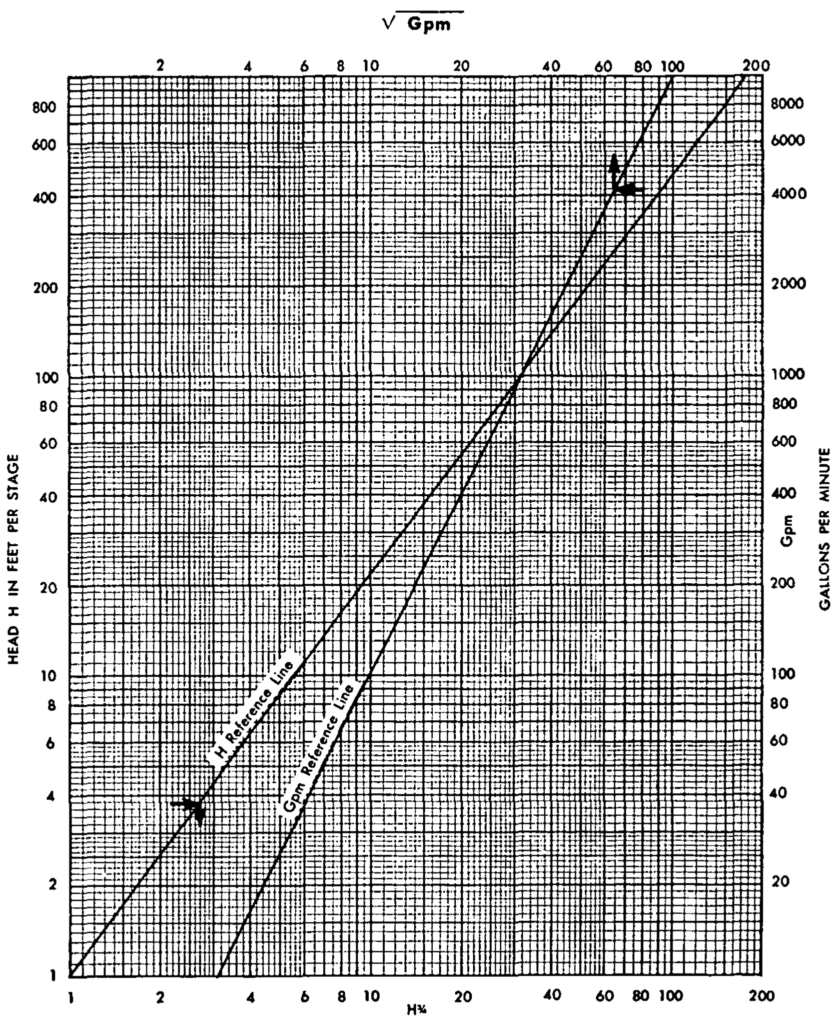



FIG. 7. Values of $H^{3/4}$ and $\sqrt{\text{gpm}}$

## SPECIFIC SPEED—SUCTION LIMITATIONS†

Among the more important factors affecting the operation of a centrifugal pump are the suction conditions. Abnormally high suction lifts (low NPSH) beyond the suction rating of the pump, usually causes serious reductions in capacity and efficiency, and often leads to serious trouble from vibration and cavitation.

*Specific Speed.* The effect of suction lift on a centrifugal pump is related to its head, capacity and speed. The relation of these factors for design purposes is expressed by an index number known as the specific speed. The formula is as follows:

$$\text{Specific Speed, } N_s = \frac{\text{rpm}\sqrt{\text{gpm}}}{H^{3/4}}$$

where $H$ = head per stage in feet (Fig. 7 shows the corresponding values of $H^{3/4}$ and $\sqrt{\text{gpm}}$).

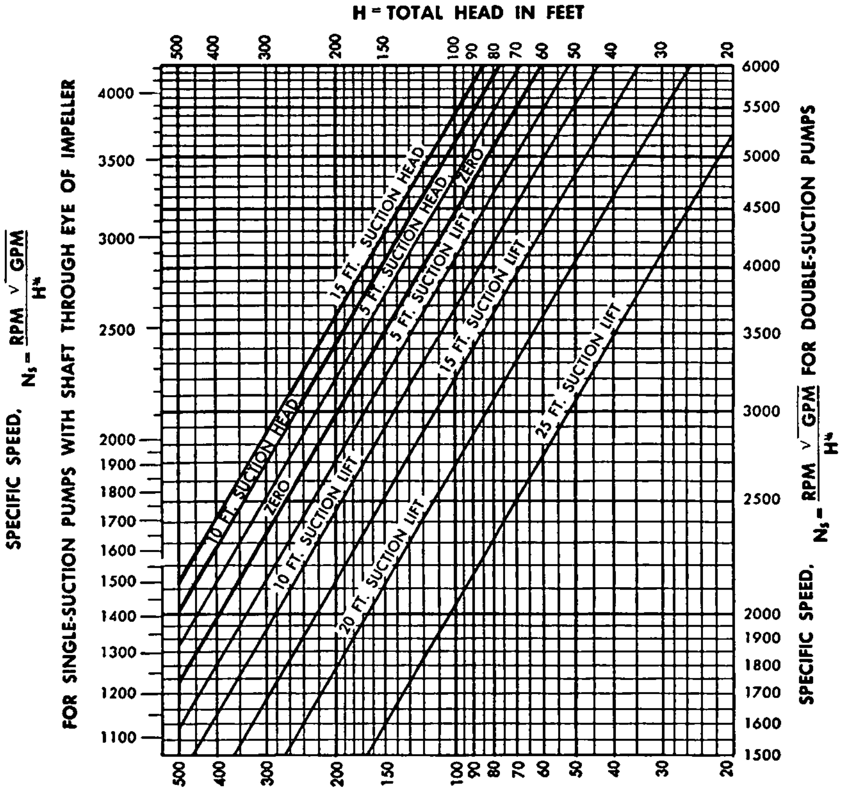



FIG. 8. Hydraulic Institute upper limits of specific speeds for single stage, single suction and double suction pumps with shaft through eye of impeller pumping clear water at sea level at 85°F.

†*Courtesy Hydraulic Institute. See page 6.*

The designed specific speed of an impeller is an index to its type when the factors in the above formula correspond to the performance at *Optimum Efficiency*. It is used when designing impellers to meet different conditions of head, capacity and speed. Impellers for high heads usually have low specific speeds and impellers for low heads usually have high specific speeds. The specific speed has been found to be a very valuable criterion in determining the permissible maximum suction lift, or minimum suction head, to avoid cavitation for various conditions of capacity, head and speed.

For a given head and capacity, a pump of low specific speed will operate safely with a greater suction lift than one of higher specific speed. If the suction lift is very high (over 15 feet) it is often necessary to use a slower speed and consequently larger pump, while if the suction lift is low, or there is a positive head on the suction, the speed may often be increased and a smaller pump may be used.

*Specific Speed Limitations.* Increased speeds without proper suction conditions often cause serious trouble from vibration, noise and pitting. Two specific speed curves (Figs. 8 and 9) represent upper limits of specific speed in respect to capacity, speed, head and suction lift. Centrifugal, mixed flow and axial flow pumps may be selected within the limits shown on these charts with reasonable assurance of freedom from cavitation.

The curves show recommended maximum specific speeds for normal rated operating conditions and are based upon the premise that the pump, at that rated condition, is operating at or near its point of *Optimum Efficiency*.

The suction lift or suction head is to be measured at the suction flange of the pump and referred to the centerline of the pump for horizontal and double suction vertical pumps, or to the entrance eye of the first stage impeller for single suction vertical pumps.

The curves apply to single stage pumps of double suction and single suction type which have the shaft through the eye of the impeller, and to single inlet mixed flow and axial flow pumps.

The first curve, Fig. 8, covers pumps of predominantly centrifugal types, for specific speeds from 1500 to 6000 for double suction pumps, and from 1100 to 4000 for single suction pumps. This type of pump finds application principally in the medium and high head range.

The second curve, Fig. 9, covers pumps of the single suction mixed flow and axial flow type for specific speeds from 4000 to 20000. Pumps of these types are applied advantageously for low head pumping.

Example I—Single suction pump with shaft through eye of impeller.

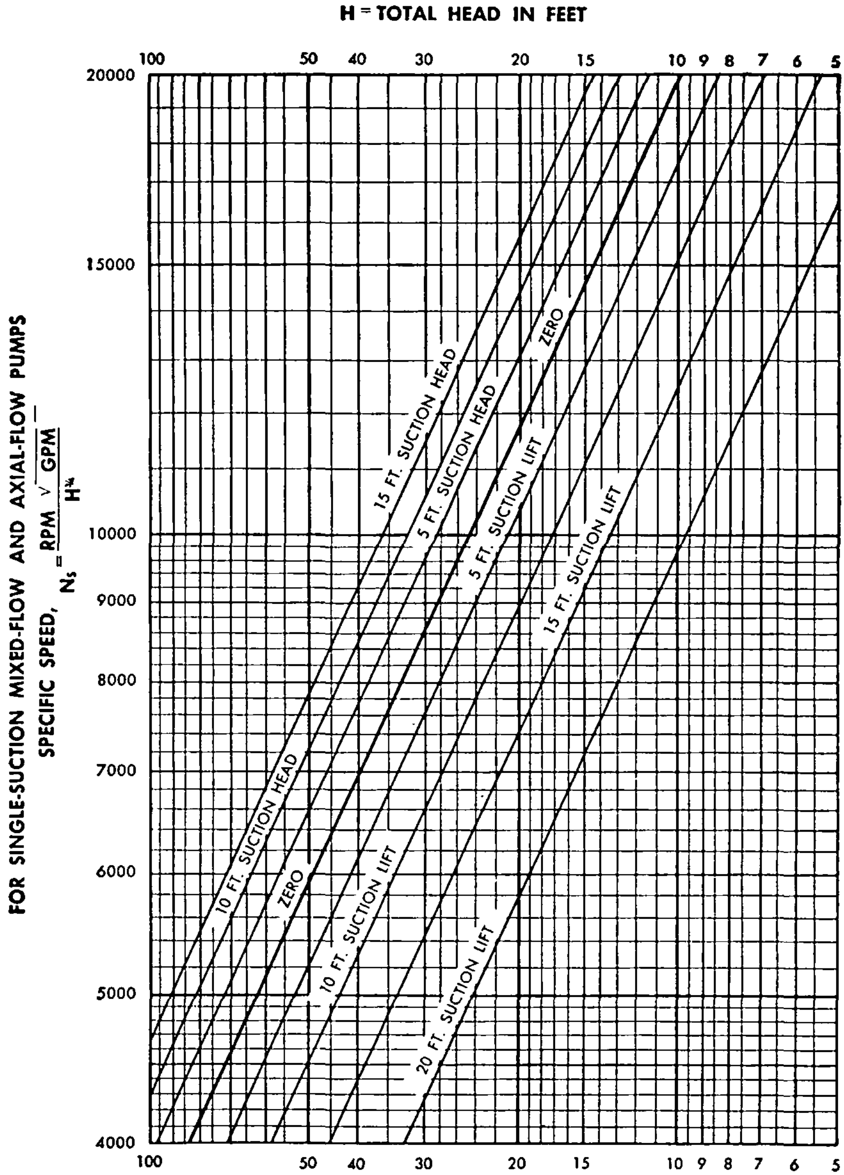



FIG. 9. Hydraulic Institute upper limits of specific speeds for single stage, single suction mixed flow and axial flow pumps pumping clear water at sea level at 85°F.

Given a total head of 100 feet and a total suction lift of 15 feet, what is the safe upper limit of specific speed to avoid danger of cavitation?

Referring to Fig. 8, the intersection, of the diagonal for 15 feet suction lift with the vertical line at total pump head of 100 feet, falls on the horizontal line corresponding to 2250 specific speed. The specific speed should not exceed this value.

Example II—Double suction pump.

Given a total head of 100 feet and a total suction lift of 15 feet, what is the safe upper limit of specific speed?

Referring to the first curve, Fig. 8, the intersection, of the diagonal for 15 feet suction lift with the vertical line for 100 feet total pump head, falls on the horizontal line corresponding to 3200 specific speed on the scale at the right side of the chart. This is the value of

$$\frac{\text{rpm}\sqrt{\text{gpm}}}{H^{3/4}} = N_s$$

in which the volume, or gpm, is the total gallons per minute capacity of the pumping unit including both suctions; and is the highest value which should be used for this head and suction lift.

Example III—Single suction mixed flow or axial flow pump.

Given a total head of 35 feet and a total suction head of 10 feet, corresponding to a submerged impeller, what is the safe upper limit of specific speed?

Referring to the second curve, Fig. 9, the intersection, of the vertical line for 35 feet total pump head and the diagonal for 10 feet suction head, falls on the horizontal line corresponding to 9400 specific speed on the scale at the left side of the chart. The specific speed should not exceed this value.

## NET POSITIVE SUCTION HEAD (NPSH)

NPSH can be defined as the head that causes liquid to flow through the suction piping and finally enter the eye of the impeller.

This head that causes flow comes from either the pressure of the atmosphere or from static head plus atmospheric pressure. A pump operating under a suction lift has as a source of pressure to cause flow only the pressure of the atmosphere. The work that can be done, therefore, on the suction side of a pump is limited, so NPSH becomes very important to the successful operation of the pump. There are two values of NPSH to consider.

REQUIRED NPSH is a function of the pump design. It varies between different makes of pumps, between different pumps of the same make and varies with the capacity and speed of any one pump. This is a value that must be supplied by the maker of the pump.

AVAILABLE NPSH is a function of the system in which the pump operates. It can be calculated for any installation. Any pump installation, to operate successfully, must have an available NPSH equal to or greater than the required NPSH of the pump at the desired pump conditions.

When the source of liquid is above the pump:

NPSH = Barometric Pressure, Ft. + Static Head on suction, ft. − friction losses in suction piping, ft. − Vapor Pressure of liquid, ft.

When the source of liquid is below the pump:

NPSH = Barometric Pressure, ft. — Static Suction lift, ft. — friction losses in Suction piping, ft. — Vapor Pressure of liquid, ft.

To illustrate the use of these equations consider the following examples:

The required NPSH of a water pump at rated capacity is 17 ft. Water Temperature 85°F. Elevation 1000 ft. above sea level. Entrance and friction losses in suction piping calculated = 2 ft. What will be the maximum suction lift permissible?

To better visualize the problem the solution is presented graphically in Fig. 10. The two horizontal lines are spaced apart a distance equal to the barometric pressure in feet.

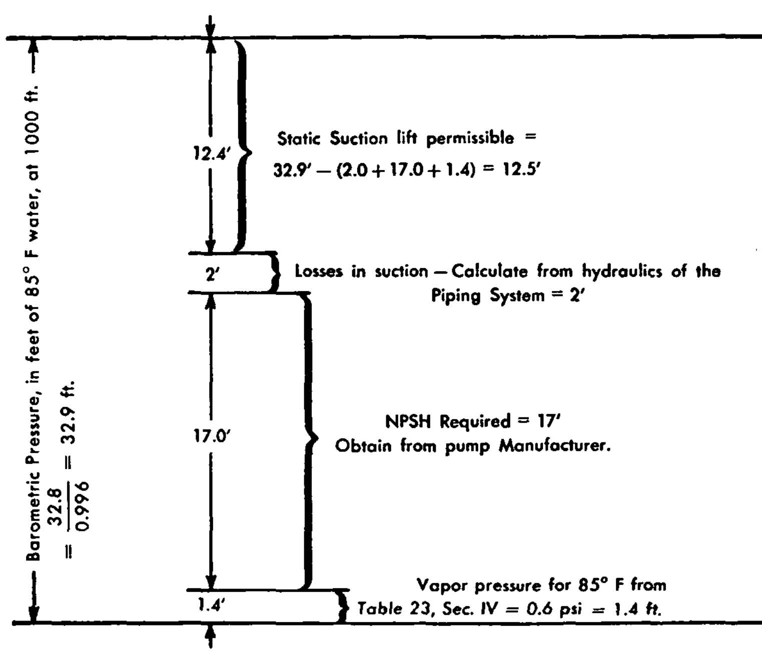



FIG. 10. Graphic solution NPSH problem for 85°F water.

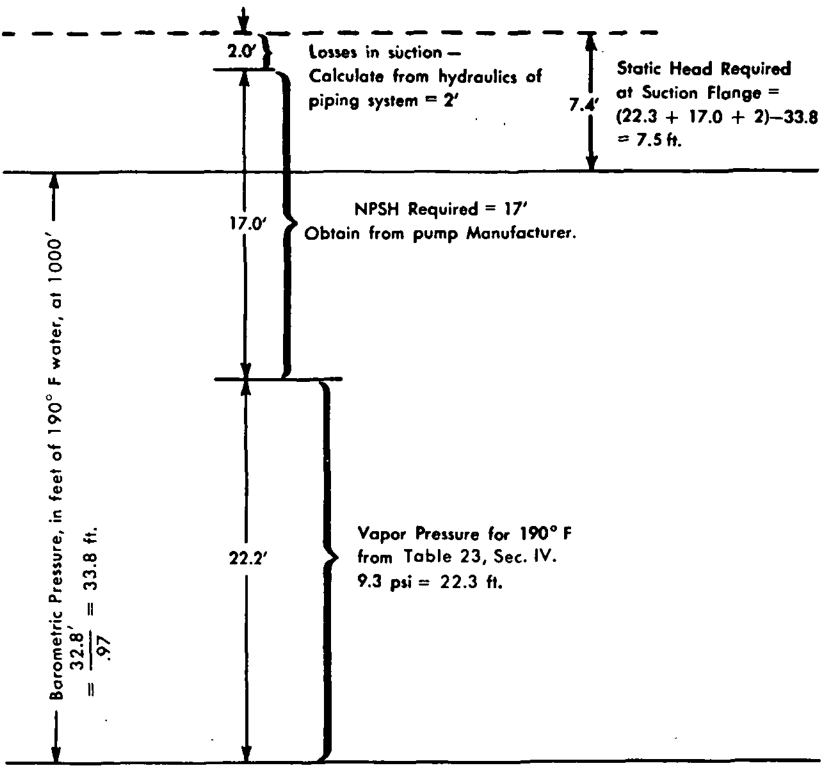



FIG. 11. Graphic solution NPSH problem for 190°F water.

As a further example consider the same data except that the water temperature is 190°F. What will be the suction lift or head required?

From Table 23 in Section IV water at 190° has a sg. of 0.97. The vapor pressure is 9.3 psi. In the graphic solution in Fig. 11 remember that all heads must be in feet of the liquid.

In this case because the sum of vapor pressure + NPSH required + losses in the suction system exceed the barometric pressure, a positive head or submergence must be provided to insure uninterrupted water flow to the pump.

This discussion of NPSH applies to any type of pump whether centrifugal, positive displacement, peripheral, angle or mixed flow or propeller. On centrifugal, angle or mixed-flow or propeller pumps the suction conditions must be correct or the pump will operate inefficiently or may fail to operate at all. However, the Westco peripheral type is more tolerant of improper suction conditions, for this type pump has the ability to pump both liquid and vapor without vapor binding. When pumping part vapor and part liquid the capacity is, of course, reduced. Advantage is taken of the suction tolerance of this pump and it is frequently installed under suction conditions quite impossible for a centrifugal pump. The manufacturer can supply ratings of their pumps under these adverse conditions.

## CAVITATION

Cavitation is a term used to describe a rather complex phenomenon that may exist in a pumping installation. In a centrifugal pump this may be explained as follows. When a liquid flows through the suction line and enters the eye of the pump impeller an increase in velocity takes place. This increase in velocity is, of course, accompanied by a reduction in pressure. If the pressure falls below the vapor pressure corresponding to the temperature of the liquid, the liquid will vaporize and the flowing stream will consist of liquid plus pockets of vapor. Flowing further through the impeller, the liquid reaches a region of higher pressure and the cavities of vapor collapse. It is this collapse of vapor pockets that causes the noise incident to cavitation.

Cavitation need not be a problem in a pump installation if the pump is properly designed and installed, and operated in accordance with the designer's recommendations. Also, cavitation is not necessarily destructive. Cavitation varies from very mild to very severe. A pump can operate rather noiselessly yet be cavitating mildly. The only effect may be a slight drop in efficiency. On the other hand severe cavitation will be very noisy and will destroy the pump impeller and/or other parts of the pump.

Any pump can be made to cavitate, so care should be taken in selecting the pump and planning the installation. For centrifugal pumps avoid as much as possible the following conditions:

1. Heads much lower than head at peak efficiency of pump.
2. Capacity much higher than capacity at peak efficiency of pump.
3. Suction lift higher or positive head lower than recommended by manufacturer.
4. Liquid temperatures higher than that for which the system was originally designed.
5. Speeds higher than manufacturer's recommendation.

The above explanation of cavitation in centrifugal pumps cannot be used when dealing with propeller pumps. The water entering a propeller pump in a large bell-mouth inlet will be guided to the smallest section, called throat, immediately ahead of the propeller. The velocity there should not be excessive and should provide a sufficiently large capacity to fill properly the ports between the propeller blades. As the propeller blades are widely spaced, not much guidance can be given to the stream of water. When the head is increased beyond a safe limit, the capacity is reduced to a quantity insufficient to fill up the space between the propeller vanes. The stream of water will separate from the propeller vanes, creating a small space where pressure is close to a perfect vacuum. In a very small fraction of a second, this small vacuum space will be smashed by the liquid hitting the smooth surface of the propeller vane with an enormous force which starts the process of surface pitting of the vane. At the same time one will hear a sound like rocks thrown around in a barrel or a mountain stream tumbling boulders.

The five rules applying to centrifugal pumps will be changed to suit propeller pumps in the following way: Avoid as much as possible,

1. Heads much higher than at peak efficiency of pump.
2. Capacity much lower than capacity at peak efficiency of pump.
3. Suction lift higher or positive head lower than recommended by manufacturer.
4. Liquid temperatures higher than that for which the system was originally designed.
5. Speeds higher than manufacturer's recommendation.

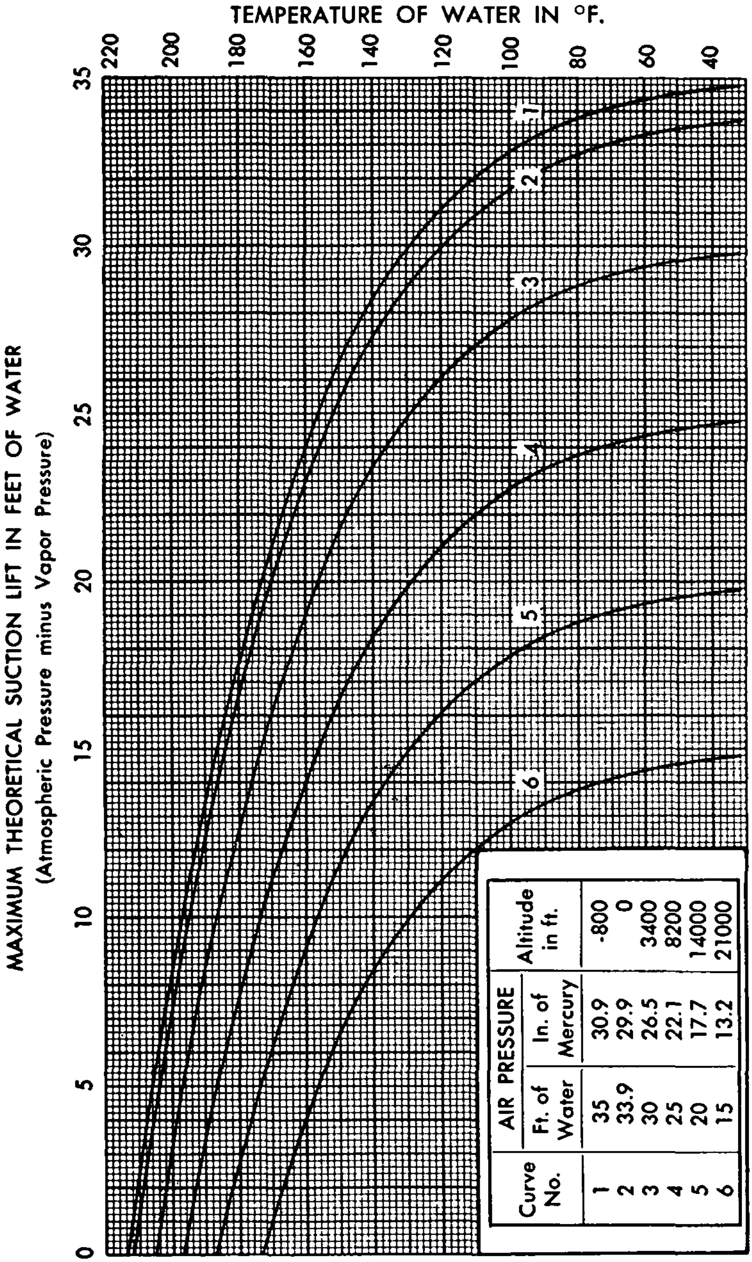
Cavitation is not confined to pumping equipment alone. It also occurs in piping systems where the liquid velocity is high and the pressure low. Cavitation should be suspected when noise is heard in pipe lines at sudden enlargements of the pipe cross-section, sharp bends, throttled valves or like situations.

## SIPHONS

It occasionally happens that a siphon can be placed in the discharge line so that the operating head of a pump is reduced. The reduction in head so obtained will lower the power costs for lifting a given amount of water and may make possible, in addition, the installation of a smaller pumping unit.

Successful operation of such a combination demands that the pump and siphon be designed as a unit under the following limitations.

1. In order to prime the siphon in starting, the pump must be able to deliver a full cross-section of water to the throat, or peak, of the siphon against the total head of that elevation and with a minimum velocity of five feet per second.




| Curve No. | AIR PRESSURE Ft. of Water | AIR PRESSURE In. of Mercury | Altitude in ft. |
|---|---|---|---|
| 1 | 35 | 30.9 | -800 |
| 2 | 33.9 | 29.9 | 0 |
| 3 | 30 | 26.5 | 3400 |
| 4 | 25 | 22.1 | 8200 |
| 5 | 20 | 17.7 | 14000 |
| 6 | 15 | 13.2 | 21000 |

FIG. 12. Siphons used with pumps.

2. After the siphon has been primed and steady flow has been established, the maximum velocity at the throat can not exceed the value for a throat pressure equal to the vapor pressure of the liquid under the operating conditions. Any attempt to exceed this limiting

velocity will result in "cavitation," or vaporization of the liquid, under the reduced pressure.

The theoretical pressure drop can be obtained from the curves in Fig. 12 which are based on the standard atmosphere as defined by the U. S. Bureau of Standards in its publication #82. A safe value for design purposes may be obtained directly from the curve for 75% of the actual atmospheric pressure. This value may be used as an estimate of the possible head reduction by the use of a siphon providing a reasonable allowance for friction losses is deducted from it.

3. The pipe section at the throat must be designed to resist the external pressure caused by the reduction of pressure below that of the atmosphere.

4. In practically all cases it is advisable that the discharge end of the siphon be sufficiently submerged to prevent the entrance of air. The exit losses at this point can be reduced by belling the end of the pipe and thus recovering a large part of the velocity head.

## AFFINITY LAWS—CENTRIFUGAL PUMPS

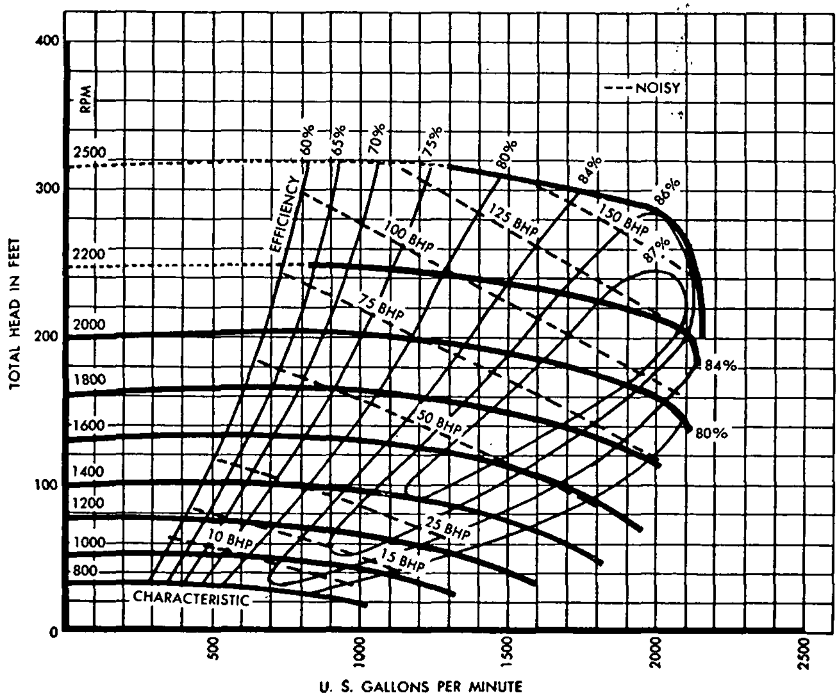



FIG. 13. Typical performance curve of a centrifugal pump with constant impeller diameter but varying speeds.

A typical characteristic curve of a centrifugal pump is shown in Fig. 13 and Fig. 14. It will be observed that both charts have plotted on them several head capacity curves with lines of constant efficiency and Hp superimposed on them. In Fig. 13 the impeller diameter is held constant and the speed varies whereas in Fig. 14 the speed is held constant and the impeller diameter varies. The mathematical relationships between these several variables are known as the affinity laws and can be expressed as follows:

| With impeller diameter held constant | | With speed held constant | |
|---|---|---|---|
| $\dfrac{Q_1}{Q_2}=\dfrac{N_1}{N_2}$ | Law 1a | $\dfrac{Q_1}{Q_2}=\dfrac{D_1}{D_2}$ | Law 2a |
| $\dfrac{H_1}{H_2}=\left(\dfrac{N_1}{N_2}\right)^2$ | Law 1b | $\dfrac{H_1}{H_2}=\left(\dfrac{D_1}{D_2}\right)^2$ | Law 2b |
| $\dfrac{\text{Bhp}_1}{\text{Bhp}_2}=\left(\dfrac{N_1}{N_2}\right)^3$ | Law 1c | $\dfrac{\text{Bhp}_1}{\text{Bhp}_2}=\left(\dfrac{D_1}{D_2}\right)^3$ | Law 2c |

Where

$Q_1$ = Capacity and $H_1$ = head at $N_1$ rpm or with impeller dia. $D_1$

$Q_2$ = Capacity and $H_2$ = head at $N_2$ rpm or with impeller dia. $D_2$

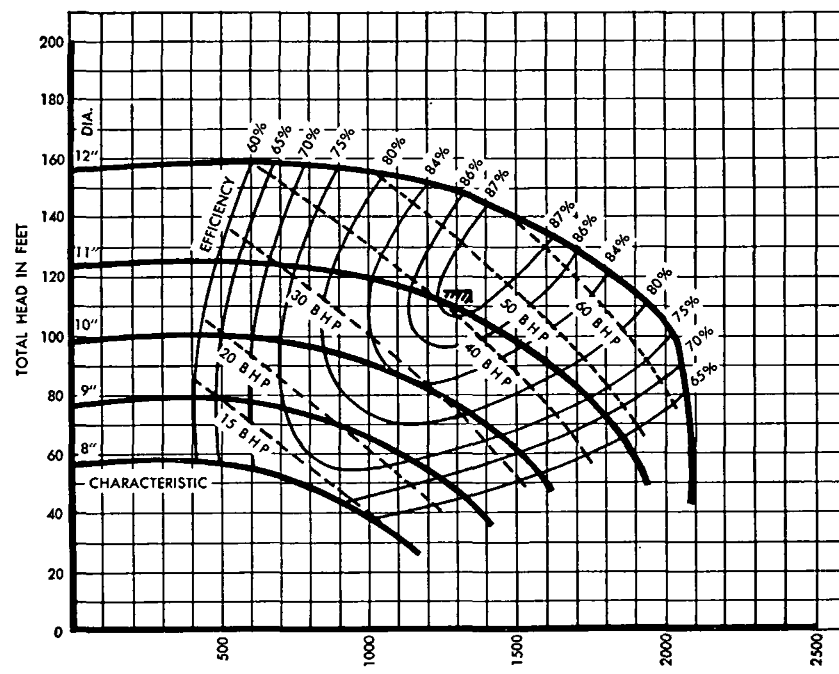



FIG. 14. Typical performance curve of a centrifugal pump at 1750 rpm but with varying impeller diameter.

These relations are graphically shown on Fig. 15.

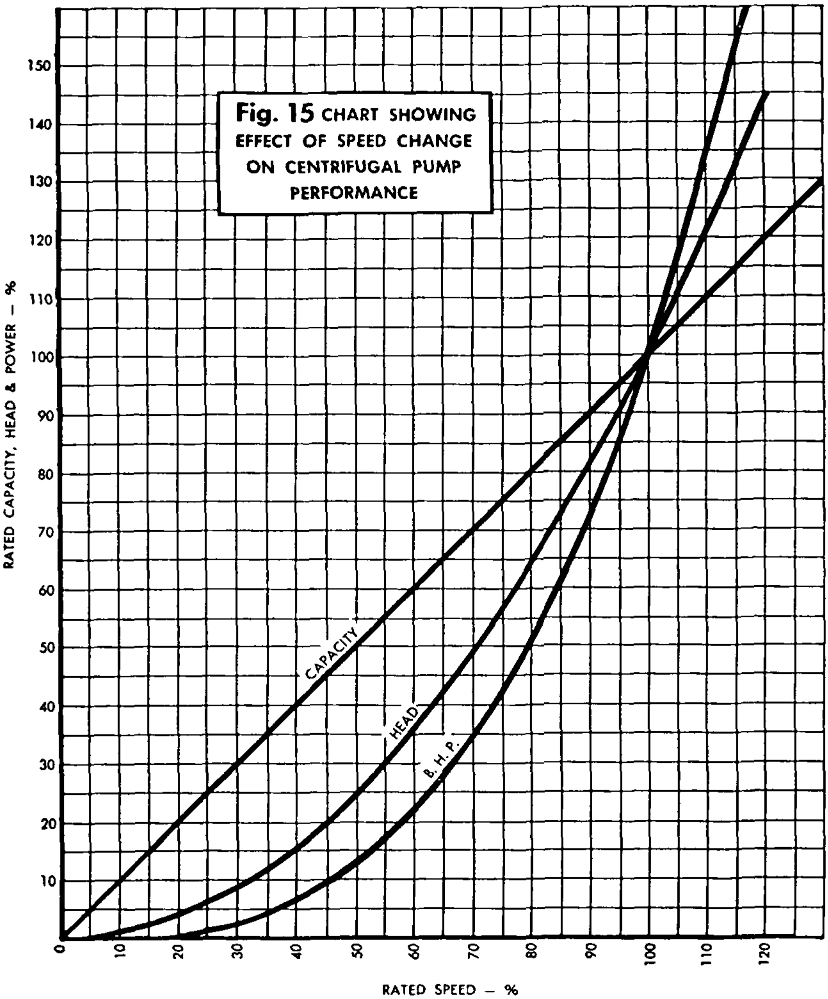



FIG. 15. Chart showing effect of speed change on centrifugal pump performance.

Where complete rating charts such as those shown in Figures 13 and 14, secured by actual test of the pump, are available, it is always best to use them to estimate intermediate points by interpolation. However, many field problems will arise where these data are not available and then approximations can be made by calculation, using the affinity laws.

Law 1a applies to Centrifugal, Angle Flow, Mixed Flow, Propeller, Peripheral, Rotary and Reciprocating pumps.

Law 1b and c apply to Centrifugal, Angle Flow, Mixed Flow, Propeller, and Peripheral pumps.

Law 2a, b, c apply to Centrifugal pumps only.

Examples illustrating the use of these laws follow. Note particularly from these examples that the calculated head-capacity characteristic using Law 1 agrees very closely to the test performance curves. However, this is true for Law 2 only under certain defined conditions. Law 2 must, therefore, be used with a great deal of caution.

Illustration Law 1

To illustrate Law 1, refer to Figure 17 which is a portion of the more complete curve shown in Figure 13. Consider that we have given the performance curve shown in Figure 17 at 2000 Rpm. We want to find, by calculation, the expected performance at 1600 Rpm. Proceed as follows:

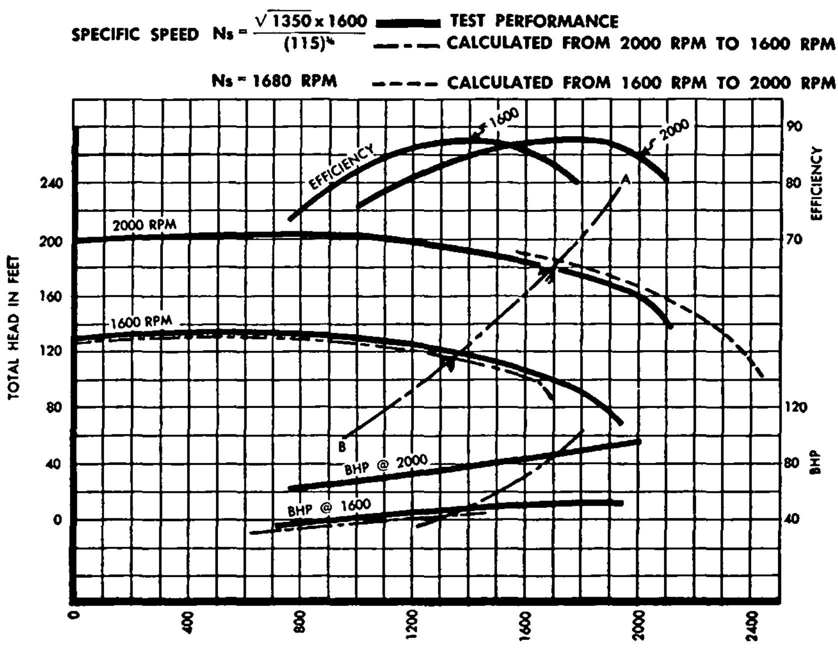



FIG. 17. Comparison of test performance with performance calculated using affinity laws for speed change.

Law 1a. $\dfrac{Q_1}{Q_2} = \dfrac{N_1}{N_2}$; $Q_1 = \dfrac{1600}{2000} \times 1700 = 1360$ gpm.

Law 1b. $\dfrac{H_1}{H_2} = \left(\dfrac{N_1}{N_2}\right)^2$; $H_1 = \left(\dfrac{1600}{2000}\right)^2 \times 180 = 115.2$ ft.

Law 1c. $\dfrac{\text{Bhp}_1}{\text{Bhp}_2} = \left(\dfrac{N_1}{N_2}\right)^3$ ; $\text{Bph}_1 = \left(\dfrac{1600}{2000}\right)^3 \times 84 = 43$ Bhp

Note the close agreement between calculated values and actual test results. The agreement is good provided pump efficiency does not change too much. If you will plot 1700 gpm at 180 ft., the original capacity and head at 2000 rpm; and the final capacity and head, 1360 gpm at 115 feet at 1600 rpm, on the complete performance chart of this pump given in Figure 13, you will note that there has been no appreciable change in efficiency. This is generally the case when conditions are changed by speed adjustment, for the pump has not been altered physically. Note that the general shape of the iso-efficiency lines in Figure 13 are parabolic.

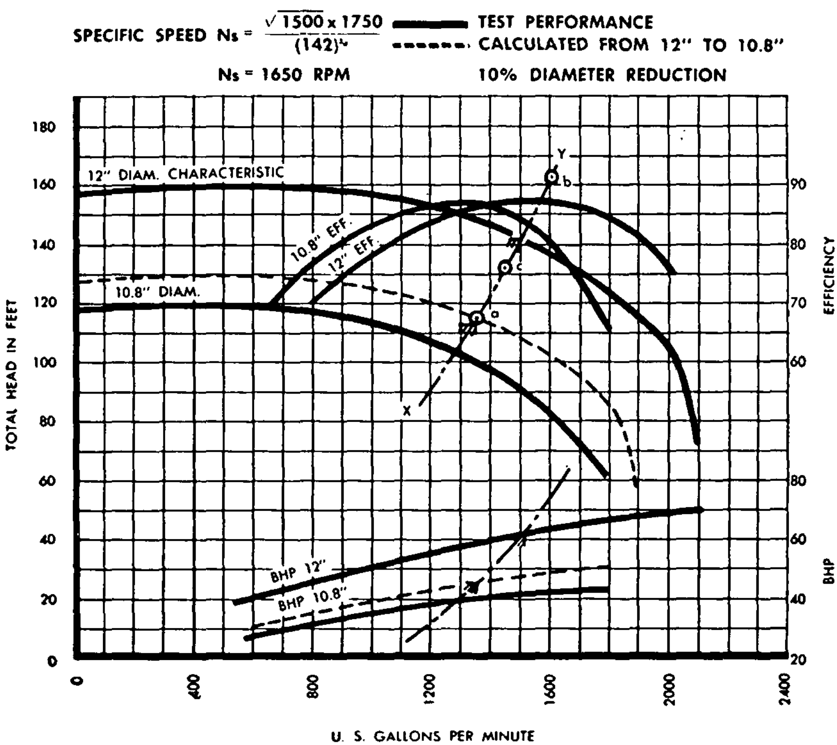



FIG. 18. Curves showing the disagreement between test and calculated performance when applying affinity laws for diameter change for a pump with specific speed Ns = 1650.

Therefore, the curve A-B in Fig. 17 passing through the two condition points on the 2000 rpm and 1600 Rpm curves, which is also parabolic, is approximately parallel to the iso-efficiency curves. The use of the Affinity Laws, therefore, to calculate performance when the speed is changed and the impeller diameter remains constant, is a quite accurate approximation. By calculating several points along a known performance curve, a new performance curve can be produced showing the approximate performance at the new speed.

Starting with the 1600 rpm characteristic and calculating the performance at 2000 rpm by the use of the affinity laws, the calculated performance exceeds the actual performance as shown in dotted curve on Figure 17. The discrepancy is slight but emphasizes the fact that the method is only a quite accurate approximation.

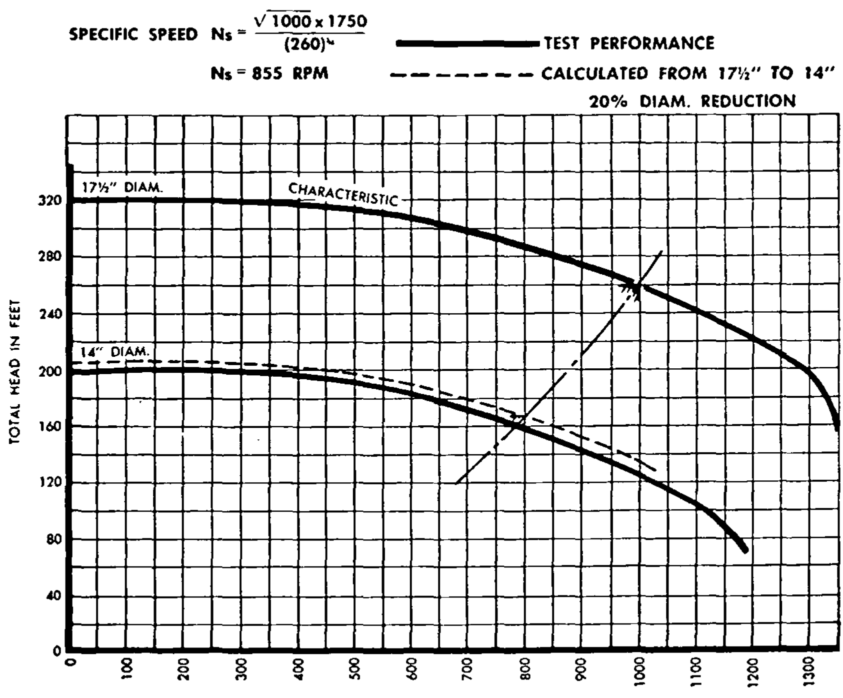



*FIG. 20. Curves showing the relative agreement between test and calculated performance when applying affinity laws for diameter change for a pump with a very low specific speed Ns = 855.*

Illustration Law 2

Probably this should not be considered as an affinity law, for when the impeller of a pump is reduced in diameter, the design relationships are changed, and in reality a new design results. Law 2, therefore, does not yield the accurate results of Law 1. It is always recommended that the pump manufacturer be consulted before changing the diameter of an impeller in the field.

Figure 20 illustrates the comparative accuracy of test performance to the calculated performance on a very low specific speed pump. Figure 18, however, shows rather wide discrepancy between test and calculated results on a pump of higher specific speed. On pumps of still higher specific speed the lack of agreement between test and calculated results is even more pronounced.

In general, agreement will be best on low specific speed pumps and the higher the specific speed the greater the disagreement. However specific speed is only one of the factors considered by the manufacturer when determining the proper impeller diameter.

When the affinity laws are used for calculating speed or diameter *increases*, it is important to consider the effect of suction lift on the characteristic for the increased velocity in the suction line and pump may result in cavitation that may substantially alter the characteristic curve of the pump.

## PARALLEL AND SERIES OPERATION†

When the pumping requirements are variable, it may be more desirable to install several small pumps in parallel rather than use a single large one. When the demand drops, one or more smaller pumps may be shut down, thus allowing the remainder to operate at or near peak efficiency. If a single pump is used with lowered demand, the discharge must be throttled, and it will operate at reduced efficiency. Moreover, when smaller units are used opportunity is provided during slack demand periods for repairing and maintaining each pump in turn, thus avoiding plant shut-downs which would be necessary with single units. Similarly, multiple pumps in series may be used when liquid must be delivered at high heads.

In planning such installations a head-capacity curve for the system must first be drawn. The head required by the system is the sum of the static head (difference in elevation and/or its pressure equivalent) plus the variable head (friction and shock losses in the pipes, heaters, etc.). The former is usually constant for a given system whereas the latter increases approximately with the square of the flow. The resulting curve is represented as line AB in Figs. 21 and 22.

†*Courtesy De Laval Steam Turbine Co. See page 6.*

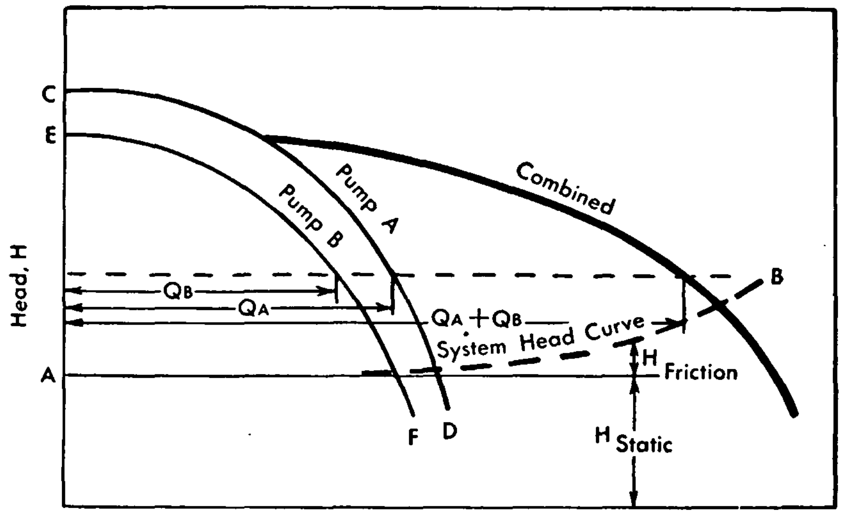



FIG. 21. Head capacity curves of pumps operating in parallel.†

Connecting two pumps in parallel to be driven by one motor is not a very common practice and, offhand, such an arrangement may appear more expensive than a single pump. However, it should be remembered that in most cases it is possible to operate such a unit at about 40 per cent higher speed, which may reduce the cost of the motor materially. Thus, the cost of two high-speed pumps may not be much greater than that of a single slow-speed pump.

For units to operate satisfactorily in parallel, they must be working on the portion of the characteristic curve which drops off with increased capacity in order to secure an even flow distribution. Consider the action of two pumps operating in parallel. The system head-capacity curve AB shown in Fig. 21 starts at H static when the flow is zero and rises parabolically with increased flow. Curve CD represents the characteristic curve of pump A operating alone; the similar curve for pump B is represented by EF. Pump B will not start delivery until the discharge pressure of pump A falls below that of the shut-off head of B (point E). The combined delivery for a given head is equal to the sum of the individual capacities of the two pumps at that head. For a given combined delivery head, the capacity is divided between the pumps as noted on the figures $Q_A$ and $Q_B$. The combined characteristic curve shown on the figure is found by plotting these summations. The combined brake horse-

†*Courtesy John Wiley & Sons, Inc. See page 6.*

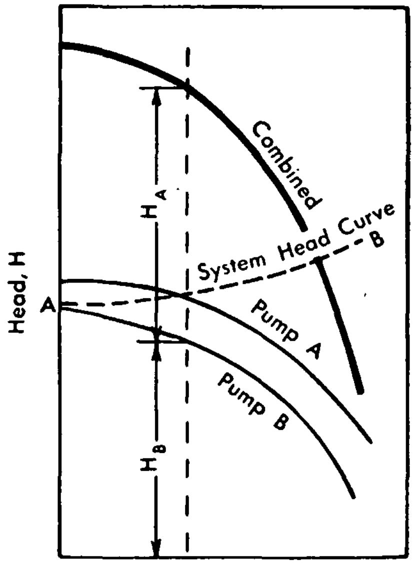



FIG. 22. Head capacity curves of pumps operating in series.†

power curve can be found by adding the brake horsepower of pump A corresponding to $Q_A$ to that of pump B corresponding to $Q_B$, and plotting this at the combined flow. The efficiency curve of the combination may be determined by the following equation.

$$\text{Eff} = \frac{(Q_B, \text{ Gpm} + Q_A, \text{ Gpm})\ H}{3960\ (\text{Bhp at } Q_B + \text{Bhp at } Q_A)}$$

If two pumps are operated in series, the combined head for any flow is equal to the sum of the individual heads as shown in Fig. 22. The combined brake horsepower curve may be found by adding the horsepowers given by the curves for the individual pumps. Points on the combined efficiency curve are found by the following equation.

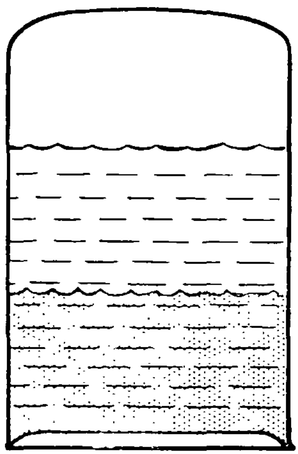
$$\text{Eff} = \frac{Q, \text{ gpm } (H_A \text{ ft.} + H_B, \text{ ft.})}{3960\ (\text{Bhp at } H_A + \text{Bhp at } H_B)}$$

## HYDRO-PNEUMATIC TANKS

In pumping installations the major use of hydro-pneumatic tanks is to make it possible to automatically supply water under pressure. They do provide relatively small quantities of water for storage, but this cannot be considered their primary function. However, this amount of water in storage is a very important factor when select-

†*Courtesy John Wiley & Sons, Inc. See page 6.*

ing the proper size tank to be used with the pump selected. The usable storage capacity should be such that the pump motor will not start frequently enough to cause overheating. Starting 10 to 15 times per hour will usually be satisfactory. The limit in the number of starts per hour depends upon the motor horsepower and speed. For the higher speeds and horse-powers use less starts per hour.



—$V_1$ = Volume of water in tank at the High or Cut-Out pressure $P_1$ psia, in per cent of tank volume.

—$V_2$ = Volume of water in tank at the Low or Cut-In pressure $P_2$ psia, in per cent of tank volume.

FIG. 23. Hydro-pneumatic tank.

To determine the amount of water that can be withdrawn from a tank when the pressure drops from $P_1$ to $P_2$ psia use the following equation.

$V_1$ - $V_2$ = Water withdrawn or storage capacity of tank, %

$$= \left(\frac{P_1}{P_2} - 1\right) \left(100 - V_1\right)$$

In this equation $P_1$ and $P_2$ must be expressed in psia—pounds per square inch absolute. $V_1$ and $V_2$ are expressed in per cent.

Example: In a 1000 gal. tank the gauge pressure at the cut-out point is 40 psi and the tank is 60% full of water. The cut-in pressure is 20 psi. What is the storage capacity of the tank?

$$\frac{P_1}{P_2} = \frac{40 + 14.7}{20 + 14.7} = \frac{54.7}{34.7} = 1.58$$

Storage Capacity = (1.58 - 1) (100 - 60) = 23.2%

Therefore in the 1000 gal. tank the storage capacity = 1000 x .232 = 232 gal.

The storage capacity of tanks in percent can be read directly from the chart Fig. 24.

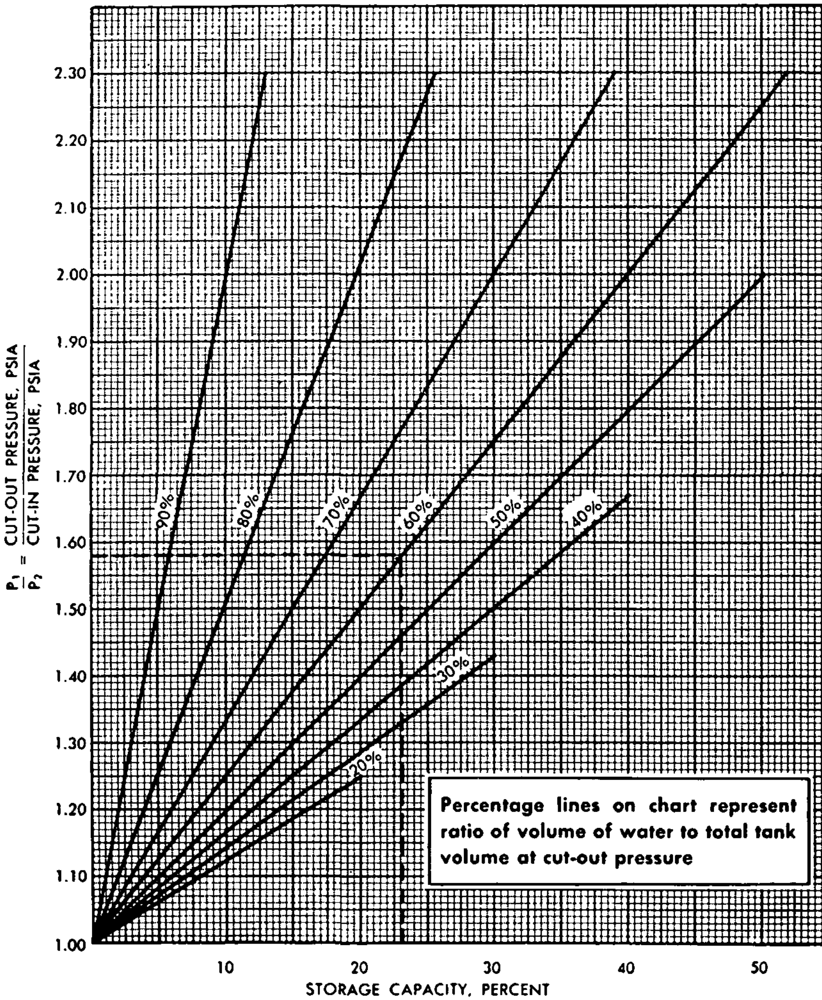



FIG. 24. Hydro-pneumatic tanks—relation between pressure range and storage capacity.

## GALVANIC CORROSION†

(a) *Definition of Galvanic Corrosion* — Galvanic corrosion may be defined as the accelerated electro-chemical corrosion produced when one metal is in electrical contact with another more noble metal, both being immersed in the same corroding medium, which is called the electrolyte. Corrosion of this type results usually in an accelerated rate of solution for one member of the couple and protection for the other. The protected member, the one that does not corrode, is called the nobler metal. Note that as galvanic corrosion is generally understood, it consists of the total corrosion, which comprises the normal

†*Courtesy Hydraulic Institute. See page 6.*

corrosion that would occur on a metal exposed alone, plus the additional amount that is due to contact with the more noble material.

(b) *Galvanic Series* — With a knowledge of the galvanic corrosion behavior of metals and alloys, it is possible to arrange them in a series which will indicate their general tendencies to form galvanic cells, and to predict the probable direction of the galvanic effects. Such a series is provided in Fig. 25.

This series should not be confused with the familiar, "Electromotive Series," which is found in many textbooks and is of value in physical chemistry and thermodynamic studies.

It will be noticed that some of the metals in Fig. 25 are grouped together. These group members have no strong tendency to produce galvanic corrosion on each other, and from the practical standpoint they are relatively safe to use in contact with each other, but the coupling of two metals from *different* groups and *distant* from each other in the list will result in galvanic, or accelerated, corrosion of the one higher in the list. The farther apart the metals stand, the greater will be the galvanic tendency. This may be determined by measurement of the electrical potential difference between them, and this is often done, but it is not practical to tabulate these differences because the voltage values for combinations of the metals will vary with every different corrosive condition. What actually determines galvanic effect, is the quantity of current generated rather than the potential difference.

The relative position of a metal within a group sometimes changes with external conditions, but it is only rarely that changes occur from group to group. It will be seen that the chromium stainless steel and chromium-nickel stainless steel alloys are in two places in the table. They frequently change positions as indicated, depending upon the corrosive media. The most important reasons for this are the oxidizing power and acidity of the solutions, and the presence of activating ions, such as halides. Inconel and nickel also occasionally behave in a similar manner, though the variations of their position are less frequent and less extensive. In environments where these alloys ordinarily demonstrate good resistance to corrosion, they will be in their passive condition and behave accordingly in galvanic couples.

(c) *To Minimize Galvanic Corrosion*

1. Select combinations of metals as close together as possible in the Galvanic Series.

2. Avoid making combinations where the area of the less noble material is relatively small.

3. Insulate dissimiliar metals wherever practical, including use of plastic washers and sleeves at flanged joints. If complete insulation cannot be achieved, anything such as a paint or plastic coating at joints will help to increase the resistances of the circuit.

4. Apply coatings with caution. For example, do not paint the less noble material without also coating the more noble; otherwise, greatly accelerated attack may be concentrated at imperfections in coatings on the less noble metal. Keep such coatings in good repair.

5. In cases where the metals cannot be painted and are connected by a conductor external to the liquid, the electrical resistance of the liquid path may be increased by designing the equipment to keep the metals as far apart as possible.

6. If practical and dependent on velocity, add suitable chemical inhibitors to the corrosive solution.

7. If you must use dissimilar materials well apart in the series, avoid joining them by threaded connections, as the threads will probably deteriorate excessively. Welded or brazed joints are preferred. Use a brazing alloy more noble than at least one of the metals to be joined.

8. If possible, install relatively small replaceable sections of the less noble material at joints, and increase its thickness in such regions. For example, extra heavy wall nipples can often be used in piping, or replaceable pieces of the less noble material can be attached in the vicinity of the galvanic contact.

9. Install pieces of bare zinc, magnesium, or steel so as to provide a counteracting effect that will suppress galvanic corrosion.

FIG. 25. GALVANIC SERIES OF METALS AND ALLOYS

Corroded End (anodic, or least noble)

Magnesium
Magnesium alloys

Zinc

Aluminum 2S

Cadmium

Aluminum 17ST

Steel or Iron
Cast Iron

Chromium stainless steel, 400 Series (active)

Austenitic nickel or nickel-copper cast iron alloy

18-8 Chromium-nickel stainless steel, Type 304 (active)
18-8-3 Chromium-nickel-molybdenum stainless steel, Type 316 (active)

Lead-tin solders
Lead
Tin

Nickel (active)
Nickel-base alloy (active)
Nickel-molybdenum-chromium-iron alloy (active)

Brasses
Copper
Bronzes
Copper-nickel alloy
Nickel-copper alloy

Silver solder

Nickel (passive)
Nickel-base alloy (passive)

Chromium stainless steel, 400 Series (passive)
18-8 Chromium-nickel stainless steel, Type 304 (passive)
18-8-3 Chromium-nickel-molybdenum stainless steel, Type 316 (passive)

Nickel-molybdenum-chromium-iron alloy (passive)

Silver

Graphite
Gold
Platinum

Protected End (cathodic, or most noble)

Non-Metallic Construction Materials

Non-metallic materials, including various plastics, ceramics, and rubber, either in the solid state or as coatings on metals, are being used to a limited extent in pumps for particular services. These materials generally show excellent corrosion resistance. They should only be considered, however, for applications where the expected temperature range is suitable for the specific material to be used. Further, where coatings are involved, precautions must be taken to assure freedom from pin holes; otherwise, the corrosive liquid may attack the base metal and loosen the covering. In general, the plastics and ceramics are characterized by relatively poor strength which limits their use to pumps where the application is suitable.

## GRAPHITIZATION

The surface of cast iron in contact with sea water or other electrolytes is gradually converted into a mechanical mixture of graphite and iron oxide by a galvanic reaction between the graphite flakes and the iron matrix. The phenomenon is known as graphitization. The graphitized layer, although cathodic to the base iron, becomes increasingly impervious to the penetration of the water as it increases in depth and, hence, the rate of attack on the underlying base iron is correspondingly decreased. Cast iron is thus a useful material in many applications as long as the graphitized surface remains intact. The layer, however, is comparatively soft and if constantly removed by high velocities or turbulence, the exposed anodic base iron is subject to continuous, rapid attack. The useful life of impellers and wearing rings made of cast iron, when handling corrosive waters, may be short unless the liquid velocities are quite low. The use of bronze and certain types of stainless steels for such parts is generally advisable. The cathodic nature of the graphitized iron explains the rather rapid failure of replacement parts when installed in contact with older, graphitized parts, and at the same time accounts for the usually false impression that the new iron is inferior to the old.

# SECTION II—PIPE FRICTION—WATER



## CONTENTS

## SECTION II—FRICTION OF WATER

### INTRODUCTION:

The flow of water is basic to all hydraulics. Friction losses incident to water flow may seriously affect the selection or performance of hydraulic machinery. The major portion of the head against which many pumps operate is due largely to the friction losses caused by the created flow. A basic understanding of the nature of the loss and an accurate means of estimating its magnitude is therefore essential.

### GENERAL:

It is well established that either laminar or turbulent flow of incompressible fluids in pipe lines can be treated by the basic formula:

$$h_f = f\frac{L}{D}\,\frac{V^2}{2g}$$

where: $h_f$ = friction loss in feet of liquid.
$f$ = friction factor
$L$ = length of pipe in feet
$D$ = average internal diameter of pipe in feet
$V$ = average velocity in pipe in feet per second
$g$ = acceleration due to gravity in feet per second per second

The theoretical and empirical studies of engineers who have worked on this problem comprise a roster of names that includes practically every important hydraulic authority for the past century. This work has provided a simple method for determining friction factor "$f$" as a function of relative pipe roughness and/or the Reynolds Number of flow.

A comprehensive anaylsis of this mass of experimentation has recently been conducted under the sponsorship of the Hydraulic Institute. A very complete treatise, "Pipe Friction" has been published as a Technical Pamphlet by the Hydraulic Institute; it is an important contribution to the authoritative literature on the subject.

The following tables are a condensation of these data in a form convenient for use. The tables show frictional resistance for water flowing in new schedule #40 steel pipe (ASA specification B36.10) or in new asphalt-dipped cast-iron pipe.

The tables show discharge in U. S. gallons per minute, the average velocity in feet per second for circular pipe, the corresponding velocity head, and the friction loss ($h_f$) in feet of fluid per 100 feet of pipe for 60°F water or any liquid having a Kinematic viscosity $\nu$ = 0.00001216 square feet per second (1.130 centistokes).

Table 1. for new schedule #40 steel pipe is based upon an absolute roughness $\epsilon$ = 0.00015 feet. Table 2. for new asphalt-dipped cast-iron pipe is based upon an absolute roughness of 0.0004 feet.

# TABLE 1.
## FRICTION LOSS PER 100 FEET FOR WATER IN NEW WROUGHT IRON OR SCHEDULE 40 STEEL PIPE†

### 1/4"
0.364" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|
| 0.8 | 2.47 | 0.09 | 12.7 |
| 1.0 | 3.08 | 0.15 | 19.1 |
| 1.2 | 3.70 | 0.21 | 26.7 |
| 1.4 | 4.32 | 0.29 | 35.3 |
| 1.6 | 4.93 | 0.38 | 45.2 |
| 1.8 | 5.55 | 0.48 | 56.4 |
| 2.0 | 6.17 | 0.59 | 69.0 |
| 2.5 | 7.71 | 0.92 | 105.0 |
| 3.0 | 9.25 | 1.33 | 148.0 |
| 3.5 | 10.79 | 1.81 | 200.0 |
| 4.0 | 12.33 | 2.36 | 259.0 |
| 5.0 | 15.42 | 3.69 | 398.0 |

### 3/8"
0.493" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|
| 1.4 | 2.35 | 0.09 | 7.85 |
| 1.6 | 2.68 | 0.11 | 10.1 |
| 1.8 | 3.02 | 0.14 | 12.4 |
| 2.0 | 3.36 | 0.18 | 15.0 |
| 2.5 | 4.20 | 0.27 | 22.6 |
| 3.0 | 5.04 | 0.39 | 31.8 |
| 3.5 | 5.88 | 0.54 | 42.6 |
| 4.0 | 6.72 | 0.70 | 54.9 |
| 5.0 | 8.40 | 1.10 | 83.5 |
| 6.0 | 10.08 | 1.58 | 118.0 |
| 7.0 | 11.80 | 2.15 | 158.0 |
| 8.0 | 13.40 | 2.81 | 205.0 |
| 9.0 | 15.10 | 3.56 | 258.0 |
| 10.0 | 16.80 | 4.39 | 316.0 |

### 1/2"
0.622" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|
| 2.0 | 2.11 | 0.07 | 4.78 |
| 2.5 | 2.64 | 0.11 | 7.16 |
| 3.0 | 3.17 | 0.16 | 10.0 |
| 3.5 | 3.70 | 0.21 | 13.3 |
| 4.0 | 4.22 | 0.28 | 17.1 |
| 5.0 | 5.28 | 0.43 | 25.8 |
| 6.0 | 6.34 | 0.62 | 36.5 |
| 7.0 | 7.39 | 0.85 | 48.7 |
| 8.0 | 8.45 | 1.11 | 62.7 |
| 9.0 | 9.50 | 1.40 | 78.3 |
| 10.0 | 10.56 | 1.73 | 95.9 |
| 12.0 | 12.70 | 2.49 | 136.0 |
| 14.0 | 14.80 | 3.40 | 183.0 |
| 16.0 | 16.90 | 4.43 | 235.0 |

### 3/4"
0.824" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|
| 3.0 | 1.81 | 0.05 | 2.50 |
| 3.5 | 2.11 | 0.07 | 3.30 |
| 4.0 | 2.41 | 0.09 | 4.21 |
| 5.0 | 3.01 | 0.14 | 6.32 |
| 6.0 | 3.61 | 0.20 | 8.87 |
| 7.0 | 4.21 | 0.28 | 11.8 |
| 8.0 | 4.81 | 0.36 | 15.0 |
| 9.0 | 5.42 | 0.46 | 18.8 |
| 10.0 | 6.02 | 0.56 | 23.0 |
| 12.0 | 7.22 | 0.81 | 32.6 |
| 14.0 | 8.42 | 1.10 | 43.5 |
| 16.0 | 9.63 | 1.44 | 56.3 |
| 18.0 | 10.80 | 1.82 | 70.3 |
| 20.0 | 12.00 | 2.25 | 86.1 |
| 22.0 | 13.20 | 2.72 | 104.0 |
| 24.0 | 14.40 | 3.24 | 122.0 |
| 26.0 | 15.60 | 3.80 | 143.0 |
| 28.0 | 16.80 | 4.41 | 164.0 |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

†*Courtesy Hydraulic Institute. See Page 6.*

## TABLE 1. (Cont.)
## FRICTION LOSS PER 100 FEET FOR WATER IN NEW WROUGHT IRON OR SCHEDULE 40 STEEL PIPE

| 1" 1.049" inside dia. | | | | 1¼" 1.380" inside dia. | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 6 | 2.23 | 0.08 | 2.68 | 10 | 2.15 | 0.72 | 1.77 |
| 8 | 2.97 | 0.14 | 4.54 | 12 | 2.57 | 0.10 | 2.48 |
| 10 | 3.71 | 0.21 | 6.86 | 14 | 3.00 | 0.14 | 3.28 |
| 12 | 4.45 | 0.31 | 9.62 | 16 | 3.43 | 0.18 | 4.20 |
| 14 | 5.20 | 0.42 | 12.8 | 18 | 3.86 | 0.23 | 5.22 |
| 16 | 5.94 | 0.55 | 16.5 | 20 | 4.29 | 0.29 | 6.34 |
| 18 | 6.68 | 0.69 | 20.6 | 22 | 4.72 | 0.35 | 7.58 |
| 20 | 7.42 | 0.86 | 25.1 | 24 | 5.15 | 0.41 | 8.92 |
| 22 | 8.17 | 1.04 | 30.2 | 25 | 5.36 | 0.45 | 9.6 |
| 24 | 8.91 | 1.23 | 35.6 | 30 | 6.44 | 0.64 | 13.6 |
| 25 | 9.27 | 1.34 | 38.7 | 35 | 7.51 | 0.87 | 18.2 |
| 30 | 11.1 | 1.93 | 54.6 | 40 | 8.58 | 1.14 | 23.5 |
| 35 | 13.0 | 2.63 | 73.3 | 45 | 9.65 | 1.44 | 29.4 |
| 40 | 14.8 | 3.43 | 95.0 | 50 | 10.7 | 1.79 | 36.0 |
| 45 | 16.7 | 4.34 | 119.0 | 55 | 11.8 | 2.16 | 43.2 |
| 50 | 18.6 | 5.35 | 146.0 | 60 | 12.9 | 2.57 | 51.0 |
| 55 | 20.4 | 6.46 | 176.0 | 65 | 13.9 | 3.02 | 59.6 |
| 60 | 22.3 | 7.71 | 209.0 | 70 | 15.0 | 3.50 | 68.8 |
| 65 | 24.2 | 9.10 | 245.0 | 75 | 16.1 | 4.03 | 78.7 |
| 70 | 26.0 | 10.49 | 283.0 | 80 | 17.2 | 4.58 | 89.2 |
| 75 | 27.9 | 12.10 | 324.0 | 85 | 18.2 | 5.15 | 100.0 |
| 80 | 29.7 | 13.7 | 367.0 | 90 | 19.3 | 5.79 | 112.0 |
| | | | | 95 | 20.4 | 6.45 | 125.0 |
| | | | | 100 | 21.5 | 7.15 | 138.0 |
| | | | | 120 | 25.7 | 10.3 | 197.0 |
| | | | | 140 | 30.0 | 14.0 | 267.0 |

### 1½"
1.610" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|---|---|---|---|
| 14 | 2.21 | 0.08 | 1.53 | 65 | 10.24 | 1.63 | 27.1 |
| 16 | 2.52 | 0.10 | 1.96 | 70 | 11.03 | 1.89 | 31.3 |
| 18 | 2.84 | 0.12 | 2.42 | 75 | 11.8 | 2.16 | 35.8 |
| 20 | 3.15 | 0.15 | 2.94 | 80 | 12.6 | 2.47 | 40.5 |
| 22 | 3.47 | 0.19 | 3.52 | 85 | 13.4 | 2.79 | 45.6 |
| 24 | 3.78 | 0.22 | 4.14 | 90 | 14.2 | 3.13 | 51.0 |
| 25 | 3.94 | 0.24 | 4.48 | 95 | 15.0 | 3.49 | 56.5 |
| 30 | 4.73 | 0.38 | 6.26 | 100 | 15.8 | 3.86 | 62.2 |
| 35 | 5.51 | 0.47 | 8.37 | 120 | 18.9 | 5.56 | 88.3 |
| 40 | 6.30 | 0.62 | 10.79 | 140 | 22.1 | 7.56 | 119.0 |
| 45 | 7.04 | 0.78 | 13.45 | 160 | 25.2 | 9.88 | 156.0 |
| 50 | 7.88 | 0.97 | 16.4 | 180 | 28.4 | 12.50 | 196.0 |
| 55 | 8.67 | 1.17 | 19.7 | 200 | 31.5 | 15.40 | 241.0 |
| 60 | 9.46 | 1.39 | 23.2 | | | | |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

# TABLE 1. (Cont.)

## FRICTION LOSS PER 100 FEET FOR WATER IN NEW WROUGHT IRON OR SCHEDULE 40 STEEL PIPE

### 2"

2.067" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|
| 24 | 2.29 | 0.08 | **1.20** |
| 25 | 2.39 | 0.09 | **1.29** |
| 30 | 2.87 | 0.13 | **1.82** |
| 35 | 3.35 | 0.17 | **2.42** |
| 40 | 3.82 | 0.23 | **3.10** |
| 45 | 4.30 | 0.29 | **3.85** |
| 50 | 4.78 | 0.36 | **4.67** |
| 55 | 5.25 | 0.43 | **5.51** |
| 60 | 5.74 | 0.51 | **6.59** |
| 65 | 6.21 | 0.60 | **7.70** |
| 70 | 6.69 | 0.70 | **8.86** |
| 75 | 7.16 | 0.80 | **10.15** |
| 80 | 7.65 | 0.91 | **11.40** |
| 85 | 8.11 | 1.03 | **12.6** |
| 90 | 8.60 | 1.15 | **14.2** |
| 95 | 9.09 | 1.29 | **15.8** |
| 100 | 9.56 | 1.42 | **17.4** |
| 120 | 11.5 | 2.05 | **24.7** |
| 140 | 13.4 | 2.78 | **33.2** |
| 160 | 15.3 | 3.64 | **43.0** |
| 180 | 17.2 | 4.60 | **54.1** |
| 200 | 19.1 | 5.68 | **66.3** |
| 220 | 21.0 | 6.88 | **80.0** |
| 240 | 22.9 | 8.18 | **95.0** |
| 260 | 24.9 | 9.60 | **111.0** |
| 280 | 26.8 | 11.14 | **128.0** |
| 300 | 28.7 | 12.8 | **146.0** |

### 2½"

2.469" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|
| 25 | 1.68 | 0.04 | **0.54** |
| 30 | 2.01 | 0.06 | **0.75** |
| 35 | 2.35 | 0.09 | **1.00** |
| 40 | 2.68 | 0.11 | **1.28** |
| 45 | 3.02 | 0.14 | **1.60** |
| 50 | 3.35 | 0.17 | **1.94** |
| 60 | 4.02 | 0.25 | **2.72** |
| 70 | 4.69 | 0.34 | **3.63** |
| 80 | 5.36 | 0.45 | **4.66** |
| 90 | 6.03 | 0.57 | **5.82** |
| 100 | 6.70 | 0.70 | **7.11** |
| 120 | 8.04 | 1.00 | **10.0** |
| 140 | 9.38 | 1.37 | **13.5** |
| 160 | 10.7 | 1.79 | **17.4** |
| 180 | 12.1 | 2.26 | **21.9** |
| 200 | 13.4 | 2.79 | **26.7** |
| 220 | 14.7 | 3.38 | **32.2** |
| 240 | 16.1 | 4.02 | **38.1** |
| 260 | 17.4 | 4.72 | **44.5** |
| 280 | 18.8 | 5.47 | **51.3** |
| 300 | 20.1 | 6.28 | **58.5** |
| 350 | 23.5 | 8.55 | **79.2** |
| 400 | 26.8 | 11.2 | **103.0** |

### 3"

3.068" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|
| 50 | 2.17 | 0.07 | **0.66** |
| 60 | 2.60 | 0.11 | **0.92** |
| 70 | 3.04 | 0.14 | **1.22** |
| 80 | 3.47 | 0.19 | **1.57** |
| 90 | 3.91 | 0.24 | **1.96** |
| 100 | 4.34 | 0.29 | **2.39** |
| 120 | 5.21 | 0.42 | **3.37** |
| 140 | 6.08 | 0.57 | **4.51** |
| 160 | 6.94 | 0.75 | **5.81** |
| 180 | 7.81 | 0.95 | **7.28** |
| 200 | 8.68 | 1.17 | **8.90** |
| 220 | 9.55 | 1.42 | **10.7** |
| 240 | 10.4 | 1.69 | **12.6** |
| 260 | 11.3 | 1.98 | **14.7** |
| 280 | 12.2 | 2.29 | **16.9** |
| 300 | 13.0 | 2.63 | **19.2** |
| 350 | 15.2 | 3.58 | **26.1** |
| 400 | 17.4 | 4.68 | **33.9** |
| 500 | 21.7 | 7.32 | **52.5** |
| 550 | 23.8 | 8.85 | **63.2** |
| 600 | 26.0 | 10.5 | **74.8** |
| 700 | 30.4 | 14.3 | **101.0** |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

# TABLE 1. (Cont.)
## FRICTION LOSS PER 100 FEET FOR WATER IN NEW WROUGHT IRON OR SCHEDULE 40 STEEL PIPE

| 4″ 4.026″ inside dia. | | | | 5″ 5.047″ inside dia. | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 90 | 2.27 | 0.08 | 0.52 | 140 | 2.25 | 0.08 | 0.380 |
| 100 | 2.52 | 0.10 | 0.62 | 160 | 2.57 | 0.10 | 0.487 |
| 120 | 3.02 | 0.14 | 0.88 | 180 | 2.89 | 0.13 | 0.606 |
| 140 | 3.53 | 0.19 | 1.17 | 200 | 3.21 | 0.16 | 0.736 |
| 160 | 4.03 | 0.25 | 1.49 | 220 | 3.53 | 0.19 | 0.879 |
| 180 | 4.54 | 0.32 | 1.86 | 240 | 3.85 | 0.23 | 1.035 |
| 200 | 5.04 | 0.40 | 2.27 | 260 | 4.17 | 0.27 | 1.200 |
| 220 | 5.54 | 0.48 | 2.72 | 280 | 4.49 | 0.31 | 1.38 |
| 240 | 6.05 | 0.57 | 3.21 | 300 | 4.81 | 0.36 | 1.58 |
| 260 | 6.55 | 0.67 | 3.74 | 350 | 5.61 | 0.49 | 2.11 |
| 280 | 7.06 | 0.77 | 4.30 | 400 | 6.41 | 0.64 | 2.72 |
| 300 | 7.56 | 0.89 | 4.89 | 450 | 7.22 | 0.81 | 3.41 |
| 350 | 8.82 | 1.21 | 6.55 | 500 | 8.02 | 1.00 | 4.16 |
| 400 | 10.10 | 1.58 | 8.47 | 550 | 8.81 | 1.21 | 4.94 |
| 450 | 11.4 | 2.00 | 10.65 | 600 | 9.62 | 1.44 | 5.88 |
| 500 | 12.6 | 2.47 | 13.0 | 700 | 11.20 | 1.96 | 7.93 |
| 550 | 13.9 | 3.00 | 15.7 | 800 | 12.80 | 2.56 | 10.22 |
| 600 | 15.1 | 3.55 | 18.6 | 900 | 14.40 | 3.24 | 12.90 |
| 700 | 17.6 | 4.84 | 25.0 | 1000 | 16.00 | 4.00 | 15.80 |
| 800 | 20.2 | 6.32 | 32.4 | 1200 | 19.20 | 5.76 | 22.50 |
| 900 | 22.7 | 8.00 | 40.8 | 1400 | 22.50 | 7.83 | 30.40 |
| 1000 | 25.2 | 9.87 | 50.2 | 1600 | 25.7 | 10.2 | 39.5 |
| | | | | 1800 | 28.80 | 12.90 | 49.70 |

| 6″ 6.065″ inside dia. | | | | | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 200 | 2.22 | 0.08 | 0.30 | 800 | 8.88 | 1.23 | 4.03 |
| 220 | 2.44 | 0.09 | 0.357 | 850 | 9.43 | 1.39 | 4.50 |
| 240 | 2.66 | 0.11 | 0.419 | 900 | 9.99 | 1.55 | 5.05 |
| 260 | 2.89 | 0.13 | 0.487 | 950 | 10.55 | 1.73 | 5.61 |
| 280 | 3.11 | 0.15 | 0.56 | 1000 | 11.10 | 1.92 | 6.17 |
| 300 | 3.33 | 0.17 | 0.637 | 1100 | 12.20 | 2.32 | 7.41 |
| 350 | 3.89 | 0.24 | 0.851 | 1200 | 13.30 | 2.76 | 8.76 |
| 400 | 4.44 | 0.31 | 1.09 | 1300 | 14.40 | 3.24 | 10.2 |
| 450 | 5.00 | 0.39 | 1.36 | 1400 | 15.50 | 3.76 | 11.8 |
| 500 | 5.55 | 0.48 | 1.66 | 1500 | 16.70 | 4.31 | 13.5 |
| 600 | 6.66 | 0.69 | 2.34 | 1600 | 17.80 | 4.91 | 15.4 |
| 650 | 7.21 | 0.81 | 2.72 | 1700 | 18.90 | 5.54 | 17.3 |
| 700 | 7.77 | 0.94 | 3.13 | 1800 | 20.00 | 6.21 | 19.4 |
| 750 | 8.32 | 1.08 | 3.59 | 1900 | 21.10 | 6.92 | 21.6 |
| | | | | 2000 | 22.20 | 7.67 | 23.8 |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

# TABLE 1. (Cont.)
## FRICTION LOSS PER 100 FEET FOR WATER IN NEW WROUGHT IRON OR SCHEDULE 40 STEEL PIPE

| 8" 7.981" inside dia. | | | | 10" 10.020" inside dia. | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 400 | 2.57 | 0.10 | 0.279 | 600 | 2.44 | 0.093 | 0.190 |
| 450 | 2.89 | 0.13 | 0.348 | 650 | 2.64 | 0.108 | 0.224 |
| 500 | 3.21 | 0.16 | 0.424 | 700 | 2.85 | 0.126 | 0.256 |
| 600 | 3.85 | 0.23 | 0.597 | 750 | 3.05 | 0.145 | 0.291 |
| 650 | 4.16 | 0.27 | 0.694 | 800 | 3.25 | 0.164 | 0.328 |
| 700 | 4.49 | 0.31 | 0.797 | 850 | 3.46 | 0.187 | 0.366 |
| 750 | 4.80 | 0.36 | 0.911 | 900 | 3.66 | 0.209 | 0.410 |
| 800 | 5.13 | 0.41 | 1.02 | 950 | 3.87 | 0.233 | 0.455 |
| 850 | 5.45 | 0.46 | 1.13 | 1000 | 4.07 | 0.257 | 0.500 |
| 900 | 5.77 | 0.52 | 1.27 | 1100 | 4.48 | 0.311 | 0.600 |
| 950 | 6.10 | 0.58 | 1.42 | 1200 | 4.88 | 0.370 | 0.703 |
| 1000 | 6.41 | 0.64 | 1.56 | 1300 | 5.29 | 0.435 | 0.818 |
| 1100 | 7.05 | 0.77 | 1.87 | 1400 | 5.70 | 0.505 | 0.94 |
| 1200 | 7.70 | 0.92 | 2.20 | 1500 | 6.10 | 0.579 | 1.07 |
| 1300 | 8.34 | 1.08 | 2.56 | 1600 | 6.51 | 0.659 | 1.21 |
| 1400 | 8.98 | 1.25 | 2.95 | 1700 | 6.92 | 0.743 | 1.36 |
| 1500 | 9.62 | 1.44 | 3.37 | 1800 | 7.32 | 0.835 | 1.52 |
| 1600 | 10.3 | 1.64 | 3.82 | 1900 | 7.73 | 0.930 | 1.68 |
| 1700 | 10.9 | 1.85 | 4.29 | 2000 | 8.14 | 1.030 | 1.86 |
| 1800 | 11.5 | 2.07 | 4.79 | 2100 | 8.55 | 1.135 | 2.05 |
| 1900 | 12.2 | 2.31 | 5.31 | 2200 | 8.94 | 1.240 | 2.25 |
| 2000 | 12.8 | 2.56 | 5.86 | 2500 | 10.2 | 1.62 | 2.86 |
| 2100 | 13.5 | 2.83 | 6.43 | 3000 | 12.2 | 2.31 | 4.06 |
| 2200 | 14.1 | 3.08 | 7.02 | 3500 | 14.2 | 3.14 | 5.46 |
| 2500 | 16.0 | 4.00 | 8.90 | 4000 | 16.3 | 4.12 | 7.07 |
| 3000 | 19.2 | 5.75 | 12.8 | 4500 | 18.3 | 5.20 | 8.91 |
| 3500 | 22.4 | 7.84 | 17.5 | 5000 | 20.3 | 6.42 | 11.00 |
| 4000 | 25.7 | 10.2 | 22.6 | 6000 | 24.4 | 9.29 | 15.90 |

| 12" 11.938" inside dia. | | | | | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 800 | 2.29 | 0.08 | 0.140 | 2000 | 5.73 | 0.51 | 0.776 |
| 850 | 2.44 | 0.09 | 0.154 | 2100 | 6.01 | 0.56 | 0.853 |
| 900 | 2.58 | 0.10 | 0.173 | 2200 | 6.29 | 0.61 | 0.936 |
| 950 | 2.72 | 0.12 | 0.191 | 2500 | 7.17 | 0.80 | 1.187 |
| 1000 | 2.87 | 0.13 | 0.210 | 3000 | 8.60 | 1.15 | 1.68 |
| 1100 | 3.15 | 0.15 | 0.251 | 3500 | 10.0 | 1.56 | 2.25 |
| 1200 | 3.44 | 0.18 | 0.296 | 4000 | 11.5 | 2.04 | 2.92 |
| 1300 | 3.73 | 0.22 | 0.344 | 4500 | 12.9 | 2.59 | 3.65 |
| 1400 | 4.01 | 0.25 | 0.395 | 5000 | 14.3 | 3.19 | 4.47 |
| 1500 | 4.30 | 0.29 | 0.450 | 6000 | 17.2 | 4.60 | 6.39 |
| 1600 | 4.59 | 0.33 | 0.509 | 7000 | 20.1 | 6.26 | 8.63 |
| 1700 | 4.87 | 0.37 | 0.572 | 8000 | 22.9 | 8.17 | 11.20 |
| 1800 | 5.16 | 0.41 | 0.636 | 9000 | 25.8 | 10.3 | 14.10 |
| 1900 | 5.45 | 0.46 | 0.704 | | | | |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

II

## TABLE 1. (Cont.)
## FRICTION LOSS PER 100 FEET FOR WATER IN NEW WROUGHT IRON OR SCHEDULE 40 STEEL PIPE

| 14" 13.126" inside dia. | | | | 16" 15.000" inside dia. | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 1000 | 2.37 | 0.09 | 0.131 | 1400 | 2.54 | 0.10 | 0.127 |
| 1100 | 2.61 | 0.11 | 0.157 | 1500 | 2.72 | 0.12 | 0.14 |
| 1200 | 2.85 | 0.13 | 0.185 | 1600 | 2.90 | 0.13 | 0.163 |
| 1300 | 3.08 | 0.15 | 0.215 | 1700 | 3.09 | 0.15 | 0.183 |
| 1400 | 3.32 | 0.17 | 0.247 | 1800 | 3.27 | 0.17 | 0.203 |
| 1500 | 3.56 | 0.20 | 0.281 | 1900 | 3.45 | 0.19 | 0.225 |
| 1600 | 3.79 | 0.22 | 0.317 | 2000 | 3.63 | 0.21 | 0.248 |
| 1700 | 4.03 | 0.25 | 0.355 | 2500 | 4.54 | 0.32 | 0.377 |
| 1800 | 4.27 | 0.28 | 0.395 | 3000 | 5.45 | 0.46 | 0.535 |
| 1900 | 4.50 | 0.32 | 0.438 | 3500 | 6.35 | 0.63 | 0.718 |
| 2000 | 4.74 | 0.35 | 0.483 | 4000 | 7.26 | 0.82 | 0.921 |
| 2500 | 5.93 | 0.55 | 0.738 | 4500 | 8.17 | 1.04 | 1.15 |
| 3000 | 7.11 | 0.79 | 1.04 | 5000 | 9.08 | 1.28 | 1.41 |
| 3500 | 8.30 | 1.07 | 1.40 | 6000 | 10.9 | 1.84 | 2.01 |
| 4000 | 9.48 | 1.40 | 1.81 | 7000 | 12.7 | 2.51 | 2.69 |
| 4500 | 10.7 | 1.78 | 2.27 | 8000 | 14.5 | 3.28 | 3.49 |
| 5000 | 11.9 | 2.18 | 2.78 | 9000 | 16.3 | 4.15 | 4.38 |
| 6000 | 14.2 | 3.14 | 3.95 | 10000 | 18.2 | 5.12 | 5.38 |
| 7000 | 16.6 | 4.28 | 5.32 | 11000 | 20.0 | 6.22 | 6.50 |
| 8000 | 19.0 | 5.59 | 6.90 | 12000 | 21.8 | 7.38 | 7.69 |
| 9000 | 21.3 | 7.08 | 8.70 | 13000 | 23.6 | 8.66 | 8.95 |
| 10000 | 23.7 | 8.74 | 10.7 | 14000 | 25.4 | 10.04 | 10.40 |
| 11000 | 26.0 | 10.55 | 12.9 | 15000 | 27.2 | 11.50 | 11.90 |
| 12000 | 28.5 | 12.60 | 15.2 | 16000 | 29.0 | 13.10 | 13.50 |

### 18"
16.876" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|---|---|---|---|
| 1800 | 2.58 | 0.10 | 0.114 | 7000 | 10.0 | 1.57 | 1.49 |
| 1900 | 2.73 | 0.12 | 0.126 | 8000 | 11.5 | 2.05 | 1.93 |
| 2000 | 2.87 | 0.13 | 0.139 | 9000 | 12.9 | 2.59 | 2.42 |
| 2500 | 3.59 | 0.20 | 0.211 | 10000 | 14.3 | 3.20 | 2.97 |
| 3000 | 4.30 | 0.29 | 0.297 | 11000 | 15.8 | 3.89 | 3.57 |
| 3500 | 5.02 | 0.39 | 0.397 | 12000 | 17.2 | 4.60 | 4.21 |
| 4000 | 5.74 | 0.51 | 0.511 | 13000 | 18.6 | 5.37 | 4.89 |
| 4500 | 6.45 | 0.65 | 0.639 | 14000 | 20.1 | 6.27 | 5.69 |
| 5000 | 7.17 | 0.80 | 0.781 | 15000 | 21.5 | 7.18 | 6.50 |
| 6000 | 8.61 | 1.15 | 1.11 | 16000 | 22.9 | 8.19 | 7.41 |
| | | | | 18000 | 25.8 | 10.36 | 9.33 |
| | | | | 20000 | 28.7 | 12.8 | 11.5 |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

# TABLE 1. (Cont.)
## FRICTION LOSS PER 100 FEET FOR WATER IN NEW WROUGHT IRON OR SCHEDULE 40 STEEL PIPE

| 20" 18.814" inside dia. | | | | 24" 22.626" inside dia. | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Per Gals. Min. | $V$ vel. f.p.s. | vel. $V^2/2g$ head feet | frict. loss $h_f$ feet |
| 2000 | 2.31 | 0.08 | 0.0812 | 3000 | 2.39 | 0.09 | 0.070 |
| 2500 | 2.89 | 0.13 | 0.123 | 3500 | 2.79 | 0.12 | 0.093 |
| 3000 | 3.46 | 0.19 | 0.174 | 4000 | 3.19 | 0.16 | 0.120 |
| 3500 | 4.04 | 0.25 | 0.232 | 4500 | 3.59 | 0.20 | 0.149 |
| 4000 | 4.62 | 0.33 | 0.298 | 5000 | 3.99 | 0.25 | 0.181 |
| 4500 | 5.19 | 0.42 | 0.372 | 6000 | 4.79 | 0.36 | 0.257 |
| 5000 | 5.77 | 0.52 | 0.455 | 7000 | 5.59 | 0.49 | 0.343 |
| 6000 | 6.92 | 0.75 | 0.645 | 8000 | 6.38 | 0.63 | 0.441 |
| 7000 | 8.08 | 1.01 | 0.862 | 9000 | 7.18 | 0.80 | 0.551 |
| 8000 | 9.23 | 1.32 | 1.11 | 10000 | 7.98 | 0.99 | 0.671 |
| 9000 | 10.39 | 1.68 | 1.39 | 11000 | 8.78 | 1.20 | 0.810 |
| 10000 | 11.5 | 2.07 | 1.70 | 12000 | 9.58 | 1.42 | 0.959 |
| 11000 | 12.7 | 2.51 | 2.05 | 13000 | 10.4 | 1.68 | 1.12 |
| 12000 | 13.8 | 2.98 | 2.44 | 14000 | 11.2 | 1.94 | 1.29 |
| 13000 | 15.0 | 3.50 | 2.86 | 15000 | 12.0 | 2.24 | 1.48 |
| 14000 | 16.2 | 4.08 | 3.29 | 16000 | 12.8 | 2.53 | 1.67 |
| 15000 | 17.3 | 4.65 | 3.75 | 17000 | 13.6 | 2.88 | 1.88 |
| 16000 | 18.5 | 5.30 | 4.26 | 18000 | 14.4 | 3.21 | 2.10 |
| 18000 | 20.8 | 6.71 | 5.35 | 19000 | 15.2 | 3.59 | 2.33 |
| 20000 | 32.1 | 8.28 | 6.56 | 20000 | 16.0 | 3.96 | 2.58 |
| 22000 | 25.4 | 10.02 | 7.91 | 25000 | 20.0 | 6.20 | 4.04 |
| 24000 | 27.7 | 11.9 | 9.39 | 30000 | 23.9 | 8.91 | 5.68 |
| | | | | 35000 | 27.9 | 12.20 | 7.73 |

## 30"
29.000" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|---|---|---|---|
| 5000 | 2.43 | 0.09 | 0.053 | 15000 | 7.28 | 0.83 | 0.426 |
| 6000 | 2.91 | 0.13 | 0.075 | 16000 | 7.77 | 0.94 | 0.478 |
| 7000 | 3.40 | 0.18 | 0.100 | 17000 | 8.25 | 1.06 | 0.538 |
| 8000 | 3.89 | 0.24 | 0.129 | 18000 | 8.74 | 1.19 | 0.598 |
| 9000 | 4.37 | 0.30 | 0.161 | 19000 | 9.21 | 1.32 | 0.661 |
| 10000 | 4.86 | 0.37 | 0.196 | 20000 | 9.71 | 1.47 | 0.732 |
| 11000 | 5.35 | 0.44 | 0.237 | 25000 | 12.1 | 2.29 | 1.13 |
| 12000 | 5.83 | 0.53 | 0.277 | 30000 | 14.6 | 3.30 | 1.61 |
| 13000 | 6.31 | 0.62 | 0.320 | 35000 | 17.0 | 4.49 | 2.17 |
| 14000 | 6.80 | 0.72 | 0.371 | 40000 | 19.4 | 5.87 | 2.83 |
| | | | | 45000 | 21.9 | 7.42 | 3.56 |
| | | | | 50000 | 24.3 | 9.17 | 4.38 |
| | | | | 60000 | 29.1 | 13.2 | 6.23 |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

## TABLE 1. (Cont.)
## FRICTION LOSS PER 100 FEET FOR WATER IN NEW WROUGHT IRON OR SCHEDULE 40 STEEL PIPE

| 36" 36.000" inside dia. | | | | 42" 42.000" inside dia. | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 8000 | 2.52 | 0.10 | 0.044 | 10000 | 2.32 | 0.08 | 0.0314 |
| 9000 | 2.84 | 0.13 | 0.055 | 11000 | 2.55 | 0.10 | 0.0380 |
| 10000 | 3.15 | 0.15 | 0.067 | 12000 | 2.78 | 0.12 | 0.0441 |
| 11000 | 3.46 | 0.19 | 0.081 | 13000 | 3.01 | 0.14 | 0.0511 |
| 12000 | 3.78 | 0.22 | 0.094 | 14000 | 3.24 | 0.16 | 0.0591 |
| 13000 | 4.10 | 0.26 | 0.109 | 15000 | 3.47 | 0.19 | 0.0680 |
| 14000 | 4.41 | 0.30 | 0.126 | 16000 | 3.71 | 0.21 | 0.0758 |
| 15000 | 4.73 | 0.35 | 0.144 | 17000 | 3.94 | 0.24 | 0.0852 |
| 16000 | 5.04 | 0.40 | 0.162 | 18000 | 4.17 | 0.27 | 0.0944 |
| 17000 | 5.35 | 0.45 | 0.182 | 19000 | 4.40 | 0.30 | 0.104 |
| 18000 | 5.67 | 0.50 | 0.203 | 20000 | 4.63 | 0.33 | 0.115 |
| 19000 | 5.98 | 0.57 | 0.224 | 25000 | 5.79 | 0.52 | 0.176 |
| 20000 | 6.30 | 0.62 | 0.248 | 30000 | 6.95 | 0.75 | 0.250 |
| 25000 | 7.88 | 0.97 | 0.378 | 35000 | 8.11 | 1.02 | 0.334 |
| 30000 | 9.46 | 1.39 | 0.540 | 40000 | 9.26 | 1.33 | 0.433 |
| 35000 | 11.0 | 1.89 | 0.724 | 45000 | 10.4 | 1.69 | 0.545 |
| 40000 | 12.6 | 2.47 | 0.941 | 50000 | 11.6 | 2.08 | 0.668 |
| 45000 | 14.1 | 3.13 | 1.18 | 60000 | 13.9 | 3.00 | 0.946 |
| 50000 | 15.8 | 3.86 | 1.45 | 70000 | 16.2 | 4.08 | 1.27 |
| 60000 | 18.9 | 5.56 | 2.07 | 80000 | 18.5 | 5.33 | 1.66 |
| 70000 | 22.1 | 7.56 | 2.81 | 90000 | 20.8 | 6.75 | 2.08 |
| 80000 | 25.2 | 9.88 | 3.66 | 100000 | 23.2 | 8.33 | 2.57 |
| 90000 | 28.4 | 12.5 | 4.59 | 120000 | 27.8 | 12.0 | 3.67 |

### 48"
48" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|---|---|---|---|
| 14000 | 2.48 | 0.10 | 0.031 | 60000 | 10.64 | 1.76 | 0.484 |
| 16000 | 2.84 | 0.13 | 0.039 | 70000 | 12.4 | 2.39 | 0.652 |
| 18000 | 3.19 | 0.16 | 0.049 | 80000 | 14.2 | 3.13 | 0.849 |
| 20000 | 3.55 | 0.20 | 0.060 | 90000 | 16.0 | 3.96 | 1.06 |
| 25000 | 4.43 | 0.31 | 0.091 | 100000 | 17.7 | 4.89 | 1.30 |
| 30000 | 5.32 | 0.44 | 0.128 | 120000 | 21.3 | 7.03 | 1.87 |
| 35000 | 6.21 | 0.60 | 0.172 | 140000 | 24.8 | 9.57 | 2.51 |
| 40000 | 7.09 | 0.78 | 0.222 | 160000 | 28.4 | 12.5 | 3.26 |
| 45000 | 7.98 | 0.99 | 0.278 | | | | |
| 50000 | 8.87 | 1.22 | 0.341 | | | | |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

## TABLE 1. (Cont.)
## FRICTION LOSS PER 100 FEET FOR WATER IN NEW WROUGHT IRON OR SCHEDULE 40 STEEL PIPE

| 54" — 54" inside dia. | | | | 60" — 60" inside dia. | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 18000 | 2.52 | 0.10 | 0.027 | 20000 | 2.27 | 0.08 | 0.020 |
| 20000 | 2.80 | 0.12 | 0.033 | 25000 | 2.84 | 0.13 | 0.030 |
| 25000 | 3.50 | 0.19 | 0.050 | 30000 | 3.40 | 0.18 | 0.042 |
| 30000 | 4.20 | 0.27 | 0.071 | 35000 | 3.97 | 0.25 | 0.057 |
| 35000 | 4.90 | 0.37 | 0.096 | 40000 | 4.54 | 0.32 | 0.073 |
| 40000 | 5.60 | 0.49 | 0.124 | 45000 | 5.11 | 0.41 | 0.092 |
| 45000 | 6.30 | 0.62 | 0.155 | 50000 | 5.67 | 0.50 | 0.112 |
| 50000 | 7.00 | 0.76 | 0.189 | 60000 | 6.81 | 0.72 | 0.158 |
| 60000 | 8.40 | 1.10 | 0.267 | 70000 | 7.94 | 0.98 | 0.213 |
| 70000 | 9.81 | 1.49 | 0.358 | 80000 | 9.08 | 1.28 | 0.275 |
| 80000 | 11.21 | 1.95 | 0.465 | 90000 | 10.21 | 1.62 | 0.344 |
| 90000 | 12.6 | 2.47 | 0.586 | 100000 | 11.3 | 2.00 | 0.420 |
| 100000 | 14.0 | 3.05 | 0.715 | 120000 | 13.6 | 2.88 | 0.600 |
| 120000 | 16.8 | 4.39 | 1.02 | 140000 | 15.9 | 3.92 | 0.806 |
| 140000 | 19.6 | 5.98 | 1.38 | 160000 | 18.2 | 5.12 | 1.040 |
| 160000 | 22.4 | 7.81 | 1.80 | 180000 | 20.4 | 6.48 | 1.32 |
| 180000 | 25.2 | 9.88 | 2.26 | 200000 | 22.7 | 8.00 | 1.62 |
| 200000 | 28.0 | 12.2 | 2.77 | 250000 | 28.4 | 12.5 | 2.52 |

### 72"
72" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|
| 30000 | 2.37 | 0.09 | 0.017 |
| 35000 | 2.76 | 0.12 | 0.023 |
| 40000 | 3.16 | 0.16 | 0.030 |
| 45000 | 3.55 | 0.20 | 0.037 |
| 50000 | 3.94 | 0.24 | 0.045 |
| 60000 | 4.73 | 0.35 | 0.064 |
| 70000 | 5.52 | 0.47 | 0.085 |
| 80000 | 6.31 | 0.62 | 0.110 |
| 90000 | 7.10 | 0.78 | 0.138 |
| 100000 | 7.89 | 0.97 | 0.168 |
| 120000 | 9.47 | 1.39 | 0.237 |
| 140000 | 11.0 | 1.89 | 0.321 |
| 160000 | 12.6 | 2.47 | 0.414 |
| 180000 | 14.2 | 3.13 | 0.522 |
| 200000 | 15.8 | 3.87 | 0.642 |
| 250000 | 19.7 | 6.04 | 1.00 |
| 300000 | 23.7 | 8.70 | 1.42 |
| 350000 | 27.6 | 11.8 | 1.92 |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

# TABLE 2. FRICTION LOSS PER 100 FEET FOR WATER IN NEW ASPHALT DIPPED CAST IRON PIPE†

| 3" — 3" inside dia. | | | | 4" — 4" inside dia | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| **50** | 2.27 | 0.08 | **0.83** | **90** | 2.30 | 0.08 | **0.59** |
| **60** | 2.72 | 0.12 | **1.17** | **100** | 2.55 | 0.10 | **0.72** |
| **70** | 3.18 | 0.16 | **1.56** | **120** | 3.06 | 0.15 | **1.03** |
| **80** | 3.63 | 0.21 | **2.02** | **140** | 3.57 | 0.20 | **1.38** |
| **90** | 4.08 | 0.26 | **2.55** | **160** | 4.08 | 0.26 | **1.78** |
| **100** | 4.54 | 0.32 | **3.10** | **180** | 4.60 | 0.33 | **2.24** |
| **120** | 5.45 | 0.46 | **4.40** | **200** | 5.11 | 0.41 | **2.74** |
| **140** | 6.35 | 0.63 | **5.93** | **220** | 5.62 | 0.49 | **3.28** |
| **160** | 7.26 | 0.82 | **7.71** | **240** | 6.13 | 0.58 | **3.88** |
| **180** | 8.17 | 1.04 | **9.73** | **260** | 6.64 | 0.69 | **4.54** |
| **200** | 9.08 | 1.28 | **11.90** | **280** | 7.15 | 0.79 | **5.25** |
| **220** | 9.98 | 1.55 | **14.30** | **300** | 7.66 | 0.91 | **6.03** |
| **240** | 10.90 | 1.85 | **17.00** | **350** | 8.94 | 1.25 | **8.22** |
| **260** | 11.80 | 2.17 | **19.80** | **400** | 10.20 | 1.62 | **10.70** |
| **280** | 12.70 | 2.51 | **22.80** | **450** | 11.50 | 2.05 | **13.40** |
| **300** | 13.60 | 2.88 | **26.10** | **500** | 12.80 | 2.53 | **16.60** |
| **350** | 15.90 | 3.93 | **35.70** | **550** | 14.00 | 3.05 | **19.90** |
| **400** | 18.20 | 5.12 | **46.80** | **600** | 15.30 | 3.65 | **23.60** |
| **450** | 20.50 | 6.50 | **59.70** | **700** | 17.90 | 4.96 | **32.10** |
| **500** | 22.70 | 8.00 | **72.30** | **800** | 20.40 | 6.48 | **41.60** |
| **550** | 25.00 | 9.73 | **87.70** | **900** | 23.00 | 8.20 | **52.30** |
| **600** | 27.20 | 11.50 | **102.00** | **1000** | 25.50 | 10.10 | **64.20** |
| | | | | **1200** | 30.60 | 14.60 | **92.80** |

## 6"
6" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|---|---|---|---|
| **200** | 2.27 | 0.08 | **0.35** | **550** | 6.24 | 0.61 | **2.42** |
| **220** | 2.50 | 0.10 | **0.42** | **600** | 6.81 | 0.72 | **2.84** |
| **240** | 2.72 | 0.12 | **0.49** | **700** | 7.94 | 0.98 | **3.87** |
| **260** | 2.95 | 0.14 | **0.57** | **800** | 9.08 | 1.28 | **5.06** |
| **280** | 3.18 | 0.16 | **0.66** | **900** | 10.20 | 1.62 | **6.34** |
| **300** | 3.40 | 0.18 | **0.75** | **1000** | 11.30 | 2.00 | **7.73** |
| **350** | 3.97 | 0.25 | **1.01** | **1200** | 13.60 | 2.88 | **11.20** |
| **400** | 4.55 | 0.32 | **1.30** | **1400** | 15.90 | 3.92 | **15.10** |
| **450** | 5.11 | 0.41 | **1.64** | **1600** | 18.20 | 5.12 | **19.80** |
| **500** | 5.67 | 0.50 | **2.02** | **1800** | 20.40 | 6.48 | **24.80** |
| | | | | **2000** | 22.70 | 8.00 | **30.50** |
| | | | | **2200** | 25.00 | 9.73 | **37.00** |
| | | | | **2500** | 28.40 | 12.50 | **47.10** |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

†*Courtesy Hydraulic Institute.* *See Page 6.*

## TABLE 2. (Cont.) FRICTION LOSS PER 100 FEET FOR WATER IN NEW ASPHALT DIPPED CAST IRON PIPE

| 8" — 8" inside dia. | | | | 10" — 10" inside dia. | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 400 | 2.55 | 0.10 | 0.30 | 600 | 2.45 | 0.09 | 0.21 |
| 450 | 2.87 | 0.13 | 0.38 | 700 | 2.86 | 0.13 | 0.29 |
| 500 | 3.19 | 0.16 | 0.46 | 800 | 3.27 | 0.17 | 0.37 |
| 550 | 3.51 | 0.19 | 0.56 | 900 | 3.68 | 0.21 | 0.46 |
| 600 | 3.83 | 0.23 | 0.66 | 1000 | 4.09 | 0.26 | 0.57 |
| 700 | 4.47 | 0.31 | 0.88 | 1200 | 4.90 | 0.37 | 0.81 |
| 800 | 5.11 | 0.41 | 1.14 | 1400 | 5.72 | 0.51 | 1.09 |
| 900 | 5.74 | 0.51 | 1.44 | 1600 | 6.54 | 0.66 | 1.42 |
| 1000 | 6.38 | 0.63 | 1.76 | 1800 | 7.35 | 0.84 | 1.78 |
| 1200 | 7.66 | 0.91 | 2.53 | 2000 | 8.17 | 1.04 | 2.17 |
| 1400 | 8.93 | 1.24 | 3.40 | 2200 | 8.99 | 1.26 | 2.64 |
| 1600 | 10.20 | 1.62 | 4.45 | 2400 | 9.80 | 1.49 | 3.12 |
| 1800 | 11.50 | 2.05 | 5.58 | 2600 | 10.60 | 1.75 | 3.63 |
| 2000 | 12.80 | 2.53 | 6.84 | 2800 | 11.40 | 2.03 | 4.18 |
| 2200 | 14.00 | 3.05 | 8.26 | 3000 | 12.30 | 2.33 | 4.79 |
| 2500 | 15.90 | 3.96 | 10.60 | 3200 | 13.10 | 2.66 | 5.47 |
| 3000 | 19.10 | 5.70 | 16.20 | 3400 | 13.90 | 3.00 | 6.18 |
| 3500 | 22.30 | 7.77 | 20.70 | 3600 | 14.70 | 3.36 | 6.91 |
| 4000 | 25.50 | 10.10 | 27.00 | 3800 | 15.50 | 3.74 | 7.68 |
| 4500 | 28.70 | 12.80 | 34.20 | 4000 | 16.30 | 4.15 | 8.50 |
| | | | | 4500 | 18.40 | 5.25 | 10.70 |
| | | | | 5000 | 20.40 | 6.48 | 13.20 |
| | | | | 5500 | 22.50 | 7.85 | 15.90 |
| | | | | 6000 | 24.50 | 9.43 | 18.90 |
| | | | | 6500 | 26.60 | 11.00 | 22.20 |
| | | | | 7000 | 28.60 | 12.70 | 25.80 |
| | | | | 8000 | 32.70 | 16.60 | 33.60 |

### 12" — 12" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|---|---|---|---|
| 800 | 2.27 | 0.08 | 0.15 | 3600 | 10.20 | 1.62 | 2.70 |
| 900 | 2.55 | 0.10 | 0.18 | 3800 | 10.80 | 1.81 | 3.00 |
| 1000 | 2.84 | 0.13 | 0.22 | 4000 | 11.30 | 2.00 | 3.31 |
| 1200 | 3.40 | 0.18 | 0.32 | 4500 | 12.80 | 2.53 | 4.18 |
| 1400 | 3.97 | 0.25 | 0.43 | 5000 | 14.20 | 3.12 | 5.13 |
| 1600 | 4.54 | 0.32 | 0.55 | 5500 | 15.60 | 3.78 | 6.17 |
| 1800 | 5.11 | 0.41 | 0.70 | 6000 | 17.00 | 4.50 | 7.30 |
| 2000 | 5.67 | 0.50 | 0.86 | 6500 | 18.40 | 5.28 | 8.55 |
| 2200 | 6.24 | 0.61 | 1.03 | 7000 | 19.90 | 6.13 | 9.92 |
| 2400 | 6.81 | 0.72 | 1.22 | 8000 | 22.70 | 8.00 | 13.00 |
| 2600 | 7.38 | 0.85 | 1.43 | 9000 | 25.50 | 10.10 | 16.40 |
| 2800 | 7.94 | 0.98 | 1.65 | 10000 | 28.40 | 12.50 | 20.20 |
| 3000 | 8.51 | 1.13 | 1.88 | | | | |
| 3200 | 9.08 | 1.28 | 2.13 | | | | |
| 3400 | 9.65 | 1.45 | 2.41 | | | | |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

## TABLE 2. (Cont.) FRICTION LOSS PER 100 FEET FOR WATER IN NEW ASPHALT DIPPED CAST IRON PIPE

| 14" 14" inside dia. | | | | 16" 16" inside dia. | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 1200 | 2.50 | 0.10 | 0.15 | 1400 | 2.23 | 0.08 | 0.11 |
| 1400 | 2.92 | 0.13 | 0.20 | 1600 | 2.55 | 0.10 | 0.13 |
| 1600 | 3.33 | 0.17 | 0.25 | 1800 | 2.87 | 0.13 | 0.16 |
| 1800 | 3.75 | 0.22 | 0.32 | 2000 | 3.19 | 0.16 | 0.20 |
| 2000 | 4.17 | 0.27 | 0.39 | 2200 | 3.51 | 0.19 | 0.24 |
| 2200 | 4.59 | 0.33 | 0.47 | 2400 | 3.83 | 0.23 | 0.29 |
| 2400 | 5.00 | 0.39 | 0.56 | 2600 | 4.15 | 0.27 | 0.33 |
| 2600 | 5.42 | 0.46 | 0.65 | 2800 | 4.47 | 0.31 | 0.38 |
| 2800 | 5.83 | 0.53 | 0.75 | 3000 | 4.79 | 0.36 | 0.44 |
| 3000 | 6.25 | 0.61 | 0.86 | 3200 | 5.11 | 0.41 | 0.49 |
| 3200 | 6.67 | 0.69 | 0.97 | 3400 | 5.42 | 0.46 | 0.55 |
| 3400 | 7.08 | 0.78 | 1.10 | 3600 | 5.74 | 0.51 | 0.62 |
| 3600 | 7.50 | 0.87 | 1.22 | 3800 | 6.06 | 0.57 | 0.68 |
| 3800 | 7.92 | 0.97 | 1.35 | 5000 | 6.38 | 0.63 | 0.75 |
| 4000 | 8.34 | 1.08 | 1.50 | 4500 | 7.18 | 0.80 | 0.95 |
| 4500 | 9.38 | 1.37 | 1.88 | 5000 | 7.98 | 0.99 | 1.17 |
| 5000 | 10.40 | 1.69 | 2.30 | 5500 | 8.78 | 1.20 | 1.41 |
| 5500 | 11.50 | 2.04 | 2.79 | 6000 | 9.57 | 1.42 | 1.66 |
| 6000 | 12.50 | 2.43 | 3.31 | 6500 | 10.40 | 1.67 | 1.95 |
| 6500 | 13.60 | 2.86 | 3.89 | 7000 | 11.20 | 1.94 | 2.26 |
| 7000 | 14.60 | 3.30 | 4.50 | 8000 | 12.80 | 2.53 | 2.96 |
| 8000 | 16.70 | 4.32 | 5.87 | 9000 | 14.40 | 3.20 | 3.73 |
| 9000 | 18.80 | 5.47 | 7.42 | 10000 | 16.00 | 3.96 | 4.57 |
| 10000 | 20.80 | 6.75 | 9.15 | 12000 | 19.00 | 5.70 | 6.52 |
| 12000 | 25.00 | 9.72 | 13.00 | 14000 | 22.30 | 7.75 | 8.81 |
| 14000 | 29.20 | 13.20 | 17.60 | 16000 | 25.50 | 10.10 | 11.50 |
| | | | | 18000 | 28.70 | 12.80 | 14.60 |

### 18"

18" inside dia

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|---|---|---|---|
| 2500 | 3.15 | 0.15 | 0.166 | 10000 | 12.60 | 2.47 | 2.480 |
| 3000 | 3.78 | 0.22 | 0.240 | 12000 | 15.10 | 3.55 | 3.560 |
| 3500 | 4.41 | 0.30 | 0.326 | 14000 | 17.70 | 4.84 | 4.850 |
| 4000 | 5.04 | 0.40 | 0.415 | 16000 | 20.20 | 6.32 | 6.340 |
| 4500 | 5.67 | 0.50 | 0.525 | 18000 | 22.70 | 8.00 | 8.020 |
| 5000 | 6.30 | 0.62 | 0.645 | 20000 | 25.20 | 9.88 | 9.880 |
| 6000 | 7.56 | 0.89 | 0.920 | 22000 | 27.70 | 12.00 | 11.900 |
| 7000 | 8.83 | 1.21 | 1.240 | | | | |
| 8000 | 10.09 | 1.84 | 1.610 | | | | |
| 9000 | 11.30 | 1.99 | 2.020 | | | | |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

# TABLE 2. (Cont.) FRICTION LOSS PER 100 FEET FOR WATER IN NEW ASPHALT DIPPED CAST IRON PIPE

| 20" 20" inside dia. | | | | 24" 24" inside dia. | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 2500 | 2.55 | 0.10 | 0.0998 | 3500 | 2.48 | 0.10 | 0.0759 |
| 3000 | 3.06 | 0.15 | 0.140 | 4000 | 2.84 | 0.13 | 0.098 |
| 3500 | 3.57 | 0.20 | 0.188 | 4500 | 3.19 | 0.16 | 0.122 |
| 4000 | 4.08 | 0.26 | 0.243 | 5000 | 3.55 | 0.20 | 0.149 |
| 4500 | 4.59 | 0.33 | 0.306 | 6000 | 4.26 | 0.28 | 0.211 |
| 5000 | 5.11 | 0.41 | 0.376 | 7000 | 4.96 | 0.38 | 0.284 |
| 6000 | 6.13 | 0.58 | 0.533 | 8000 | 5.67 | 0.50 | 0.368 |
| 7000 | 7.15 | 0.79 | 0.721 | 9000 | 6.38 | 0.63 | 0.464 |
| 8000 | 8.17 | 1.04 | 0.935 | 10000 | 7.09 | 0.78 | 0.571 |
| 9000 | 9.19 | 1.31 | 1.18 | 12000 | 8.51 | 1.13 | 0.816 |
| 10000 | 10.20 | 1.62 | 1.45 | 14000 | 9.93 | 1.53 | 1.11 |
| 12000 | 12.30 | 2.33 | 2.07 | 16000 | 11.35 | 2.00 | 1.43 |
| 14000 | 14.30 | 3.18 | 2.80 | 18000 | 12.76 | 2.53 | 1.80 |
| 16000 | 16.30 | 4.15 | 3.66 | 20000 | 14.20 | 3.13 | 2.21 |
| 18000 | 18.40 | 5.25 | 4.62 | 22000 | 15.60 | 3.78 | 2.67 |
| 20000 | 20.40 | 6.48 | 5.67 | 24000 | 17.00 | 4.50 | 3.16 |
| 22000 | 22.50 | 7.84 | 6.85 | 26000 | 18.40 | 5.28 | 3.71 |
| 24000 | 24.50 | 9.33 | 8.13 | 28000 | 19.80 | 6.10 | 4.30 |
| 26000 | 26.50 | 10.95 | 9.54 | 30000 | 21.30 | 7.03 | 4.97 |
| 28000 | 28.50 | 12.64 | 11.05 | 35000 | 24.90 | 9.58 | 6.78 |
| 30000 | 30.60 | 14.60 | 12.70 | 40000 | 28.40 | 12.50 | 8.75 |

| 30" 30" inside dia. | | | | | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 5000 | 2.27 | 0.08 | 0.0488 | 20000 | 9.08 | 1.28 | 0.703 |
| 6000 | 2.72 | 0.12 | 0.069 | 22000 | 10.00 | 1.55 | 0.856 |
| 7000 | 3.18 | 0.16 | 0.092 | 24000 | 10.90 | 1.84 | 1.01 |
| 8000 | 3.63 | 0.21 | 0.119 | 26000 | 11.80 | 2.16 | 1.17 |
| 9000 | 4.08 | 0.26 | 0.149 | 28000 | 12.70 | 2.50 | 1.34 |
| 10000 | 4.54 | 0.32 | 0.183 | 30000 | 13.60 | 2.88 | 1.57 |
| 12000 | 5.45 | 0.46 | 0.260 | 35000 | 15.90 | 3.92 | 2.13 |
| 14000 | 6.35 | 0.63 | 0.351 | 40000 | 18.20 | 5.12 | 2.77 |
| 16000 | 7.26 | 0.82 | 0.455 | 45000 | 20.40 | 6.48 | 3.50 |
| 18000 | 8.17 | 1.04 | 0.572 | 50000 | 22.70 | 8.00 | 4.30 |
| | | | | 60000 | 27.20 | 11.50 | 6.19 |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

II

# TABLE 2. (Cont.) FRICTION LOSS PER 100 FEET FOR WATER IN NEW ASPHALT DIPPED CAST IRON PIPE

| 36" 36" inside dia. | | | | 42" 42" inside dia. | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 8000 | 2.52 | 0.10 | 0.0475 | 10000 | 2.32 | 0.08 | 0.0337 |
| 9000 | 2.84 | 0.13 | 0.0593 | 12000 | 2.78 | 0.12 | 0.0477 |
| 10000 | 3.15 | 0.15 | 0.0724 | 14000 | 3.24 | 0.16 | 0.0641 |
| 12000 | 3.78 | 0.22 | 0.103 | 16000 | 3.71 | 0.21 | 0.0829 |
| 14000 | 4.41 | 0.30 | 0.139 | 18000 | 4.17 | 0.27 | 0.104 |
| 16000 | 5.04 | 0.40 | 0.180 | 20000 | 4.63 | 0.33 | 0.127 |
| 18000 | 5.67 | 0.50 | 0.227 | 22000 | 5.09 | 0.40 | 0.154 |
| 20000 | 6.30 | 0.62 | 0.279 | 24000 | 5.55 | 0.48 | 0.181 |
| 22000 | 6.93 | 0.75 | 0.338 | 25000 | 5.79 | 0.52 | 0.196 |
| 24000 | 7.56 | 0.89 | 0.400 | 26000 | 6.01 | 0.56 | 0.212 |
| 25000 | 7.88 | 0.97 | 0.430 | 28000 | 6.49 | 0.65 | 0.243 |
| 26000 | 8.20 | 1.05 | 0.464 | 30000 | 6.95 | 0.74 | 0.279 |
| 28000 | 8.83 | 1.21 | 0.538 | 35000 | 8.11 | 1.02 | 0.377 |
| 30000 | 9.46 | 1.39 | 0.617 | 40000 | 9.26 | 1.33 | 0.490 |
| 35000 | 11.03 | 1.89 | 0.832 | 45000 | 10.42 | 1.69 | 0.619 |
| 40000 | 12.60 | 2.47 | 1.08 | 50000 | 11.60 | 2.08 | 0.760 |
| 45000 | 14.10 | 3.13 | 1.36 | 55000 | 12.75 | 2.53 | 0.915 |
| 50000 | 15.80 | 3.86 | 1.68 | 60000 | 13.90 | 3.00 | 1.09 |
| 55000 | 17.40 | 4.73 | 2.03 | 70000 | 16.20 | 4.08 | 1.48 |
| 60000 | 18.90 | 5.56 | 2.40 | 80000 | 18.50 | 5.33 | 1.92 |
| 70000 | 22.10 | 7.56 | 3.25 | 90000 | 20.80 | 6.75 | 2.42 |
| 80000 | 25.20 | 9.88 | 4.23 | 100000 | 23.20 | 8.33 | 2.98 |
| 90000 | 28.40 | 12.50 | 5.35 | 120000 | 27.80 | 12.00 | 4.30 |

## 48"

48" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|---|---|---|---|
| 14000 | 2.48 | 0.10 | 0.0327 | 35000 | 6.21 | 0.60 | 0.192 |
| 16000 | 2.84 | 0.13 | 0.0422 | 40000 | 7.09 | 0.78 | 0.248 |
| 18000 | 3.19 | 0.16 | 0.0529 | 45000 | 7.98 | 0.99 | 0.314 |
| 20000 | 3.55 | 0.20 | 0.0648 | 50000 | 8.87 | 1.22 | 0.384 |
| 22000 | 3.90 | 0.24 | 0.0776 | 55000 | 9.75 | 1.48 | 0.459 |
| 24000 | 4.25 | 0.28 | 0.0917 | 60000 | 10.64 | 1.76 | 0.548 |
| 25000 | 4.43 | 0.31 | 0.0996 | 70000 | 12.40 | 2.39 | 0.742 |
| 26000 | 4.60 | 0.33 | 0.107 | 80000 | 14.20 | 3.13 | 0.968 |
| 28000 | 4.97 | 0.38 | 0.124 | 90000 | 16.00 | 3.96 | 1.22 |
| 30000 | 5.32 | 0.44 | 0.142 | 100000 | 17.70 | 4.89 | 1.50 |
| | | | | 120000 | 21.30 | 7.03 | 2.15 |
| | | | | 140000 | 24.80 | 9.57 | 2.92 |
| | | | | 160000 | 28.40 | 12.50 | 3.81 |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

# TABLE 2. (Cont.) FRICTION LOSS PER 100 FEET FOR WATER IN NEW ASPHALT DIPPED CAST IRON PIPE

| 54" 54" inside dia. | | | | 60" 60" inside dia. | | | |
|---|---|---|---|---|---|---|---|
| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
| 18000 | 2.52 | 0.10 | 0.0294 | 20000 | 2.27 | 0.08 | 0.0212 |
| 20000 | 2.80 | 0.12 | 0.0360 | 25000 | 2.84 | 0.13 | 0.0325 |
| 25000 | 3.50 | 0.19 | 0.0550 | 30000 | 3.40 | 0.18 | 0.0460 |
| 30000 | 4.20 | 0.27 | 0.0782 | 35000 | 3.97 | 0.25 | 0.0618 |
| 35000 | 4.90 | 0.37 | 0.106 | 40000 | 4.54 | 0.32 | 0.0800 |
| 40000 | 5.60 | 0.49 | 0.137 | 45000 | 5.11 | 0.41 | 0.100 |
| 45000 | 6.30 | 0.62 | 0.172 | 50000 | 5.67 | 0.50 | 0.124 |
| 50000 | 7.00 | 0.76 | 0.211 | 60000 | 6.81 | 0.72 | 0.176 |
| 60000 | 8.40 | 1.10 | 0.301 | 70000 | 7.94 | 0.98 | 0.237 |
| 70000 | 9.81 | 1.49 | 0.408 | 80000 | 9.08 | 1.28 | 0.307 |
| 80000 | 11.21 | 1.95 | 0.530 | 90000 | 10.21 | 1.62 | 0.387 |
| 90000 | 12.60 | 2.47 | 0.668 | 100000 | 11.30 | 2.00 | 0.478 |
| 100000 | 14.00 | 3.05 | 0.820 | 120000 | 13.60 | 2.88 | 0.688 |
| 120000 | 16.80 | 4.39 | 1.180 | 140000 | 15.90 | 3.92 | 0.930 |
| 140000 | 19.60 | 5.98 | 1.590 | 160000 | 18.20 | 5.12 | 1.20 |
| 160000 | 22.40 | 7.81 | 2.070 | 180000 | 20.40 | 6.48 | 1.52 |
| 180000 | 25.20 | 9.88 | 2.620 | 200000 | 22.70 | 8.00 | 1.87 |
| 200000 | 28.00 | 12.20 | 3.220 | 250000 | 28.40 | 12.50 | 2.92 |

## 72"

72" inside dia.

| U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet | U.S. Gals. Per Min. | vel. $V$ f.p.s. | vel. head $V^2/2g$ feet | frict. loss $h_f$ feet |
|---|---|---|---|---|---|---|---|
| 30000 | 2.37 | 0.09 | 0.0184 | 120000 | 9.47 | 1.39 | 0.271 |
| 35000 | 2.76 | 0.12 | 0.0248 | 140000 | 11.04 | 1.89 | 0.365 |
| 40000 | 3.16 | 0.16 | 0.0320 | 160000 | 12.60 | 2.47 | 0.475 |
| 45000 | 3.55 | 0.20 | 0.0402 | 180000 | 14.20 | 3.13 | 0.600 |
| 50000 | 3.94 | 0.24 | 0.0493 | 200000 | 15.80 | 3.87 | 0.736 |
| 60000 | 4.73 | 0.35 | 0.0700 | 250000 | 19.70 | 6.04 | 1.14 |
| 70000 | 5.52 | 0.47 | 0.0940 | 300000 | 23.70 | 8.70 | 1.64 |
| 80000 | 6.31 | 0.62 | 0.122 | 350000 | 27.60 | 11.80 | 2.23 |
| 90000 | 7.10 | 0.78 | 0.154 | | | | |
| 100000 | 7.89 | 0.97 | 0.189 | | | | |

CAUTION: No allowance has been made for age, differences in diameter resulting from manufacturing tolerances or any abnormal conditions of interior pipe surface. It is recommended that for commercial application a reserve or margin of safety to cover these effects be added to the values shown in the tables. Where no careful analysis of these effects are made a reserve of 15% is recommended.

## FRICTION LOSS IN PIPE FITTINGS:

The resistance to flow caused by a valve or fitting may be computed from the equation:

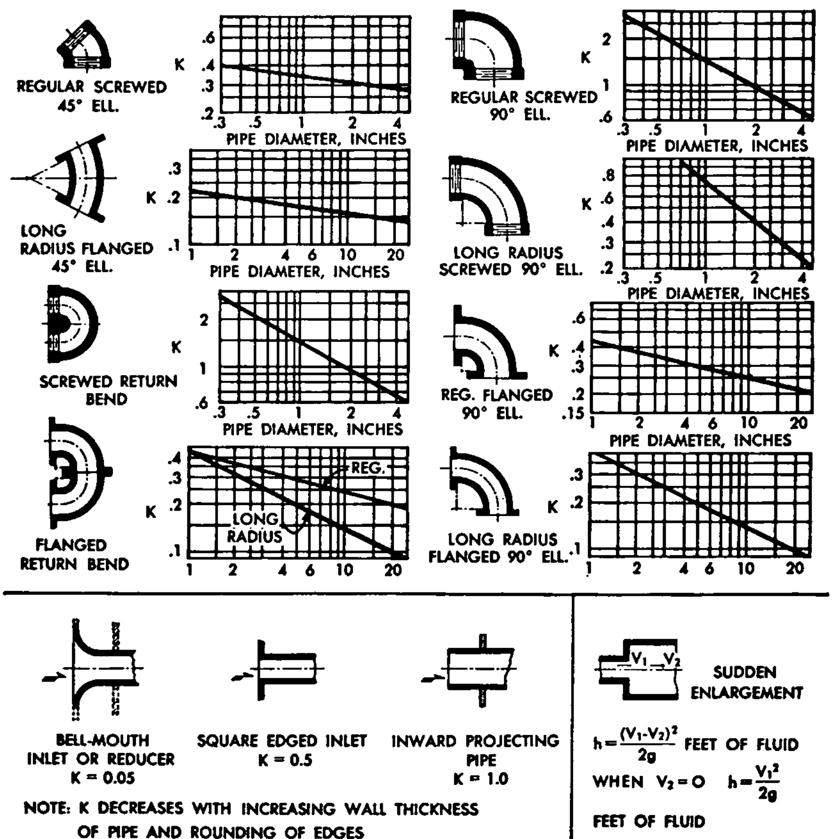
$$h = K\frac{V^2}{2g}$$

where $h$ = frictional resistance in feet of fluid
$V$ = average velocity in feet per second in pipe of corresponding diameter.
$K$ = resistance coefficient for fitting

Values of $K$ for frequently used fittings may be found in Table 3. Wide differences in the values of $K$ are found in the published literature. Flanged fittings should have lower resistance coefficients than screwed fittings. Resistance coefficients usually decrease with increase in pipe size.

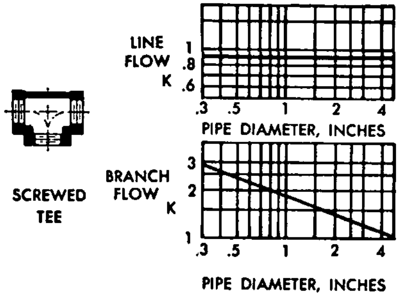
For convenience Table 4 shows the friction loss in fittings ex-

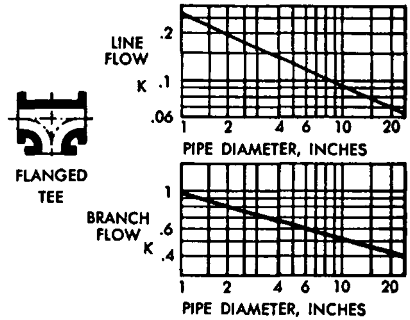
### TABLE 3. VALUES OF RESISTANCE COEFFICIENT FOR PIPE FITTINGS†

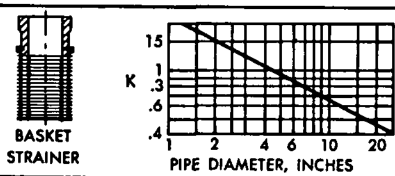


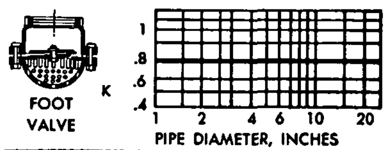

†*Courtesy Hydraulic Institute. See page 6.*

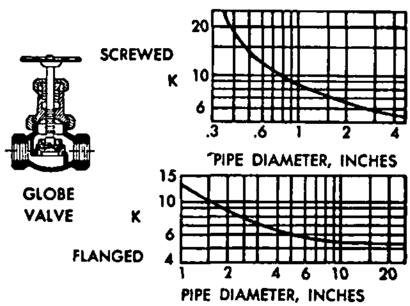
TABLE 3. (Cont.)

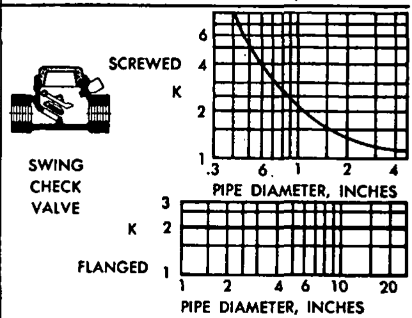


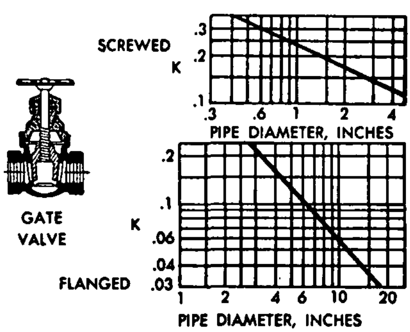



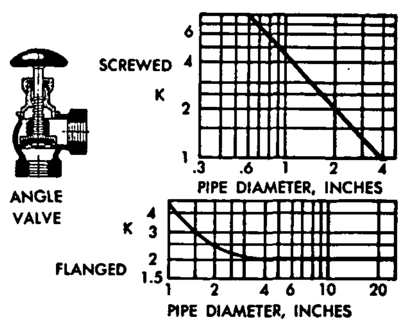



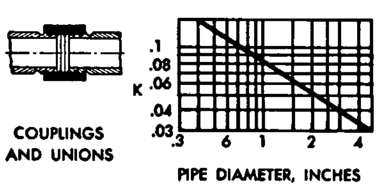



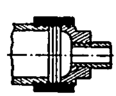



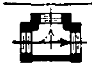
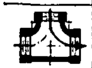



REDUCING BUSHING AND COUPLING

USED AS REDUCER K = 0.05–2.0

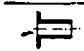
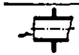
USED AS INCREASER LOSS IS UP TO 40% MORE THAN THAT CAUSED BY A SUDDEN ENLARGEMENT

# TABLE 4. EQUIVALENT LENGTH OF STRAIGHT PIPE FOR VARIOUS FITTINGS TURBULENT FLOW ONLY†

| FITTINGS | | | PIPE SIZE | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ¼ | ⅜ | ½ | ¾ | 1 | 1¼ | 1½ | 2 | 2½ | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
|  REGULAR 90° ELL | SCREWED | STEEL | 2.3 | 3.1 | 3.6 | 4.4 | 5.2 | 6.6 | 7.4 | 8.5 | 9.3 | 11.0 | 13.0 | | | | | | | | | | |
| | | C. I. | | | | | | | | | | 9.0 | 11.0 | | | | | | | | | | |
| | FLANGED | STEEL | | | .92 | 1.2 | 1.6 | 2.1 | 2.4 | 3.1 | 3.6 | 4.4 | 5.9 | 7.3 | 8.9 | 12.0 | 14.0 | 17.0 | 18.0 | 21.0 | 23.0 | 25.0 | 30.0 |
| | | C. I. | | | | | | | | | | 3.6 | 4.8 | | 7.2 | 9.8 | 12.0 | 15.0 | 17.0 | 19.0 | 22.0 | 24.0 | 28.0 |
|  LONG RADIUS 90° ELL | SCREWED | STEEL | 1.5 | 2.0 | 2.2 | 2.3 | 2.7 | 3.2 | 3.4 | 3.6 | 3.6 | 4.0 | 4.6 | | | | | | | | | | |
| | | C. I. | | | | | | | | | | 3.3 | 3.7 | | | | | | | | | | |
| | FLANGED | STEEL | | | 1.1 | 1.3 | 1.6 | 2.0 | 2.3 | 2.7 | 2.9 | 3.4 | 4.2 | 5.0 | 5.7 | 7.0 | 8.0 | 9.0 | 9.4 | 10.0 | 11.0 | 12.0 | 14.0 |
| | | C. I. | | | | | | | | | | 2.8 | 3.4 | | 4.7 | 5.7 | 6.8 | 7.8 | 8.6 | 9.6 | 11.0 | 11.0 | 13.0 |
|  REGULAR 45° ELL | SCREWED | STEEL | .34 | .52 | .71 | .92 | 1.3 | 1.7 | 2.1 | 2.7 | 3.2 | 4.0 | 5.5 | | | | | | | | | | |
| | | C. I. | | | | | | | | | | 3.3 | 4.5 | | | | | | | | | | |
| | FLANGED | STEEL | | | .45 | .59 | .81 | 1.1 | 1.3 | 1.7 | 2.0 | 2.6 | 3.5 | 4.5 | 5.6 | 7.7 | 9.0 | 11.0 | 13.0 | 15.0 | 16.0 | 18.0 | 22.0 |
| | | C. I. | | | | | | | | | | 2.1 | 2.9 | | 4.5 | 6.3 | 8.1 | 9.7 | 12.0 | 13.0 | 15.0 | 17.0 | 20.0 |
|  TEE-LINE FLOW | SCREWED | STEEL | .79 | 1.2 | 1.7 | 2.4 | 3.2 | 4.6 | 5.6 | 7.7 | 9.3 | 12.0 | 17.0 | | | | | | | | | | |
| | | C. I. | | | | | | | | | | 9.9 | 14.0 | | | | | | | | | | |
| | FLANGED | STEEL | | | .69 | .82 | 1.0 | 1.3 | 1.5 | 1.8 | 1.9 | 2.2 | 2.8 | 3.3 | 3.8 | 4.7 | 5.2 | 6.0 | 6.4 | 7.2 | 7.6 | 8.2 | 9.6 |
| | | C. I. | | | | | | | | | | 1.9 | 2.2 | | 3.1 | 3.9 | 4.6 | 5.2 | 5.9 | 6.5 | 7.2 | 7.7 | 8.8 |
|  TEE-BRANCH FLOW | SCREWED | STEEL | 2.4 | 3.5 | 4.2 | 5.3 | 6.6 | 8.7 | 9.9 | 12.0 | 13.0 | 17.0 | 21.0 | | | | | | | | | | |
| | | C. I. | | | | | | | | | | 14.0 | 17.0 | | | | | | | | | | |
| | FLANGED | STEEL | | | 2.0 | 2.6 | 3.3 | 4.4 | 5.2 | 6.6 | 7.5 | 9.4 | 12.0 | 15.0 | 18.0 | 24.0 | 30.0 | 34.0 | 37.0 | 43.0 | 47.0 | 52.0 | 62.0 |
| | | C. I. | | | | | | | | | | 7.7 | 10.0 | | 15.0 | 20.0 | 25.0 | 30.0 | 35.0 | 39.0 | 44.0 | 49.0 | 57.0 |
|  180° RETURN BEND | SCREWED | STEEL | 2.3 | 3.1 | 3.6 | 4.4 | 5.2 | 6.6 | 7.4 | 8.5 | 9.3 | 11.0 | 13.0 | | | | | | | | | | |
| | | C. I. | | | | | | | | | | 9.0 | 11.0 | | | | | | | | | | |
| | REG. FLANGED | STEEL | | | .92 | 1.2 | 1.6 | 2.1 | 2.4 | 3.1 | 3.6 | 4.4 | 5.9 | 7.3 | 8.9 | 12.0 | 14.0 | 17.0 | 18.0 | 21.0 | 23.0 | 25.0 | 30.0 |
| | | C. I. | | | | | | | | | | 3.6 | 4.8 | | 7.2 | 9.8 | 12.0 | 15.0 | 17.0 | 19.0 | 22.0 | 24.0 | 28.0 |
| | LONG RAD. FLANGED | STEEL | | | 1.1 | 1.3 | 1.6 | 2.0 | 2.3 | 2.7 | 2.9 | 3.4 | 4.2 | 5.0 | 5.7 | 7.0 | 8.0 | 9.0 | 9.4 | 10.0 | 11.0 | 12.0 | 14.0 |
| | | C. I. | | | | | | | | | | 2.8 | 3.4 | | 4.7 | 5.7 | 6.8 | 7.8 | 8.6 | 9.6 | 11.0 | 11.0 | 13.0 |

†*Courtesy of, Hydraulic Institute.* *See page 6.*

# TABLE 4. (Cont.) EQUIVALENT LENGTH OF STRAIGHT PIPE FOR VARIOUS FITTINGS TURBULENT FLOW ONLY

| FITTINGS | | | PIPE SIZE | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ¼ | ⅜ | ½ | ¾ | 1 | 1¼ | 1½ | 2 | 2½ | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
|  GLOBE VALVE | SCREWED | STEEL | 21.0 | 22.0 | 22.0 | 24.0 | 29.0 | 37.0 | 42.0 | 54.0 | 62.0 | 79.0 | 110.0 | | | | | | | | | | |
| | | C. I. | | | | | | | | | | 65.0 | 86.0 | | | | | | | | | | |
| | FLANGED | STEEL | | | 38.0 | 40.0 | 45.0 | 54.0 | 59.0 | 70.0 | 77.0 | 94.0 | 120.0 | 150.0 | 190.0 | 260.0 | 310.0 | 390.0 | | | | | |
| | | C. I. | | | | | | | | | | 77. | 99.0 | | 150.0 | 210.0 | 270.0 | 330.0 | | | | | |
|  GATE VALVE | SCREWED | STEEL | .32 | .45 | .56 | .67 | .84 | 1.1 | 1.2 | 1.5 | 1.7 | 1.9 | 2.5 | | | | | | | | | | |
| | | C. I. | | | | | | | | | | 1.6 | 2.0 | | | | | | | | | | |
| | FLANGED | STEEL | | | | | | | | 2.6 | 2.7 | 2.8 | 2.9 | 3.1 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |
| | | C. I. | | | | | | | | | | 2.3 | 2.4 | | 2.6 | 2.7 | 2.8 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.0 |
|  ANGLE VALVE | SCREWED | STEEL | 12.8 | 15.0 | 15.0 | 15.0 | 17.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | | | | | | | | | | |
| | | C. I. | | | | | | | | | | 15.0 | 15.0 | | | | | | | | | | |
| | FLANGED | STEEL | | | 15.0 | 15.0 | 17.0 | 18.0 | 18.0 | 21.0 | 22.0 | 28.0 | 38.0 | 50.0 | 63.0 | 90.0 | 120.0 | 140.0 | 160.0 | 190.0 | 210.0 | 240.0 | 300.0 |
| | | C. I. | | | | | | | | | | 23.0 | 31.0 | | 52.0 | 74.0 | 98.0 | 120.0 | 150.0 | 170.0 | 200.0 | 230.0 | 280.0 |
|  SWING CHECK VALVE | SCREWED | STEEL | 7.2 | 7.3 | 8.0 | 8.8 | 11.0 | 13.0 | 15.0 | 19.0 | 22.0 | 27.0 | 38.0 | | | | | | | | | | |
| | | C. I. | | | | | | | | | | 22.0 | 31.0 | | | | | | | | | | |
| | FLANGED | STEEL | | | 3.8 | 5.3 | 7.2 | 10.0 | 12.0 | 17.0 | 21.0 | 27.0 | 38.0 | 50.0 | 63.0 | 90.0 | 120.0 | 140.0 | | | | | |
| | | C. I. | | | | | | | | | | 22.0 | 31.0 | | 52.0 | 74.0 | 98.0 | 120.0 | | | | | |
| COUPLING OR UNION | SCREWED | STEEL | .14 | .18 | .21 | .24 | .29 | .36 | .39 | .45 | .47 | .53 | .65 | | | | | | | | | | |
| | | C. I. | | | | | | | | | | .44 | .52 | | | | | | | | | | |
|  | BELL MOUTH INLET | STEEL | .04 | .07 | .10 | .13 | .18 | .26 | .31 | .43 | .52 | .67 | .95 | 1.3 | 1.6 | 2.3 | 2.9 | 3.5 | 4.0 | 4.7 | 5.3 | 6.1 | 7.6 |
| | | C. I. | | | | | | | | | | .55 | .77 | | 1.3 | 1.9 | 2.4 | 3.0 | 3.6 | 4.3 | 5.0 | 5.7 | 7.0 |
|  | SQUARE MOUTH INLET | STEEL | .44 | .68 | .96 | 1.3 | 1.8 | 2.6 | 3.1 | 4.3 | 5.2 | 6.7 | 9.5 | 13.0 | 16.0 | 23.0 | 29.0 | 35.0 | 40.0 | 47.0 | 53.0 | 61.0 | 76.0 |
| | | C. I. | | | | | | | | | | 5.5 | 7.7 | | 13.0 | 19.0 | 24.0 | 30.0 | 36.0 | 43.0 | 50.0 | 57.0 | 70.0 |
|  | RE-ENTRANT PIPE | STEEL | .88 | 1.4 | 1.9 | 2.6 | 3.6 | 5.1 | 6.2 | 8.5 | 10.0 | 13.0 | 19.0 | 25.0 | 32.0 | 45.0 | 58.0 | 70.0 | 80.0 | 95.0 | 110.0 | 120.0 | 150.0 |
| | | C. I. | | | | | | | | | | 11.0 | 15.0 | | 26.0 | 37.0 | 49.0 | 61.0 | 73.0 | 86.0 | 100.0 | 110.0 | 140.0 |
|  | SUDDEN ENLARGEMENT | $h=\frac{(V_1-V_2)^2}{2g}$ FEET OF FLUID; IF $V_2=O$ $h=\frac{V_1^2}{2g}$ FEET OF FLUID | | | | | | | | | | | | | | | | | | | | | |

pressed as an equivalent length of straight pipe. This presentation is simple to use on complicated piping layouts involving an assortment of different fittings and is especially well suited to the preparation of station curves where varying rates of flow are involved.

## FRICTION IN OTHER TYPES OF PIPE

The preceding tabulations for friction loss in pipes apply to new schedule #40 steel pipe and new asphalt-dipped cast-iron pipe as noted. Friction loss in other types of pipe vary from these values due to the difference in the average relative roughness of the interior surface of such pipes as commercially manufactured.

The following chart Fig. 26 shows relative roughness factors $\left(\frac{\epsilon}{D}\right)$ for new clean pipes as commercially manufactured plotted against pipe diameter in inches. The curves for schedule #40 steel pipe (absolute roughness 0.00015′) and asphalt-dipped cast-iron pipe (absolute roughness 0.0004′) on which the previous Tables 1 and 2 are based are shown on this curve.

The ratio of the friction factor for any pipe to that for schedule #40 steel pipe may be used as a multiplier to adjust the friction losses shown in Table 1 to apply to the other type of pipe.

It must be recognized that various types of pipe as commercially manufactured are subject to a considerable variation in roughness.

Average values for good clean new pipe however yield the multipliers recommended in the following Table 5.

### TABLE 5. MULTIPLIERS TO APPLY TO VALUES FROM TABLE 1 TO OBTAIN FRICTION LOSS IN OTHER TYPES OF PIPE OR CONDUIT.

| Type of New Conduit or Pipe | Multiplier to Apply to Table 1 Values of Friction Loss |
|---|---|
| Rubber lined hose | 0.72 |
| Spun cement line pipe | 0.76 |
| Spun bitumastic enameled pipe | 0.76 |
| Aluminum irrigation pipe | 0.81 |
| Transite Pipe | 0.85 |
| Copper or Brass pipe | 0.86 |
| Seamless steel tubing | 0.86 |
| Glass tube or pipe | 0.86 |
| Schedule #40 steel pipe | 1.00 |
| Wood Stave pipe | 1.15 |
| Galvanized iron pipe | 1.22 |
| Vitrified pipe | 1.36 |
| Spiral riveted pipe (flow with lap) | 1.40 |
| Spiral riveted pipe (flow against lap) | 1.70 |
| Unlined linen hose | 1.80 |

The multipliers in Table 5 provide for the difference in type of pipe only. They do not include deviations in internal diameter from schedule #40 steel pipe.

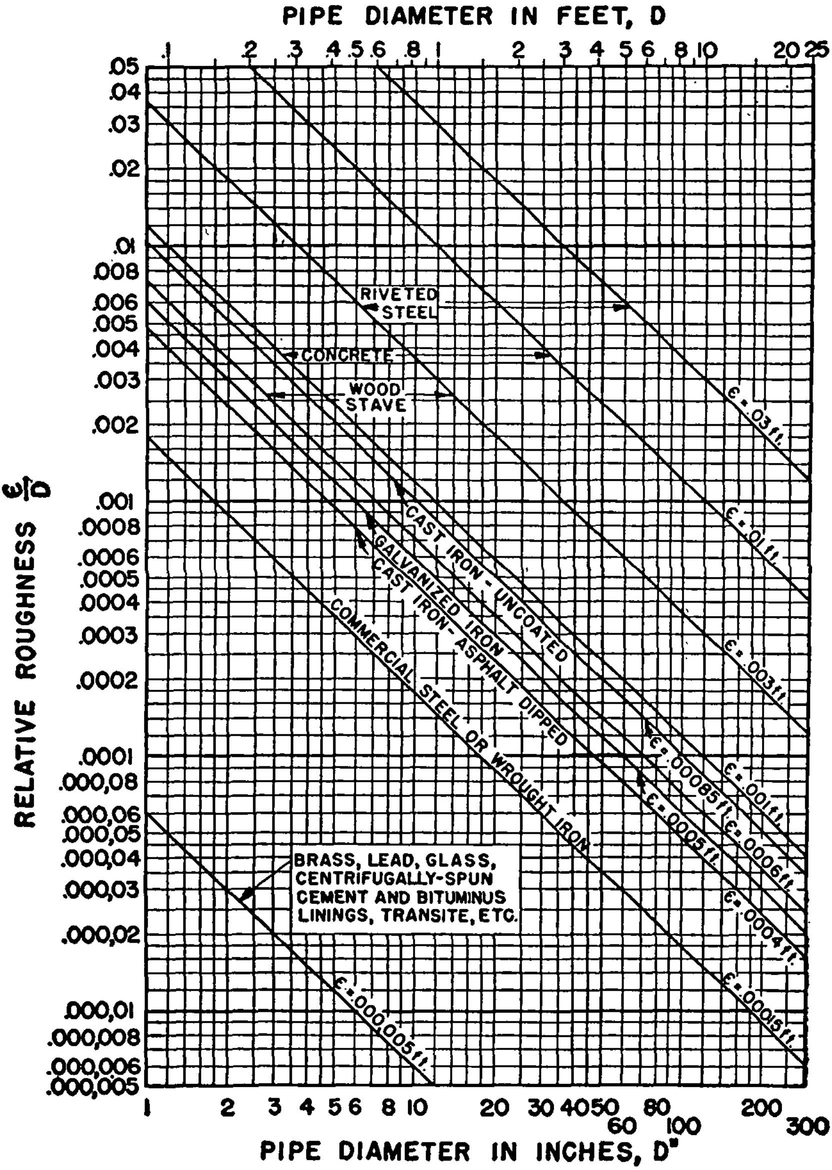



Fig. 26. Relative roughness factors for new clean pipes.†

## FRICTION LOSS AS AFFECTED BY AGING OF PIPE

The deterioration of pipes with age depends upon the chemical properties of the liquid flowing and the characteristics of the material from which the pipe is made. In general, the flow carry-

† *Courtesy Hydraulic Institute. See page 6.*

ing capacity of a pipe line decreases with age due to a roughening of the interior surface caused by corrosive products, tubercules and the like or an actual reduction in area caused by chemical deposits. The effect corresponds to a variation in friction factor due to increasing relative roughness.

A wide variation in waters over the country makes impossible any precise estimation of this aging effect. No reputable authority will go on record to endorse friction factors for other than new pipe. This fact, however, does not eliminate the deterioration of friction factor and some means of estimation is required. Whereever records are available on the aging effect of local or similar waters, it is recommended that they be studied and applied as a correction to the computation of friction loss for new pipe from the previous tables. This is a sound and logical approach for a specific problem.

In many instances either the economics of the project do not warrant the expense of this detailed investigation or there are no available records on local or similar waters. For those occasions, Table 6 may be used with caution and discretion. It is based upon the best known available data.

TABLE 6 INCREASE IN FRICTION LOSS DUE TO AGING OF PIPE

Multipliers for use with Table 1

| Age of Pipe in Years | Small Pipes 4"-10" | Large Pipes 12"-60" |
|---|---|---|
| New | 1.00 | 1.00 |
| 5 | 1.40 | 1.30 |
| 10 | 2.20 | 1.60 |
| 15 | 3.60 | 1.80 |
| 20 | 5.00 | 2.00 |
| 25 | 6.30 | 2.10 |
| 30 | 7.25 | 2.20 |
| 35 | 8.10 | 2.30 |
| 40 | 8.75 | 2.40 |
| 45 | 9.25 | 2.60 |
| 50 | 9.60 | 2.86 |
| 55 | 9.80 | 3.26 |
| 60 | 10.00 | 3.70 |
| 65 | 10.05 | 4.25 |
| 70 | 10.10 | 4.70 |

It will be obvious that there is no sudden increase in aging effect between 10" and 12" pipe as indicated from Table 6. The values shown are composites of many tests grouped by the experimenter. A reasonable amount of interpretation and logic must be used in selecting and applying a multiplier for each specific problem.

It must also be borne in mind that some test data on aging of pipe may vary up to fifty percent from the averages as shown in Table 6.

## SECTION III—CONVERSION FACTORS

### CONTENTS



III

## TABLE 7. CONVERSION FACTORS—UNITS OF LENGTH

Examples: 2 Yards x 3 = 6 Feet. 3 Feet x 0.333 = 1 Yard

| Unit | Inch | Foot | Yard | Centimeter | Meter |
|---|---|---|---|---|---|
| Inch | 1 | .0833 | .0278 | 2.54 | .0254 |
| Foot | 12 | 1 | .333 | 30.48 | .3048 |
| Yard | 36 | 3 | 1 | 91.44 | .9144 |
| Centimeters | .3937 | .0328 | .0109 | 1 | .01 |
| Meter | 39.37 | 3.281 | 1.094 | 100 | 1 |

1 Rod = 16.5 ft. = 5.5 yards = 5.029 meters
1 Mile = 5280 ft. = 1760 yards = 1609.3 meters = 1.61 Kilometers
1 Kilometer = 1000 meters = 1093.6 yards = .62137 miles

## TABLE 8. CONVERSION FACTORS—UNITS OF AREA

Examples: 6 sq. ft. x .1111 = .6666 sq. yds.
3 sq. yds. x 9 = 27 sq. ft.

| Unit | Sq. In. | Sq. Ft. | Sq. Yd. | Sq. Cm. | Sq. Meter |
|---|---|---|---|---|---|
| Sq. In. | 1.00 | 0.00694 | 0.000772 | 6.452 | 0.000645 |
| Sq. Ft. | 144.00 | 1.00 | 0.1111 | 929.00 | 0.0929 |
| Sq. Yd. | 1296.00 | 9.00 | 1.00 | 8360.00 | 0.836 |
| Sq. Cm. | 0.1550 | 0.001076 | 0.00012 | 1.00 | 0.0001 |
| Sq. M. | 1550.00 | 10.76 | 1.196 | 10,000.00 | 1.00 |

1 Sq Mile = 640 Acres = 259 Hectares = 2.59 Sq. Kilometers
1 Acre = 43560 Sq. Ft. = 4840 Sq. Yds. = 4047 Sq. Meters
1 Hectare = 107,639 Sq. Ft. = 2.471 Acres = .01 Sq. Km.

## TABLE 9. CONVERSION FACTORS—UNITS OF PRESSURE

(Density at 39.2°F)

Example: 15 Ft. Water × .433 = 6.49 Psi
15 Psi × 2.31 = 34.65 Ft. Water

| | In. Water | Ft. Water | Psi | In. Hg. | Mm. Hg. | Gr./ Sq. Cm. | Kg./ Sq. Cm. |
|---|---|---|---|---|---|---|---|
| In. Water | 1.0 | .0833 | .0361 | .0736 | 1.870 | 2.538 | .0025 |
| Ft. Water | 12.0 | 1.0 | .433 | .883 | 22.43 | 30.45 | .0304 |
| Psi. | 27.72 | 2.31 | 1.0 | 2.040 | 51.816 | 70.31 | .0703 |
| In. Hg. | 13.596 | 1.133 | .4906 | 1.0 | 25.40 | 34.49 | .0345 |
| Mm. Hg. | .5353 | .0446 | .0193 | .03937 | 1.0 | 1.357 | .0014 |
| Gr./Sq. Cm. | .3936 | .0328 | .0142 | .02897 | .7360 | 1.0 | .001 |
| Kg./Sq. Cm. | 393.6 | 32.80 | 14.22 | 28.97 | 736.03 | 1000.0 | 1.0 |
| Kilopascal | 4.0135 | .3344 | .1451 | .2954 | 7.505 | 10.20 | .0102 |

## TABLE 10. CONVERSION FACTORS: UNITS OF VOLUME

Example: 10 U.S. Gal. × .1337 = 1.337 Cu. Ft. or 5 Cu. Ft. × 7.481 = 37.405 U.S. Gal.

| Unit | U.S. Gal. | Imp. Gal. | Cu. In. | Cu. Ft. | Cu. Yd. | Acre In. | Acre Ft. | Lb. Water at 60°F. | Cu. Meter | Qt. | Liter |
|---|---|---|---|---|---|---|---|---|---|---|---|
| U.S. Gal. | 1.0 | .833 | 231.0 | .1337 | .00495 | ........ | ........ | 8.33 | .003785 | 4.0 | 3.785 |
| Imp. Gal. | 1.2 | 1.0 | 277.4 | .1605 | .00595 | ........ | ........ | 10.0 | .004546 | 4.8 | 4.546 |
| Cu. In. | .00433 | .00361 | 1.0 | ........ | ........ | ........ | ........ | .0361 | ........ | .0173 | .0164 |
| Cu. Ft. | 7.481 | 6.232 | 1728.0 | 1.0 | .037 | ........ | ........ | 62.37 | .0283 | 29.92 | 28.32 |
| Cu. Yd. | 202.0 | 168.4 | 46,656.0 | 27.0 | 1.0 | ........ | ........ | 1684.0 | .7646 | 808.0 | 764.6 |
| Acre In. | 27,157.0 | 22,611.0 | ........ | 3,630.0 | ........ | 1.0 | .0833 | ........ | ........ | ........ | ........ |
| Acre Ft. | 325,892.0 | 271,335.0 | ........ | 43,560.0 | ........ | 12.0 | 1.0 | ........ | 1233.5 | ........ | ........ |
| Lb. Water | .120 | .10 | 27.7 | .0160 | ........ | ........ | ........ | 1.0 | ........ | .48 | .454 |
| Cu. Meter | 264.2 | 220.0 | 61,023.0 | 35.31 | 1.308 | ........ | .000811 | 2204.0 | 1.0 | 1057.0 | 1000.0 |
| Qt. | .25 | .208 | 57.75 | .0334 | ........ | ........ | ........ | 2.086 | ........ | 1.0 | .9464 |
| Liter | .2642 | .220 | 61.023 | .0353 | ........ | ........ | ........ | 2.204 | .001 | 1.057 | 1.0 |

Barrel volume differs in different industries: Beer—31 gal., Wine—31½ gal., Oil—42 gal., Whiskey—45 gal.

# TABLE 11. CONVERSION FACTORS: UNITS OF FLOW

Examples: 500 U.S. Gpm × .00144 = .72 U.S. Mgd. 10 U.S. Mgd × 694.5 = 6945 U.S. Gpm

| Unit | U.S. Gpm | Imp. Gpm | U.S. Mgd (2) | Imperial Mgd (2) | Cu.Ft. /Sec. | Cu. Meters /Hr. | Liters /Sec. | Miners Inch A* | Miners Inch B* | Miners Inch C* | Acre Inches /Hr. | Acre Ft. /24 Hrs. | Barrels /Min. (3) | Barrels /24 Hrs. (3) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U.S. Gal./Min. | 1. | .833 | .00144 | .00120 | .00223 | .227 | .0631 | .0891 | .1114 | .0856 | .0022 | .00442 | .0238 | 34.25 |
| Imp. Gal./Min. | 1.2 | 1. | .00173 | .00144 | .00268 | .272 | .0757 | ...... | ...... | ...... | .0026 | .00530 | .0286 | 41.09 |
| U.S. Mgd (2) | 694.4 | 578.7 | 1. | .833 | 1.547 | 157.73 | 43.8 | 61.89 | 77.36 | 59.44 | 1.535 | 3.07 | 16.53 | 23786.6 |
| Imperial Mgd (2) | 833.4 | 694.5 | 1.2 | 1. | 1.856 | 189.28 | 52.56 | ...... | ...... | ...... | 1.842 | 3.68 | 19.83 | 28544.0 |
| Cu. Ft./Sec. | 448.8 | 374. | .646 | .538 | 1. | 101.9 | 28.32 | 40. | 50. | 38.4 | .992 | 1.984 | 10.68 | 15360.4 |
| Cu. Meters/Hr. | 4.403 | 3.67 | .00634 | .00528 | .00981 | 1. | .2778 | ...... | ...... | ...... | .00973 | 1.946 | .1047 | 150.80 |
| Liters/Sec. | 15.85 | 13.21 | .0228 | .0190 | .0353 | 3.60 | 1. | ...... | ...... | ...... | .0350 | .0700 | .377 | 542.86 |
| Miners Inch A* | 11.22 | ....... | .01618 | ....... | .0250 | ........ | ....... | 1. | 1.25 | .960 | .0248 | .0496 | ...... | ....... |
| Miners Inch B* | 8.98 | ....... | .01294 | ....... | .0200 | ........ | ....... | .80 | 1. | .768 | .0198 | .0396 | ...... | ....... |
| Miners Inch C* | 11.69 | ....... | .01682 | ....... | .0260 | ........ | ....... | 1.042 | 1.302 | 1. | .0258 | .0516 | ...... | ....... |
| Acre Inches/Hr. | 452.4 | 376.9 | .651 | .542 | 1.010 | 1.030 | .286 | 40.32 | 50.40 | 38.71 | 1. | 2.0 | ...... | ....... |
| Acre Feet/24 Hrs. | 226.2 | 188.5 | .326 | .271 | .505 | .515 | .143 | 20.16 | 25.20 | 19.36 | .5 | 1. | ...... | ....... |
| Barrels/Min. (3) | 42. | 34.99 | .0605 | .0504 | .0937 | 9.534 | 2.65 | ...... | ...... | ...... | ...... | ...... | 1. | 1440. |
| Barrels/24 Hrs. (3) | .0292 | .0243 | .000042 | .000035 | .000065 | .00662 | .00184 | ...... | ...... | ...... | ...... | ...... | .000694 | 1. |

*Miners Inch A established by law in States of Arizona, California(1), Montana, Nevada, Oregon.

*Miners Inch B established by law in States of Idaho, Kansas, Nebraska, New Mexico, North Dakota, South Dakota, Utah.

*Miners Inch C established by law in States of Colorado.

(1) The general practice in Southern California is to use 9 Gpm per miners inch.

(2) US Mgd = Million U.S. gallons per 24 hr. day. Imp Mgd = Million Imperial gallons per 24 hr. day.

(3) 42 gal. bbl.

TABLE 12.
CONVERSION TABLE—MGD. AND CU. FT./SEC. TO GPM.

| Million Gal. per 24 Hrs. Mgd. | Gpm. | Cu. Ft. per Sec. | Million Gal. per 24 Hrs. Mgd. | Gpm. | Cu. Ft. per Sec. |
|---|---|---|---|---|---|
| **0.100** | 69 | 0.15 | 5.816 | 4039 | **9.00** |
| 0.129 | 90 | **0.20** | **6.000** | 4167 | 9.28 |
| **0.200** | 139 | 0.31 | 6.463 | 4488 | **10.00** |
| 0.259 | 180 | **0.40** | **7.000** | 4861 | 10.83 |
| **0.300** | 208 | 0.46 | **8.000** | 5556 | 12.38 |
| 0.388 | 269 | **0.60** | **9.000** | 6250 | 13.92 |
| **0.400** | 278 | 0.62 | **10.000** | 6944 | 15.47 |
| **0.500** | 347 | 0.77 | 12.925 | 8976 | **20.00** |
| 0.517 | 359 | **0.80** | 19.388 | 13,464 | **30.00** |
| **0.600** | 417 | 0.93 | **20.000** | 13,889 | 30.94 |
| 0.646 | 449 | **1.00** | 25.851 | 17,952 | **40.00** |
| **0.700** | 486 | 1.08 | **30.000** | 20,833 | 46.41 |
| **0.800** | 556 | 1.24 | 32.314 | 22,440 | **50.00** |
| **0.900** | 625 | 1.39 | 38.776 | 26,928 | **60.00** |
| 0.969 | 673 | **1.50** | **40.000** | 27,778 | 61.88 |
| **1.000** | 694 | 1.55 | 45.239 | 31,416 | **70.00** |
| 1.293 | 898 | **2.00** | **50.000** | 34,722 | 77.35 |
| 1.616 | 1122 | **2.50** | 51.702 | 35,904 | **80.00** |
| 1.939 | 1346 | **3.00** | 58.164 | 40,392 | **90.00** |
| **2.000** | 1389 | 3.09 | **60.000** | 41,667 | 92.82 |
| 2.262 | 1571 | **3.50** | 64.627 | 44,880 | **100.00** |
| 2.585 | 1795 | **4.00** | **70.000** | 48,611 | 108.29 |
| 2.908 | 2020 | **4.50** | 71.090 | 49,368 | **110.00** |
| **3.000** | 2083 | 4.64 | 77.553 | 53,856 | **120.00** |
| 3.231 | 2244 | **5.00** | **80.000** | 55,556 | 123.76 |
| 3.878 | 2693 | **6.00** | 84.015 | 58,344 | **130.00** |
| **4.000** | 2778 | 6.19 | **90.000** | 62,500 | 139.23 |
| 4.524 | 3142 | **7.00** | 90.478 | 62,832 | **140.00** |
| **5.000** | 3472 | 7.74 | 96.941 | 67,320 | **150.00** |
| 5.170 | 3590 | **8.00** | **100.000** | 69,444 | 154.72 |

## TABLE 13.

## CONVERSION TABLE—UNITS OF PRESSURE (DENSITY AT 39.2°F)

| In. Water | Ft. Water | In. Hg. | Psi. |
|---|---|---|---|
| **1.00** | .08 | .07 | .04 |
| **2.00** | .17 | .15 | .07 |
| **3.00** | .25 | .22 | .11 |
| **4.00** | .33 | .29 | .14 |
| **5.00** | .42 | .37 | .18 |
| **6.00** | .50 | .44 | .22 |
| **7.00** | .58 | .52 | .25 |
| **8.00** | .67 | .59 | .29 |
| **9.00** | .75 | .66 | .32 |
| **10.00** | .83 | .74 | .36 |
| **11.00** | .92 | .81 | .40 |
| **12.00** | **1.00** | .88 | .43 |
| 13.60 | 1.13 | **1.00** | .49 |
| 24.00 | **2.00** | 1.77 | .87 |
| 27.19 | 2.27 | **2.00** | .98 |
| 27.72 | 2.31 | 2.04 | **1.00** |
| 36.00 | **3.00** | 2.65 | 1.30 |
| 40.79 | 3.40 | **3.00** | 1.47 |
| 48.00 | **4.00** | 3.53 | 1.73 |
| 54.38 | 4.53 | **4.00** | 1.96 |
| 55.44 | 4.62 | 4.08 | **2.00** |
| 60.00 | **5.00** | 4.42 | 2.17 |

| Ft. Water | In. Hg. | Psi. | Ft. Water | In. Hg. | Psi. |
|---|---|---|---|---|---|
| 5.67 | **5.00** | 2.45 | **7.00** | 6.18 | 3.03 |
| **6.00** | 5.30 | 2.60 | 7.93 | **7.00** | 3.43 |
| 6.80 | **6.00** | 2.94 | **8.00** | 7.06 | 3.46 |
| 6.93 | 6.12 | **3.00** | **9.00** | 7.95 | 3.90 |

TABLE 13. (Cont.)

CONVERSION TABLE—UNITS OF PRESSURE

| Ft. Water | In. Hg. | Psi. | Ft. Water | In. Hg. | Psi. |
|---|---|---|---|---|---|
| 9.06 | **8.00** | 3.92 | **22.00** | 19.43 | 9.53 |
| 9.24 | 8.16 | **4.00** | 22.66 | **20.00** | 9.81 |
| **10.00** | 8.83 | 4.33 | **23.00** | 20.31 | 9.96 |
| 10.20 | **9.00** | 4.42 | 23.10 | 20.40 | **10.00** |
| **11.00** | 9.71 | 4.76 | 23.79 | **21.00** | 10.30 |
| 11.33 | **10.00** | 4.91 | **24.00** | 21.19 | 10.39 |
| 11.55 | 10.20 | **5.00** | 24.93 | **22.00** | 10.79 |
| **12.00** | 10.60 | 5.20 | **25.00** | 22.08 | 10.83 |
| 12.46 | **11.00** | 5.40 | 25.41 | 22.44 | **11.00** |
| **13.00** | 11.48 | 5.63 | **26.00** | 22.96 | 11.26 |
| 13.60 | **12.00** | 5.89 | 26.06 | **23.00** | 11.28 |
| 13.86 | 12.24 | **6.00** | **27.00** | 23.84 | 11.69 |
| **14.00** | 12.36 | 6.06 | 27.19 | **24.00** | 11.77 |
| 14.73 | **13.00** | 6.38 | 27.72 | 24.48 | **12.00** |
| **15.00** | 13.25 | 6.50 | **28.00** | 24.72 | 12.12 |
| 15.86 | **14.00** | 6.87 | 28.33 | **25.00** | 12.27 |
| **16.00** | 14.13 | 6.93 | **29.00** | 25.61 | 12.56 |
| 16.17 | 14.28 | **7.00** | 29.46 | **26.00** | 12.76 |
| **17.00** | **15.00** | 7.36 | **30.00** | 26.49 | 12.99 |
| **18.00** | 15.89 | 7.79 | 30.03 | 26.52 | **13.00** |
| 18.13 | **16.00** | 7.85 | 30.59 | **27.00** | 13.25 |
| 18.48 | 16.32 | **8.00** | **31.00** | 27.37 | 13.42 |
| **19.00** | 16.78 | 8.23 | 31.72 | **28.00** | 13.74 |
| 19.26 | **17.00** | 8.34 | **32.00** | 28.26 | 13.86 |
| **20.00** | 17.66 | 8.66 | 32.34 | 28.56 | **14.00** |
| 20.39 | **18.00** | 8.83 | 32.86 | **29.00** | 14.23 |
| 20.79 | 18.36 | **9.00** | **33.00** | 29.14 | 14.29 |
| **21.00** | 18.54 | 9.09 | 33.90 | 29.92 | 14.70 |
| 21.53 | **19.00** | 9.32 | | | |

III

TABLE 13. (Cont.)

CONVERSION TABLE — UNITS OF PRESSURE

| Ft. Water | Psi. | Ft. Water | Psi. | Ft. Water | Psi. |
|---|---|---|---|---|---|
| 34.0 | 14.72 | 240.0 | 103.96 | 550.0 | 238.25 |
| 34.7 | 15.00 | 250.0 | 108.29 | 554.4 | 240.00 |
| 40.0 | 17.32 | 254.1 | 110.00 | 577.5 | 250.00 |
| 46.2 | 20.00 | 260.0 | 112.62 | 600.0 | 259.90 |
| 50.0 | 21.65 | 270.0 | 116.96 | 600.6 | 260.00 |
| 60.0 | 25.99 | 277.2 | 120.00 | 623.7 | 270.00 |
| 69.3 | 30.00 | 280.0 | 121.29 | 646.8 | 280.00 |
| 70.0 | 30.32 | 290.0 | 125.62 | 650.0 | 281.56 |
| 80.0 | 34.65 | 300.0 | 129.95 | 669.9 | 290.00 |
| 90.0 | 38.98 | 300.3 | 130.00 | 693.0 | 300.00 |
| 92.4 | 40.00 | 310.0 | 134.28 | 700.0 | 303.22 |
| 100.0 | 43.31 | 320.0 | 138.62 | 716.1 | 310.00 |
| 110.0 | 47.64 | 323.4 | 140.00 | 739.2 | 320.00 |
| 115.5 | 50.00 | 330.0 | 142.95 | 750.0 | 324.88 |
| 120.0 | 51.98 | 340.0 | 147.28 | 762.3 | 330.00 |
| 130.0 | 56.31 | 346.5 | 150.00 | 785.4 | 340.00 |
| 138.6 | 60.00 | 350.0 | 151.61 | 800.0 | 346.54 |
| 140.0 | 60.64 | 360.0 | 155.94 | 808.5 | 350.00 |
| 150.0 | 64.97 | 369.6 | 160.00 | 831.6 | 360.00 |
| 160.0 | 69.31 | 370.0 | 160.27 | 850.0 | 368.20 |
| 161.7 | 70.00 | 380.0 | 164.61 | 854.7 | 370.00 |
| 170.0 | 73.64 | 390.0 | 168.94 | 877.8 | 380.00 |
| 180.0 | 77.97 | 392.7 | 170.00 | 900.0 | 389.86 |
| 184.8 | 80.00 | 400.0 | 173.27 | 900.9 | 390.00 |
| 190.0 | 82.30 | 415.8 | 180.00 | 924.0 | 400.00 |
| 200.0 | 86.63 | 438.9 | 190.00 | 1000.0 | 433.18 |
| 207.9 | 90.00 | 450.0 | 195.00 | 1039.5 | 450.00 |
| 210.0 | 90.96 | 462.0 | 200.00 | 1155.0 | 500.00 |
| 220.0 | 95.30 | 485.1 | 210.00 | 1270.5 | 550.00 |
| 230.0 | 99.63 | 500.0 | 216.58 | 1386.0 | 600.00 |
| 231.0 | 100.00 | 508.2 | 220.00 | 1500.0 | 649.70 |
| | | 531.3 | 230.00 | | |

# TABLE 14. CONVERSION FACTORS—WORK—POWER—TORQUE

Examples: 20 Hp Hrs. × .746 = 14.92 Kw Hrs. 20 Kw Hrs. × 1.341 = 26.82 Hp Hrs.

| | Hp | Metric Hp | Kw | Ft. Lb. | Kg. M. | Ft. Lbs. /Min. | Hp Hr. | Kw Hr. | Btu |
|---|---|---|---|---|---|---|---|---|---|
| Horse Power | 1.0 | 1.014 | .746 | ........ | ........ | 33,000.0 | ........ | ........ | ........ |
| Metric Hp | .986 | 1.0 | .736 | ........ | ........ | 32,550.0 | ........ | ........ | ........ |
| Kilowatt | 1.341 | 1.360 | 1.0 | ........ | ........ | 44,253.0 | ........ | ........ | ........ |
| Ft. Lbs. | ........ | ........ | ........ | 1.0 | .1383 | ........ | ........ | ........ | .001285 |
| Kg. Meter | ........ | ........ | ........ | 7.235 | 1.0 | ........ | ........ | ........ | .00930 |
| Ft. Lbs./Min. | .0000303 | .0000307 | .0000226 | ........ | ........ | 1.0 | ........ | ........ | ........ |
| Hp Hr. | ........ | ........ | ........ | 1,980,000.0 | 273,834.0 | ........ | 1.0 | .746 | 2545.0 |
| Kw Hr. | ........ | ........ | ........ | 2,656,000.0 | 367,325.0 | ........ | 1.341 | 1.0 | 3413.0 |
| Btu | ........ | ........ | ........ | 778.4 | 107.6 | ........ | .000393 | .000293 | 1.0 |

## TABLE 15. POWER CONSUMED PUMPING 1000 GALLONS OF CLEAR WATER AT ONE FOOT TOTAL HEAD—VARIOUS EFFICIENCIES

| Overall Efficiency Pump Unit | Kwh Per 1000 Gallons at One Ft. Total Head | Overall Efficiency Pump Unit | Kwh Per 1000 Gallons at One Ft. Total Head | Overall Efficiency Pump Unit | Kwh Per 1000 Gallons at One Ft. Total Head |
|---|---|---|---|---|---|
| 32 | .00980 | 51.5 | .00609 | 71 | .00442 |
| 32.5 | .00958 | 52 | .00603 | 71.5 | .00439 |
| 33 | .00951 | 52.5 | .00597 | 72 | .00435 |
| 33.5 | .00937 | 53 | .00592 | 72.5 | .00432 |
| 34 | .00922 | 53.5 | .00586 | 73 | .00430 |
| 34.5 | .00909 | 54 | .00581 | 73.5 | .00427 |
| 35 | .00896 | 54.5 | .00575 | 74 | .00424 |
| 35.5 | .00884 | 55 | .00570 | 74.5 | .00421 |
| 36 | .00871 | 55.5 | .00565 | 75 | .00418 |
| 36.5 | .00860 | 56 | .00560 | 75.5 | .00415 |
| 37 | .00848 | 56.5 | .00555 | 76 | .00413 |
| 37.5 | .00837 | 57 | .00550 | 76.5 | .00410 |
| 38 | .00826 | 57.5 | .00545 | 77 | .00407 |
| 38.5 | .00815 | 58 | .00541 | 77.5 | .00405 |
| 39 | .00804 | 58.5 | .00536 | 78 | .00402 |
| 39.5 | .00794 | 59 | .00532 | 78.5 | .00399 |
| 40 | .00784 | 59.5 | .00527 | 79 | .00397 |
| 40.5 | .00775 | 60 | .00523 | 79.5 | .00394 |
| 41 | .00765 | 60.5 | .00518 | 80 | .00392 |
| 41.5 | .00756 | 61 | .00514 | 80.5 | .00389 |
| 42 | .00747 | 61.5 | .00510 | 81 | .00387 |
| 42.5 | .00738 | 62 | .00506 | 81.5 | .00385 |
| 43 | .00730 | 62.5 | .00502 | 82 | .00382 |
| 43.5 | .00721 | 63 | .00498 | 82.5 | .00380 |
| 44 | .00713 | 63.5 | .00494 | 83 | .00378 |
| 44.5 | .00705 | 64 | .00490 | 83.5 | .00375 |
| 45 | .00697 | 64.5 | .00486 | 84 | .00373 |
| 45.5 | .00689 | 65 | .00482 | 84.5 | .00371 |
| 46 | .00682 | 65.5 | .00479 | 85 | .00369 |
| 46.5 | .00675 | 66 | .00475 | 85.5 | .00367 |
| 47 | .00667 | 66.5 | .00472 | 86 | .00365 |
| 47.5 | .00660 | 67 | .00468 | 86.5 | .00362 |
| 48 | .00653 | 67.5 | .00465 | 87 | .00360 |
| 48.5 | .00647 | 68 | .00461 | 87.5 | .00358 |
| 49 | .00640 | 68.5 | .00458 | 88 | .00356 |
| 49.5 | .00634 | 69 | .00454 | 88.5 | .00354 |
| 50 | .00627 | 69.5 | .00451 | 89 | .00352 |
| 50.5 | .00621 | 70 | .00448 | 89.5 | .00350 |
| 51 | .00615 | 70.5 | .00445 | 90 | .00348 |

Overall efficiency = true Input-Output efficiency of motor x pump efficiency.

$Kwh/1000$ gal. $= K \cdot H$

Where $K = Kwh/1000$ gal. at one ft. head. $H =$ Total Head.

Example: Overall efficiency = 72%. Total Head at the rated capacity = 150 ft.

$Kwh/1000$ gal. = .00435 x 150 = 0.653

$$\text{Deg. F.} = \frac{9}{5}\,\text{Deg. C.} + 32. \qquad \text{Deg. C.} = \frac{5}{9}\,(\text{Deg. F.} - 32)$$

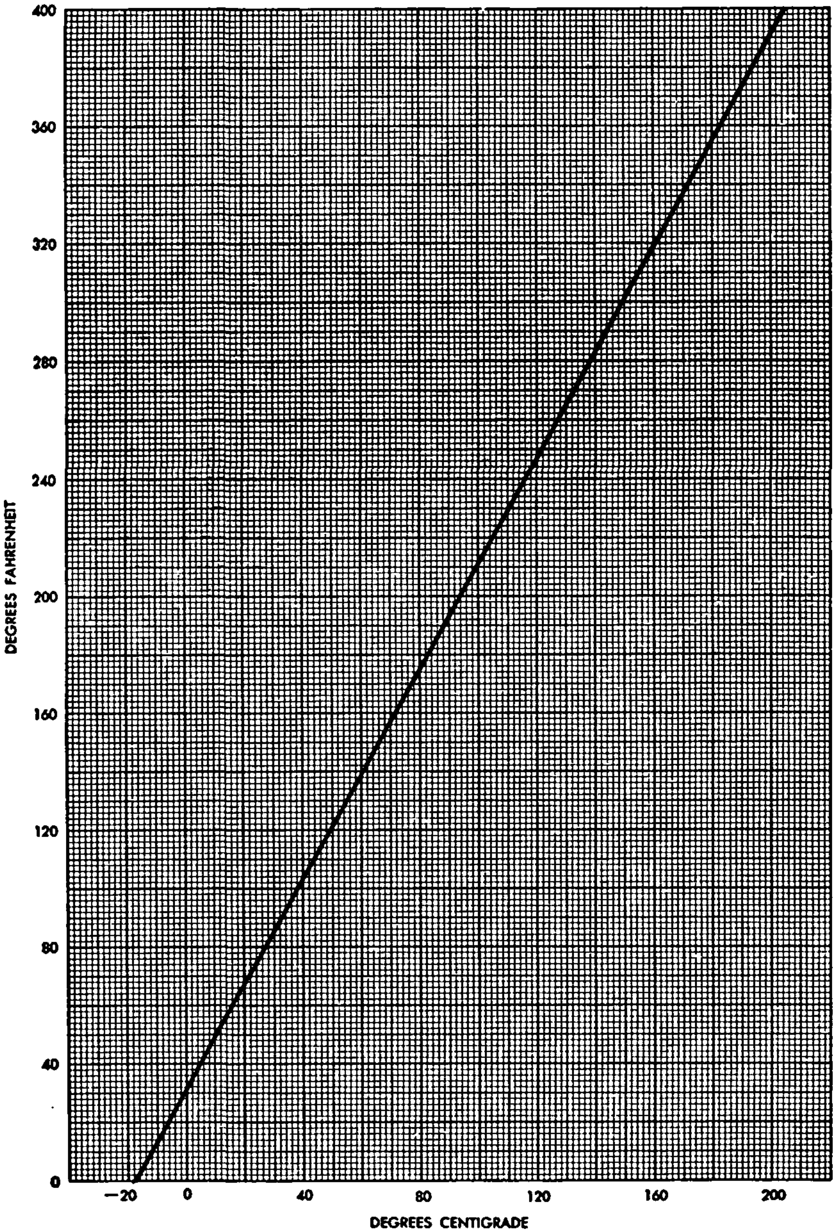



FIG. 27. Conversion chart. Fahrenheit - Centigrade.

III

# TABLE 16. UNITED STATES STANDARD BAUME SCALES

Relation Between Baume Degrees and Specific Gravity

## LIQUIDS HEAVIER THAN WATER

$$\text{Formula—sp gr} = \frac{145}{145 - {}^\circ\ \text{Baume}}$$

| Baume degrees | Sp Gr 60°—60°F | Baume degrees | Sp Gr 60°—60°F | Baume degrees | Sp Gr 60°—60°F | Baume degrees | Sp Gr 60°—60°F |
|---|---|---|---|---|---|---|---|
| 0 | 1.00000 | 20 | 1.16000 | 40 | 1.38095 | 60 | 1.70588 |
| 1 | 1.00694 | 21 | 1.16935 | 41 | 1.39423 | 61 | 1.72619 |
| 2 | 1.01399 | 22 | 1.17886 | 42 | 1.40777 | 62 | 1.74699 |
| 3 | 1.02113 | 23 | 1.18852 | 43 | 1.42157 | 63 | 1.76829 |
| 4 | 1.02837 | 24 | 1.19835 | 44 | 1.43564 | 64 | 1.79012 |
| 5 | 1.03571 | 25 | 1.20833 | 45 | 1.45000 | 65 | 1.81250 |
| 6 | 1.04317 | 26 | 1.21849 | 46 | 1.46465 | 66 | 1.83544 |
| 7 | 1.05072 | 27 | 1.22881 | 47 | 1.47959 | 67 | 1.85897 |
| 8 | 1.05839 | 28 | 1.23932 | 48 | 1.49485 | 68 | 1.88312 |
| 9 | 1.06618 | 29 | 1.25000 | 49 | 1.51042 | 69 | 1.90789 |
| 10 | 1.07407 | 30 | 1.26087 | 50 | 1.52632 | 70 | 1.93333 |
| 11 | 1.08209 | 31 | 1.27193 | 51 | 1.54255 | 71 | 1.95946 |
| 12 | 1.09023 | 32 | 1.28319 | 52 | 1.55914 | 72 | 1.98630 |
| 13 | 1.09848 | 33 | 1.29464 | 53 | 1.57609 | 73 | 2.01389 |
| 14 | 1.10687 | 34 | 1.30631 | 54 | 1.59341 | 74 | 2.04225 |
| 15 | 1.11538 | 35 | 1.31818 | 55 | 1.61111 | 75 | 2.07143 |
| 16 | 1.12403 | 36 | 1.33028 | 56 | 1.62921 | 76 | 2.10145 |
| 17 | 1.13281 | 37 | 1.34259 | 57 | 1.64773 | 77 | 2.13235 |
| 18 | 1.14173 | 38 | 1.35514 | 58 | 1.66667 | 78 | 2.16418 |
| 19 | 1.15079 | 39 | 1.36792 | 59 | 1.68605 | 79 | 2.19697 |

## LIQUIDS LIGHTER THAN WATER

$$\text{Formula—sp gr} = \frac{140}{130 + {}^\circ\ \text{Baume}}$$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10 | 1.00000 | 30 | 0.87500 | 50 | 0.77778 | 70 | 0.70000 |
| 11 | .99291 | 31 | .86957 | 51 | .77348 | 71 | .69652 |
| 12 | .98592 | 32 | .86420 | 52 | .76923 | 72 | .69307 |
| 13 | .97902 | 33 | .85890 | 53 | .76503 | 73 | .68966 |
| 14 | .97222 | 34 | .85366 | 54 | .76087 | 74 | .68627 |
| 15 | .96552 | 35 | .84848 | 55 | .75676 | 75 | .68293 |
| 16 | .95890 | 36 | .84337 | 56 | .75269 | 76 | .67961 |
| 17 | .95238 | 37 | .83832 | 57 | .74866 | 77 | .67633 |
| 18 | .94595 | 38 | .83333 | 58 | .74468 | 78 | .67308 |
| 19 | .93960 | 39 | .82840 | 59 | .74074 | 79 | .66986 |
| 20 | .93333 | 40 | .82353 | 60 | .73684 | 80 | .66667 |
| 21 | .92715 | 41 | .81871 | 61 | .73298 | 81 | .66351 |
| 22 | .92105 | 42 | .81395 | 62 | .72917 | 82 | .66038 |
| 23 | .91503 | 43 | .80925 | 63 | .72539 | 83 | .65728 |
| 24 | .90909 | 44 | .80460 | 64 | .72165 | 84 | .65421 |
| 25 | .90323 | 45 | .80000 | 65 | .71795 | 85 | .65117 |
| 26 | .89744 | 46 | .79545 | 66 | .71428 | 86 | .64815 |
| 27 | .89172 | 47 | .79096 | 67 | .71066 | 87 | .64516 |
| 28 | .88608 | 48 | .78652 | 68 | .70707 | 88 | .64220 |
| 29 | .88050 | 49 | .78212 | 69 | .70352 | 89 | .63927 |

From Circular No. 59 Bureau of Standards.

# TABLE 17. RELATION BETWEEN SPECIFIC GRAVITY AND DEG. API AT 60°F.

$$\text{Specific Gravity} = \frac{141.5}{131.5 + {}^{\circ}\text{API}}$$

| Degrees A.P.I. | Specific Gravity | Degrees A.P.I. | Specific Gravity | Degrees A.P.I. | Specific Gravity |
|---|---|---|---|---|---|
| 10 | 1.0000 | 40 | .8251 | 70 | .7022 |
| 11 | .9930 | 41 | .8203 | 71 | .6988 |
| 12 | .9861 | 42 | .8155 | 72 | .6952 |
| 13 | .9792 | 43 | .8109 | 73 | .6919 |
| 14 | .9725 | 44 | .8063 | 74 | .6886 |
| 15 | .9659 | 45 | .8017 | 75 | .6852 |
| 16 | .9593 | 46 | .7972 | 76 | .6819 |
| 17 | .9529 | 47 | .7927 | 77 | .6787 |
| 18 | .9465 | 48 | .7883 | 78 | .6754 |
| 19 | .9402 | 49 | .7839 | 79 | .6722 |
| 20 | .9340 | 50 | .7796 | 80 | .6690 |
| 21 | .9279 | 51 | .7753 | 81 | .6659 |
| 22 | .9218 | 52 | .7711 | 82 | .6628 |
| 23 | .9159 | 53 | .7669 | 83 | .6597 |
| 24 | .9100 | 54 | .7628 | 84 | .6566 |
| 25 | .9042 | 55 | .7587 | 85 | .6536 |
| 26 | .8984 | 56 | .7547 | 86 | .6506 |
| 27 | .8927 | 57 | .7507 | 87 | .6476 |
| 28 | .8871 | 58 | .7467 | 88 | .6446 |
| 29 | .8816 | 59 | .7428 | 89 | .6417 |
| 30 | .8762 | 60 | .7389 | 90 | .6388 |
| 31 | .8708 | 61 | .7351 | 91 | .6360 |
| 32 | .8654 | 62 | .7313 | 92 | .6331 |
| 33 | .8602 | 63 | .7275 | 93 | .6303 |
| 34 | .8550 | 64 | .7238 | 94 | .6275 |
| 35 | .8498 | 65 | .7201 | 95 | .6247 |
| 36 | .8448 | 66 | .7165 | 96 | .6220 |
| 37 | .8398 | 67 | .7128 | 97 | .6193 |
| 38 | .8348 | 68 | .7093 | 98 | .6166 |
| 39 | .8299 | 69 | .7057 | 99 | .6139 |
| | | | | 100 | .6112 |

## TABLE 18. DEGREES BRIX†

Per Cent Sugar (Degrees Balling's or Brix) with Corresponding Specific Gravity and Degrees Baume. Temperature 60°F

| Per cent sugar Balling's or Brix 60°F—15.56°C | Specific gravity 60°/60°F | Degrees Baume 60°F | Per cent sugar Balling's or Brix 60°F—15.56°C | Specific gravity 60°/60°F | Degrees Baume 60°F |
|---|---|---|---|---|---|
| 0 | 1.0000 | 0.00 | 50 | 1.2328 | 27.38 |
| 1 | 1.0039 | 0.56 | 51 | 1.2384 | 27.91 |
| 2 | 1.0078 | 1.13 | 52 | 1.2439 | 28.43 |
| 3 | 1.0118 | 1.68 | 53 | 1.2496 | 28.96 |
| 4 | 1.0157 | 2.24 | 54 | 1.2552 | 29.48 |
| 5 | 1.0197 | 2.80 | 55 | 1.2609 | 30.00 |
| 6 | 1.0238 | 3.37 | 56 | 1.2667 | 30.53 |
| 7 | 1.0278 | 3.93 | 57 | 1.2724 | 31.05 |
| 8 | 1.0319 | 4.49 | 58 | 1.2782 | 31.56 |
| 9 | 1.0360 | 5.04 | 59 | 1.2841 | 32.08 |
| 10 | 1.0402 | 5.60 | 60 | 1.2900 | 32.60 |
| 11 | 1.0443 | 6.15 | 61 | 1.2959 | 33.11 |
| 12 | 1.0485 | 6.71 | 62 | 1.3019 | 33.63 |
| 13 | 1.0528 | 7.28 | 63 | 1.3079 | 34.13 |
| 14 | 1.0570 | 7.81 | 64 | 1.3139 | 34.64 |
| 15 | 1.0613 | 8.38 | 65 | 1.3200 | 35.15 |
| 16 | 1.0657 | 8.94 | 66 | 1.3261 | 35.66 |
| 17 | 1.0700 | 9.49 | 67 | 1.3323 | 36.16 |
| 18 | 1.0744 | 10.04 | 68 | 1.3384 | 36.67 |
| 19 | 1.0788 | 10.59 | 69 | 1.3447 | 37.17 |
| 20 | 1.0833 | 11.15 | 70 | 1.3509 | 37.66 |
| 21 | 1.0878 | 11.70 | 71 | 1.3573 | 38.17 |
| 22 | 1.0923 | 12.25 | 72 | 1.3636 | 38.66 |
| 23 | 1.0968 | 12.80 | 73 | 1.3700 | 39.16 |
| 24 | 1.1014 | 13.35 | 74 | 1.3764 | 39.65 |
| 25 | 1.1060 | 13.90 | 75 | 1.3829 | 40.15 |
| 26 | 1.1107 | 14.45 | 76 | 1.3894 | 40.64 |
| 27 | 1.1154 | 15.00 | 77 | 1.3959 | 41.12 |
| 28 | 1.1201 | 15.54 | 78 | 1.4025 | 41.61 |
| 29 | 1.1248 | 16.19 | 79 | 1.4091 | 42.10 |
| 30 | 1.1296 | 16.63 | 80 | 1.4157 | 42.58 |
| 31 | 1.1345 | 17.19 | 81 | 1.4224 | 43.06 |
| 32 | 1.1393 | 17.73 | 82 | 1.4291 | 43.54 |
| 33 | 1.1442 | 18.28 | 83 | 1.4359 | 44.02 |
| 34 | 1.1491 | 18.81 | 84 | 1.4427 | 44.49 |
| 35 | 1.1541 | 19.36 | 85 | 1.4495 | 44.96 |
| 36 | 1.1591 | 19.90 | 86 | 1.4564 | 45.44 |
| 37 | 1.1641 | 20.44 | 87 | 1.4633 | 45.91 |
| 38 | 1.1692 | 20.98 | 88 | 1.4702 | 46.37 |
| 39 | 1.1743 | 21.52 | 89 | 1.4772 | 46.84 |
| 40 | 1.1794 | 22.06 | 90 | 1.4842 | 47.31 |
| 41 | 1.1846 | 22.60 | 91 | 1.4913 | 47.77 |
| 42 | 1.1898 | 23.13 | 92 | 1.4984 | 48.23 |
| 43 | 1.1950 | 23.66 | 93 | 1.5055 | 48.69 |
| 44 | 1.2003 | 24.20 | 94 | 1.5126 | 49.14 |
| 45 | 1.2057 | 24.74 | 95 | 1.5198 | 49.59 |
| 46 | 1.2110 | 25.26 | 96 | 1.5270 | 50.04 |
| 47 | 1.2164 | 25.80 | 97 | 1.5343 | 50.49 |
| 48 | 1.2218 | 26.32 | 98 | 1.5416 | 50.94 |
| 49 | 1.2273 | 26.86 | 99 | 1.5489 | 51.39 |
| | | | 100 | 1.5563 | 51.93 |

**The above table is from the determinations of Dr. F. Plato, and has been adopted as standard by the United States Bureau of Standards.**

†*Courtesy Ingersoll-Rand Co. See page 6.*

## TABLE 19. CONVERSION FACTORS—WATER ANALYSIS

Examples: 5 Gr./gal. × 17.1 = 85.5 Ppm    103 Ppm × .07 = 7.21 Gr./Imp. Gal.

| | Grains per U.S. Gallon | Grains per Imp. Gallon | Parts per Million or Mg./liter |
|---|---|---|---|
| Grains per U.S. Gal. | 1.00 | 1.20 | 17.1 |
| Grains per Imp. Gal. | 0.835 | 1.00 | 14.3 |
| Parts/Million or Milligrams/liter | 0.0585 | 0.07 | 1.0 |

## TABLE 20. POUNDS PER CUBIC FOOT AT VARIOUS SPECIFIC GRAVITIES

| Specific Gravity | Lb. Per Cu. Ft. | Specific Gravity | Lb. Per Cu. Ft. | Specific Gravity | Lb. Per Cu. Ft. |
|---|---|---|---|---|---|
| .90 | 56.16 | 1.40 | 87.36 | 1.90 | 118.56 |
| .91 | 56.78 | 1.41 | 87.98 | 1.91 | 119.18 |
| .92 | 57.41 | 1.42 | 88.61 | 1.92 | 119.81 |
| .93 | 58.03 | 1.43 | 89.23 | 1.93 | 120.43 |
| .94 | 58.66 | 1.44 | 89.86 | 1.94 | 121.06 |
| .95 | 59.28 | 1.45 | 90.48 | 1.95 | 121.68 |
| .96 | 59.90 | 1.46 | 91.10 | 1.96 | 122.30 |
| .97 | 60.53 | 1.47 | 91.73 | 1.97 | 122.93 |
| .98 | 61.15 | 1.48 | 92.35 | 1.98 | 123.55 |
| .99 | 61.78 | 1.49 | 92.98 | 1.99 | 124.18 |
| 1.00 | 62.40 | 1.50 | 93.60 | 2.00 | 124.80 |
| 1.01 | 63.02 | 1.51 | 94.22 | 2.01 | 125.42 |
| 1.02 | 63.65 | 1.52 | 94.85 | 2.02 | 126.05 |
| 1.03 | 64.27 | 1.53 | 95.47 | 2.03 | 126.67 |
| 1.04 | 64.90 | 1.54 | 96.10 | 2.04 | 127.30 |
| 1.05 | 65.52 | 1.55 | 96.72 | 2.05 | 127.92 |
| 1.06 | 66.14 | 1.56 | 97.34 | 2.06 | 128.54 |
| 1.07 | 66.77 | 1.57 | 97.97 | 2.07 | 129.17 |
| 1.08 | 67.39 | 1.58 | 98.59 | 2.08 | 129.79 |
| 1.09 | 68.02 | 1.59 | 99.22 | 2.09 | 130.42 |
| 1.10 | 68.64 | 1.60 | 99.84 | 2.10 | 131.04 |
| 1.11 | 69.26 | 1.61 | 100.46 | 2.11 | 131.66 |
| 1.12 | 69.89 | 1.62 | 101.09 | 2.12 | 132.29 |
| 1.13 | 70.51 | 1.63 | 101.71 | 2.13 | 132.91 |
| 1.14 | 71.14 | 1.64 | 102.34 | 2.14 | 133.54 |
| 1.15 | 71.76 | 1.65 | 102.96 | 2.15 | 134.16 |
| 1.16 | 72.38 | 1.66 | 103.58 | 2.16 | 134.78 |
| 1.17 | 73.01 | 1.67 | 104.21 | 2.17 | 135.41 |
| 1.18 | 73.63 | 1.68 | 104.83 | 2.18 | 136.03 |
| 1.19 | 74.26 | 1.69 | 105.46 | 2.19 | 136.66 |
| 1.20 | 74.88 | 1.70 | 106.08 | 2.20 | 137.28 |
| 1.21 | 75.50 | 1.71 | 106.70 | 2.21 | 137.90 |
| 1.22 | 76.13 | 1.72 | 107.33 | 2.22 | 138.53 |
| 1.23 | 76.75 | 1.73 | 107.95 | 2.23 | 139.15 |
| 1.24 | 77.38 | 1.74 | 108.58 | 2.24 | 139.78 |
| 1.25 | 78.00 | 1.75 | 109.20 | 2.25 | 140.40 |
| 1.26 | 78.62 | 1.76 | 109.82 | 2.26 | 141.02 |
| 1.27 | 79.25 | 1.77 | 110.45 | 2.27 | 141.65 |
| 1.28 | 79.87 | 1.78 | 111.07 | 2.28 | 142.27 |
| 1.29 | 80.50 | 1.79 | 111.70 | 2.29 | 142.90 |
| 1.30 | 81.12 | 1.80 | 112.32 | 2.30 | 143.52 |
| 1.31 | 81.74 | 1.81 | 112.94 | 2.31 | 144.14 |
| 1.32 | 82.37 | 1.82 | 113.57 | 2.32 | 144.77 |
| 1.33 | 82.99 | 1.83 | 114.19 | 2.33 | 145.39 |
| 1.34 | 83.62 | 1.84 | 114.82 | 2.34 | 146.02 |
| 1.35 | 84.24 | 1.85 | 115.44 | 2.35 | 146.64 |
| 1.36 | 84.86 | 1.86 | 116.06 | 2.36 | 147.26 |
| 1.37 | 85.49 | 1.87 | 116.69 | 2.37 | 147.89 |
| 1.38 | 86.11 | 1.88 | 117.31 | 2.38 | 148.51 |
| 1.39 | 86.74 | 1.89 | 117.94 | 2.39 | 149.14 |

III

# DECIMAL EQUIVALENTS

| 64ths | 32nds | DECIMALS OF A FOOT | | | | | | | | | | | | 64ths | 32nds | Decimals of an Inch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0" | 1" | 2" | 3" | 4" | 5" | 6" | 7" | 8" | 9" | 10" | 11" | | | |
| | 0 | 0.0000 | 0.0833 | 0.1667 | 0.2500 | 0.3333 | 0.4167 | 0.5000 | 0.5833 | 0.6667 | 0.7500 | 0.8333 | 0.9167 | | 0 | |
| 1 | | 0.0013 | 0.0846 | 0.1680 | 0.2513 | 0.3346 | 0.4180 | 0.5013 | 0.5846 | 0.6680 | 0.7513 | 0.8346 | 0.9180 | 1 | | 0.015625 |
| | 1/32 | 0.0026 | 0.0859 | 0.1693 | 0.2526 | 0.3359 | 0.4193 | 0.5026 | 0.5859 | 0.6693 | 0.7526 | 0.8359 | 0.9193 | | 1/32 | 0.031250 |
| 3 | | 0.0039 | 0.0872 | 0.1706 | 0.2539 | 0.3372 | 0.4206 | 0.5039 | 0.5872 | 0.6706 | 0.7539 | 0.8372 | 0.9206 | 3 | | 0.046875 |
| | 1/16 | 0.0052 | 0.0885 | 0.1719 | 0.2552 | 0.3385 | 0.4219 | 0.5052 | 0.5885 | 0.6719 | 0.7552 | 0.8385 | 0.9219 | | 1/16 | 0.062500 |
| 5 | | 0.0065 | 0.0898 | 0.1732 | 0.2565 | 0.3398 | 0.4232 | 0.5065 | 0.5898 | 0.6732 | 0.7565 | 0.8398 | 0.9232 | 5 | | 0.078125 |
| | 3/32 | 0.0078 | 0.0911 | 0.1745 | 0.2578 | 0.3411 | 0.4245 | 0.5078 | 0.5911 | 0.6745 | 0.7578 | 0.8411 | 0.9245 | | 3/32 | 0.093750 |
| 7 | | 0.0091 | 0.0924 | 0.1758 | 0.2591 | 0.3424 | 0.4258 | 0.5091 | 0.5924 | 0.6758 | 0.7591 | 0.8424 | 0.9258 | 7 | | 0.109375 |
| | 1/8 | 0.0104 | 0.0937 | 0.1771 | 0.2604 | 0.3437 | 0.4271 | 0.5104 | 0.5937 | 0.6771 | 0.7604 | 0.8437 | 0.9271 | | 1/8 | 0.125000 |
| 9 | | 0.0117 | 0.0951 | 0.1784 | 0.2617 | 0.3451 | 0.4284 | 0.5117 | 0.5951 | 0.6784 | 0.7617 | 0.8451 | 0.9284 | 9 | | 0.140625 |
| | 5/32 | 0.0130 | 0.0964 | 0.1797 | 0.2630 | 0.3464 | 0.4297 | 0.5130 | 0.5964 | 0.6797 | 0.7630 | 0.8464 | 0.9297 | | 5/32 | 0.156250 |
| 11 | | 0.0143 | 0.0977 | 0.1810 | 0.2643 | 0.3477 | 0.4310 | 0.5143 | 0.5977 | 0.6810 | 0.7643 | 0.8477 | 0.9310 | 11 | | 0.171875 |
| | 3/16 | 0.0156 | 0.0990 | 0.1823 | 0.2656 | 0.3490 | 0.4323 | 0.5156 | 0.5990 | 0.6823 | 0.7656 | 0.8490 | 0.9323 | | 3/16 | 0.187500 |
| 13 | | 0.0169 | 0.1003 | 0.1836 | 0.2669 | 0.3503 | 0.4336 | 0.5169 | 0.6003 | 0.6836 | 0.7669 | 0.8503 | 0.9336 | 13 | | 0.203125 |
| | 7/32 | 0.0182 | 0.1016 | 0.1849 | 0.2682 | 0.3516 | 0.4349 | 0.5182 | 0.6016 | 0.6849 | 0.7682 | 0.8516 | 0.9349 | | 7/32 | 0.218750 |
| 15 | | 0.0195 | 0.1029 | 0.1862 | 0.2695 | 0.3529 | 0.4362 | 0.5195 | 0.6029 | 0.6862 | 0.7695 | 0.8529 | 0.9362 | 15 | | 0.234375 |
| | 1/4 | 0.0208 | 0.1042 | 0.1875 | 0.2708 | 0.3542 | 0.4375 | 0.5208 | 0.6042 | 0.6875 | 0.7708 | 0.8542 | 0.9375 | | 1/4 | 0.250000 |
| 17 | | 0.0221 | 0.1055 | 0.1888 | 0.2721 | 0.3555 | 0.4388 | 0.5221 | 0.6055 | 0.6888 | 0.7721 | 0.8555 | 0.9388 | 17 | | 0.265625 |
| | 9/32 | 0.0234 | 0.1068 | 0.1901 | 0.2734 | 0.3568 | 0.4401 | 0.5234 | 0.6068 | 0.6901 | 0.7734 | 0.8568 | 0.9401 | | 9/32 | 0.281250 |
| 19 | | 0.0247 | 0.1081 | 0.1914 | 0.2747 | 0.3581 | 0.4414 | 0.5247 | 0.6081 | 0.6914 | 0.7747 | 0.8581 | 0.9414 | 19 | | 0.296875 |
| | 5/16 | 0.0260 | 0.1094 | 0.1927 | 0.2760 | 0.3594 | 0.4427 | 0.5260 | 0.6094 | 0.6927 | 0.7760 | 0.8594 | 0.9427 | | 5/16 | 0.312500 |
| 21 | | 0.0273 | 0.1107 | 0.1940 | 0.2773 | 0.3607 | 0.4440 | 0.5273 | 0.6107 | 0.6940 | 0.7773 | 0.8607 | 0.9440 | 21 | | 0.328125 |
| | 11/32 | 0.0286 | 0.1120 | 0.1953 | 0.2786 | 0.3620 | 0.4453 | 0.5286 | 0.6120 | 0.6953 | 0.7786 | 0.8620 | 0.9453 | | 11/32 | 0.343750 |
| 23 | | 0.0299 | 0.1133 | 0.1966 | 0.2799 | 0.3633 | 0.4466 | 0.5299 | 0.6133 | 0.6966 | 0.7799 | 0.8633 | 0.9466 | 23 | | 0.359375 |
| | 3/8 | 0.0312 | 0.1146 | 0.1979 | 0.2812 | 0.3646 | 0.4479 | 0.5312 | 0.6146 | 0.6979 | 0.7812 | 0.8646 | 0.9479 | | 3/8 | 0.375000 |
| 25 | | 0.0326 | 0.1159 | 0.1992 | 0.2826 | 0.3659 | 0.4492 | 0.5326 | 0.6159 | 0.6992 | 0.7826 | 0.8659 | 0.9492 | 25 | | 0.390625 |
| | 13/32 | 0.0339 | 0.1172 | 0.2005 | 0.2839 | 0.3672 | 0.4505 | 0.5339 | 0.6172 | 0.7005 | 0.7839 | 0.8672 | 0.9505 | | 13/32 | 0.406250 |
| 27 | | 0.0352 | 0.1185 | 0.2018 | 0.2852 | 0.3685 | 0.4518 | 0.5352 | 0.6185 | 0.7018 | 0.7852 | 0.8685 | 0.9518 | 27 | | 0.421875 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7/16 | **0.0365** | **0.1198** | **0.2031** | **0.2865** | **0.3698** | **0.4531** | **0.5365** | **0.6198** | **0.7031** | **0.7865** | **0.8698** | **0.9531** | | 7/16 | **0.437500** |
| 29 | | 0.0378 | 0.1211 | 0.2044 | 0.2878 | 0.3711 | 0.4544 | 0.5378 | 0.6211 | 0.7044 | 0.7878 | 0.8711 | 0.9544 | 29 | | 0.453125 |
| | 15/32 | **0.0391** | **0.1224** | **0.2057** | **0.2891** | **0.3724** | **0.4557** | **0.5391** | **0.6224** | **0.7057** | **0.7891** | **0.8724** | **0.9557** | | 15/32 | **0.468750** |
| 31 | | 0.0404 | 0.1237 | 0.2070 | 0.2904 | 0.3737 | 0.4570 | 0.5404 | 0.6237 | 0.7070 | 0.7904 | 0.8737 | 0.9570 | 31 | | 0.484375 |
| | 1/2 | **0.0417** | **0.1250** | **0.2083** | **0.2917** | **0.3750** | **0.4583** | **0.5417** | **0.6250** | **0.7083** | **0.7917** | **0.8750** | **0.9583** | | 1/2 | **0.500000** |
| 33 | | 0.0430 | 0.1263 | 0.2096 | 0.2930 | 0.3763 | 0.4596 | 0.5430 | 0.6263 | 0.7096 | 0.7930 | 0.8763 | 0.9596 | 33 | | 0.515625 |
| | 17/32 | **0.0443** | **0.1276** | **0.2109** | **0.2943** | **0.3776** | **0.4609** | **0.5443** | **0.6276** | **0.7109** | **0.7943** | **0.8776** | **0.9609** | | 17/32 | **0.531250** |
| 35 | | 0.0456 | 0.1289 | 0.2122 | 0.2956 | 0.3789 | 0.4622 | 0.5456 | 0.6289 | 0.7122 | 0.7956 | 0.8789 | 0.9622 | 35 | | 0.546875 |
| | 9/16 | **0.0469** | **0.1302** | **0.2135** | **0.2969** | **0.3802** | **0.4635** | **0.5469** | **0.6302** | **0.7135** | **0.7969** | **0.8802** | **0.9635** | | 9/16 | **0.562500** |
| 37 | | 0.0482 | 0.1315 | 0.2148 | 0.2982 | 0.3815 | 0.4648 | 0.5482 | 0.6315 | 0.7148 | 0.7982 | 0.8815 | 0.9648 | 37 | | 0.578125 |
| | 19/32 | **0.0495** | **0.1328** | **0.2161** | **0.2995** | **0.3828** | **0.4661** | **0.5495** | **0.6328** | **0.7161** | **0.7995** | **0.8828** | **0.9661** | | 19/32 | **0.593750** |
| 39 | | 0.0508 | 0.1341 | 0.2174 | 0.3008 | 0.3841 | 0.4674 | 0.5508 | 0.6341 | 0.7174 | 0.8008 | 0.8841 | 0.9674 | 39 | | 0.609375 |
| | 5/8 | **0.0521** | **0.1354** | **0.2188** | **0.3021** | **0.3854** | **0.4688** | **0.5521** | **0.6354** | **0.7188** | **0.8021** | **0.8854** | **0.9688** | | 5/8 | **0.625000** |
| 41 | | 0.0534 | 0.1367 | 0.2201 | 0.3034 | 0.3867 | 0.4701 | 0.5534 | 0.6367 | 0.7201 | 0.8034 | 0.8867 | 0.9701 | 41 | | 0.640625 |
| | 21/32 | **0.0547** | **0.1380** | **0.2214** | **0.3047** | **0.3880** | **0.4714** | **0.5547** | **0.6380** | **0.7214** | **0.8047** | **0.8880** | **0.9714** | | 21/32 | **0.656250** |
| 43 | | 0.0560 | 0.1393 | 0.2227 | 0.3060 | 0.3893 | 0.4727 | 0.5560 | 0.6393 | 0.7227 | 0.8060 | 0.8893 | 0.9727 | 43 | | 0.671875 |
| | 11/16 | **0.0573** | **0.1406** | **0.2240** | **0.3073** | **0.3906** | **0.4740** | **0.5573** | **0.6406** | **0.7240** | **0.8073** | **0.8906** | **0.9740** | | 11/16 | **0.687500** |
| 45 | | 0.0586 | 0.1419 | 0.2253 | 0.3086 | 0.3919 | 0.4753 | 0.5586 | 0.6419 | 0.7253 | 0.8086 | 0.8919 | 0.9753 | 45 | | 0.703125 |
| | 23/32 | **0.0599** | **0.1432** | **0.2266** | **0.3099** | **0.3932** | **0.4766** | **0.5599** | **0.6432** | **0.7266** | **0.8099** | **0.8932** | **0.9766** | | 23/32 | **0.718750** |
| 47 | | 0.0612 | 0.1445 | 0.2279 | 0.3112 | 0.3945 | 0.4779 | 0.5612 | 0.6445 | 0.7279 | 0.8112 | 0.8945 | 0.9779 | 47 | | 0.734375 |
| | 3/4 | **0.0625** | **0.1458** | **0.2292** | **0.3125** | **0.3958** | **0.4792** | **0.5625** | **0.6458** | **0.7292** | **0.8125** | **0.8958** | **0.9792** | 49 | 3/4 | **0.750000** |
| 49 | | 0.0638 | 0.1471 | 0.2305 | 0.3138 | 0.3971 | 0.4805 | 0.5638 | 0.6471 | 0.7305 | 0.8138 | 0.8971 | 0.9805 | | | 0.765625 |
| | 25/32 | **0.0651** | **0.1484** | **0.2318** | **0.3151** | **0.3984** | **0.4818** | **0.5651** | **0.6484** | **0.7318** | **0.8151** | **0.8984** | **0.9818** | | 25/32 | **0.781250** |
| 51 | | 0.0664 | 0.1497 | 0.2331 | 0.3164 | 0.3997 | 0.4831 | 0.5664 | 0.6497 | 0.7331 | 0.8164 | 0.8997 | 0.9831 | 51 | | 0.796875 |
| | 13/16 | **0.0677** | **0.1510** | **0.2344** | **0.3177** | **0.4010** | **0.4844** | **0.5677** | **0.6510** | **0.7344** | **0.8177** | **0.9010** | **0.9844** | | 13/16 | **0.812500** |
| 53 | | 0.0690 | 0.1523 | 0.2357 | 0.3190 | 0.4023 | 0.4857 | 0.5690 | 0.6523 | 0.7357 | 0.8190 | 0.9023 | 0.9857 | 53 | | 0.828125 |
| | 27/32 | **0.0703** | **0.1536** | **0.2370** | **0.3203** | **0.4036** | **0.4870** | **0.5703** | **0.6536** | **0.7370** | **0.8203** | **0.9036** | **0.9870** | | 27/32 | **0.843750** |
| 55 | | 0.0716 | 0.1549 | 0.2383 | 0.3216 | 0.4049 | 0.4883 | 0.5716 | 0.6549 | 0.7383 | 0.8216 | 0.9049 | 0.9883 | 55 | | 0.859375 |
| | 7/8 | **0.0729** | **0.1562** | **0.2396** | **0.3229** | **0.4062** | **0.4896** | **0.5729** | **0.6562** | **0.7396** | **0.8229** | **0.9062** | **0.9896** | | 7/8 | **0.875000** |
| 57 | | 0.0742 | 0.1576 | 0.2409 | 0.3242 | 0.4076 | 0.4909 | 0.5742 | 0.6576 | 0.7409 | 0.8242 | 0.9076 | 0.9909 | 57 | | 0.890625 |
| | 29/32 | **0.0755** | **0.1589** | **0.2422** | **0.3255** | **0.4089** | **0.4922** | **0.5755** | **0.6589** | **0.7422** | **0.8255** | **0.9089** | **0.9922** | | 29/32 | **0.906250** |
| 59 | | 0.0768 | 0.1602 | 0.2435 | 0.3268 | 0.4102 | 0.4935 | 0.5768 | 0.6602 | 0.7435 | 0.8268 | 0.9102 | 0.9935 | 59 | | 0.921875 |
| | 15/16 | **0.0781** | **0.1615** | **0.2448** | **0.3281** | **0.4115** | **0.4948** | **0.5781** | **0.6615** | **0.7448** | **0.8281** | **0.9115** | **0.9948** | | 15/16 | **0.937500** |
| 61 | | 0.0794 | 0.1628 | 0.2461 | 0.3294 | 0.4128 | 0.4961 | 0.5794 | 0.6628 | 0.7461 | 0.8294 | 0.9128 | 0.9961 | 61 | | 0.953125 |
| | 31/32 | **0.0807** | **0.1641** | **0.2474** | **0.3307** | **0.4141** | **0.4974** | **0.5807** | **0.6641** | **0.7474** | **0.8307** | **0.9141** | **0.9974** | | 31/32 | **0.968750** |
| 63 | | 0.0820 | 0.1654 | 0.2487 | 0.3320 | 0.4154 | 0.4987 | 0.5820 | 0.6654 | 0.7487 | 0.8320 | 0.9154 | 0.9987 | 63 | | 0.984375 |

## TABLE 21A. CONVERSION TABLE FOR APPROXIMATE HARDNESS NUMBERS OBTAINED BY DIFFERENT METHODS†

(Compiled mainly from manufacturers' tables)

| Brinell, 3000-kg load, 10 mm ball | | Rockwell Number | | | |
|---|---|---|---|---|---|
| Diameter of Indentation, $d$ mm | Hardness Number | C Scale, 150 kg load, 120° diamond cone | B Scale, 100 kg load, 1/16 in. ball | Shore Sclero-scope Number | Vickers Pyramid Number |
| 2.40 | 653 | 62 | ............ | 86 | 783 |
| 2.60 | 555 | 55 | ............ | 75 | 622 |
| 2.80 | 477 | 49 | ............ | 66 | 513 |
| 3.00 | 415 | 44 | ............ | 58 | 439 |
| 3.10 | 388 | 41 | ............ | 54 | 404 |
| 3.20 | 363 | 39 | ............ | 51 | 374 |
| 3.30 | 341 | 37 | ............ | 48 | 352 |
| 3.40 | 321 | 35 | ............ | 45 | 329 |
| 3.50 | 302 | 32 | ............ | 42 | 303 |
| 3.60 | 285 | 30 | ............ | 40 | 285 |
| 3.70 | 269 | 27 | ............ | 37 | 269 |
| 3.80 | 255 | 25 | ............ | 35 | 255 |
| 3.90 | 241 | 23 | 99 | 33 | 241 |
| 4.00 | 229 | 20 | 98 | 32 | 229 |
| 4.10 | 217 | ............ | 96 | 30 | 217 |
| 4.20 | 207 | ............ | 95 | 29 | 207 |
| 4.30 | 197 | ............ | 93 | 28 | 197 |
| 4.40 | 187 | ............ | 91 | 27 | 187 |
| 4.50 | 179 | ............ | 89 | 25 | 179 |
| 4.60 | 170 | ............ | 87 | 24 | 170 |
| 4.70 | 163 | ............ | 85 | 23 | 163 |
| 4.80 | 156 | ............ | 82 | 23 | 156 |
| 4.90 | 149 | ............ | 80 | 22 | 149 |
| 5.00 | 143 | ............ | 78 | 21 | 143 |
| 5.10 | 137 | ............ | 75 | 20 | 137 |
| 5.20 | 131 | ............ | 73 | 19 | 131 |
| 5.30 | 126 | ............ | 70 | 18 | 126 |
| 5.40 | 121 | ............ | 68 | 17 | 121 |
| 5.50 | 116 | ............ | 65 | 16 | 116 |
| 5.60 | 111 | ............ | 62 | ........ | 111 |
| 5.70 | 107 | ............ | 60 | ........ | 107 |
| 5.80 | 103 | ............ | 57 | ........ | 103 |
| 5.90 | 99.2 | ............ | 55 | ........ | 99.2 |
| 6.00 | 95.5 | ............ | 52 | ........ | 95.5 |
| 6.10 | 92.0 | ............ | 49 | ........ | 92.0 |
| 6.20 | 88.7 | ............ | 47 | ........ | 88.7 |
| 6.30 | 85.5 | ............ | 44 | ........ | 85.5 |
| 6.40 | 82.5 | ............ | 42 | ........ | 82.5 |

†*Courtesy John Wiley and Sons. See page 6.*

# SECTION IV—WATER DATA

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Page

# SECTION IV—WATER DATA

## PROPERTIES OF WATER—VISCOSITY

In this handbook, the specific gravity is referred to water at 39.2°F (4°C) as 1.000. This is its point of maximum density. Quite often, however, it is referred to water at 60°F (15.6°C) as 1.000. Based on water at 39.2°F as 1.000, water at 60°F has a specific gravity of 0.999+. Therefore, the base which is selected for use makes no practical difference in pumping problems.

### TABLE 22. VISCOSITY OF WATER

| Temp—°F. | Absolute Viscosity | Kinematic Viscosity | | |
|---|---|---|---|---|
| | Centipoises | Centistokes | SSU | $ft^2/sec$ |
| 32 | 1.79 | 1.79 | 33.0 | 0.00001931 |
| 50 | 1.31 | 1.31 | 31.6 | 0.00001410 |
| 60 | 1.12 | 1.12 | 31.2 | 0.00001217 |
| 70 | 0.98 | 0.98 | 30.9 | 0.00001059 |
| 80 | 0.86 | 0.86 | 30.6 | 0.00000930 |
| 85 | 0.81 | 0.81 | 30.4 | 0.00000869 |
| 100 | 0.68 | 0.69 | 30.2 | 0.00000739 |
| 120 | 0.56 | 0.57 | 30.0 | 0.00000609 |
| 140 | 0.47 | 0.48 | 29.7 | 0.00000514 |
| 160 | 0.40 | 0.41 | 29.6 | 0.00000442 |
| 180 | 0.35 | 0.36 | 29.5 | 0.00000385 |
| 212 | 0.28 | 0.29 | 29.3 | 0.00000319 |

### TABLE 23. PROPERTIES OF WATER

| Temp. °F. | Absolute Vapor Pressure | | Specific Gravity (Water at 39.2°F = 1.000) | Temp. °F. | Absolute Vapor Pressure | | Specific Gravity (Water at 39.2°F = 1.000) |
|---|---|---|---|---|---|---|---|
| | Psi. | Ft. Water | | | Psi. | Ft. Water | |
| 60 | 0.26 | 0.59 | 0.999 | 160 | 4.74 | 11.2 | 0.977 |
| 70 | 0.36 | 0.89 | 0.998 | 161 | 4.85 | 11.5 | 0.977 |
| 80 | 0.51 | 1.2 | 0.997 | 162 | 4.97 | 11.7 | 0.977 |
| 85 | 0.60 | 1.4 | 0.996 | 163 | 5.09 | 12.0 | 0.976 |
| 90 | 0.70 | 1.6 | 0.995 | 164 | 5.21 | 12.3 | 0.976 |
| 100 | 0.95 | 2.2 | 0.993 | 165 | 5.33 | 12.6 | 0.976 |
| 110 | 1.27 | 3.0 | 0.991 | 166 | 5.46 | 12.9 | 0.975 |
| 120 | 1.69 | 3.9 | 0.989 | 167 | 5.59 | 13.3 | 0.975 |
| 130 | 2.22 | 5.0 | 0.986 | 168 | 5.72 | 13.6 | 0.974 |
| 140 | 2.89 | 6.8 | 0.983 | 169 | 5.85 | 13.9 | 0.974 |
| 150 | 3.72 | 8.8 | 0.981 | 170 | 5.99 | 14.2 | 0.974 |
| 151 | 3.81 | 9.0 | 0.981 | 171 | 6.13 | 14.5 | 0.973 |
| 152 | 3.90 | 9.2 | 0.980 | 172 | 6.27 | 14.9 | 0.973 |
| 153 | 4.00 | 9.4 | 0.980 | 173 | 6.42 | 15.2 | 0.973 |
| 154 | 4.10 | 9.7 | 0.979 | 174 | 6.56 | 15.6 | 0.972 |
| 155 | 4.20 | 9.9 | 0.979 | 175 | 6.71 | 15.9 | 0.972 |
| 156 | 4.31 | 10.1 | 0.979 | 176 | 6.87 | 16.3 | 0.972 |
| 157 | 4.41 | 10.4 | 0.978 | 177 | 7.02 | 16.7 | 0.971 |
| 158 | 4.52 | 10.7 | 0.978 | 178 | 7.18 | 17.1 | 0.971 |
| 159 | 4.63 | 10.9 | 0.978 | 179 | 7.34 | 17.4 | 0.971 |

## TABLE 23. (Cont.) PROPERTIES OF WATER

| Temp. °F. | Absolute Vapor Pressure | | Specific Gravity (Water at 39.2°F = 1.000) | Temp. °F. | Absolute Vapor Pressure | | Specific Gravity (Water at 39.2°F = 1.000) |
|---|---|---|---|---|---|---|---|
| | Psi. | Ft. Water | | | Psi. | Ft. Water | |
| 180 | 7.51 | 17.8 | 0.970 | 225 | 18.92 | 45.9 | 0.953 |
| 181 | 7.68 | 18.3 | 0.970 | 226 | 19.28 | 46.8 | 0.953 |
| 182 | 7.85 | 18.7 | 0.970 | 227 | 19.65 | 47.7 | 0.952 |
| 183 | 8.02 | 19.1 | 0.969 | 228 | 20.02 | 48.6 | 0.952 |
| 184 | 8.20 | 19.5 | 0.969 | 229 | 20.40 | 49.5 | 0.951 |
| 185 | 8.38 | 20.0 | 0.969 | 230 | 20.78 | 50.5 | 0.951 |
| 186 | 8.57 | 20.4 | 0.968 | 231 | 21.17 | 51.4 | 0.951 |
| 187 | 8.76 | 20.9 | 0.968 | 232 | 21.57 | 52.5 | 0.950 |
| 188 | 8.95 | 21.4 | 0.967 | 233 | 21.97 | 53.5 | 0.950 |
| 189 | 9.14 | 21.8 | 0.967 | 234 | 22.38 | 54.5 | 0.950 |
| 190 | 9.34 | 22.3 | 0.966 | 235 | 22.80 | 55.5 | 0.949 |
| 191 | 9.54 | 22.8 | 0.966 | 236 | 23.22 | 56.6 | 0.949 |
| 192 | 9.75 | 23.3 | 0.965 | 237 | 23.65 | 57.8 | 0.948 |
| 193 | 9.96 | 23.8 | 0.965 | 238 | 24.09 | 58.8 | 0.948 |
| 194 | 10.17 | 24.3 | 0.965 | 239 | 24.53 | 59.8 | 0.948 |
| 195 | 10.38 | 24.9 | 0.964 | 240 | 24.97 | 61.0 | 0.947 |
| 196 | 10.60 | 25.4 | 0.964 | 241 | 25.43 | 62.1 | 0.947 |
| 197 | 10.83 | 25.9 | 0.963 | 242 | 25.89 | 63.3 | 0.946 |
| 198 | 11.06 | 26.6 | 0.963 | 243 | 26.36 | 64.5 | 0.946 |
| 199 | 11.29 | 27.1 | 0.963 | 244 | 26.83 | 65.6 | 0.946 |
| 200 | 11.53 | 27.6 | 0.963 | 245 | 27.31 | 66.8 | 0.945 |
| 201 | 11.77 | 28.2 | 0.962 | 250 | 29.83 | 73.2 | 0.943 |
| 202 | 12.01 | 28.8 | 0.962 | 260 | 35.44 | 87.4 | 0.938 |
| 203 | 12.26 | 29.4 | 0.962 | 270 | 41.87 | 103.6 | 0.933 |
| 204 | 12.51 | 30.0 | 0.961 | 280 | 49.22 | 122.8 | 0.927 |
| 205 | 12.77 | 30.6 | 0.961 | 290 | 57.57 | 144.0 | 0.923 |
| 206 | 13.03 | 31.2 | 0.960 | 300 | 67.0 | 168.6 | 0.918 |
| 207 | 13.30 | 32.0 | 0.960 | 310 | 77.7 | 197.0 | 0.913 |
| 208 | 13.57 | 32.6 | 0.960 | 320 | 89.7 | 228.4 | 0.908 |
| 209 | 13.84 | 33.2 | 0.959 | 330 | 103.0 | 264.0 | 0.902 |
| 210 | 14.12 | 33.9 | 0.959 | 340 | 118.0 | 305.0 | 0.896 |
| 211 | 14.41 | 34.6 | 0.958 | 350 | 134.6 | 349.0 | 0.891 |
| 212 | 14.70 | 35.4 | 0.958 | 360 | 153.0 | 399.2 | 0.886 |
| 213 | 14.99 | 36.2 | 0.957 | 380 | 195.8 | 517.7 | 0.874 |
| 214 | 15.29 | 37.0 | 0.957 | 400 | 247.3 | 663.9 | 0.861 |
| 215 | 15.59 | 37.7 | 0.957 | 420 | 308.8 | 842.4 | 0.847 |
| 216 | 15.90 | 38.4 | 0.956 | 440 | 381.6 | 1058.5 | 0.833 |
| 217 | 16.22 | 39.2 | 0.956 | 460 | 466.9 | 1318.0 | 0.818 |
| 218 | 16.54 | 40.0 | 0.956 | 480 | 566.1 | 1630.5 | 0.802 |
| 219 | 16.86 | 40.8 | 0.955 | 500 | 680.8 | 2000.1 | 0.786 |
| 220 | 17.19 | 41.6 | 0.955 | 520 | 812.4 | 2445.5 | 0.767 |
| 221 | 17.52 | 42.5 | 0.955 | 540 | 962.5 | 2980.4 | 0.746 |
| 222 | 17.86 | 43.3 | 0.954 | | | | |
| 223 | 18.21 | 44.2 | 0.954 | | | | |
| 224 | 18.56 | 45.0 | 0.953 | | | | |

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## TABLE 24. ATMOSPHERIC PRESSURE, BAROMETER READING AND BOILING POINT OF WATER AT VARIOUS ALTITUDES

| Altitude | | Barometer Reading | | Atmos. Press. | | Boiling Point of Water |
|---|---|---|---|---|---|---|
| Feet | Meters | In. Hg. | Mm. Hg. | psia | Ft. Water | °F |
| − 1000 | − 304.8 | 31.0 | 788 | 15.2 | 35.2 | 213.8 |
| − 500 | − 152.4 | 30.5 | 775 | 15.0 | 34.6 | 212.9 |
| 0 | 0.0 | 29.9 | 760 | 14.7 | 33.9 | 212.0 |
| + 500 | + 152.4 | 29.4 | 747 | 14.4 | 33.3 | 211.1 |
| + 1000 | 304.8 | 28.9 | 734 | 14.2 | 32.8 | 210.2 |
| 1500 | 457.2 | 28.3 | 719 | 13.9 | 32.1 | 209.3 |
| 2000 | 609.6 | 27.8 | 706 | 13.7 | 31.5 | 208.4 |
| 2500 | 762.0 | 27.3 | 694 | 13.4 | 31.0 | 207.4 |
| 3000 | 914.4 | 26.8 | 681 | 13.2 | 30.4 | 206.5 |
| 3500 | 1066.8 | 26.3 | 668 | 12.9 | 29.8 | 205.6 |
| 4000 | 1219.2 | 25.8 | 655 | 12.7 | 29.2 | 204.7 |
| 4500 | 1371.6 | 25.4 | 645 | 12.4 | 28.8 | 203.8 |
| 5000 | 1524.0 | 24.9 | 633 | 12.2 | 28.2 | 202.9 |
| 5500 | 1676.4 | 24.4 | 620 | 12.0 | 27.6 | 201.9 |
| 6000 | 1828.8 | 24.0 | 610 | 11.8 | 27.2 | 201.0 |
| 6500 | 1981.2 | 23.5 | 597 | 11.5 | 26.7 | 200.1 |
| 7000 | 2133.6 | 23.1 | 587 | 11.3 | 26.2 | 199.2 |
| 7500 | 2286.0 | 22.7 | 577 | 11.1 | 25.7 | 198.3 |
| 8000 | 2438.4 | 22.2 | 564 | 10.9 | 25.2 | 197.4 |
| 8500 | 2590.8 | 21.8 | 554 | 10.7 | 24.7 | 196.5 |
| 9000 | 2743.2 | 21.4 | 544 | 10.5 | 24.3 | 195.5 |
| 9500 | 2895.6 | 21.0 | 533 | 10.3 | 23.8 | 194.6 |
| 10000 | 3048.0 | 20.6 | 523 | 10.1 | 23.4 | 193.7 |

## TABLE 25. WATER REQUIRED TO FEED BOILERS, U. S. GPM.

| Boiler Hp | gpm | lb./hr. | Boiler Hp | gpm | lb./hr. |
|---|---|---|---|---|---|
| 10 | 0.7 | 345 | 175 | 12.1 | 6037 |
| 20 | 1.4 | 690 | 200 | 13.8 | 6900 |
| 30 | 2.1 | 1035 | 225 | 15.5 | 7762 |
| 40 | 2.8 | 1380 | 250 | 17.2 | 8625 |
| 50 | 3.5 | 1725 | 300 | 20.7 | 10350 |
| 60 | 4.1 | 2070 | 350 | 24.1 | 12075 |
| 70 | 4.8 | 2415 | 400 | 27.6 | 13800 |
| 80 | 5.5 | 2760 | 450 | 31.1 | 15525 |
| 90 | 6.2 | 3105 | 500 | 34.5 | 17250 |
| 100 | 6.9 | 3450 | 600 | 41.4 | 20700 |
| 125 | 8.6 | 4312 | 750 | 51.8 | 25875 |
| 150 | 10.4 | 5175 | 1000 | 69.0 | 34500 |

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A Boiler horsepower is equivalent to the evaporation of 34.5 lbs. of water per hour from a feed water temperature of 212°F into steam at 212°F or, in other terms, is equal to the evaporation of 0.069 gpm per Boiler hp. The accompanying table of water requirements is based on these values.

In selecting a Boiler Feed Pump it should be remembered that most Boilers are operated at more than 100% of their rating. With modern firing methods 200% to 300% is not uncommon even with small Boilers. For example a 200 Hp Boiler operating at 300% of rating will actually evaporate 600 Boiler Hp or 41.4 gpm.

A Boiler Feed pump should always develop a pressure higher than the Boiler pressure. The amount the pump pressure exceeds the Boiler pressure is called the Excess Pressure. This excess pressure is needed to overcome the friction losses in the check valve, regulating valve, piping and in the static elevation difference between the pump location and the water level in the boiler. The amount of excess pressure required should be determined from the layout of the installation. Generally, for estimating purposes, excess pressures of 25 lbs. for 100 lb. pressure Boilers to 50 lbs. for 300 lb. Boilers can be used.

# TABLE 26. WATER REQUIREMENTS—INDUSTRIAL

The quantities reported below are clearly those of water intake—that is, the amount which is piped into an establishment—rather than consumptive use—the amount discharged to the atmosphere or incorporated into the products of a process. Thus, the wide ranges sometimes given reflect not only differences in processes or products, but differences in the use of water. In arid areas, where even the most rigorous conservation methods are economically feasible, "intake" is only a fraction of what it may be in areas where water is abundant, although "consumptive use" is virtually the same.

| CHEMICALS | UNIT | WATER REQUIRED *gal* |
|---|---|---|
| Alcohol, industrial, (100 proof) | gal | 120 |
| Alumina (Bayer process) | ton | 6,300 |
| Ammonium sulfate | ton | 200,000 |
| Butadiene | ton | 20,000-660,000* |
| Calcium carbide | ton | 30,000 |
| Carbon dioxide (from flue gas) | ton | 20,000 |
| Cottonseed oil | gal | 20 |
| Gunpowder or explosives | ton | 200,000 |
| Hydrogen | ton | 660,000 |
| Oxygen, liquid | 1,000 cu ft | 2,000 |
| Soap (laundry) | ton | 500 |
| Soda ash (ammonia soda process) 58% | ton | 18,000 |
| Sodium chlorate | ton | 60,000 |
| Sulfuric acid (contact process) 100% | ton | 650-4,875* |

| FOODS | | |
|---|---|---|
| Bread | ton | 500-1,000† |
| Canning | 100 cases #2 cans | 750-25,000† |
| Corn (wet-milling) | bu. corn | 140-240† |
| Corn syrup | bu. corn | 30-40† |
| Gelatin (edible) | ton | 13,200-20,000† |
| Meat: | | |
| Packing | ton live animals | 4,130 |
| Packing house operation | 100 hog units | 55,000 |
| Milk and milk products: | | |
| Butter | ton | 5,000 |
| Cheese | ton | 4,000 |
| Receiving & bottling | ton | 9,000 |
| Sugar: | | |
| Beet sugar | ton | 2,160 |
| Cane sugar | ton | 1,000 |

| PAPER & PULP | | |
|---|---|---|
| Ground wood pulp | ton dry | 4,000-50,000* |
| Kraft pulp | ton dry | 93,000 |
| Soda pulp | ton dry | 85,000 |
| Sulfate pulp | ton dry | 70,000 |
| Sulfite pulp | ton dry | 70,000-133,000* |
| Paper | ton | 39,000 |

## TABLE 26. (Continued)

| | UNIT | WATER REQUIRED *gal* |
|---|---|---|
| PAPER & PULP (Cont.) | | |
| Paperboard | ton | 15,000-90,000* |
| Strawboard | ton | 26,000 |
| PETROLEUM | | |
| Gasoline, natural | gal | 20 |
| Oil refining | 100 bbl. | 77,000 |
| Refined products | 100 bbl. | 15,000-1,500,000* |
| SYNTHETIC FUEL | | |
| By coal hydrogenation | 100 bbl. | 728,600 |
| From coal | 100 bbl. | 1,115,000 |
| From natural gas | 100 bbl. | 373,600 |
| From shale | 100 bbl. | 87,300 |
| TEXTILES | | |
| Cotton: | | |
| Bleaching | ton produced | 60,000-80,000 |
| Dyeing | ton produced | 8,000-16,000 |
| Rayon: | | |
| Cuprammonium (11% moisture) | ton yarn | 90,000-160,000† |
| Viscose | ton yarn | 200,000 |
| Weave, dye & finish | 1,000 yard | 15,000 |
| Woolens | ton produced | 140,000 |
| MISCELLANEOUS | | |
| Cement, portland | ton | 750 |
| Coal & coke: | | |
| By product coke | ton | 1,500-3,600† |
| Washing | ton | 200 |
| Electric power, steam generated | kwhr | 80-170* |
| Hospitals | bed per day | 135-150 |
| Iron ore (brown) | ton | 1,000 |
| Laundries: | | |
| Commercial | ton work | 8,600-11,400† |
| Institutional | ton work | 6,000 |
| Leather tanning: | | |
| Vegetable | 100 bbl. raw hide | 800 |
| Chrome | 100 bbl. raw hide | 800 |
| Rock wool | ton | 5,000 |
| Rubber, synthetic: | | |
| Buna S | ton | 631,450 |
| GR-S | ton | 28,000-670,000* |
| Steel (rolled) | net ton | 15,000-110,000* |
| Sulfur mining | ton | 3,000 |

—*Compiled* by the American Water Works Assn., New York (Dec. 1953).

*Range from no reuse to maximum recycling.

†Range covers various products or processes involved.

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# TABLE 27. WATER REQUIREMENTS—PUBLIC BUILDINGS

| Kind of Building | | Number of Fixtures | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0-50 | 51-100 | 101-200 | 201-400 | 401-800 | 801-1200 | Over 1200 | See Notes |
| Hotels and Clubs | Gpm per Fixture | .65 | .55 | .45 | .35 | .27 | .25 | .20 | A B |
| | Min. Capacity, Gpm | 25 | 35 | 60 | 100 | 150 | 225 | 300 | |
| | Max. Capacity Gpm | 33 | 55 | 90 | 140 | 210 | 300 | ...... | |
| Hospitals | Gpm per Fixture | 1.0 | .8 | .6 | .5 | .4 | .4 | .4 | A B |
| | Min. Capacity, Gpm | 25 | 55 | 85 | 125 | 210 | 330 | 500 | |
| | Max. Capacity Gpm | 50 | 80 | 120 | 200 | 320 | 480 | ...... | |
| Apartments and Apartment Hotels | Gpm per Fixture | .5 | .35 | .30 | .28 | .25 | .24 | .24 | A |
| | Min. Capacity, Gpm | 16 | 30 | 40 | 65 | 120 | 210 | 300 | |
| | Max. Capacity Gpm | 25 | 35 | 60 | 115 | 200 | 290 | ...... | |
| Mercantile | Gpm per Fixture | 1.3 | .75 | .70 | .60 | .55 | .50 | .50 | A C |
| | Min. Capacity, Gpm | 40 | 70 | 80 | 150 | 250 | 460 | 620 | |
| | Max. Capacity Gpm | 65 | 75 | 140 | 240 | 440 | 600 | ...... | |
| Office | Gpm per Fixture | 1.1 | .70 | .60 | .50 | .37 | .30 | .27 | A C |
| | Min. Capacity, Gpm | 35 | 60 | 80 | 140 | 210 | 320 | 380 | |
| | Max. Capacity Gpm | 55 | 70 | 120 | 200 | 300 | 360 | ...... | |
| Schools | Gpm per Fixture | 1.0 | .60 | .50 | .40 | .40 | .40 | .40 | A |
| | Min. Capacity, Gpm | 20 | 50 | 70 | 110 | 180 | 340 | 500 | |
| | Max. Capacity Gpm | 50 | 60 | 100 | 160 | 320 | 480 | ...... | |

A. Tables are based on equal number men and women. If major number of occupants are women increase capacity 15%.

B. Where laundry is operated in connection with building increase capacity 10%.

C. These estimates do not include water for special process work. The extra amount should be determined and added to the total capacity.

## WATER REQUIREMENTS — SWIMMING POOLS†

Table 28. indicates capacity required for swimming pools, depending upon the number of bathers accommodated per day. Many localities require that the period of recirculation must not exceed 8 hr.; others are less exacting. The period of refiltration of the pool takes into account the amount of water per bather per day, determined empirically.

The pump requirements depend upon various factors comprising the head, and upon the rate of refiltration and backwash of filter. The head is comprised of total friction in the pipes leaving the pool and draining it into the filters, as well as of the back pressure at inlets, strainers, and the resistance to filter beds. Total head is usually figured between 40 and 60 ft., depending upon pool size.

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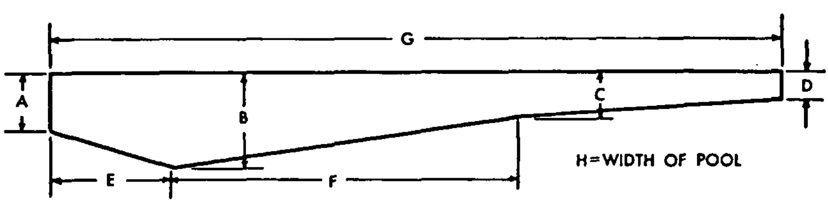
In selecting the capacity of pump, the local requirement of the minimum period of refiltration is used. In addition to the duty of recirculating, the pump must also be capable of supplying water for backwash. The flow through each filter when backwashing is four times the normal flow.

When the filter installation consists of three or more filters, and only one is backwashed at a time, then the pool circulating pump will have ample capacity for backwashing.

If a single filter is used, a separate backwash pump should be provided with a capacity aproximately four times that of the circulating pump.

## TABLE 28. WATER REQUIREMENTS—SWIMMING POOLS




| Holding Capacity, Gallons | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 55,500 | 8' | 9' | 5' | 3'3" | 15" | 20' | 60' | 20' |
| 80,800 | 8' | 9' | 5' | 3'3" | 15" | 20' | 75' | 25' |
| 120,000 | 8' | 9'6" | 5' | 3'3" | 18" | 25' | 90' | 30' |
| 155,600 | 8' | 10' | 5' | 3'3" | 18" | 25' | 105' | 35' |
| 207,600 | 8' | 10' | 5' | 3'3" | 20" | 30' | 120' | 40' |
| 254,000 | 8' | 10' | 5' | 3'3" | 20" | 30' | 135' | 45' |
| 306,000 | 8' | 10' | 5' | 3'3" | 20" | 30' | 150' | 50' |
| 422,400 | 8' | 10' | 5' | 3'3" | 20" | 30' | 180' | 60' |
| 558,000 | 8' | 10' | 5' | 3'3" | 20" | 30' | 210' | 70' |

†*Courtesy McGraw-Hill Book Co.* *See page 6.*

BATHING CAPACITY PER DAY ASSUMING 24-HOUR OPERATION ON BASIS OF REFILTRATION IN—

| Holding Capacity, Gallons | 8 Hours 400 Gallons Per Bather | | 10 Hours 625 Gallons Per Bather | | 12 Hours 900 Gallons Per Bather | | 16 Hours 1600 Gallons Per Bather | |
|---|---|---|---|---|---|---|---|---|
| | Bathers | Pump Capacity Gpm | Bathers | Pump Capacity Gpm | Bathers | Pump Capacity Gpm | Bathers | Pump Capacity Gpm |
| 55,500 | 418 | 116 | 214 | 93 | 124 | 72 | 53 | 58 |
| 80,800 | 606 | 168 | 311 | 135 | 180 | 112 | 76 | 84 |
| 120,000 | 900 | 250 | 461 | 200 | 267 | 167 | 113 | 125 |
| 155,600 | 1170 | 324 | 597 | 260 | 346 | 216 | 146 | 162 |
| 207,600 | 1555 | 432 | 796 | 346 | 461 | 288 | 195 | 216 |
| 254,000 | 1905 | 530 | 975 | 423 | 565 | 353 | 238 | 264 |
| 306,000 | 2300 | 638 | 1177 | 510 | 681 | 425 | 288 | 318 |
| 422,400 | 3170 | 880 | 1623 | 705 | 950 | 586 | 397 | 440 |
| 558,000 | 4180 | 1160 | 2145 | 930 | 1242 | 775 | 524 | 581 |

## WATER REQUIREMENTS: DOMESTIC HOT WATER SERVICE

Where a hot water system has long runs of pipe with numerous elbows, the friction may be sufficient to prevent the normal and natural circulation of the hot water. In which event, a pump is installed to supply the circulation.

When a pump is installed, it is connected in the return end of the system where the return pipe connects to the cold water side of the heater.

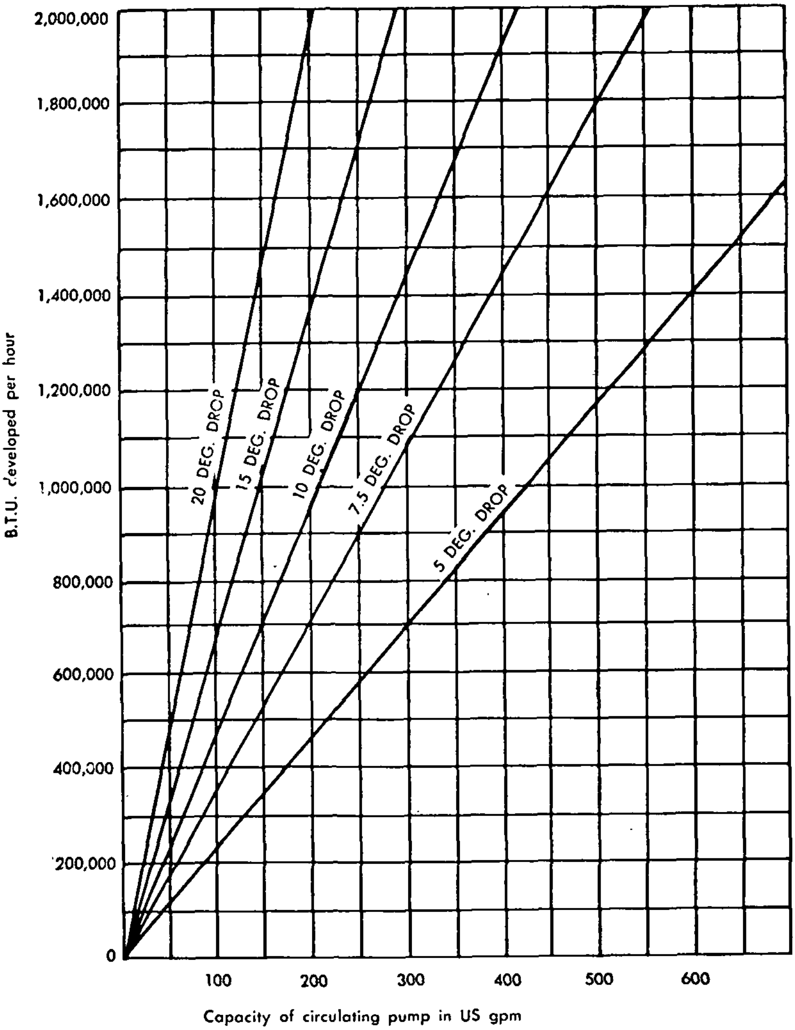
The purpose of the pump is not to pump the hot water to the fixtures, but to circulate the water in the system rapidly enough so that when a faucet is opened, hot water may be almost instantly drawn. Therefore, the capacity of the pump should be such that it moves the water through the pipes sufficiently fast to prevent it from cooling.

The capacity of a pump, determined by the following rule, will insure proper circulation so that a supply of hot water may always be available at the faucet.

> *ONE gallon per minute for each twenty fixtures using hot water where hot water pipes are covered.*
>
> *ONE gallon per minute for each four fixtures using hot water where hot water pipes are not covered.*

The friction in a domestic hot water system is usually nominal; therefore, the head against which the pump must discharge will very rarely exceed fifteen to twenty feet.

FIG. 28. PUMP CAPACITY FOR FORCED HOT WATER CIRCULATION AT VARIOUS TEMPERATURE DROPS IN HEATING SYSTEM




*Example:* 1,000,000 B.T.U. are being dissipated hourly and the temperature drop in the system is 15 deg. F. The pump must handle 150 U.S. g.p.m.

## TABLE 29.

## WATER REQUIREMENTS — RURAL & DOMESTIC

Residence—Rural:

| | |
|---|---|
| Each person per day, for all purposes | 60 gal. |
| Each horse, dry cow or beef animal per day | 12 gal. |
| Each milking cow per day | 35 gal. |
| Each hog per day | 4 gal. |
| Each sheep per day | 2 gal. |
| Each 100 chickens per day | 6 gal. |

Residence—Urban:

| | |
|---|---|
| Drinking fountain, continuously flowing | 50 to 100 gal. per day |
| Each shower bath | 25 to 60 gal. |
| To fill bathtub | 35 gal. |
| To flush toilet | 3 to 7 gal. |
| To fill lavatory | 1 to 2 gal. |
| To sprinkle ¼" of water on each 1000 square feet of lawn | 160 gal. |
| Dish Washing Machine — per load | 10 to 20 gal. |
| Automatic washer — per load | 30 to 50 gal. |
| Regeneration of Domestic Water Softener | 50-150 gal. |

By Fixtures:

| | |
|---|---|
| Shower | 4 to 6 gpm |
| Bathtub | 4 to 8 gpm |
| Toilet | 4 to 5 gpm |
| Lavatory | 1 to 4 gpm |
| Kitchen sink | 2 to 5 gpm |
| ½" hose and nozzle | 200 gph |
| ¾" hose and nozzle | 360 gph |
| Lawn sprinkler | 3 to 7 gpm |

Above requirements are average and consumption or use will vary with location, persons, animals and weather.

## WATER REQUIRED — IRRIGATION†

In the spring of the year after the heavy rains have ceased, the soil is wet to its maximum water holding capacity but it cannot be maintained in this condition through the summer growing season without the addition of water. The purpose of irrigation is to supplement natural rainfall and to supply the requisite amount of water to a cropped soil. The correct amount of water to apply will depend upon the type of crop—which determines the depth of penetration required—and upon the type of soil—which determines the amount of water that the soil can hold.

†*Courtesy Armco Drainage and Metal Products, Inc.* *See page 6.*

## TABLE 30.

## AMOUNT OF WATER NECESSARY TO IRRIGATE A SOIL TO A FIVE-FOOT DEPTH

| Soil Type | Inches of water required to increase moisture content from permanent wilting percentage to maximum field capacity. |
|---|---|
| Sandy Soils .................... | 3 to 5 inches |
| Medium Soils .................. | 6 to 10 inches |
| Heavy Soils ................... | 12 to 15 inches |

Permanent wilting percentage is the percentage of moisture at which crop plants commence to wilt and below which moisture should not be allowed to fall.

Maximum field capacity is the maximum percentage of moisture a soil will retain after irrigation.

IV

Clay soils may hold as much as 40 per cent of their dry weight in moisture, whereas sandy soils may retain only 8 per cent. Not all of this moisture, however, is available to plants. A certain percentage is held tightly by the soil particles and can not be taken up by the plant roots. The percentage so held may be as low as 2 per cent in sandy soils, but as high as 25 per cent in clay soils. When the water contents of these soils are permitted to fall to these percentages, plants will wilt and will perish unless water is added. Water should be applied before these wilting percentages are reached, to prevent damage to crops.

In applying water, best results are obtained when just enough water is applied to increase the moisture content of the root zone to the maximum water holding capacity of the soil. If more than this amount is applied it will move downward below the reach of the plant roots and will be lost. On the other hand, too shallow an irrigation should be avoided to eliminate high evaporation losses.

Since light sandy soils retain little moisture they require more frequent irrigations with relatively smaller amounts of water. A one-inch application on a sandy soil will penetrate twelve inches or more. Medium loam soils retain more moisture than sandy soils so may be irrigated at greater intervals, but with larger amounts. A one-inch application on a loam soil will penetrate six to ten inches.

Since heavy clay soils will hold a higher percentage of water than the other types, when once well moistened throughout the root zone they will retain moisture for a longer time and therefore require less frequent irrigations. The rate of application of water to clay soils must be much slower than for the lighter types, however, since water penetrates such soils slowly. One inch of water slowly applied to a heavy clay soil will penetrate 4 or 5 inches.

## TABLE 31.

## AMOUNT OF WATER AND FREQUENCY OF IRRIGATION REQUIRED FOR VARIOUS CROPS

| Crop | Amount of Water to be Applied at Each Irrigation, Inches | Time Between Irrigation, Days |
|---|---|---|
| Pastures | 2 to 3 | 14 to 21 |
| Alfalfa | 3 to 6 | 30 to 45 |
| Root Crops | 2 to 3 | 15 to 30 |
| Vegetables | 2 to 3 | 14 to 21 |
| Berries | 2 to 3 | 15 to 30 |
| Orchards | 4 to 6 | 30 to 60 |
| Ladino Clover | 2 to 3 | 14 to 21 |

The number of irrigations required will depend upon the time of planting, the time of harvest and the occurence of natural rainfall.

Generally speaking at most any place in the world 4" of precipitation per month will produce a crop. Irrigation should add the amount natural rainfall lacks. Water should never be put on the soil faster than the soil can absorb it.

## TABLE 32. PEAK MOISTURE USE FOR COMMON IRRIGATED CROPS AND OPTIMUM YIELDS*†

| | Cool Climate | | Moderate Climate | | Hot Climate | |
|---|---|---|---|---|---|---|
| Crop | Acre Inches /Acre/Day | Gpm/ Acre (1) | Acre Inches /Acre/Day | Gpm/ Acre | Acre Inches /Acre/Day | Gpm/ Acre |
| Alfalfa | .15 | 2.8 | .20 | 3.8 | .30 | 5.7 |
| Pasture | .12 | 2.3 | .16 | 3.0 | .25 | 4.7 |
| Grain | .15 | 2.8 | .20 | 3.8 | .22 | 4.2 |
| Potatoes | .10 | 1.9 | .12 | 2.3 | .14 | 2.6 |
| Beets | .12 | 2.3 | .15 | 2.8 | .20 | 3.8 |
| Deciduous Orchard | .15 | 2.8 | .20 | 3.8 | .25 | 4.7 |
| Orchard with Cover | .20 | 3.8 | .25 | 4.7 | .30 | 5.7 |

*A. W. McCulloch, S.D.S. U.S.D.A.

(1) Continuous flow required per acre at 100% irrigation efficiency. Multiply values given by the following factors:

| | |
|---|---|
| For Hot dry climate | 1.67 |
| For Moderate climate | 1.43 |
| For Humid or Cool climate | 1.25 |

Maximum precipitation rates for overhead irrigation on level ground:

Light sandy soils—1.5" to 0.75" per hr.—679 to 339 gpm per acre.
Medium textured soils—0.75" to 0.50" per hr.—339 to 226 gpm per acre.
Heavy textured soils—0.50" to 0.20" per hr.—226 to 90 gpm per acre.

Allowable rates increase with adequate cover and decrease with land slopes.

†*Courtesy Rain Bird Sprinkler Mfg. Corp. See page 6.*

Table 33 is based on 100% irrigation efficiency and 24 hour per day operation.

Example: 2″ of precipitation is to be applied every 15 days, sprinkler system operated 8 hours per day in a moderate climate.

$2.55 \times 3 \times 1.43 = 10.94$ gpm per acre.

$1.43 =$ factor obtained from footnote (1) of Table 32.

## TABLE 33. G.P.M. PER ACRE REQUIRED FOR OVERHEAD IRRIGATION—24 HOUR OPERATION†

| Frequency | Inches per Irrigation 1 | 1½ | 2 | 2½ | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|
| 7 days | 2.69 | 4.03 | 5.37 | 6.70 | 8.06 | 10.75 | 13.43 | 16.1 |
| 8 ″ | 2.36 | 3.52 | 4.70 | 5.88 | 7.05 | 9.40 | 11.75 | 14.1 |
| 9 ″ | 2.10 | 3.14 | 4.19 | 5.23 | 6.28 | 8.36 | 10.47 | 12.58 |
| 10 ″ | 1.88 | 2.82 | 3.76 | 4.70 | 5.65 | 7.54 | 9.40 | 11.3 |
| 11 ″ | 1.71 | 2.56 | 3.42 | 4.27 | 5.13 | 6.84 | 8.55 | 10.28 |
| 12 ″ | 1.57 | 2.36 | 3.14 | 3.92 | 4.71 | 6.27 | 7.85 | 9.40 |
| 13 ″ | 1.45 | 2.18 | 2.90 | 3.62 | 4.35 | 5.80 | 7.25 | 8.70 |
| 14 ″ | 1.35 | 2.02 | 2.69 | 3.36 | 4.04 | 5.38 | 6.73 | 8.08 |
| 15 ″ | 1.26 | 1.88 | 2.55 | 3.14 | 3.76 | 5.02 | 6.28 | 7.54 |
| 16 ″ | 1.18 | 1.77 | 2.36 | 2.94 | 3.54 | 4.71 | 5.90 | 7.06 |
| 17 ″ | 1.11 | 1.66 | 2.22 | 2.77 | 3.33 | 4.44 | 5.55 | 6.65 |
| 18 ″ | 1.05 | 1.57 | 2.09 | 2.62 | 3.14 | 4.18 | 5.24 | 6.28 |
| 19 ″ | 0.99 | 1.49 | 1.98 | 2.48 | 2.98 | 3.97 | 4.96 | 5.95 |
| 20 ″ | 0.94 | 1.41 | 1.88 | 2.36 | 2.83 | 3.77 | 4.71 | 5.66 |
| 21 ″ | 0.90 | 1.35 | 1.80 | 2.24 | 2.69 | 3.59 | 4.49 | 5.39 |
| 22 ″ | 0.86 | 1.28 | 1.71 | 2.14 | 2.57 | 3.43 | 4.28 | 5.14 |
| 23 ″ | 0.82 | 1.23 | 1.64 | 2.05 | 2.46 | 3.28 | 4.09 | 4.91 |
| 24 ″ | 0.78 | 1.18 | 1.57 | 1.96 | 2.36 | 3.14 | 3.92 | 4.71 |
| 25 ″ | 0.75 | 1.13 | 1.51 | 1.88 | 2.26 | 3.02 | 3.76 | 4.52 |
| 26 ″ | 0.72 | 1.09 | 1.45 | 1.81 | 2.18 | 2.90 | 3.62 | 4.35 |
| 27 ″ | 0.70 | 1.05 | 1.40 | 1.75 | 2.10 | 2.78 | 3.49 | 4.18 |
| 28 ″ | 0.67 | 1.01 | 1.35 | 1.68 | 2.02 | 2.69 | 3.36 | 4.03 |
| 29 ″ | 0.65 | 0.97 | 1.30 | 1.62 | 1.95 | 2.60 | 3.25 | 3.90 |
| 30 ″ | 0.63 | 0.94 | 1.26 | 1.57 | 1.88 | 2.51 | 3.14 | 3.76 |

For 12 hour operation multiply by 2. For 8 hour operation multiply by 3, etc.

IV

## WATER REQUIREMENTS — IRRIGATION OF TURF— GOLF COURSES, PARKS, AIRPORTS, CEMETERIES

The U. S. Department of Agriculture estimates that good healthy turf requires *one inch of water per week* but that no stand of turf can use more than a quarter inch of water per hour. (If water is applied at a faster rate, flooding occurs). This one

†*Courtesy Rain Bird Sprinkler Mfg. Corp. See page 6.*

# TABLE 34. IRRIGATION TABLE†

| Gal. min. | Cu. ft. sec. | Cu. ft. min. | Number of Acres covered in twelve hours pumping. 1 in. deep | 2 in. deep | 3 in. deep | 4 in. deep | 6 in. deep | 8 in. deep | 10 in. deep | 12 in. deep |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | .0446 | 2.675 | .529 | .2645 | .1765 | .1324 | .08825 | .06625 | .0529 | .04415 |
| 50 | .1112 | 6.68 | 1.328 | .664 | .4425 | .332 | .2213 | .166 | .1328 | .1105 |
| 100 | .2225 | 13.37 | 2.96 | 1.325 | .883 | .6625 | .442 | .3313 | .265 | .221 |
| 150 | .3345 | 20.05 | 3.98 | 1.991 | 1.328 | .995 | .664 | .4975 | .398 | .332 |
| 225 | .502 | 30.05 | 5.97 | 2.985 | 1.990 | 1.492 | .994 | .747 | .597 | .4975 |
| 300 | .668 | 40.01 | 7.96 | 3.980 | 2.655 | 1.99 | 1.327 | .995 | .796 | .663 |
| 400 | .891 | 53.40 | 10.61 | 5.305 | 3.535 | 2.652 | 1.770 | 1.328 | 1.061 | .884 |
| 700 | 1.560 | 93.50 | 18.58 | 9.28 | 6.18 | 4.64 | 3.095 | 2.32 | 1.858 | 1.548 |
| 900 | 2.008 | 120.40 | 23.85 | 11.95 | 7.96 | 5.97 | 3.98 | 2.975 | 2.385 | 1.99 |
| 1200 | 2.675 | 160.50 | 31.82 | 15.92 | 10.61 | 7.95 | 5.305 | 3.975 | 3.182 | 2.65 |
| 1600 | 3.565 | 213.50 | 42.35 | 21.20 | 14.15 | 10.61 | 7.075 | 5.305 | 4.235 | 3.536 |
| 3000 | 6.68 | 400.50 | 79.50 | 39.75 | 26.50 | 19.88 | 13.25 | 9.94 | 7.95 | 6.625 |
| 4500 | 10.03 | 602.00 | 119.30 | 59.70 | 39.75 | 29.85 | 19.90 | 14.93 | 11.93 | 9.95 |
| 6000 | 13.36 | 802.00 | 159.10 | 79.60 | 53.00 | 39.75 | 26.52 | 18.89 | 15.91 | 13.26 |
| 7000 | 15.61 | 936.00 | 185.70 | 92.80 | 61.90 | 46.45 | 30.95 | 23.20 | 18.57 | 15.47 |
| 8500 | 18.95 | 1137.00 | 225.50 | 112.80 | 75.20 | 56.35 | 37.60 | 28.19 | 22.55 | 18.79 |
| 10000 | 22.25 | 1337.00 | 266.00 | 132.50 | 88.30 | 66.25 | 44.20 | 33.15 | 26.50 | 22.10 |
| 14000 | 31.15 | 1871.00 | 371.00 | 185.50 | 123.70 | 92.75 | 61.80 | 46.35 | 37.10 | 30.95 |

1 Acrefoot = 1 acre covered to a depth of 1 ft. = 43,560 cubic feet.

†*Courtesy Ingersoll-Rand Co. See page 6.*

## TABLE 35. IRRIGATION QUANTITY TABLES

| Amount of water required to cover one acre to given depths. | | | *Second Feet and gallons per minute reduced to Gallons and Acre Feet. | | | | Gallons required to cover a given number of acres to a depth of one foot (Acre foot) | |
|---|---|---|---|---|---|---|---|---|
| Depth in feet and inches (Acre feet and acre inches) | Cubic feet contained in one acre to depths given in first column | Gallons | Second feet | Gallons per minute | Gallons per pumping day of 12 hours | Acre feet per pumping day of 12 hours | Acres (or number of acre feet) | Gallons |
| 0′- 1″ | 3,630 | 27,154 | ¼ | 112.2 | 80,790 | .2479 | 1 | 325,851 |
| 0′- 2″ | 7,260 | 54,309 | ½ | 224.4 | 161,579 | .4959 | 2 | 651,703 |
| 0′- 3″ | 10,890 | 81,463 | ¾ | 336.6 | 242,369 | .7438 | 3 | 977,554 |
| 0′- 4″ | 14,520 | 108,617 | 1 | 448.8 | 323,158 | .9917 | 4 | 1,303,406 |
| 0′- 5″ | 18,150 | 135,771 | 1¼ | 561.0 | 403,948 | 1.2397 | 5 | 1,629,257 |
| 0′- 6″ | 21,780 | 162,826 | 1½ | 673.2 | 484,738 | 1.4876 | 6 | 1,955,109 |
| 0′- 7″ | 25,410 | 190,080 | 1¾ | 785.5 | 565,527 | 1.7355 | 7 | 2,280,960 |
| 0′- 8″ | 29,040 | 217,234 | 2 | 897.7 | 646,317 | 1.9835 | 8 | 2,606,812 |
| 0′- 9″ | 32,670 | 244,389 | 2½ | 1,122.1 | 807,896 | 2.4793 | 9 | 2,932,663 |
| 0′-10″ | 36,300 | 271,542 | 3 | 1,346.5 | 969,475 | 2.9752 | 10 | 3,258,515 |
| 0′-11″ | 39,930 | 298,697 | 4 | 1,795.3 | 1,292,634 | 3.9669 | 15 | 4,887,772 |
| 1′-00″ | 43,560 | 325,851 | 5 | 2,244.2 | 1,615,792 | 4.9586 | 20 | 6,512,029 |
| 1′- 2″ | 50,820 | 380,160 | 6 | 2,693.0 | 1,938,951 | 5.9503 | 25 | 8,146,286 |
| 1′- 4″ | 58,080 | 434,469 | 7 | 3,141.8 | 2,262,109 | 6.9421 | 30 | 9,775,544 |
| 1′- 6″ | 65,340 | 488,777 | 8 | 3,590.6 | 2,585,268 | 7.9338 | 40 | 13,034,058 |
| 1′- 8″ | 72,600 | 543,086 | 9 | 4,039.5 | 2,908,426 | 8.9255 | 60 | 19,551,087 |
| 1′-10″ | 79,860 | 597,394 | 10 | 4,488.3 | 3,231,585 | 9.9173 | 80 | 26,068,116 |
| 2′-00″ | 87,120 | 651,703 | 20 | 8.976.6 | 6.463,170 | 19.8345 | 160 | 52,136,232 |

*One cubic foot of water per second (exact 7.48052 gallons) constant flow is known as the "Second Foot." The "Acre Foot" is the quantity of water required to cover one acre to a depth of one foot.

inch of water per week can fall in the form of rain, heavy dews, or be mechanically applied by sprinkling systems. The sprinkling system should be of ample capacity to supply sufficient water without rain or dew. One inch of water per week on an acre represents 27,150 gallons of water weekly. One acre is equal to 43,560 square feet.

The best results are obtained with water at atmospheric temperature. For this reason, if the water supply is from a deep well, it is usually brought to the surface with deep well pumps and discharged into artificial lakes or ponds. From the lakes or ponds the water is taken by the sprinkler pump.

On the average 18 hole golf course the greens and tees are always watered and in the majority of cases a pump with a capacity of 150 to 175 Gpm is ample. The fairways averaging 300 yards long and approximately 60 yards wide represent 52 acres of fairway. If we figure 27,150 gallons per acre per week, the 52 acres of fairway will require approximately 1,415,000 gallons of water per week. If it is estimated that the sprinkler pumping will be done in fifty hours per week (3000 minutes) the pumping rate will be 472 Gpm. This is about the usual practice, the sprinkling is done in a little over seven hours per night, seven nights a week. The average eighteen hole golf course requires a pump approximately 500 Gpm for fairway watering.

## LAND DRAINAGE — PUMPED OUTLETS

Each installation must be analized before determining the pump capacity. For preliminary estimates the following factors may be found helpful.

Multiply the land area to be drained in acres by the factor below to obtain the pump capacity in gpm:

Tile systems, subsurface drainage only—7 gpm per acre.

Surface drainage by ditch or tile, field crops—10 gpm per acre.

Surface drainage by ditch or tile, truck crops—15 gpm per acre.

# SECTION V—VISCOUS LIQUIDS

## CONTENTS

# SECTION V — PUMPING VISCOUS LIQUIDS

## PROPERTIES OF LIQUIDS

In order to solve problems involving liquids other than water, it is essential that certain liquid properties, and their relations to each other, be understood and utilized correctly. These are specific gravity, sg; density, $\rho$ (Greek letter Rho); absolute viscosity, $\mu$ (Greek letter mu); and kinematic viscosity, $\nu$ (Greek letter nu).

## SPECIFIC GRAVITY (sg)

The specific gravity of a liquid is a relative term, which shows the fluid's density with reference to fresh water at 39.2 deg. F, the point at which its density is 1.0 gr. per cu. cm.

Gravity of liquids may be given in either specific gravity directly, degrees Baume, degrees API (for oils) or Degrees Brix (for sugar) and many others, all of which are definitely related. Some of these relations are given in Section III.

## DENSITY $\rho$ (Greek Letter rho)

The density of a liquid is the mass per unit volume and in the English system is expressed as $w/g$ where $w$ is always the weight in lbs./cu. ft. and $g$ is the acceleration caused by gravity and is taken as 32.2 ft./sec./sec., or ft./sec$^2$. Density may also be computed for any liquid as follows.

Density, $(\rho) = sg \times 62.4/32.2$ slugs/cu. ft.

## VISCOSITY

The viscosity of a liquid is a measure of the internal friction tending to resist flow. This resistance to flow, expressed as a coefficient of absolute viscosity, is the force required to overcome the unit shear stress at a unit rate of shearing strain.

Viscosity is expressed in two ways, namely Absolute or Dynamic viscosity, $\mu$ (Greek letter mu) and Kinematic viscosity $\nu$ (Greek letter nu).

(1) The unit of Absolute viscosity in the metric system is the dyne-second per square centimeter. This unit is called a poise. The unit of Absolute viscosity in the English system has no name but is measured in pound seconds per square foot which may also be expressed as slugs per foot-second. To convert from one system of measurement to another:

100 centipoises = 1 poise = .00209 lb. sec./ft.$^2$

(2) Kinematic viscosity in the metric system is measured in stokes, the unit of which is centimeters squared per second. In the English system the unit is feet squared per second. To convert:

100 centistokes = 1 stoke = .00108 ft.$^2$/sec.

The above two expressions of viscosity are related for any liquid because the Kinematic viscosity is the ratio of the Absolute viscosity to the density. Hence Kinematic viscosity equals $\mu/\rho$ (mu/rho).

When the English system is used it is recommended that the Kinematic viscosity (ft.$^2$/sec.) always be determined by dividing the Absolute viscosity (lb. sec./sq.ft.) by the Density expressed as $w/g$ (lbs. per ft.$^3$ divided by 32.2 ft./sec.$^2$).

Engineers often prefer the use of centistokes because arithmetical errors are reduced as the numerical values in centistokes are almost always whole numbers rather than decimals. When using $\nu$ = ft.$^2$/sec. decimal point errors must be guarded against.

## VISCOSITY, SSU

In many tables and diagrams the variables are shown in relation to Kinematic viscosity expressed as Seconds Saybolt Universal (SSU) directly. In others the Kinematic viscosity, $\nu$ (nu), is expressed at ft.$^2$/sec. The relation between the two is shown in Fig. 32. It may be computed approximately as follows:

$$\nu \text{ (ft.}^2\text{/sec.)} = 0.000002433 \text{ SSU} - 0.00210/\text{SSU}$$

SSU in this equation being 100 or less

$$\nu \text{ (ft.}^2\text{/sec.)} = 0.000002368 \text{ SSU} - 0.00145/\text{SSU}$$

SSU in this equation being greater than 100.

V

For conversion to ft.$^2$/sec. from other viscosity determinations such as Saybolt Furol, Redwood, Engler, Barbey and centistokes see Table 36A.

## TABLE 36.
## KINEMATIC VISCOSITY OF COMMON LIQUIDS‡

| Liquid | *Sg. at 60° F | VISCOSITY SSU | At ° F |
|---|---|---|---|
| ASPHALTS: | | | |
| Unblended or virgin asphalts | 1.1 to 1.5 | 2,500 to 12,000 | 250 |
| | | 600 to 3,600 | 300 |
| Blended Asphalt | | | |
| RS-1, MS-1 or SS-1 emulsified primer or binder | Approx 1.0 | 155 to 1,000 | 77 |
| | | 90 to 350 | 100 |
| RC-O, MC-O or SC-O cutbacks or binders | Approx 1.0 | 737 to 1,500 | 77 |
| | | 280 to 500 | 100 |
| RC-1, MC-1 or SC-1 cutbacks or binders | Approx 1.0 | 2,400 to 5,000 | 100 |
| | | 737 to 1,500 | 122 |
| RC-2, MC-2 or SC-2 cutbacks or binders | Approx 1.0 | 2,400 to 5,000 | 122 |
| | | 1,000 to 2,000 | 140 |
| RC-3, MC-3 or SC-3 cutbacks or binders | Approx 1.0 | 6,000 to 13,000 | 122 |
| | | 2,500 to 5,000 | 140 |
| RC-4, MC-4 or SC-4 cutbacks or binders | Approx 1.0 | 8,000 to 20,000 | 140 |
| | | 1,250 to 2,500 | 180 |
| RC-5, MC-5 or SC-5 cutbacks or binders | Approx 1.0 | 28,000 to 85,000 | 140 |
| | | 3,000 to 6,000 | 180 |
| Asphalt Emulsion Type I Federal Specification | Approx 1.0 | 1,000 to 7,000 | 77 |
| | | 350 to 1,700 | 100 |
| Asphalt Emulsion Types II, V and VI Federal Specification | Approx 1.0 | 155 to 1,000 | 77 |
| | | 90 to 350 | 100 |
| CHEMICALS: | | | |
| Acetic Acid (100%) | 1.05 | 31.2† | 68 |
| Acetone (100%) | .79 | 29.6† | 68 |

*Unless otherwise noted.
†Data added from other sources.

‡*Courtesy Hydraulic Institute. See page 6.*

# TABLE 36. (Cont.)
# KINEMATIC VISCOSITY OF COMMON LIQUIDS

| Liquid | *Sg. at 60° F | VISCOSITY SSU | At ° F |
|---|---|---|---|
| Alcohol-Ethyl (100%) | .79 | 32.3† | 68 |
| Benzol | .88 @ 68° F | 30.3† | 68 |
| Black Liquor (typical) | 1.30 | 5.000 | 122 |
| | | 2.500 | 130 |
| Carbon Tetrachloride | 1.59 @ 68° F | 30.1† | 68 |
| Caustic Soda Solutions: | | | |
| 20% Na OH | 1.22 | 39.4 | 65 |
| 30% Na OH | 1.33 | 58.1 | 65 |
| 40% Na OH | 1.43 | 110.1 | 65 |
| Ethyl Acetate | .90 @ 68° F | 29.7† | 68 |
| Formic Acid | 1.22 @ 68° F | 32.4† | 68 |
| Freon | 1.37 to 1.49 @ 70° F | 29.3† | 70 |
| Glycerine (100%) | 1.26 @ 68° F | 2,950 | 68.6 |
| | | 813 | 100 |
| Glycol: | | | |
| Propylene | 1.04† | 240.6 | 70 |
| Triethylene | 1.13† | 185.7 | 70 |
| Diethylene | 1.12 | 149.7 | 70 |
| Ethylene | 1.13 | 88.4 | 70 |
| Hydrochloric Acid (31.5%) | 1.15† | 33† | 68 |
| Mercury | 13.6 | | 70 |
| Nitric Acid† | 1.41 | 31.5 | 68 |
| Phenol (Carbolic Acid) | .95 to 1.08 | 65 | 65 |
| Silicate of Soda | 1.38 | 365 | 100 |
| | 1.41 | 637.6 | 100 |
| Sulfuric Acid (100%) | 1.83 | 75.7 | 68 |
| FISH AND ANIMAL OILS: | | | |
| Bone Oil | .92 | 220 | 130 |
| | | 65 | 212 |
| Cod Oil | .93 | 150 | 100 |
| | | 95 | 130 |
| Lard | .96 | 287 | 100 |
| | | 160 | 130 |
| Lard Oil | .91 to .93 | 190 to 220 | 100 |
| | | 112 to 128 | 130 |
| Menhadden Oil | .93 | 140 | 100 |
| | | 90 | 130 |
| Neatsfoot Oil | .92 | 230 | 100 |
| | | 130 | 130 |
| Sperm Oil | .88 | 110 | 100 |
| | | 78 | 130 |
| Whale Oil | .93 | 163 to 184 | 100 |
| | | 97 to 112 | 130 |
| MINERAL OILS | | | |
| Automobile Cranckcase Oils (Average Midcontinent Paraffin Base): | | | |
| SAE 10 | **.88 to .94 | 165 to 240 | 100 |
| | | 90 to 120 | 130 |
| SAE 20 | **.88 to .94 | 240 to 400 | 100 |
| | | 120 to 185 | 130 |
| SAE 30 | **.88 to .94 | 400 to 580 | 100 |
| | | 185 to 255 | 130 |
| SAE 40 | **.88 to .94 | 580 to 950 | 100 |
| | | 255 to | 130 |
| | | 80 | 210 |
| SAE 50 | **.88 to .94 | 950 to 1,600 | 100 |
| | | 80 to 105 | 210 |
| SAE 60 | **.88 to .94 | 1,600 to 2,300 | 100 |
| | | 105 to 125 | 210 |
| SAE 70 | **.88 to .94 | 2,300 to 3,100 | 100 |
| | | 125 to 150 | 210 |

*Unless otherwise noted.
**Depends on origin or percent and type of solvent.
†Data added from other sources.

## TABLE 36. (Cont.)
## KINEMATIC VISCOSITY OF COMMON LIQUIDS

| Liquid | *Sg. at 60° F | VISCOSITY SSU | At ° F |
|---|---|---|---|
| SAE 10W | **.88 to .94 | 5,000 to 10,000 | 0 |
| SAE 20W | **.88 to .94 | 10,000 to 40,000 | 0 |
| Automobile Transmission Lubricants: | | | |
| SAE 80 | **.88 to .94 | 100,000 max | 0 |
| SAE 90 | **.88 to .94 | 800 to 1,500 | 100 |
| | | 300 to 500 | 130 |
| SAE 140 | **.88 to .94 | 950 to 2,300 | 130 |
| | | 120 to 200 | 210 |
| SAE 250 | **.88 to .94 | Over 2,300 | 130 |
| | | Over 200 | 210 |
| Crude Oils: | | | |
| Texas, Oklahoma | .81 to .92 | 40 to 783 | 60 |
| | | 34.2 to 210 | 100 |
| Wyoming, Montana | .86 to .88 | 74 to 1,215 | 60 |
| | | 46 to 320 | 100 |
| California | .78 to .92 | 40 to 4,840 | 60 |
| | | 34 to 700 | 100 |
| Pennsylvania | .8 to .85 | 46 to 216 | 60 |
| | | 38 to 86 | 100 |
| Diesel Engine Lubricating Oils (Based on Average Midcontinent Paraffin Base): | | | |
| Federal Specification No. 9110 | **.88 to .94 | 165 to 240 | 100 |
| | | 90 to 120 | 130 |
| Federal Specification No. 9170 | **.88 to .94 | 300 to 410 | 100 |
| | | 140 to 180 | 130 |
| Federal Specification No. 9250 | **.88 to .94 | 470 to 590 | 100 |
| | | 200 to 255 | 130 |
| Federal Specification No. 9370 | **.88 to .94 | 800 to 1,100 | 100 |
| | | 320 to 430 | 130 |
| Federal Specification No. 9500 | **.88 to .94 | 490 to 600 | 130 |
| | | 92 to 105 | 210 |
| Diesel Fuel Oils: | | | |
| No. 2 D | **.82 to .95 | 32.6 to 45.5 | 100 |
| | | 39 | 130 |
| No. 3 D | **.82 to .95 | 45.5 to 65 | 100 |
| | | 39 to 48 | 130 |
| No. 4 D | **.82 to .95 | 140 max | 100 |
| | | 70 max | 130 |
| No. 5 D | **.82 to .95 | 400 max | 122 |
| | | 165 max | 160 |
| Fuel Oils: | | | |
| No. 1 | **.82 to .95 | 34 to 40 | 70 |
| | | 32 to 35 | 100 |
| No. 2 | **.82 to .95 | 36 to 50 | 70 |
| | | 33 to 40 | 100 |
| No. 3 | **.82 to .95 | 35 to 45 | 100 |
| | | 32.8 to 39 | 130 |
| No. 5A | **.82 to .95 | 50 to 125 | 100 |
| | | 42 to 72 | 130 |
| No. 5B | **.82 to .95 | 125 to | 100 |
| | | 400 | 122 |
| | | 72 to 310 | 130 |
| No. 6 | **.82 to .95 | 450 to 3,000 | 122 |
| | | 175 to 780 | 160 |
| Fuel Oil—Navy Specification | **.99 max | 110 to 225 | 122 |
| | | 63 to 115 | 160 |
| Fuel Oil—Navy II | 1.0 max | 1,500 max | 122 |
| | | 480 max | 160 |
| Gasoline | .68 to .74 | 30† | 60 |
| | | 29.9† | 100 |
| Gasoline (Natural) | .68 | 29.6† | 68 |

*Unless otherwise noted.
**Depends on origin or percent and type of solvent.
†Data added from other sources.

## TABLE 36. (Cont.)
## KINEMATIC VISCOSITY OF COMMON LIQUIDS

| Liquid | *Sg. at 60° F | VISCOSITY SSU | At ° F |
|---|---|---|---|
| Gas Oil | .89 | 73 | 70 |
| | | 50 | 100 |
| Insulating Oil: | | | |
| Transformer, switches and circuit breakers | | 115 max | 70 |
| | | 65 max | 100 |
| Kerosene | .78 to .82 | 35 | 68 |
| | | 32.6 | 100 |
| Machine Lubricating Oil (Average Pennsylvania Paraffin Base): | | | |
| Federal Specification No. 8 | **.88 to .94 | 112 to 160 | 100 |
| | | 70 to 90 | 130 |
| Federal Specification No. 10 | **.88 to .94 | 160 to 235 | 100 |
| | | 90 to 120 | 130 |
| Federal Specification No. 20 | **.88 to .94 | 235 to 385 | 100 |
| | | 120 to 185 | 130 |
| Federal Specification No. 30 | **.88 to .94 | 385 to 550 | 100 |
| | | 185 to 255 | 130 |
| Mineral Lard Cutting Oil: | | | |
| Federal Specification Grade 1 | | 140 to 190 | 100 |
| | | 86 to 110 | 130 |
| Federal Specification Grade 2 | | 190 to 220 | 100 |
| | | 110 to 125 | 130 |
| Petrolatum | .83 | 100 | 130 |
| | | 77 | 160 |
| Turbine Lubricating Oil: | | | |
| Federal Specification (Penn Base) | .91 Average | 400 to 440 | 100 |
| | | 185 to 205 | 130 |
| VEGETABLE OILS: | | | |
| Castor Oil | .96 @ 68° F | 1,200 to 1,500 | 100 |
| | | 450 to 600 | 130 |
| China Wood Oil | .94 | 1,425 | 69 |
| | | 580 | 100 |
| Cocoanut Oil | .93† | 140 to 148 | 100 |
| | | 76 to 80 | 130 |
| Corn Oil | .92 | 135 | 130 |
| | | 54 | 212 |
| Cotton Seed Oil | .90† | 176 | 100 |
| | | 100 | 130 |
| Creosote† | 1.04 to 1.10 | 70 | 68 |
| Linseed Oil, Raw | .94† | 143 | 100 |
| | | 93 | 130 |
| Olive Oil | .92† | 200 | 100 |
| | | 115 | 130 |
| Palm Oil | .92 | 221 | 100 |
| | | 125 | 130 |
| Peanut Oil | .92 | 195 | 100 |
| | | 112 | 130 |
| Rape Seed Oil | .92 | 250 | 100 |
| | | 145 | 130 |
| Rosin Oil | .98 | 1,500 | 100 |
| | | 600 | 130 |
| Rosin (Wood) | 1.09 (Avg.) | 500 to 20,000 | 200 |
| | | 1,000 to 50,000 | 190 |
| Sesame Oil | .92 | 184 | 100 |
| | | 110 | 130 |
| Soja Bean Oil (Soya) | .93 to .98 | 165 | 100 |
| | | 96 | 130 |
| Turpentine | .87 | 33 | 60 |
| | | 32.6 | 100 |
| SUGAR, SYRUPS, MOLASSES, ETC. | | | |
| Corn Syrups | 1.5 | 5,000 to 500,000 | 100 |
| | | 1,500 to 60,000 | 130 |
| Glucose | 1.4 | 35,000 to 100,000 | 100 |
| | | 4, to 11,000 | 150 |
| Honey (Raw) | | 340 | 100 |

*Unless otherwise noted.
**Depends on origin or percent and type of solvent.
†Data added from other sources.

## TABLE 36. (Cont.)
## KINEMATIC VISCOSITY OF COMMON LIQUIDS

| Liquid | *Sg. at 60° F | VISCOSITY SSU | At ° F |
|---|---|---|---|
| Molasses "A" (First) | 1.5 | 1,300 to 23,000<br>700 to 8,000 | 100<br>130 |
| Molasses "B" (Second) | 1.5 | 6,400 to 60,000<br>3,000 to 15,000 | 100<br>130 |
| Molasses "C" (Blackstrap or final) | 1.5 | 17,000 to 250,000<br>6,000 to 75,000 | 100<br>130 |
| Sucrose Solutions (Sugar Syrups): | | | |
| 60 Brix | 1.29 | 230<br>92 | 70<br>100 |
| 62 Brix | 1.30 | 310<br>111 | 70<br>100 |
| 64 Brix | 1.31 | 440<br>148 | 70<br>100 |
| 66 Brix | 1.33 | 650<br>195 | 70<br>100 |
| 68 Brix | 1.34 | 1,000<br>275 | .70<br>100 |
| 70 Brix | 1.35 | 1,650<br>400 | 70<br>100 |
| 72 Brix | 1.36 | 2,700<br>640 | 70<br>100 |
| 74 Brix | 1.38 | 5,500<br>1,100 | 70<br>100 |
| 76 Brix | 1.39 | 10,000<br>2,000 | 70<br>100 |
| TARS: | | | |
| Tar-Coke Oven | 1.12+ | 3,000 to 8,000<br>650 to 1,400 | 71<br>100 |
| Tar-Gas House | 1.16 to 1.30 | 15,000 to 300,000<br>2,000 to 20,000 | 70<br>100 |
| Road Tar: | | | |
| Grade RT-2 | 1.07+ | 200 to 300<br>55 to 60 | 122<br>212 |
| Grade RT-4 | 1.08+ | 400 to 700<br>65 to 75 | 122<br>212 |
| Grade RT-6 | 1.09+ | 1,000 to 2,000<br>85 to 125 | 122<br>212 |
| Grade RT-8 | 1.13+ | 3,000 to 8,000<br>150 to 225 | 122<br>212 |
| Grade RT-10 | 1.14+ | 20,000 to 60,000<br>250 to 400 | 122<br>212 |
| Grade RT-12 | 1.15+ | 114,000 to 456,000<br>500 to 800 | 122<br>212 |
| Pine Tar | 1.06 | 2,500<br>500 | 100<br>132 |
| MISCELLANEOUS | | | |
| *Corn Starch Solutions:* | | | |
| 22 °B | 1.18 | 150<br>130 | 70<br>100 |
| 24 | 1.20 | 600<br>440 | 70<br>100 |
| 25 | 1.21 | 1,400<br>800 | 70<br>100 |
| Ink—Printers | 1.00 to 1.38 | 2,500 to 10,000<br>1,100 to 3,000 | 100<br>130 |
| Tallow | .92 (Avg.) | 56 | 212 |
| Milk | 1.02 to 1.05 | .31.2† | 68 |
| Varnish—Spar | .9 | 1,425<br>650 | 68<br>100 |

*Unless otherwise noted.

†Data added from other sources.

V

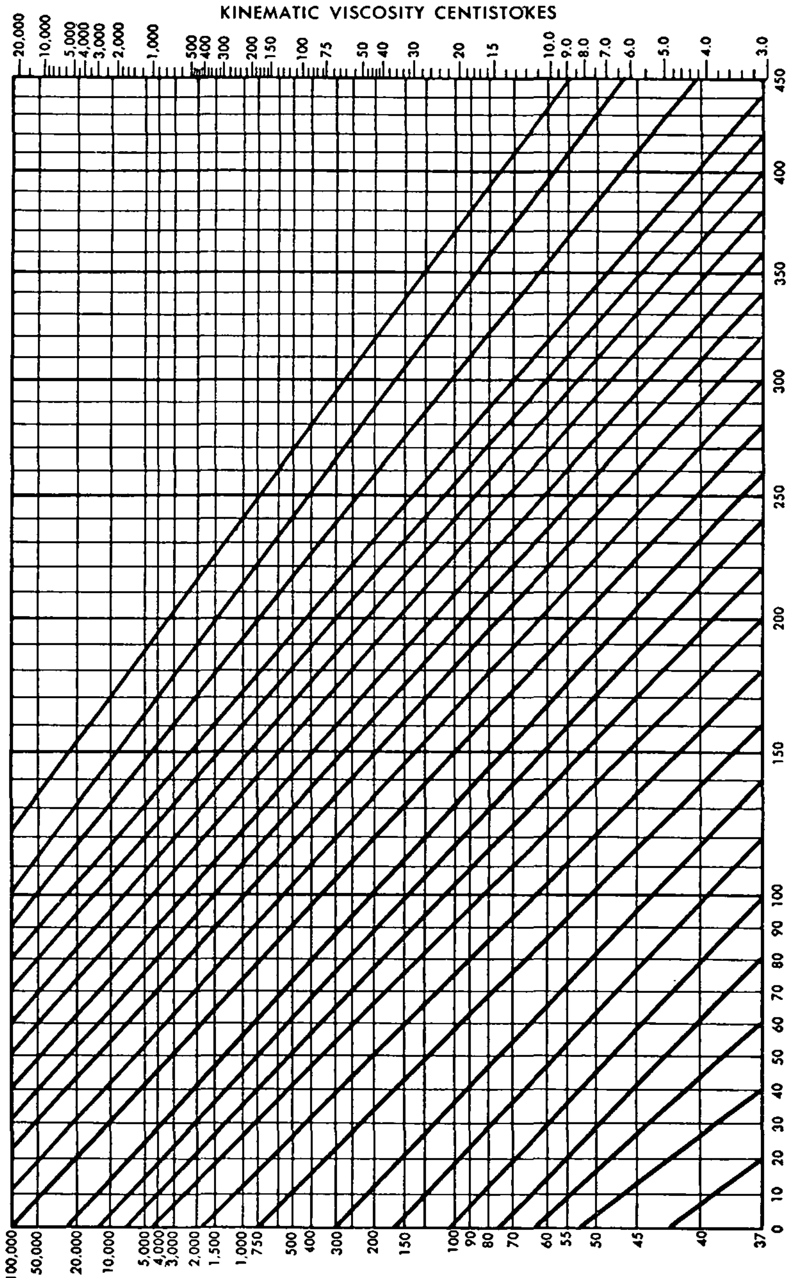



FIG. 29. Viscosity—temperature chart.†

†*Courtesy Byron Jackson Co. See page 6.*

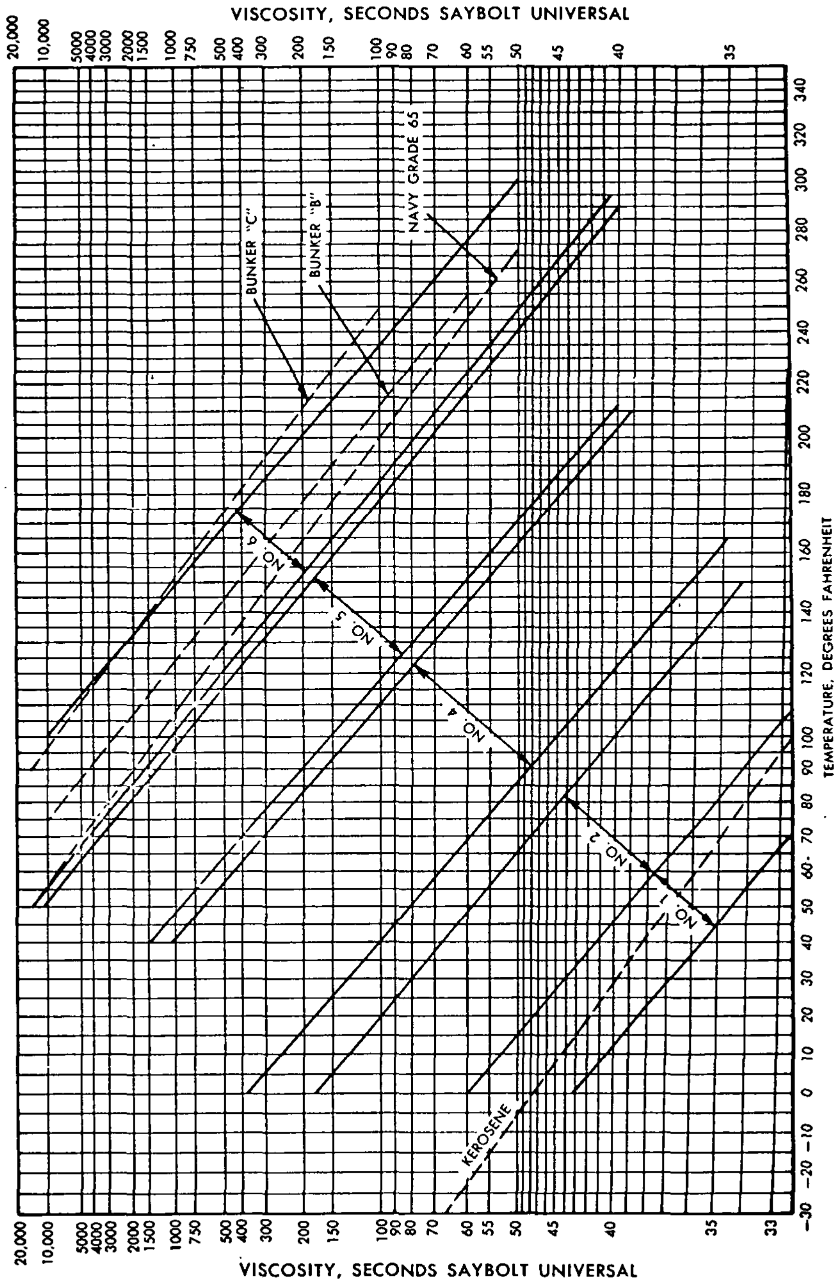



FIG. 30. Fuel oil viscosity limits. 1951 Navy grades.

V

## USE OF VISCOSITY BLENDING CHART

Many liquids designated by such names as asphalt, molasses, oil, varnish, etc., are actually blends or cut-backs and have lower viscosities than the unblended liquids of the same name. On Figure 31, let oil, A, have the higher viscosity and oil, B, the lower viscosity. Mark the viscosity of A and B on the right and left hand scales, respectively, and draw a straight line connecting the two as shown. The viscosity of any blend of A and B will be shown by the intersection of the vertical line representing the percentage composition and the line described below.

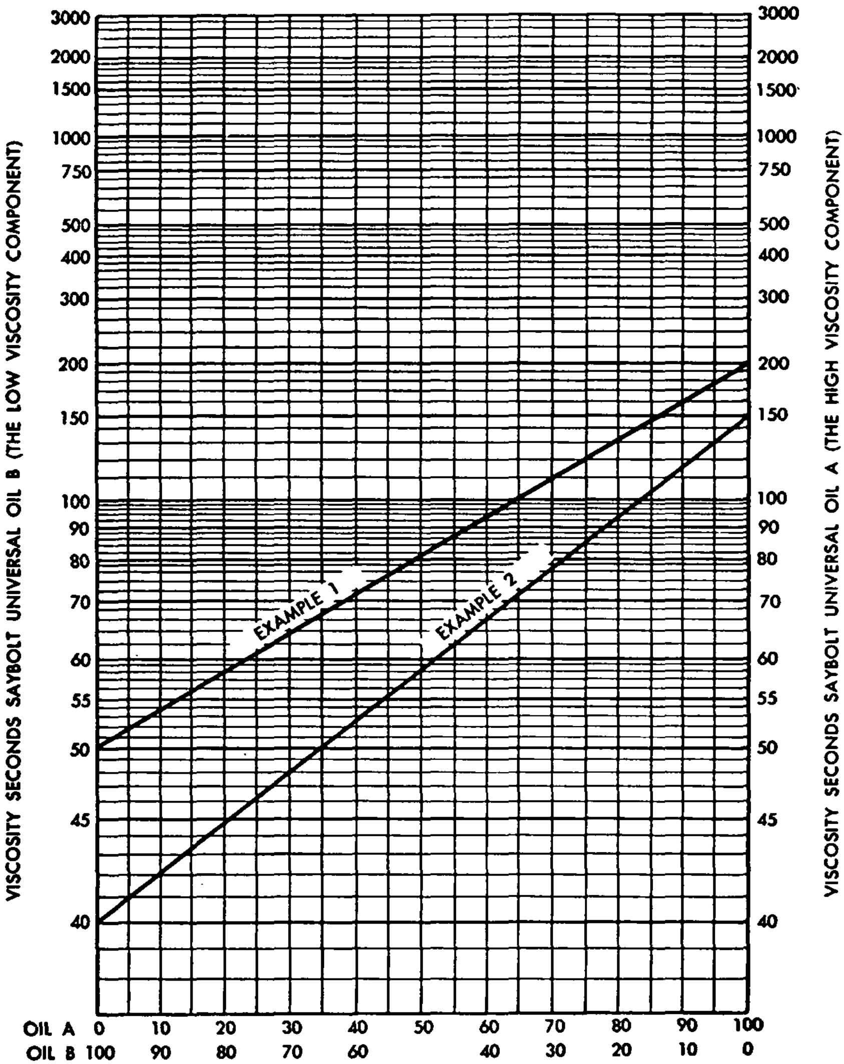



FIG. 31. Viscosity ble‑di ‑g chart.

# TABLE 36A. VISCOSITY CONVERSION TABLE†

| Seconds Saybolt Universal ssu | Kinematic Viscosity Centistokes * | Seconds Saybolt Furol ssf | Seconds Redwood 1 (Standard) | Seconds Redwood 2 (Admiralty) | Degrees Engler | Degrees Barbey | Seconds Parlin Cup #7 | Seconds Parlin Cup #10 | Seconds Parlin Cup #15 | Seconds Parlin Cup #20 | Seconds Ford Cup #3 | Seconds Ford Cup #4 | Approx. Seconds Mac Michael | Approx. Gardner Holt Bubble | Seconds Zahn Cup #1 | Seconds Zahn Cup #2 | Seconds Zahn Cup #3 | Seconds Zahn Cup #4 | Seconds Zahn Cup #5 | Seconds Demmler Cup #1 | Seconds Demmler Cup #10 | Approx. Seconds Stormer 100 gm Load | Seconds Pratt and Lambert "F" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 1.00 | – | 29 | – | 1.00 | 6200 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 35 | 2.56 | – | 32.1 | – | 1.16 | 2420 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 40 | 4.30 | – | 36.2 | 5.10 | 1.31 | 1440 | – | – | – | – | – | – | – | – | – | – | – | – | – | 1.3 | – | – | – |
| 50 | 7.40 | – | 44.3 | 5.83 | 1.58 | 838 | – | – | – | – | – | – | – | – | – | – | – | – | – | 2.3 | – | 2.6 | – |
| 60 | 10.3 | – | 52.3 | 6.77 | 1.88 | 618 | – | – | – | – | – | – | – | – | – | – | – | – | – | 3.2 | – | 3.6 | – |
| 70 | 13.1 | 12.95 | 60.9 | 7.60 | 2.17 | 483 | – | – | – | – | – | – | – | – | – | – | – | – | – | 4.1 | – | 4.6 | – |
| 80 | 15.7 | 13.70 | 69.2 | 8.44 | 2.45 | 404 | – | – | – | – | – | – | – | – | – | – | – | – | – | 4.9 | – | 5.5 | – |
| 90 | 18.2 | 14.44 | 77.6 | 9.30 | 2.73 | 348 | – | – | – | – | – | – | – | – | – | – | – | – | – | 5.7 | – | 6.4 | – |
| 100 | 20.6 | 15.24 | 85.6 | 10.12 | 3.02 | 307 | – | – | – | – | – | – | 125 | – | 38 | 18 | – | – | – | 6.5 | – | 7.3 | – |
| 150 | 32.1 | 19.30 | 128 | 14.48 | 4.48 | 195 | – | – | – | – | – | – | 145 | – | 47 | 20 | – | – | – | 10.0 | 1.0 | 11.3 | – |
| 200 | 43.2 | 23.5 | 170 | 18.90 | 5.92 | 144 | 40 | – | – | – | – | – | 165 | A | 54 | 23 | – | – | – | 13.5 | 1.4 | 15.2 | – |
| 250 | 54.0 | 28.0 | 212 | 23.45 | 7.35 | 114 | 46 | – | – | – | – | – | 198 | A | 62 | 26 | – | – | – | 16.9 | 1.7 | 19 | – |
| 300 | 65.0 | 32.5 | 254 | 28.0 | 8.79 | 95 | 52.5 | 15 | 6.0 | 3.0 | 30 | 20 | 225 | B | 73 | 29 | – | – | – | 20.4 | 2.0 | 23 | – |
| 400 | 87.60 | 41.9 | 338 | 37.1 | 11.70 | 70.8 | 66 | 21 | 7.2 | 3.2 | 42 | 28 | 270 | C | 90 | 37 | – | – | – | 27.4 | 2.7 | 31 | 7 |
| 500 | 110.0 | 51.6 | 423 | 46.2 | 14.60 | 56.4 | 79 | 25 | 7.8 | 3.4 | 50 | 34 | 320 | D | – | 46 | – | – | – | 34.5 | 3.5 | 39 | 8 |
| 600 | 132 | 61.4 | 508 | 55.4 | 17.50 | 47.0 | 92 | 30 | 8.5 | 3.6 | 58 | 40 | 370 | F | – | 55 | – | – | – | 41 | 4.1 | 46 | 9 |
| 700 | 154 | 71.1 | 592 | 64.6 | 20.45 | 40.3 | 106 | 35 | 9.0 | 3.9 | 67 | 45 | 420 | G | – | 63 | 22.5 | – | – | 48 | 4.8 | 54 | 9.5 |
| 800 | 176 | 81.0 | 677 | 73.8 | 23.35 | 35.2 | 120 | 39 | 9.8 | 4.1 | 74 | 50 | 470 | – | – | 72 | 24.5 | – | – | 55 | 5.5 | 62 | 10.8 |
| 900 | 198 | 91.0 | 762 | 83.0 | 26.30 | 31.3 | 135 | 41 | 10.7 | 4.3 | 82 | 57 | 515 | H | – | 80 | 27 | 18 | – | 62 | 6.2 | 70 | 11.9 |
| 1000 | 220 | 100.7 | 896 | 92.1 | 29.20 | 28.2 | 149 | 43 | 11.5 | 4.5 | 90 | 62 | 570 | I | – | 88 | 29 | 20 | 13 | 69 | 6.9 | 77 | 12.4 |
| 1500 | 330 | 150 | 1270 | 138.2 | 43.80 | 18.7 | – | 65 | 15.2 | 6.3 | 132 | 90 | 805 | M | – | – | 40 | 28 | 18 | 103 | 10.3 | 116 | 16.8 |
| 2000 | 440 | 200 | 1690 | 184.2 | 58.40 | 14.1 | – | 86 | 19.5 | 7.5 | 172 | 118 | 1070 | Q | – | – | 51 | 34 | 24 | 137 | 13.7 | 154 | 22 |
| 2500 | 550 | 250 | 2120 | 230 | 73.0 | 11.3 | – | 108 | 24 | 9 | 218 | 147 | 1325 | T | – | – | 63 | 41 | 29 | 172 | 17.2 | 193 | 27.6 |
| 3000 | 660 | 300 | 2540 | 276 | 87.60 | 9.4 | – | 129 | 28.5 | 11 | 258 | 172 | 1690 | U | – | – | 75 | 48 | 33 | 206 | 20.6 | 232 | 33.7 |
| 4000 | 880 | 400 | 3380 | 368 | 117.0 | 7.05 | – | 172 | 37 | 14 | 337 | 230 | 2110 | V | – | – | – | 63 | 43 | 275 | 27.5 | 308 | 45 |
| 5000 | 1100 | 500 | 4230 | 461 | 146 | 5.64 | – | 215 | 47 | 18 | 425 | 290 | 2635 | W | – | – | – | 77 | 50 | 344 | 34.4 | 385 | 55.8 |
| 6000 | 1320 | 600 | 5080 | 553 | 175 | 4.70 | – | 258 | 57 | 22 | 520 | 350 | 3145 | X | – | – | – | – | 65 | 413 | 41.3 | 462 | 65.5 |
| 7000 | 1540 | 700 | 5920 | 645 | 204.5 | 4.03 | – | 300 | 67 | 25 | 600 | .410 | 3670 | – | – | – | – | – | 75 | 481 | 48 | 540 | 77 |
| 8000 | 1760 | 800 | 6770 | 737 | 233.5 | 3.52 | – | 344 | 76 | 29 | 680 | 465 | 4170 | Y | – | – | – | – | 86 | 550 | 55 | 618 | 89 |
| 9000 | 1980 | 900 | 7620 | 829 | 263 | 3.13 | – | 387 | 86 | 32 | 780 | 520 | 4700 | – | – | – | – | – | 96 | 620 | 62 | 695 | 102 |
| 10000 | 2200 | 1000 | 8460 | 921 | 292 | 2.82 | – | 430 | 96 | 35 | 850 | 575 | 5220 | Z | – | – | – | – | – | 690 | 69 | 770 | 113 |
| 15000 | 3300 | 1500 | 13700 | – | 438 | 2.50 | – | 650 | 147 | 53 | 1280 | 860 | 7720 | Z2 | – | – | – | – | – | 1030 | 103 | 1160 | 172 |
| 20000 | 4400 | 2000 | 18400 | – | 584 | 1.40 | – | 860 | 203 | 70 | 1715 | 1150 | 10500 | Z3 | – | – | – | – | – | 1370 | 137 | 1540 | 234 |

$$\text{* Kinematic Viscosity (in centistokes)} = \frac{\text{Absolute viscosity (in centipoises)}}{\text{Density}}$$

Above 250 SSUm use the following approximate conversion:

SSU = Centistokes x 4.62

Above the range of this table and within the range of the viscosimeter, multiply their rating by the following factors to convert to SSU:

| Viscosimeter | Factor |
|---|---|
| Saybolt Furol | 10. |
| Redwood Standard | 1.095 |
| Redwood Admiralty | 10.87 |
| Engler - Degrees | 34.5 |

| Viscosimeter | Factor |
|---|---|
| Parlin cup #15 | 98.2 |
| Parlin cup #20 | 187.0 |
| Ford cup # 4 | 17.4 |

| Viscosimeter | Factor |
|---|---|
| Mac Michael | 1.92 (approx.) |
| Demmler #1 | 14.6 |
| Demmler #10 | 146. |
| Stormer | 13. (approx.) |

*†Courtesy Hydraulic Institute See page 6.*

## PIPE LINE LOSSES

The loss of head in a pipe line may be computed by the Darcy-Weisbach formula for either viscous liquids or water, or may be read from tables which take into account the viscosity of the liquid being pumped.

To compute the loss by the formula various factors must first be selected or computed. They are: Relative Roughness, $\epsilon/D$ (Greek letter epsilon in inches divided by diameter in inches); Reynolds Number $R$; and friction factor, $f$.

## RELATIVE ROUGHNESS $\epsilon/D$.

Relative roughness is a ratio of the heights of protrusions inside the pipe to the average inside diameter of the pipe, both Epsilon ($\epsilon$) and $D$ are expressed in inches in the English system. From direct measurement and friction loss tests, it has been found a relation exists between relative roughness and the diameter of a pipe for a given material and method of fabrication. This is shown in Fig. 26.

## REYNOLDS NUMBER, $R$.

Reynolds Number, $R$, is a dimensionless number or ratio of velocity in ft. per sec. times the internal diameter of the pipe in feet times the density in slugs per cu.ft. divided by the absolute viscosity in lb.sec. per sq.ft.

$$R = \frac{VD\rho}{\mu}$$

This is equivalent to $R = VD/\nu$ ($VD$ divided by the kinematic viscosity). Reynolds Number is of great significance because it determines the type of flow, either laminar or turbulent, which will occur in any pipe line, the only exception being a critical zone roughly between an $R$ of 2000 to 3500. Within this zone it is recommended that problems be solved by assuming that turbulent flow is likely to occur. Computation using this assumption gives the greatest value of friction loss and hence the result is on the safe side.

It is believed use of the charts shown herein will appeal to those solving problems involving viscous liquids. When discharge in gallons per minute are known or assumed, tables 1 and 2 give the velocity quickly. Hence by simple arithmetic and use of Fig. 32 the Reynolds Number is quickly obtained with adequate accuracy. For those who prefer the greater precision of an algebraic equation, Reynolds Number for a pipe line may also be computed from the following formula:

$$R = \frac{Q}{29.4\ d\ \nu}$$

where $Q$ is in Gpm, $d$ is inside diameter of pipe in inches, and $\nu$ (nu) is kinematic viscosity in ft.$^2$/sec.

## HEAD LOSS IN PUMPING LIQUIDS

Fundamentals necessary to an understanding of movement of a liquid have been reviewed. It now remains for us to apply these fundamentals to field problems.

When Relative Roughness and Reynolds Number are selected and computed respectively, the friction factor $f$ in the Darcy-Weisbach formula

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

may be found in Fig. 33 for both the laminar and tubulent flow ranges remembering that relative roughness is significant only in the turbulent flow range. This selected value of $f$, when used in the above equation, together with the length ($L$) and diameter ($D$) in feet, and the velocity ($V$) in feet per second, the friction loss $h_f$ is obtained and is expressed in feet of liquid flowing.

V

*Explanation of Tables*

Table 38 gives the loss in head expressed in feet of liquid flowing per 100 feet of new clean Schedule 40 steel pipe.

EXAMPLE: Find the friction loss of 50 Gpm of oil in 200 feet of 2 inch schedule 40 pipe. The oil has a viscosity of 440 centistokes and a specific gravity of 0.90. From Fig. 32 the viscosity in SSU is 2000. From Table 38 the loss in 100 feet of pipe is 74.2 feet of oil.

*Use of Viscous Fluids Friction Tables*

For LAMINAR FLOW, the pressure loss is directly proportional to the kinematic viscosity and the velocity of flow. Therefore, for intermediate values of kinematic viscosity and rate of flow (Gpm), the head loss can be obtained by direct interpolation of Table 38. For pipe sizes not shown, the pressure loss will vary inversely as the fourth power of the inside diameters for the same discharge rate. The values of head loss which will be found in the shaded area of Table 38 fall within the turbulent flow region rather than in the laminar or viscous flow region. For determination of rate of flow and pipe size in this region of turbulent flow, the method described above under heading "Head loss in pumping liquids" should be used.

## FRICTION LOSS IN FITTINGS WITH VISCOUS FLOW†

When the piping system includes valves and fittings the following must be considered:

a) For TURBULENT flow the values of the equivalent lengths of straight pipe for valves and fittings as given in Table 4 should be used.

†*Courtesy Hydraulic Institute. See page 6.*

b) For LAMINAR flow the losses in valves and fittings can only be approximated. For fluids of relatively low viscosity, where the flow is adjacent to the turbulent region, the values of the equivalent straight pipe for valves and fittings, given in Table 4, can be used.

For viscosities above 500,000 SSU, the effect of the valve or fitting is small and it is probably necessary only to include its actual length as part of the pipe length. For the intermediate viscosities the approximate equivalent length can be estimated by interpolation using the following table as a guide:

TABLE 37. FRICTION LOSS IN FITTINGS—LAMINAR FLOW.

| | 3-30 GPM | 30-50 GPM | 50-100 GPM | 100-250 GPM | 250-1000 GPM |
|---|---|---|---|---|---|
| Use full value from Table 4 when viscosity is: | 100 SSU | 200 SSU | 300 SSU | 400 SSU | 500 SSU |
| Use ¾ value from Table 4 when viscosity is: | 1000 SSU | 2000 SSU | 3000 SSU | 4000 SSU | 5000 SSU |
| Use ½ value from Table 4 when viscosity is: | 10,000 SSU | 20,000 SSU | 30,000 SSU | 40,000 SSU | 50,000 SSU |
| Use ¼ value from Table 4 when viscosity is: | 100,000 SSU | 200,000 SSU | 300,000 SSU | 400,000 SSU | 500,000 SSU |
| Use actual length of valve and fittings when the viscosity exceeds: | 500,000 SSU | 500,000 SSU | — | — | — |

It must be noted that the above is only an approximation. Very little reliable test data on losses in valves and fittings for LAMINAR flow are available.

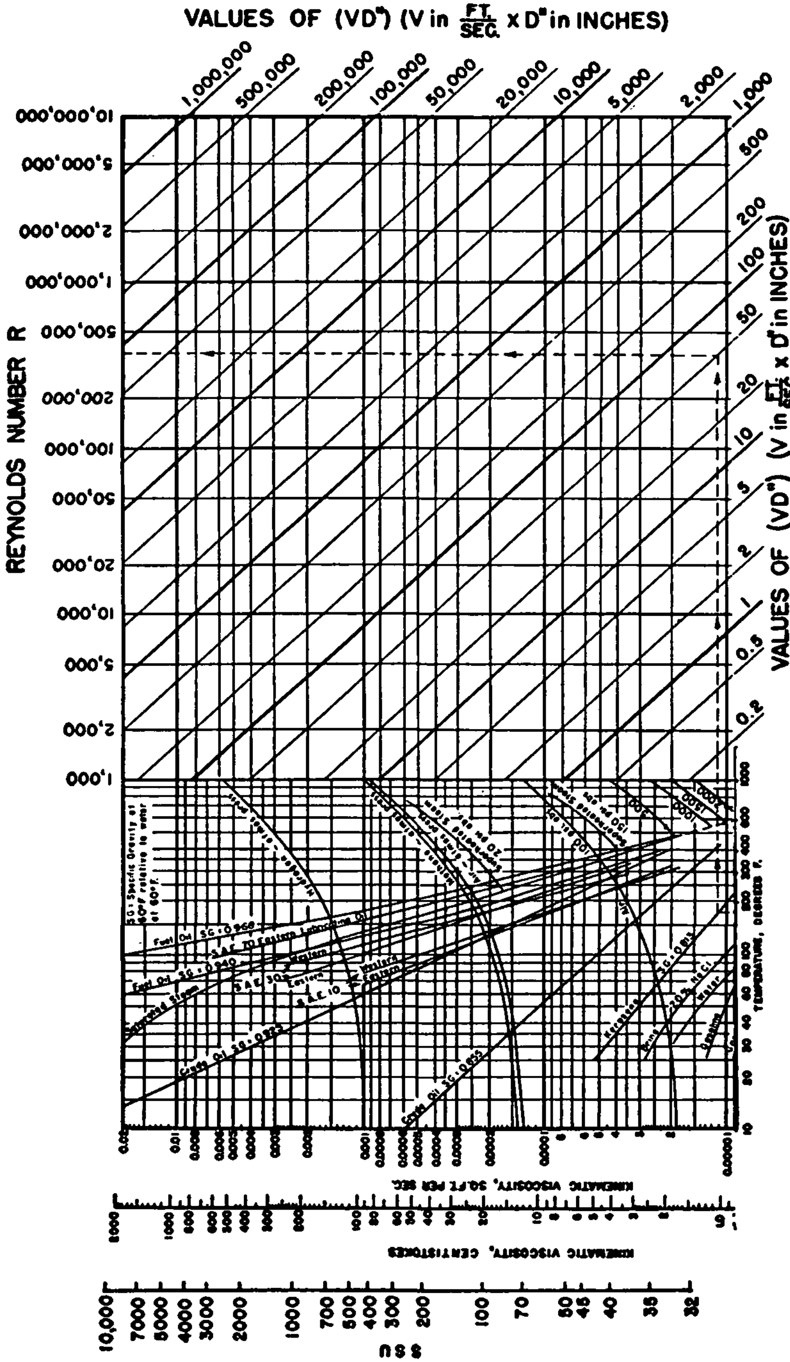





FIG. 32. Kinematic Viscosity and Reynolds Number Chart.†

†*Courtesy Hydraulic Institute. See page 6.*

# TABLE 38. FRICTION LOSS IN HEAD FOR VISCOUS LIQUIDS†

## Loss In Feet of Liquid Flowing in 100 Feet of New Schedule 40 Steel Pipe

| | | KINEMATIC VISCOSITY - SECONDS SAYBOLT UNIVERSAL | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gpm | Pipe Size | 100 | 200 | 300 | 400 | 500 | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 8000 | 10,000 | 15,000 |
| 3 | ½ | 25.9 | 54.5 | 81.5 | 108.1 | 136.3 | 272.6 | 545.2 | 815.4 | 1088.0 | 1360.6 | 1630.9 | 2176.0 | —— | —— |
| | ¾ | 8.5 | 17.6 | 26.6 | 35.3 | 44.1 | 88.2 | 175.6 | 265.7 | 353.4 | 441.2 | 529.0 | 706.9 | 882.4 | 1323.6 |
| | 1 | 3.2 | 6.7 | 10.2 | 13.4 | 16.9 | 33.5 | 67.2 | 100.7 | 134.0 | 168.6 | 201.0 | 268.0 | 335.0 | 503.6 |
| 5 | ¾ | 14.1 | 29.3 | 44.1 | 58.9 | 73.7 | 147.8 | 293.4 | 441.2 | 589.1 | 736.9 | 882.4 | 1178.1 | 1471.5 | 2208.4 |
| | 1 | 5.3 | 11.3 | 16.9 | 22.4 | 28.0 | 55.9 | 112.0 | 168.6 | 224.1 | 279.5 | 335.0 | 448.1 | 559.0 | 838.5 |
| | 1¼ | 1.8 | 3.7 | 5.5 | 7.6 | 9.5 | 18.7 | 37.4 | 56.1 | 75.1 | 93.8 | 112.5 | 150.2 | 187.1 | 281.8 |
| 7 | ¾ | 19.6 | 41.3 | 61.9 | 82.5 | 103.0 | 205.6 | 411.2 | 619.1 | 824.7 | 1030.6 | 1235.9 | 1647.0 | 2060.5 | —— |
| | 1 | 7.4 | 15.7 | 23.6 | 31.4 | 39.3 | 78.3 | 157.1 | 235.6 | 314.2 | 392.7 | 469.0 | 626.0 | 783.1 | 1175.8 |
| | 1¼ | 2.5 | 5.3 | 7.8 | 10.4 | 13.2 | 26.3 | 52.4 | 78.8 | 104.9 | 131.7 | 157.1 | 210.2 | 263.3 | 392.7 |
| 10 | 1 | 11.3 | 22.4 | 33.5 | 44.8 | 55.9 | 112.0 | 224.1 | 335.0 | 448.1 | 559.0 | 672.2 | 896.3 | 1120.4 | 1679.4 |
| | 1¼ | 3.7 | 7.6 | 11.3 | 15.0 | 18.7 | 37.4 | 75.1 | 112.5 | 150.2 | 187.1 | 224.1 | 300.3 | 374.2 | 561.3 |
| | 1½ | 1.9 | 4.2 | 6.0 | 8.1 | 10.2 | 20.3 | 40.4 | 60.8 | 80.9 | 101.2 | 122.4 | 161.7 | 203.3 | 302.6 |
| 15 | 1 | 25.4 | 33.5 | 50.4 | 67.2 | 83.9 | 168.6 | 335.0 | 503.6 | 672.2 | 838.5 | 1007.2 | 1342.1 | 1679.4 | —— |
| | 1¼ | 6.5 | 11.3 | 16.9 | 22.4 | 28.2 | 56.1 | 112.5 | 168.6 | 224.1 | 281.8 | 337.3 | 450.5 | 561.3 | 843.2 |
| | 1½ | 3.0 | 6.0 | 9.0 | 12.2 | 15.2 | 30.3 | 60.8 | 91.0 | 122.4 | 152.5 | 182.5 | 242.6 | 302.6 | 455.1 |
| 20 | 1 | 41.6 | 41.6 | 67.2 | 89.6 | 112.0 | 224.1 | 448.1 | 672.2 | 896.3 | 1120.4 | 1342.1 | 1790.3 | —— | —— |
| | 1½ | 5.3 | 8.1 | 12.2 | 16.2 | 20.3 | 40.4 | 80.9 | 122.4 | 161.7 | 203.3 | 242.6 | 323.4 | 404.3 | 607.5 |
| | 2 | 1.5 | 3.0 | 4.4 | 6.0 | 7.4 | 14.8 | 29.8 | 44.6 | 59.4 | 74.2 | 88.9 | 117.8 | 147.8 | 221.8 |
| 25 | 1½ | 8.1 | 10.2 | 15.2 | 20.8 | 25.4 | 50.6 | 101.2 | 152.5 | 203.3 | 254.1 | 302.6 | 406.6 | 505.9 | 757.7 |
| | 2 | 2.3 | 3.7 | 5.5 | 7.4 | 9.2 | 18.5 | 37.2 | 55.7 | 74.2 | 92.9 | 111.3 | 147.8 | 184.8 | 279.5 |
| | 2½ | 0.92 | 1.8 | 2.8 | 3.7 | 4.6 | 9.2 | 18.2 | 27.3 | 36.5 | 45.5 | 54.7 | 73.0 | 91.2 | 136.3 |
| 30 | 1½ | 11.6 | 12.2 | 18.2 | 24.3 | 30.3 | 60.8 | 122.4 | 182.5 | 242.6 | 302.6 | 365.0 | 485.1 | 607.5 | 910.1 |
| | 2 | 3.2 | 4.4 | 6.7 | 9.0 | 11.1 | 22.2 | 44.6 | 66.8 | 89.0 | 111.3 | 134.0 | 177.9 | 221.8 | 335.0 |
| | 2½ | 1.4 | 2.2 | 3.2 | 4.4 | 5.5 | 10.9 | 22.0 | 32.8 | 43.9 | 54.7 | 65.6 | 87.5 | 109.5 | 164.0 |
| 40 | 1½ | 19.6 | 20.8 | 24.3 | 32.3 | 40.4 | 80.8 | 161.7 | 242.6 | 323.4 | 404.2 | 485.1 | 646.8 | 808.5 | 1215.1 |
| | 2 | 5.8 | 5.8 | 9.0 | 11.8 | 14.8 | 29.8 | 59.4 | 88.9 | 117.8 | 147.8 | 177.9 | 238.0 | 298.0 | 445.8 |
| | 2½ | 2.5 | 3.0 | 4.4 | 5.8 | 7.4 | 14.6 | 29.1 | 43.9 | 58.4 | 73.0 | 87.5 | 117.8 | 145.5 | 219.4 |
| 50 | 1½ | 28.9 | 32.3 | 32.3 | 40.4 | 50.6 | 101.2 | 203.3 | 302.6 | 404.3 | 505.9 | 607.5 | 808.5 | 1011.8 | 1517.7 |
| | 2 | 8.5 | 9.2 | 11.1 | 14.8 | 18.5 | 37.2 | 74.2 | 111.3 | 147.8 | 184.8 | 221.8 | 298.0 | 372.0 | 556.7 |
| | 2½ | 3.7 | 3.9 | 5.5 | 7.4 | 9.2 | 18.2 | 36.5 | 54.7 | 73.0 | 91.2 | 109.5 | 145.5 | 182.5 | 272.6 |
| 60 | 2 | 11.6 | 13.4 | 13.4 | 17.8 | 22.2 | 44.6 | 89.0 | 134.0 | 177.9 | 221.8 | 268.0 | 355.7 | 445.8 | 667.6 |
| | 2½ | 5.1 | 5.5 | 6.5 | 8.8 | 10.9 | 22.0 | 43.9 | 65.6 | 87.5 | 109.5 | 131.7 | 175.6 | 219.5 | 328.0 |
| | 3 | 1.8 | 1.8 | 2.8 | 3.7 | 4.6 | 9.2 | 18.5 | 27.5 | 36.7 | 46.0 | 55.2 | 73.5 | 92.0 | 138.6 |
| 70 | 2½ | 6.5 | 7.4 | 7.9 | 10.2 | 12.7 | 25.7 | 51.1 | 76.7 | 102.1 | 127.1 | 152.5 | 203.3 | 256.4 | 383.5 |
| | 3 | 2.3 | 2.5 | 3.2 | 4.4 | 5.3 | 10.7 | 21.5 | 32.1 | 43.0 | 53.6 | 64.2 | 85.7 | 107.2 | 161.7 |
| | 4 | 0.62 | 0.72 | 1.1 | 1.5 | 1.8 | 3.7 | 7.2 | 10.9 | 14.5 | 18.0 | 21.7 | 28.9 | 36.0 | 54.3 |
| 80 | 2½ | 8.3 | 9.7 | 9.7 | 11.8 | 14.6 | 29.1 | 58.4 | 87.5 | 117.8 | 145.5 | 175.6 | 233.3 | 291.1 | 439.0 |
| | 3 | 3.0 | 3.2 | 3.7 | 4.8 | 6.2 | 12.2 | 24.5 | 36.7 | 49.0 | 61.2 | 73.5 | 97.9 | 122.4 | 184.8 |
| | 4 | 0.83 | 0.83 | 1.2 | 1.7 | 2.1 | 4.2 | 8.3 | 12.5 | 16.6 | 20.6 | 24.7 | 33.0 | 41.3 | 61.9 |
| 100 | 2½ | 12.2 | 14.1 | 14.8 | 14.8 | 18.5 | 36.5 | 73.0 | 109.5 | 145.5 | 182.5 | 219.5 | 293.4 | 365.0 | 547.5 |
| | 3 | 4.4 | 5.1 | 5.1 | 6.2 | 7.6 | 15.2 | 30.7 | 46.0 | 61.2 | 76.5 | 91.9 | 122.4 | 152.5 | 228.7 |
| | 4 | 1.2 | 1.3 | 1.5 | 2.1 | 2.5 | 5.1 | 10.4 | 15.5 | 20.6 | 25.9 | 31.0 | 41.3 | 51.5 | 77.4 |

TURBULENT FLOW RANGE ▭ LAMINAR OR VISCOUS FLOW RANGE ▭

†*Abridged and recalculated from Hydraulic Institute Tables.* *See page 6.*

# TABLE 38. (Cont.) FRICTION LOSS IN HEAD FOR VISCOUS LIQUIDS

## Loss In Feet of Liquid Flowing in 100 Feet of New Schedule 40 Steel Pipe

| | Pipe | KINEMATIC VISCOSITY - SECONDS SAYBOLT UNIVERSAL | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gpm | Size | 100 | 200 | 300 | 400 | 500 | 1000 | 1500 | 2000 | 4000 | 5000 | 6000 | 8000 | 10,000 | 15,000 |
| 120 | 3 | 6.2 | 7.2 | 7.4 | 7.4 | 9.2 | 18.5 | 27.5 | 36.7 | 73.5 | 91.9 | 110.2 | 147.8 | 184.8 | 274.9 |
| | 4 | 1.7 | 1.9 | 1.9 | 2.5 | 3.0 | 6.2 | 9.2 | 12.5 | 24.7 | 31.0 | 37.2 | 49.4 | 61.9 | 92.9 |
| | 6 | 0.23 | 0.25 | 0.37 | 0.49 | 0.60 | 1.2 | 1.8 | 2.3 | 4.8 | 6.0 | 7.2 | 9.7 | 12.0 | 18.0 |
| 140 | 3 | 7.9 | 9.2 | 9.9 | 9.9 | 10.6 | 21.5 | 32.9 | 43.0 | 85.7 | 107.2 | 129.4 | 170.9 | 214.8 | 321.1 |
| | 4 | 2.2 | 2.5 | 2.5 | 3.0 | 3.7 | 7.2 | 10.9 | 14.6 | 28.9 | 36.0 | 43.4 | 57.8 | 72.3 | 108.3 |
| | 6 | 0.30 | 0.35 | 0.42 | 0.55 | 0.69 | 1.4 | 2.1 | 2.8 | 5.5 | 6.9 | 8.3 | 11.3 | 14.1 | 21.0 |
| 160 | 3 | 10.2 | 11.6 | 13.2 | 13.2 | 13.2 | 24.5 | 36.7 | 49.0 | 97.9 | 122.4 | 147.8 | 196.4 | 244.9 | 367.3 |
| | 4 | 2.8 | 3.2 | 3.2 | 3.2 | 4.2 | 8.3 | 12.5 | 16.6 | 33.0 | 41.3 | 49.7 | 66.1 | 82.5 | 124.7 |
| | 6 | 0.39 | 0.42 | 0.48 | 0.65 | 0.81 | 1.6 | 2.3 | 3.2 | 6.5 | 8.1 | 9.7 | 12.7 | 15.9 | 24.0 |
| 180 | 3 | 12.2 | 14.6 | 16.2 | 16.2 | 16.2 | 27.5 | 41.3 | 55.2 | 110.2 | 138.6 | 166.3 | 219.5 | 274.9 | 413.5 |
| | 4 | 3.5 | 4.2 | 4.2 | 4.2 | 4.6 | 9.2 | 13.9 | 18.5 | 37.2 | 46.4 | 55.7 | 74.4 | 92.9 | 138.6 |
| | 6 | 0.46 | 0.55 | 0.55 | 0.72 | 0.90 | 1.8 | 2.8 | 3.7 | 7.2 | 9.0 | 10.8 | 14.3 | 18.0 | 27.0 |
| 200 | 3 | 15.0 | 17.8 | 20.3 | 20.3 | 20.3 | 30.7 | 46.0 | 61.2 | 122.4 | 152.5 | 184.8 | 244.9 | 307.2 | 459.7 |
| | 4 | 4.2 | 5.1 | 5.1 | 5.1 | 5.1 | 10.4 | 15.5 | 20.6 | 41.3 | 51.5 | 61.9 | 82.5 | 103.3 | 154.8 |
| | 6 | 0.58 | 0.69 | 0.69 | 0.81 | 0.99 | 2.0 | 3.0 | 3.9 | 8.1 | 9.9 | 12.0 | 15.9 | 20.1 | 30.0 |
| 250 | 4 | 6.0 | 7.4 | 8.1 | 8.1 | 8.1 | 12.9 | 19.4 | 25.9 | 51.5 | 64.4 | 77.4 | 103.3 | 129.4 | 194.0 |
| | 6 | 0.83 | 0.99 | 1.0 | 1.0 | 1.2 | 2.5 | 3.7 | 5.1 | 9.9 | 12.5 | 15.0 | 20.1 | 24.9 | 37.7 |
| | 8 | 0.21 | 0.28 | 0.28 | 0.35 | 0.42 | 0.83 | 1.2 | 1.7 | 3.5 | 4.2 | 5.1 | 6.7 | 8.3 | 12.5 |
| 300 | 4 | 8.5 | 9.9 | 11.6 | 11.6 | 11.6 | 15.5 | 23.3 | 31.0 | 61.9 | 77.4 | 92.9 | 124.7 | 154.8 | 233.3 |
| | 6 | 1.2 | 1.4 | 1.5 | 1.5 | 1.5 | 3.0 | 4.6 | 6.0 | 12.0 | 15.0 | 18.0 | 24.0 | 30.0 | 45.0 |
| | 8 | 0.30 | 0.39 | 0.39 | 0.42 | 0.51 | 0.99 | 1.5 | 2.0 | 3.9 | 5.1 | 6.0 | 8.1 | 9.9 | 15.0 |
| 400 | 6 | 1.9 | 2.3 | 2.5 | 2.8 | 2.8 | 3.9 | 6.0 | 8.1 | 15.9 | 20.1 | 24.0 | 32.1 | 40.0 | 60.1 |
| | 8 | 0.53 | 0.62 | 0.67 | 0.67 | 0.67 | 1.3 | 2.0 | 2.8 | 5.3 | 6.7 | 8.1 | 10.6 | 13.4 | 20.1 |
| | 10 | 0.18 | 0.21 | 0.23 | 0.23 | 0.28 | 0.53 | 0.81 | 1.1 | 2.1 | 2.8 | 3.2 | 4.4 | 5.3 | 8.1 |
| 500 | 6 | 2.8 | 3.5 | 3.7 | 4.2 | 4.2 | 5.1 | 7.4 | 9.9 | 20.1 | 24.9 | 30.0 | 40.0 | 50.1 | 75.1 |
| | 8 | 0.76 | 0.90 | 1.0 | 1.1 | 1.1 | 1.7 | 2.5 | 3.5 | 6.7 | 8.3 | 9.9 | 13.4 | 16.6 | 24.9 |
| | 10 | 0.25 | 0.32 | 0.35 | 0.35 | 0.35 | 0.67 | 1.0 | 1.3 | 2.8 | 3.5 | 4.2 | 5.3 | 6.7 | 10.2 |
| 600 | 6 | 4.2 | 5.1 | 5.3 | 5.5 | 6.0 | 6.2 | 9.0 | 12.0 | 24.0 | 30.0 | 37.0 | 48.0 | 60.0 | 90.1 |
| | 8 | 1.1 | 1.3 | 1.4 | 1.5 | 1.5 | 2.0 | 3.0 | 3.9 | 8.1 | 9.9 | 12.0 | 16.0 | 20.1 | 30.0 |
| | 10 | 0.37 | 0.42 | 0.46 | 0.51 | 0.51 | 0.81 | 1.2 | 1.6 | 3.2 | 4.2 | 4.9 | 6.5 | 8.1 | 12.0 |
| 700 | 6 | 5.3 | 6.2 | 6.9 | 7.4 | 8.1 | 8.3 | 10.6 | 14.1 | 28.0 | 35.1 | 42.5 | 56.1 | 70.0 | 105.1 |
| | 8 | 1.4 | 1.7 | 1.9 | 2.1 | 2.1 | 2.3 | 3.5 | 4.6 | 9.5 | 11.8 | 14.1 | 18.7 | 23.3 | 35.1 |
| | 10 | 0.46 | 0.58 | 0.62 | 0.69 | 0.69 | 0.95 | 1.4 | 1.9 | 3.7 | 4.6 | 5.5 | 7.6 | 9.5 | 14.1 |
| 800 | 6 | 6.5 | 8.1 | 8.5 | 9.2 | 9.7 | 11.1 | 12.0 | 16.0 | 32.1 | 40.0 | 48.0 | 64.0 | 80.2 | 120.1 |
| | 8 | 1.8 | 2.2 | 2.3 | 2.5 | 2.8 | 2.8 | 3.9 | 5.3 | 10.6 | 13.4 | 15.9 | 21.5 | 26.8 | 40.0 |
| | 10 | 0.60 | 0.69 | 0.78 | 0.88 | 0.92 | 1.1 | 1.6 | 2.1 | 4.4 | 5.3 | 6.5 | 8.5 | 10.9 | 16.2 |
| 900 | 6 | 8.1 | 9.9 | 10.6 | 11.6 | 12.0 | 13.9 | 13.9 | 18.0 | 36.0 | 45.0 | 54.1 | 72.1 | 90.1 | 135.1 |
| | 8 | 2.2 | 2.5 | 3.0 | 3.2 | 3.5 | 3.5 | 4.6 | 6.0 | 12.0 | 15.0 | 18.0 | 24.0 | 30.0 | 45.0 |
| | 10 | 0.74 | 0.85 | 0.99 | 1.1 | 1.2 | 1.2 | 1.8 | 2.5 | 4.8 | 6.0 | 7.2 | 9.7 | 12.0 | 18.2 |
| 1000 | 8 | 2.5 | 3.2 | 3.5 | 3.7 | 4.2 | 4.4 | 5.1 | 6.7 | 13.4 | 16.6 | 20.1 | 26.8 | 33.5 | 50.1 |
| | 10 | 0.88 | 1.0 | 1.2 | 1.3 | 1.4 | 1.4 | 2.0 | 2.8 | 5.3 | 6.7 | 8.1 | 10.9 | 13.4 | 20.1 |
| | 12 | 0.39 | 0.46 | 0.51 | 0.55 | 0.58 | 0.67 | 0.99 | 1.3 | 2.8 | 3.5 | 3.9 | 5.3 | 6.7 | 9.9 |

TURBULENT FLOW RANGE ▭ LAMINAR OR VISCOUS FLOW RANGE ▭

## TABLE 38. (Cont.) FRICTION LOSS IN HEAD FOR VISCOUS LIQUIDS

### Loss In Feet of Liquid Flowing in 100 Feet of New Schedule 40 Steel Pipe

| Gpm | Pipe Size | KINEMATIC VISCOSITY - SECONDS SAYBOLT UNIVERSAL | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 20,000 | 30,000 | 40,000 | 50,000 | 60,000 | 80,000 | 100,00 0 | 150,000 | 200,000 | 500,000 |
| 3 | 2 | 46.2 | 69.3 | 92.4 | 116.0 | 139.0 | 185.0 | 231.0 | 168.0 | 224.0 | 561.0 |
| | 2½ | 22.4 | 33.8 | 44.8 | 56.2 | 67.2 | 89.7 | 112.0 | 69.3 | 92.5 | 231.0 |
| | 3 | 9.25 | 13.9 | 18.5 | 23.1 | 27.7 | 37.0 | 46.1 | 347.0 | 462.0 | 1160.0 |
| 5 | 2 | 76.5 | 116.0 | 153.0 | 192.0 | 230.0 | 307.0 | 384.0 | 575.0 | 768.0 | 1910.0 |
| | 2½ | 37.5 | 56.2 | 75.0 | 93.5 | 112.0 | 149.0 | 188.0 | 282.0 | 374.0 | 938.0 |
| | 3 | 15.7 | 23.6 | 31.4 | 39.3 | 47.2 | 63.0 | 78.5 | 118.0 | 157.0 | 393.0 |
| 7 | 2 | 106.0 | 162.0 | 212.0 | 266.0 | 319.0 | 425.0 | 532.0 | 798.0 | 1060.0 | |
| | 2½ | 47.0 | 70.5 | 93.8 | 117.0 | 141.0 | 188.0 | 236.0 | 352.0 | 470.0 | 1170.0 |
| | 3 | 21.9 | 33.0 | 44.0 | 55.1 | 65.8 | 87.8 | 110.0 | 164.0 | 219.0 | 549.0 |
| 10 | 2½ | 74.0 | 110.0 | 148.0 | 185.0 | 222.0 | 296.0 | 370.0 | 555 0 | 740.0 | 1850.0 |
| | 3 | 31.4 | 47.2 | 63.0 | 78.5 | 94.2 | 126.0 | 157.0 | 252.0 | 314.0 | 785.0 |
| | 4 | 10.4 | 16.2 | 21.2 | 26.6 | 31.8 | 42.5 | 53.1 | 79.8 | 106.0 | 266.0 |
| 15 | 2½ | 111.0 | 166.0 | 222.0 | 277.0 | 333.0 | 444.0 | 555.0 | 830.0 | 1110.0 | |
| | 3 | 46.2 | 69.3 | 92.4 | 116.0 | 139.0 | 185.0 | 231.0 | 347.0 | 462.0 | 1160.0 |
| | 4 | 15.5 | 24.2 | 31.6 | 39.2 | 47.1 | 63.0 | 78.5 | 118.0 | 157.0 | 393.0 |
| 20 | 3 | 62.3 | 93.5 | 125.0 | 156.0 | 187.0 | 249.0 | 312.0 | 467.0 | 623.0 | 1560.0 |
| | 4 | 20.8 | 32.3 | 42.3 | 53.1 | 63.8 | 85.0 | 106.0 | 159.0 | 213.0 | 531.0 |
| | 6 | 4.16 | 6.23 | 8.32 | 10.6 | 12.7 | 16.9 | 21.0 | 31.7 | 42.0 | 105.0 |
| 25 | 3 | 78.5 | 118.0 | 157.0 | 196.0 | 236.0 | 318.0 | 392.0 | 590.0 | 785.0 | 1960.0 |
| | 4 | 26.1 | 40.5 | 53.1 | 66.5 | 79.8 | 106.0 | 133.0 | 199.0 | 238.0 | 665.0 |
| | 6 | 5.08 | 7.60 | 10.2 | 12.7 | 15.3 | 20.3 | 25.3 | 38.1 | 50.9 | 129.0 |
| 30 | 3 | 92.3 | 139.0 | 185.0 | 231.0 | 277.0 | 369.0 | 462.0 | 693.0 | 924.0 | |
| | 4 | 31.2 | 47.5 | 64.8 | 78.2 | 95.5 | 128.0 | 159.0 | 238.0 | 318.0 | 955.0 |
| | 6 | 6.0 | 9.01 | 12.1 | 15.0 | 18.0 | 24.1 | 30.1 | 45.1 | 60.1 | 150.0 |
| 40 | 3 | 124.0 | 187.0 | 249.0 | 312.0 | 374.0 | 500.0 | 625.0 | 935.0 | 1250.0 | |
| | 4 | 41.5 | 64.8 | 85 5 | 106.0 | 128.0 | 170.0 | 212.0 | 318.0 | 425.0 | 1060.0 |
| | 6 | 8.02 | 12.2 | 16.2 | 20.3 | 24.2 | 32.3 | 40.5 | 60.5 | 81.0 | 202.0 |
| 50 | 4 | 52.0 | 80.9 | 106.0 | 133.0 | 159.0 | 212.0 | 266.0 | 400.0 | 531.0 | 1330.0 |
| | 6 | 10.2 | 15.2 | 20.3 | 25.3 | 30.5 | 40.6 | 50.8 | 76.3 | 102.0 | 254.0 |
| | 8 | 3.46 | 5.31 | 6.93 | 8 55 | 10 4 | 13.9 | 17.3 | 26.1 | 34.6 | 86.6 |
| 60 | 4 | 62.2 | 97.0 | 126.0 | 158.0 | 190.0 | 254.0 | 316.0 | 475.0 | 632.0 | 1580.0 |
| | 6 | 12.2 | 18.5 | 24.5 | 30.7 | 36.9 | 49.3 | 61.5 | 92.0 | 123.0 | 307.0 |
| | 8 | 4.16 | 6.47 | 8.32 | 10.4 | 12.7 | 17.1 | 21.2 | 31.9 | 42.5 | 106.0 |
| 70 | 4 | 73.8 | 113.0 | 138.0 | 185.0 | 221.0 | 295.0 | 369.0 | 555.0 | 740.0 | 1847.0 |
| | 6 | 14.1 | 21.4 | 28.6 | 35.8 | 43.0 | 57.2 | 71.5 | 108.0 | 143.0 | 358.0 |
| | 8 | 4.85 | 7.40 | 9.70 | 12.2 | 14.8 | 19.6 | 24.5 | 36.7 | 48.8 | 122.0 |
| 80 | 6 | 16.2 | 24.7 | 32.8 | 41.1 | 49.2 | 65.5 | 82.0 | 123.0 | 164.0 | 410.0 |
| | 8 | 5.55 | 8.30 | 11.1 | 12.8 | 16.6 | 22.2 | 27.8 | 41.5 | 55.5 | 139.0 |
| | 10 | 2.19 | 3 00 | 4.38 | 5 31 | 6.14 | 8.55 | 11.6 | 16.2 | 21.5 | 57.8 |
| 100 | 6 | 20.3 | 30.5 | 40.6 | 50.8 | 61.0 | 81.2 | 102.0 | 152.0 | 203.0 | 508.0 |
| | 8 | 6.93 | 10.4 | 13.6 | 17.3 | 20.8 | 27.7 | 34.7 | 52.0 | 69.2 | 173.0 |
| | 10 | 2.76 | 4.16 | 5.55 | 6.93 | 8.09 | 11.1 | 16.6 | 20.7 | 27.7 | 67.0 |

LAMINAR OR VISCOUS FLOW RANGE

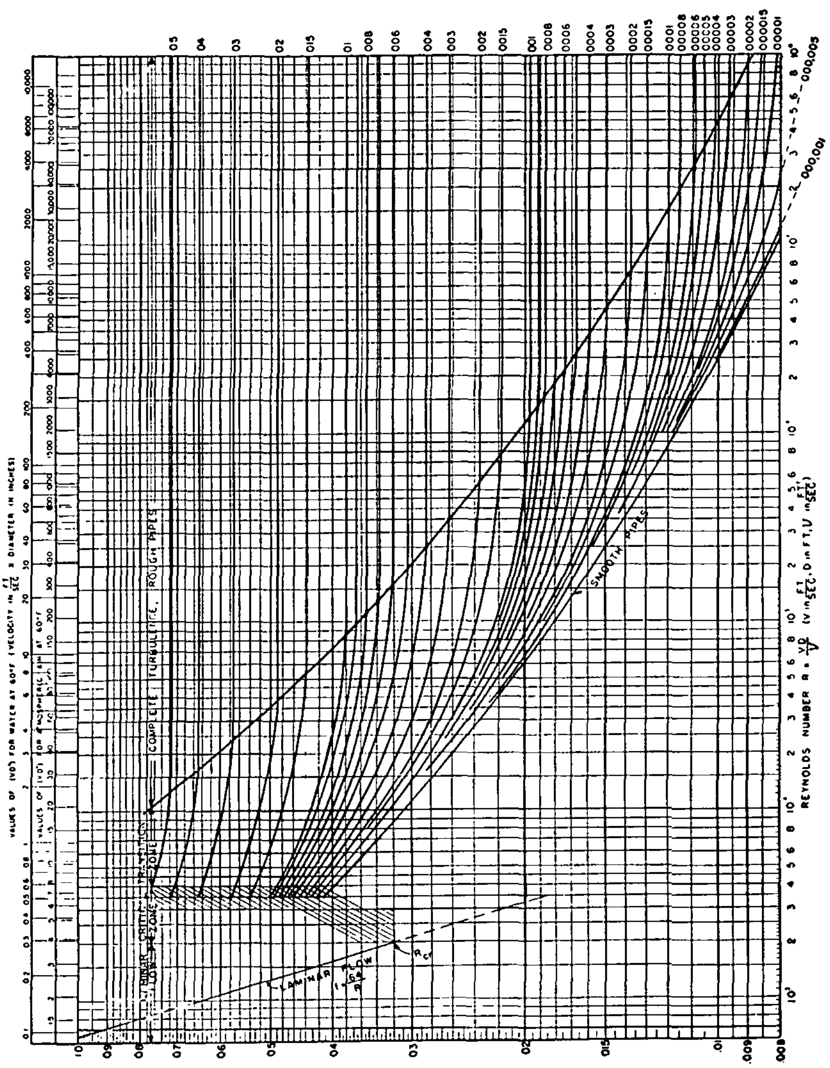
## TABLE 38. (Cont.) FRICTION LOSS IN HEAD FOR VISCOUS LIQUIDS

### Loss In Feet of Liquid Flowing in 100 Feet of New Schedule 40 Steel Pipe

| Gpm | Pipe Size | KINEMATIC VISCOSITY - SECONDS SAYBOLT UNIVERSAL | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 20,000 | 30,000 | 40,000 | 50,000 | 60,000 | 80,000 | 100,000 | 150,000 | 200,000 | 500,000 |
| 120 | 6 | 24.5 | 36.7 | 49.0 | 61.2 | 73.2 | 98.0 | 122.0 | 184.0 | 245.0 | 610.0 |
| | 8 | 8.30 | 12.4 | 16.6 | 20.7 | 24.9 | 33.3 | 41.6 | 62.3 | 83.1 | 207.0 |
| | 10 | 3.23 | 5.08 | 6.47 | 8.09 | 9.7 | 13.2 | 16.2 | 25.4 | 34.6 | 80.8 |
| 140 | 6 | 28.2 | 42.3 | 56.5 | 70.5 | 84.3 | 113.0 | 141.0 | 212.0 | 282.0 | 705.0 |
| | 8 | 9.70 | 14.5 | 19.4 | 24.2 | 29.1 | 38.8 | 48.5 | 72.5 | 97.0 | 243.0 |
| | 10 | 3.93 | 5.78 | 7.62 | 9.46 | 11.3 | 15.7 | 19.6 | 28.8 | 39.2 | 94.6 |
| 160 | 6 | 32.3 | 48.5 | 64.8 | 80.8 | 97.0 | 129.0 | 162.0 | 243.0 | 323.0 | 810.0 |
| | 8 | 11.1 | 16.6 | 22.2 | 27.7 | 33.2 | 44.5 | 55.5 | 83.0 | 111.0 | 277.0 |
| | 10 | 4.15 | 6.46 | 8.54 | 10.6 | 12.7 | 17.6 | 21.5 | 32.4 | 41.6 | 106.0 |
| 180 | 6 | 36.0 | 54.0 | 72.0 | 90.0 | 108.0 | 144.0 | 180.0 | 270.0 | 360.0 | 900.0 |
| | 8 | 12.4 | 18.5 | 24.9 | 31.2 | 37.4 | 50.0 | 62.2 | 93.7 | 125.0 | 312.0 |
| | 10 | 5.09 | 7.39 | 9.70 | 12.0 | 14.1 | 19.6 | 25.3 | 35.8 | 50.8 | 120.0 |
| 200 | 8 | 13.8 | 20.8 | 27.7 | 34.7 | 41.5 | 55.4 | 69.2 | 104.0 | 138.0 | 347.0 |
| | 10 | 5.31 | 8.08 | 10.9 | 13.6 | 15.9 | 22.4 | 2.77 | 41.6 | 53.1 | 136.0 |
| | 12 | 2.77 | 4.15 | 5.30 | 6.92 | 8.08 | 10.9 | 13.6 | 20.7 | 27.7 | 69.2 |
| 250 | 8 | 17.3 | 26.1 | 34.6 | 43.5 | 52.0 | 69.2 | 86.5 | 130.0 | 173.0 | 435.0 |
| | 10 | 6.70 | 9.94 | 13.4 | 16.6 | 19.9 | 27.7 | 34.7 | 5.09 | 69.3 | 166.0 |
| | 12 | 3.46 | 5.08 | 6.70 | 8.55 | 10.2 | 13.6 | 17.1 | 25.3 | 34.7 | 85.0 |
| 300 | 8 | 20.5 | 30.9 | 41.0 | 51.5 | 61.5 | 82.2 | 103.0 | 154.0 | 206.0 | 515.0 |
| | 10 | 8.09 | 12.0 | 16.2 | 20.6 | 25.4 | 33.7 | 42.3 | 63.4 | 80.9 | 206.0 |
| | 12 | 4.15 | 6.23 | 8.08 | 10.4 | 12.2 | 16.4 | 20.3 | 31.2 | 41.5 | 104.0 |
| 400 | 8 | 27.6 | 41.5 | 51.1 | 69.3 | 83.0 | 111.0 | 138.0 | 208.0 | 277.0 | 693.0 |
| | 10 | 1.09 | 15.9 | 21.2 | 28.4 | 34.0 | 45.3 | 53.1 | 80.9 | 109.0 | 284.0 |
| | 12 | 5.06 | 8.08 | 11.1 | 13.8 | 16.4 | 21.9 | 27.7 | 41.5 | 55.5 | 139.0 |
| 500 | 8 | 34.6 | 50.4 | 69.3 | 86.5 | 104.0 | 138.0 | 173.0 | 260.0 | 346.0 | 867.0 |
| | 10 | 13.4 | 20.1 | 28.2 | 35.0 | 42.3 | 56.0 | 67.0 | 102.0 | 134.0 | 351.0 |
| | 12 | 6.93 | 10.4 | 13.6 | 17.3 | 20.8 | 27.7 | 34.7 | 52.0 | 69.3 | 173.0 |
| 600 | 8 | 41.5 | 62.3 | 83.0 | 104.0 | 125.0 | 166.0 | 208.0 | 312.0 | 415.0 | 1040.0 |
| | 10 | 16.2 | 25.4 | 33.7 | 41.9 | 48.5 | 67.5 | 80.9 | 120.0 | 162.0 | 423.0 |
| | 12 | 8.10 | 12.4 | 16.4 | 20.8 | 24.9 | 33.3 | 41.5 | 62.2 | 83.0 | 208.0 |
| 700 | 8 | 49.0 | 73.3 | 98.0 | 122.0 | 147.0 | 196.0 | 245.0 | 367.0 | 490.0 | 1220.0 |
| | 10 | 18.9 | 29.8 | 39.7 | 49.6 | 55.5 | 79.5 | 94.6 | 139.0 | 199.0 | 496.0 |
| | 12 | 9.70 | 14.6 | 19.4 | 24.3 | 29.1 | 38.8 | 48.5 | 72.5 | 97.0 | 242.0 |
| 800 | 8 | 55.5 | 83.0 | 111.0 | 138.0 | 166.0 | 221.0 | 277.0 | 415.0 | 555.0 | 1382.0 |
| | 10 | 21.6 | 32.3 | 41.6 | 56.5 | 62.4 | 90.5 | 109.0 | 162.0 | 226.0 | 565.0 |
| | 12 | 11.1 | 16.6 | 22.2 | 27.7 | 33.2 | 44.2 | 55.5 | 83.0 | 115.0 | 277.0 |
| 900 | 8 | 62.9 | 94.2 | 125.0 | 157.0 | 188.0 | 252.0 | 314.0 | 470.0 | 628.0 | 1570.0 |
| | 10 | 25.4 | 38.1 | 50.9 | 63.5 | 71.6 | 102.0 | 120.0 | 183.0 | 254.0 | 635.0 |
| | 12 | 12.4 | 18.7 | 24.9 | 31.2 | 37.4 | 50.0 | 62.2 | 93.5 | 124.0 | 312.0 |
| 1000 | 8 | 70.0 | 105.0 | 140.0 | 175.0 | 211.0 | 282.0 | 351.0 | 528.0 | 702.0 | 1750.0 |
| | 10 | 28.6 | 43.0 | 57.3 | 67.0 | 80.9 | 114.0 | 136.0 | 204.0 | 287.0 | 670.0 |
| | 12 | 13.8 | 20.8 | 27.7 | 34.7 | 41.5 | 55.4 | 69.2 | 104.0 | 138.0 | 347.0 |

LAMINAR OR VISCOUS FLOW RANGE

Relative Roughness $\frac{\epsilon}{D}$ (Refer to Fig. 26)



Friction Factor $f = \dfrac{h_F}{\left(\dfrac{L}{D}\right)\dfrac{V^2}{2g}}$

FIG. 33. Friction for any kind and size of pipe.†

†*Courtesy Hydraulic Institute. See page 6.*

## CENTRIFUGAL PUMP PERFORMANCE WHEN HANDLING VISCOUS LIQUIDS†

It is recognized that the performance of centrifugal pumps is affected when handling viscous liquids. The effects are a marked increase in brake horsepower, a reduction in head, and some reduction in capacity at moderate and high viscosities.

It is the purpose of Fig. 34A and 34B, to provide a means of determining the performance of a conventional design of centrifugal pump handling a viscous liquid, when its performance on water is known. It is also intended to be used, by an approximate method, as an aid in selecting a pump for a given application. The corrections are based on tests of conventional single stage pumps of 2″ to 8″ size, handling petroleum oils. The correction curves are an average for several pumps and are, therefore, not exact for a particular pump. It is suggested that performance tests using the viscous liquids be conducted whenever facilities are available for an accurate test.



## LIMITATIONS FOR USE

(a) Use only within the scales shown. DO NOT extrapolate.

(b) Use only for pumps of conventional hydraulic design, in the normal operating range with open or closed impellers. DO NOT use for mixed flow or axial flow pumps or for pumps of special hydraulic design for either viscous or non-uniform liquids.

(c) Use only where adequate NPSH is available in order to avoid the effect of cavitation.

(d) Use only on Newtonian (uniform) liquids. Gels and slurries, paper stock, and other non-uniform liquids may produce widely varying results, depending on the particular characteristics of the liquid.

## INSTRUCTIONS FOR PRELIMINARY SELECTION OF A PUMP FOR GIVEN HEAD-CAPACITY-VISCOSITY CONDITION.

Given the desired capacity and head of the viscous liquid to be pumped and the viscosity and specific gravity at the pumping temperature, enter Fig. 34A & B at the bottom with the desired viscous capacity, ($Q_{vis}$) and proceed upward to the desired viscous head ($H_{vis}$) in feet of liquid. For multistage pumps, use head per stage. Proceed horizontally (either left or right) to the fluid viscosity, and then go upward to the correction curves. Divide the viscous capacity ($Q_{vis}$) by the capacity correction factor ($C_Q$) to get the approximate equivalent water capacity ($Q_W$ approx.). Divide the viscous head ($H_{vis}$) by the head correction factor ($C_H$) from the curve marked "$1.0 \times Q_n$" to get the approximate equivalent water head ($H_w$ approx.). Using this new equivalent water head-capacity point, select a pump in the usual manner.

†*Courtesy Hydraulic Institute. See page 6.*

The viscous efficiency and the viscous brake horsepower may then be calculated.

This procedure is approximate as the scales for capacity and head on the lower half of Fig. 34 A & B are based on the water performance. However, the procedure has sufficient accuracy for most pump selection purposes.

Example

Requirement: a pump to deliver 750 Gpm of oil at 100 feet total head of liquid having a viscosity of 1000 SSU and a specific gravity of 0.90 at the pumping temperature.

Enter Fig. 34B with 750 Gpm, go up to 100 feet head, over to 1000 SSU, and then up to the correction factors:

$C_Q = 0.95$ $\qquad$ $C_H = 0.92$ (for $1.0\ Q_n$) $\qquad$ $C_E = 0.635$

$Q_W = \dfrac{750}{0.95} = 790$ Gpm $\qquad$ $H_W = \dfrac{100}{0.92} = 108.8$ say 109 feet head

Select a pump for a water capacity of 790 Gpm at 109 feet head. The selection should be at or close to the maximum efficiency point for water performance. If the pump selected has an efficiency on water of 81% at 790 Gpm, the efficiency for the viscous liquid will be as follows: $E_{vis} = 0.635 \times 81\% = 51.5\%$

The brake horsepower for pumping the viscous liquid is

$$bhp_{vis} = \frac{750 \times 100 \times 0.90}{3960 \times 0.515} = 33.1\ hp$$

For performance curves of the pump selected, correct the water performance as shown in the following paragraphs.

## INSTRUCTIONS FOR DETERMINING PUMP PERFORMANCE ON A VISCOUS LIQUID WHEN PERFORMANCE ON WATER IS KNOWN.

Given the complete performance characteristics of a pump handling water to determine the performance when pumping a liquid of a specified viscosity.

From the efficiency curve, locate the water capacity ($1.0\ Q_n$) at which maximum efficiency is obtained. From this capacity, determine the capacities $0.6 \times Q_n$, $0.8 \times Q_n$ and $1.2\ Q_n$. Enter the chart at the bottom with the capacity at best efficiency ($1.0\ Q_n$), go upward to the head developed (in one stage) ($H_w$) at this capacity, then horizontally (either left or right) to the desired viscosity, and then proceed upward to the various correction curves. Read the values of $C_E$ and $C_Q$, and of $C_H$ for all four capacities. Multiply each capacity by $C_Q$ to obtain the corrected capacities. Multiply each head by its corresponding head correction factor to obtain the corrected heads. Multiply each efficiency value by $C_E$ to obtain the corrected efficiency values, which apply at the corresponding corrected capacities.

Plot corrected head and corrected efficiency against corrected capacity. Draw smooth curves through these points. The head at shut-off can be taken as approximately the same as that for water.

Calculate the viscous brake horsepower ($bph_{vis}$) from the formula given.

Plot these points and draw a smooth curve through them which should be similar to and approximately parallel to the bph curve for water.

Example†

Given the performance chart, Fig. 35 of a pump obtained by test on water, plot the performance of this pump when handling oil with a specific gravity of 0.90 and a viscosity of 1000 SSU at pumping temperature.

On the performance curve locate the best efficiency point which determines ($Q_n$), 750 Gpm. Tabulate capacity, head and efficiency for 0.6 × 750, 0.8 × 750 and 1.2 × 750 Gpm (see Table 39). Using 750 Gpm, 100 feet head and 1000 SSU, enter the chart and determine the correction factors. These are tabulated in Table 39. Multiply each value of head, capacity and efficiency by its correction factor to get the corrected values. Using the corrected values and the specific gravity, calculate brake horsepower. These calculations are shown in Table 39. Calculated points are plotted on Fig. 35 and corrected performance is represented by dashed curves.

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TABLE 39.
SAMPLE CALCULATION VISCOUS PERFORMANCE†

| | $0.6 \times Q_N$ | $0.8 \times Q_N$ | $1.0 \times Q_N$ | $1.2 \times Q_N$ |
|---|---|---|---|---|
| Water Capacity ($Q_W$) Gpm | 450.0 | 600.0 | 750.0 | 900.0 |
| Water head in feet ($H_W$) | 114.0 | 108.0 | 100.0 | 86.0 |
| Water efficiency ($E_W$) | 72.5 | 80.0 | 82.0 | 79.5 |
| Viscosity of liquid | | 1000 SSU | | |
| $C_Q$—from chart | 0.95 | 0.95 | 0.95 | 0.95 |
| $C_H$—from chart | 0.96 | 0.94 | 0.92 | 0.89 |
| $C_E$—from chart | 0.635 | 0.635 | 0.635 | 0.635 |
| Viscous capacity—$Q_W \times C_Q$ | 427.0 | 570.0 | 712.0 | 855.0 |
| Viscous head—$H_W \times C_H$ | 109.5 | 101.5 | 92.0 | 76.5 |
| Viscous efficiency—$E_W \times C_E$ | 46.0 | 50.8 | 52.1 | 50.5 |
| Specific gravity of liquid | | 0.90 | | |
| bhp viscous | 23.1 | 25.9 | 28.6 | 29.4 |

$$\text{bhp viscous} = \frac{\text{viscous capacity} \times \text{viscous head} \times \text{specific gravity}}{3960 \times \text{viscous efficiency}}$$

†*Courtesy Hydraulic Institute. See page 6.*

## VISCOSITY CORRECTIONS FOR SMALL PUMPS between 10 to 100 GPM†

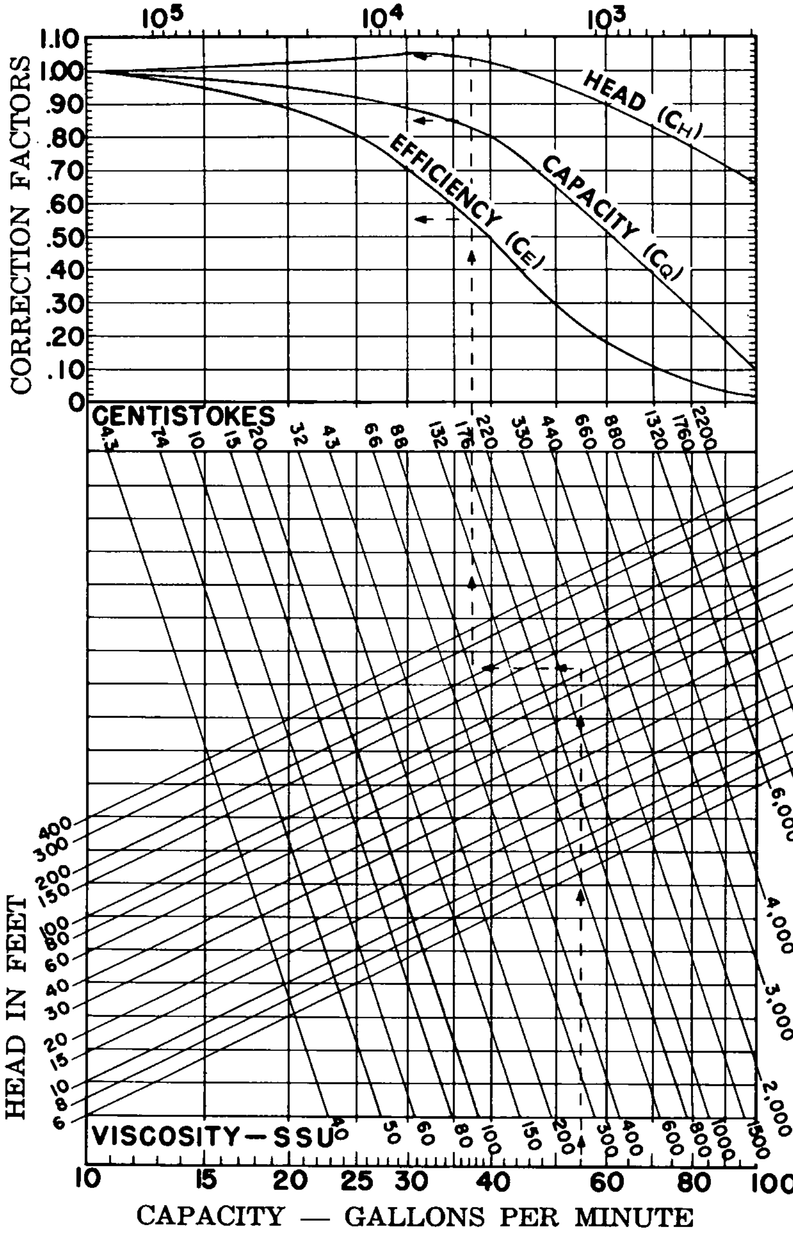


FIG. 34A. Correction factors—water performance to viscous performance for Centrifugal pumps.†

†*Courtesy Hydraulic Institute. See page 6.*

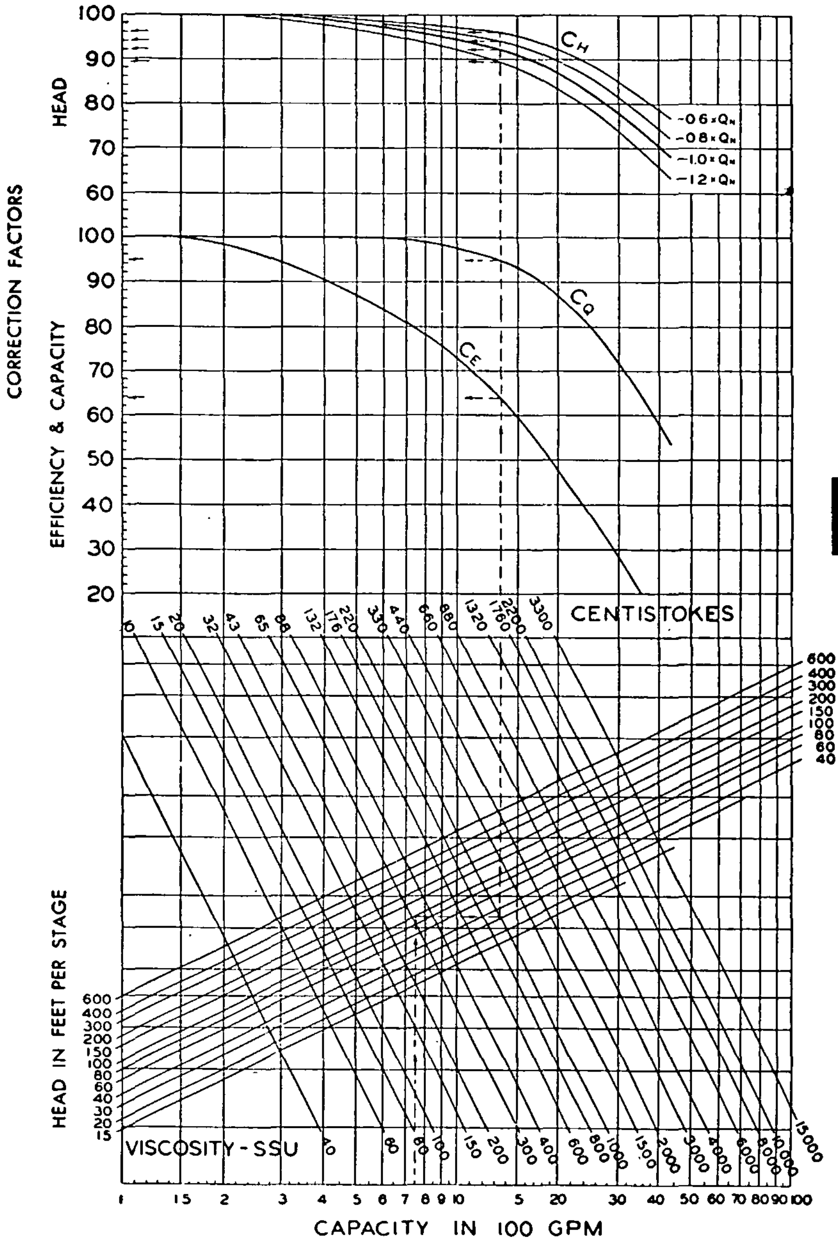


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FIG. 34B. Correction factors—water performance to viscous performance for Centrifugal pumps.†

†*Courtesy Hydraulic Institute. See page 6.*

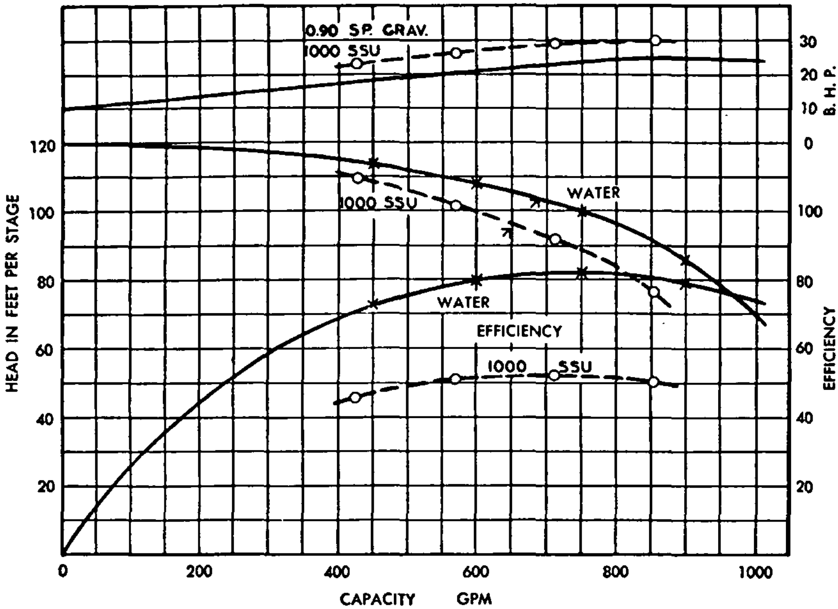


FIG. 35. Comparison of centrifugal pump performance when handling water and viscous material.†

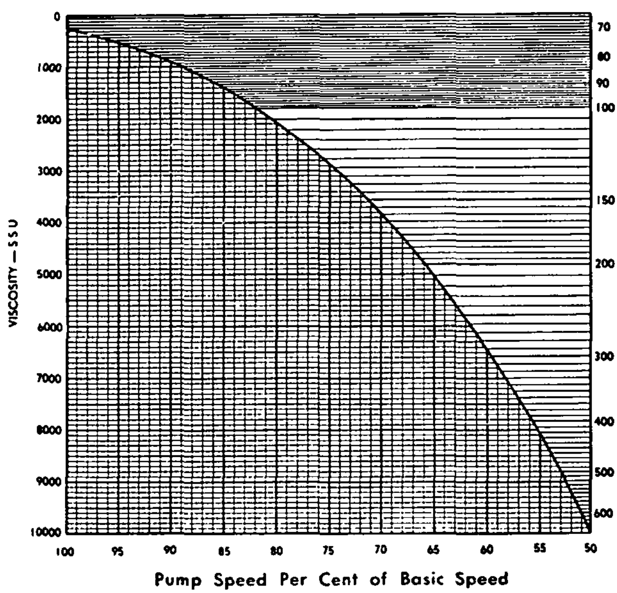


FIG. 36. Correction chart for viscosity and temperature, reciprocating pumps. †

†*Courtesy Hydraulic Institute. See page 6.*

# SECTION VI—VOLATILE LIQUIDS

## CONTENTS



VI

## SECTION VI—PUMPING VOLATILE LIQUIDS

A volatile liquid is any liquid at a temperature near its boiling point. Thus any liquid is volatile at certain conditions for any liquid, if heated sufficiently, will vaporize. In thinking of volatile liquids, such liquids as gasoline and propane come to mind, but water at atmospheric pressure and near 212°F is just as truly a volatile liquid.

Any liquid at or near its boiling point, if the pressure remains constant, will vaporize if heat is added; or also if the temperature remains constant and the pressure is reduced the liquid will boil or vaporize. This is what happens in the suction line of a pump handling volatile liquids. The absolute pressure at the suction inlet of the pump is less than the absolute pressure in the suction vessel. If this were not true the liquid would not flow toward the pump.

The problem, therefore, in pumping volatile liquids, is to keep the absolute pressure at the suction inlet to the pump higher than the absolute vapor pressure at the pumping temperature, of the liquid being pumped. In other words, as explained in Section I of this Handbook, the available NPSH of the system must exceed the required NPSH of the pump if vaporization and vapor binding are to be avoided.

To make it possible to apply the method of analysis given in the discussion of NPSH in Section I tables showing the relationship between temperature, vapor pressure and specific gravity are included in this section for some of the commonly pumped volatile liquids. Tables giving this relationship for water will be found in Section IV.

Many volatile liquids, such as Propane, Butane, Ammonia, and Freon are stored in tanks at their vapor pressure. For example a tank of commercial propane located outdoors will be subject to atmospheric temperatures and the radiant heat of the sun. If such a tank on a hot summer day has a temperature of 110°F the pressure within the tank will be 213 psia. See Table 41. If the pump location is on the same level as the liquid in the tank, the pressure drop in the suction piping between the tank and pump will be sufficient to cause the propane to boil and vapor binding may result. To make pumping such volatile liquids possible and reliable one of the following suggested procedures may be used.

1. Set the tank and pump so that the vertical distance between the pump suction inlet and minimum liquid level in the tank is equal to or greater than the required NPSH of the pump plus all losses in the suction piping.

2. Add heat by means of steam coils in the storage tank so as to raise the temperature above that of the surrounding atmoshere. This will raise the vapor pressure in the tank. Cool the liquid in the suction line by direct radiation or by means of a heat exchanger so that the temperature where the liquid enters the pump is equal to atmospheric temperature.

3. Where heat cannot be added in the storage tank a heat exchanger located near the pump suction capable of reducing the temperature of the liquid sufficiently below atmospheric temperature may be used.

The purpose of all three methods is to supply the pump with liquid at a pressure above its vapor pressure at the suction inlet to the pump impeller.

## REID VAPOR PRESSURE

The vapor pressure of gasolines is usually obtained by the Reid method. Because of the inadequacies of this test the true initial vapor pressure is not obtained. The relationship between the initial vapor pressure and the Reid vapor pressure and how they vary with temperature is given in Fig. 40.

## NPSH FOR PUMPS HANDLING HYDROCARBON LIQUIDS†

The NPSH requirements of centrifugal pumps are normally determined on the basis of handling water. It is recognized that when pumping hydrocarbons, the NPSH to obtain satisfactory operation can be reduced for certain conditions. The permissible reduction in NPSH is a function of the vapor pressure and the specific gravity of the particular hydrocarbon being pumped.

VI

It is the purpose of Fig. 37 to provide a means of estimating the NPSH required by a centrifugal pump when handling hydrocarbons of various gravities and vapor pressures in percentages of that required by the same pump when handling water. The correction curves are based on data obtained primarily from field experience. While these data had considerable variation, they have been correlated so that the curves are considered to be usable guides. The curves have the further purpose of providing a means of comparing future experience and stimulating the accumulation of additional information.

Limitations for use of net positive suction head correction chart for hydrocarbons. Fig. 37.

1. Use this chart for non-viscous hydrocarbons only.
2. Unusual operating conditions such as pumping hydrocarbons close to the cracking temperature may require additional NPSH.

## INSTRUCTIONS FOR USING NPSH CORRECTION CHARTS FOR HYDROCARBONS

Enter Fig. 37 at bottom with the specific gravity at pumping temperature of the particular hydrocarbon to be handled and proceed upward to the sloping line corresponding to the absolute vapor pressure in psi at the pumping temperature. The left hand scale

†*Courtesy Hydraulic Institute. See page 6.*

of the chart will then show the percent of the water NPSH that will be required to pump the particular hydrocarbon satisfactorily.

Example—A pump that has been selected for a given capacity and head requires 6 feet NPSH to pump water. The pump is to handle commercial isobutane at 110°F which has a vapor pressure of 85.1 psi absolute and a specific gravity of 0.53. What NPSH is required?

Enter Fig. 37 at the specific gravity (at 110°F) of 0.53 and go upward to the point corresponding to a vapor pressure of 85.1 psi absolute at 110°F. This is found by interpolation between the lines labeled 50 psi and 100 psi of the fan shaped family of absolute vapor pressure lines in the chart. The left scale will then show the value of the correction factor to be applied to the water NPSH as 0.91.

Therefore, when pumping isobutane at 110°F the pump will require 0.91 × 6 or 5.5 feet NPSH.

If the isobutane is to be pumped at a temperature of 60°F, the vapor pressure will be 38.7 psi absolute and the specific gravity will be 0.56. In this case, the NPSH is the same as required for water, i.e., 6 ft.

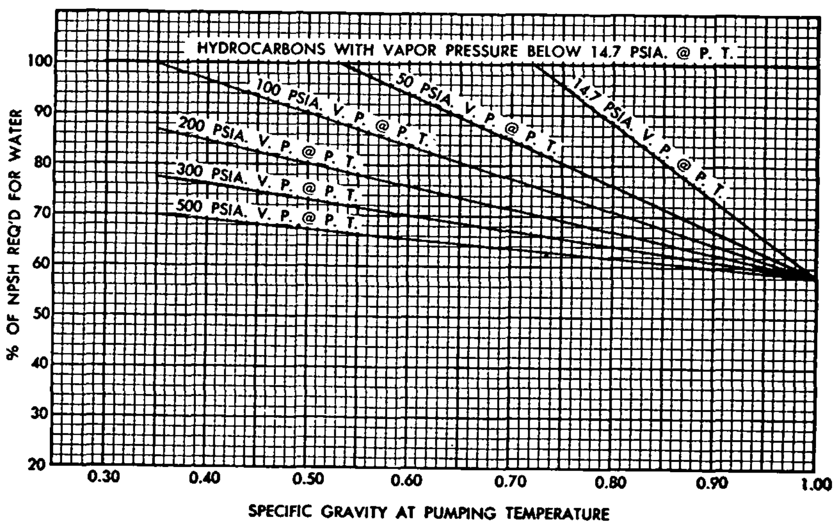


FIG. 37. NPSH correction chart for hydrocarbons. (Not to be used for other liquids.)

## TABLE 41. VOLATILE LIQUIDS—VAPOR PRESSURE AND SPECIFIC GRAVITY

| Temp °F | AMMONIA Vapor Press psia | AMMONIA Sg * | CARBON DIOXIDE Vapor Press psia | CARBON DIOXIDE Sg * | FREON 12 Vapor Press psia | FREON 12 Sg * | BUTANE Vapor Press psia | BUTANE Sg * | PROPANE Vapor Press psia | PROPANE Sg * |
|---|---|---|---|---|---|---|---|---|---|---|
| —60 | 5.6 | 0.70 | | | | | | | | |
| —50 | 7.7 | 0.70 | | | | | | | | |
| —40 | 10.4 | 0.69 | | | 9.3 | 1.51 | | | 16.2 | 0.58 |
| —30 | 13.9 | 0.68 | | | 12.0 | 1.50 | | | 20.3 | 0.57 |
| —20 | 18.3 | 0.68 | 220.6 | 1.03 | 15.3 | 1.48 | | | 25.4 | 0.57 |
| —10 | 23.7 | 0.67 | 261.7 | 1.01 | 19.2 | 1.47 | | | 31.4 | 0.56 |
| 0 | 30.4 | 0.66 | 308.6 | 0.99 | 23.9 | 1.45 | 7.3 | 0.62 | 38.2 | 0.55 |
| 10 | 38.5 | 0.66 | 361.8 | 0.97 | 29.4 | 1.43 | 9.2 | 0.61 | 46.0 | 0.55 |
| 20 | 48.2 | 0.65 | 422.0 | 0.95 | 35.8 | 1.42 | 11.6 | 0.61 | 55.5 | 0.54 |
| 30 | 59.7 | 0.64 | 489.7 | 0.92 | 43.2 | 1.40 | 14.4 | 0.60 | 66.3 | 0.53 |
| 40 | 73.3 | 0.63 | 565.0 | 0.89 | 51.7 | 1.38 | 17.7 | 0.60 | 78.0 | 0.52 |
| 50 | 89.2 | 0.63 | 650.1 | 0.85 | 61.4 | 1.36 | 21.6 | 0.59 | 91.8 | 0.52 |
| 60 | 107.6 | 0.62 | 744.3 | 0.81 | 72.4 | 1.34 | 26.3 | 0.59 | 107.1 | 0.51 |
| 70 | 128.8 | 0.61 | 848.8 | 0.76 | 84.8 | 1.32 | 31.6 | 0.58 | 124.0 | 0.50 |
| 80 | 153.0 | 0.60 | 964.4 | 0.68 | 98.8 | 1.30 | 37.6 | 0.57 | 142.8 | 0.49 |
| 90 | 180.6 | 0.59 | | | 114.3 | 1.28 | 44.5 | 0.56 | 164.0 | 0.48 |
| 100 | 211.9 | 0.58 | | | 131.6 | 1.26 | 52.2 | 0.56 | 187.0 | 0.47 |
| 110 | 247.0 | 0.57 | | | 150.7 | 1.24 | 60.8 | 0.55 | 213.0 | 0.46 |
| 120 | 286.4 | 0.56 | | | 171.8 | 1.22 | 70.8 | 0.54 | 240.0 | 0.45 |

* Water at 39.2°F = 1.00

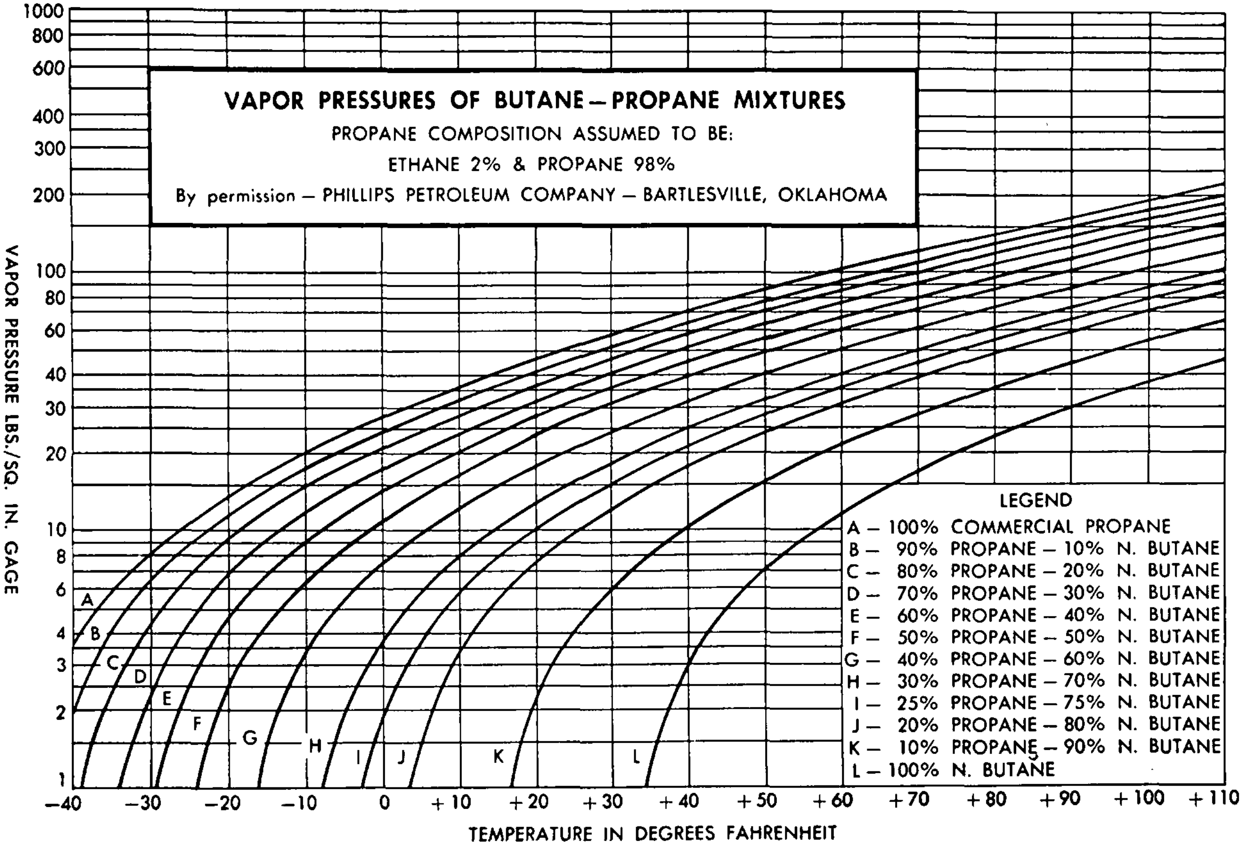


FIG. 38. Vapor pressures of Butane—Propane mixtures.

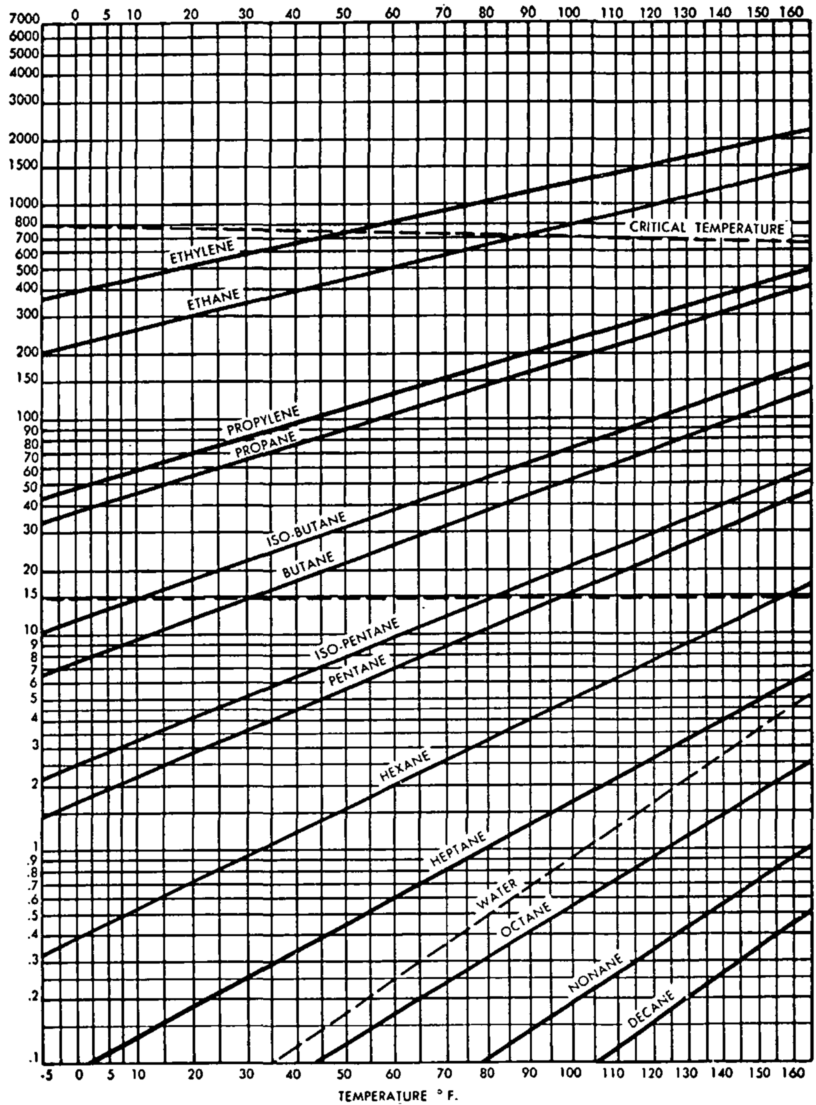


FIG. 39. Hydrocarbons—Temperature vs Vapor Pressure.

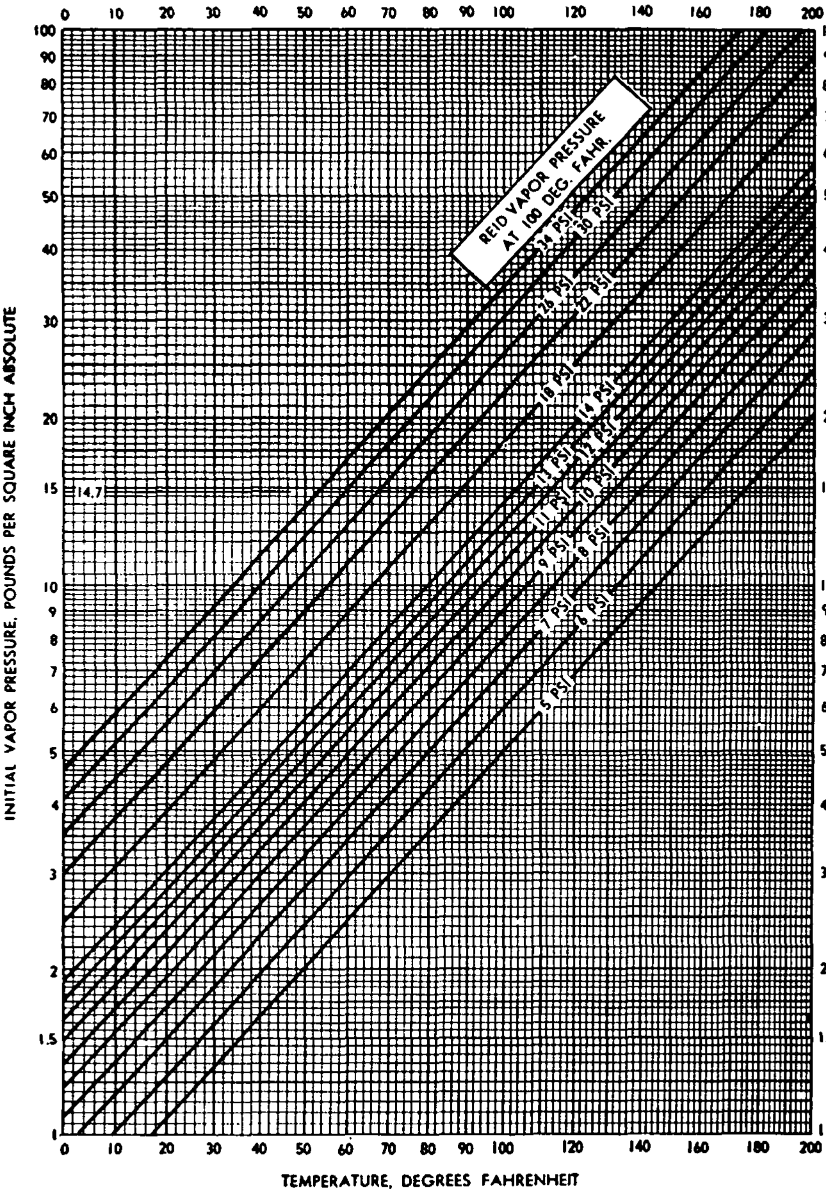


FIG. 40. Vapor pressures vs Temperatures for motor and natural gasolines.†

†*Courtesy Chicago Bridge & Iron Co. See page 6.*

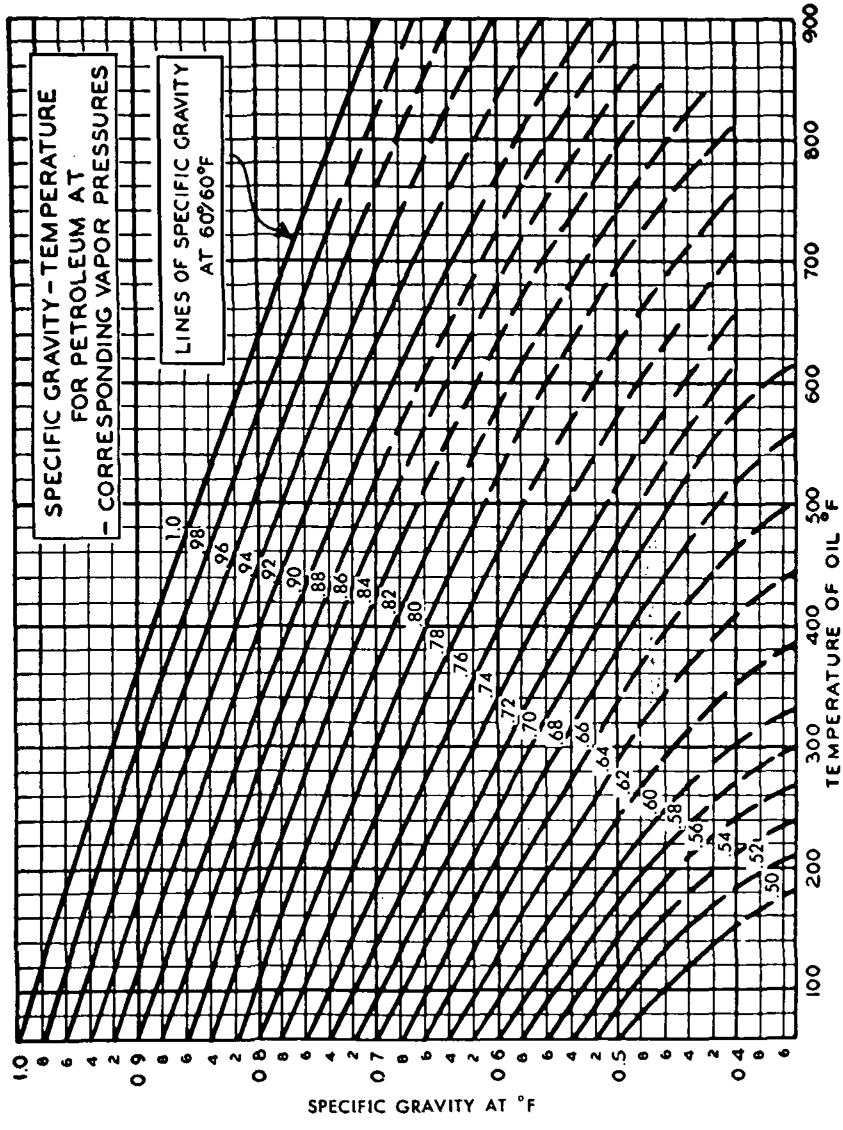


FIG. 41. Specific gravity and temperature relations of petroleum oils (approximate).†

†*Courtesy Hydraulic Institute.* *See page 6.*

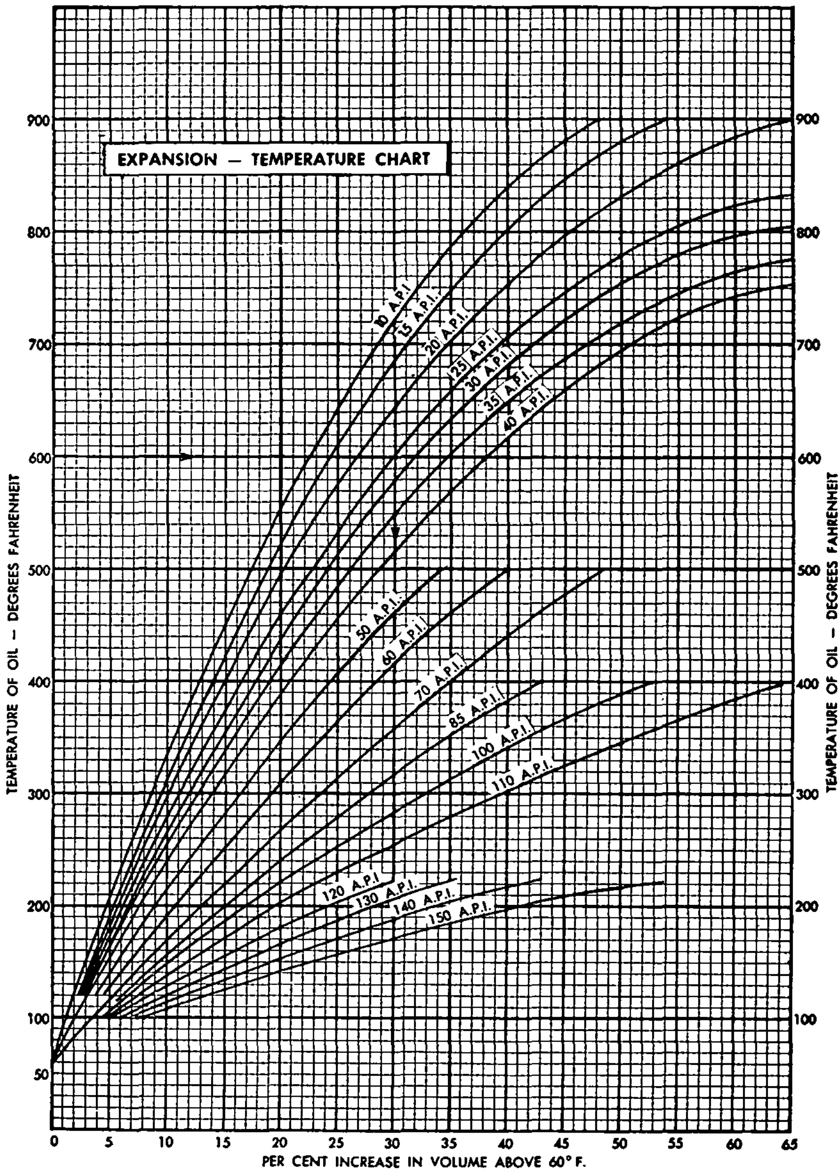


FIG. 42. Expansion—Temperature chart.†

†*Courtesy Hydraulic Institute. See page 6.*

# SECTION VII—SOLIDS IN SUSPENSION

## CONTENTS

# SECTION VII — PUMPING SOLIDS IN SUSPENSION
# SEWAGE-SAND-SLURRIES-PAPER STOCK-FOODS

## GENERAL PRINCIPLES

The pumping of a great variety of solid materials with liquid as the vehicle can be very successfully accomplished providing a few general principles are followed.

1. The pump should be located sufficiently below the liquid level in the suction bay so that the liquid reaches the suction eye of the impeller under a positive head.
2. All passages through the piping system, impeller, and volute should be large enough to pass the largest solid to be pumped.
3. Velocities through the pump and piping system should be such that the materials are held in suspension in the liquid. This results in less tendency to clog—less abrasion—less damage to the product pumped.
4. Velocity required in the pump varies with the pump characteristic and design.
5. Velocity required in the piping system depends upon the specific gravity, size, shape, consistency and friability of the material being pumped.
6. Pump materials and construction should be selected with due consideration of the substance pumped. Standard materials and design are suitable for the majority of applications but special metals, rubber linings, special stuffing box construction, or other features should be used in many instances.

## SEWAGE AND TRASH PUMPS

The pumping of sewage is a special problem for sewage may contain a great variety of solids in suspension. It is likely to contain anything that can be flushed down a toilet including towels, diapers, etc.; anything that can fall or be thrown into a manhole; anything that can flush into a catch basin on a city street including leaves, branches, etc.; or any type of industrial waste.

The principal consideration in pumping sewage is the passing of solids. Hydraulic performance and efficiency is secondary although also important. A consideration of how pumps clog will be useful in arriving at a plant design and a pump selection that will avoid this difficulty. Clogging can generally be attributed to one of the following causes:

1. Material that is too big or too long to flow through the suction piping, and around the elbows to the pump. This clogging generally occurs at an elbow. This type of clogging may be eliminated by screening to prevent large objects reaching the piping system or macerating equipment to reduce the solids in size.
2. Rags and flexible trash that wrap over the entering edge of the impeller blades. A gradual accumulation at this point will eventually cause a complete stoppage in the impeller. The solution to this problem is in the pump design. Sharp entering edges on the impeller blades are to be avoided. While they do improve the hydraulic efficiency of the pump they do so only at a sacrifice in non-clog ability. A generously rounded entering edge so that rags will have a tendency to slide off the blade reduces clogging. Since it is wrapping around the blade that causes clogging at this point, if the pump had no blades the cause would be removed. Such a "Bladeless" pump, remarkably free from clogging, has been available for several years.

Clogging has been a major problem in low capacity pumps. As the capacity and, therefore, the pump size increases the problem lessens. Large sewage and storm water pumps with relatively sharp blades have an excellent record of non-clog ability. Any pump with stationary guide or diffusor vanes is not suitable for pumping sewage.



## SLUDGE, SAND & SLURRIES

Sludges, sands, and slurries, as encountered in pumping practice, are mixtures of abrasive materials and, except in the less abrasive sludges (where reciprocating pumps may be used), centifugal pumps meet most requirements by having the casing, impeller, shaft and bearings constructed in suitable materials.

In pumping practice generally the lowest velocity that will keep the material in suspension and propel it in the center of the stream flow and away from the wall of the pipe will be the most economical, for this will result in the minimum pressure drop due to friction, the least abrasion of the pipe walls and the least damage to friable products. The range of velocities required is indicated in Table 42, which gives the particle sizes of natural abrasives together with the minimum hydraulic subsiding values or fall velocities that must prevail in pipes to keep the solids in suspension, and in Fig. 43, which shows the friction losses measured in pipe lines from dredges where high velocities must be maintained.

In the pumping of sand, test data shows that the minimum velocity is not affected much by pipe size. Experiments indicate that pipe-line pressure loss in feet of liquid is equal to the loss by the carrier (water) multiplied by the measured specific gravity of the liquid mixture. In the turbulent flow range, the velocity components continually fluctuate and cause dispersion of the solids in the pipe and assist in keeping them in suspension. A number of authors conclude that the results of flow tests in a small pipe diameter are only qualitative when used to estimate pipe-friction in a larger line.

Pump design and construction will vary considerably depending upon the abrasiveness of the material being handled. For mixtures with low abrasive qualities conventional materials and design may be satisfactory; or it may be found advisable to modify a conventional design by using special wearing rings and stuffing boxes with flushing connections. Clear flushing liquid at a pressure above the casing pressure in the pump is piped to these parts to keep them flushed free of the abrasive material. For very abrasive conditions, special materials and completely special design are required.

## DIGESTED SLUDGE

As velocities below 5 ft. per second and often 3 ft. per second are not unusual in sludge mains, the formulae used for water can be used only as a base. Field experience using data as shown in Fig. 44 indicates that the calculation of pumping heads is in reasonable agreement with head discharge curves on pumps tested in the production laboratory (based on volumetric liquid field measurements with accuracy of about 5%). Some engineers have used higher friction loss values which results in the centrifugal pump operating to the right of the selected condition point on the head-capacity curve. Installations exist where pumps are discharging a sludge at a capacity much larger than that at which they were tested in the laboratory.

M. R. Vincent Daviss, Assoc. M. Inst. C.E. in test at Saltley Works, Birmingham, England, of estimated 92% sludge at 80 cu. ft. per min. in 12-inch nominal diameter pipe, 20,000 ft. long, showed friction loss 2.6 times that of actual test made only with water in the same line. He concluded the old pipe effective diameter was 10.25 inches, which gives a velocity of about 2.3 fps. Were it a 12-inch pipe, the velocity would have been 1.7 fps. which gives a test result that correlates with Fig. 44. It is recognized that it has been quite customary to allow from 2 to 4 times the water friction loss in pumping sludges of 98% or less. L. F. Mountfort, discusser of Daviss' paper, points out that 98% sludge is in some respect easier to deal with than water. Recognizing full well the ramifications of the sludge pumping problem, it is indicated that Fig. 44 can be used safely as a guide in estimating pipe friction losses caused by flow of sludges.

## SLURRIES

A slurry is a liquid, usually water, in which foreign material is suspended in varying quantities. There are many types of slurries such as coal, salt and the like in many different industries. The application of pumping equipment for such service depends largely on the type and quantity of foreign matter present in the mixture and the properties of the liquid carrier. No definite rules of application can be set down in this Handbook, but the following has been found essentially correct:

1. Flotation tailings from the milling of iron ores can be transported at a velocity of 5 to 7 fps in non-acid water. Pipe does not endure for 15 years but scouring action keeps pipe clean and reasonably free from pitting. The use of 15 year pipe-friction modifying factor appears to be too liberal and causes oversizing and overpowering.
2. Material such as iron-pyrites ground to the fineness required for flotation when thickened to a pulp can be pumped through pipes at reasonable velocities.
3. The head per stage should be kept as low as practical so as to hold vane-tip velocity to a minimum and to reduce erosion at the wearing rings.
4. In a series of tests on a powdered glass-sand-plaster of paris mixture hardened iron impellers have proven more durable than rubber lined pumps although rubber lined pumps have their field of application.
5. In pumping coal, the maximum quantity of fines (100 mesh) appears to act as a lubricant in the mixture. Coal-water slurries up to 35% by weight can be pumped with a viscosity comparable to water at 5 fps velocity. The critical velocity for 2 to 3 inch top-size solids is 7 to 9 fps but a safe velocity is 10-12 fps in 8 inch pipe, and 11-13 fps in 10 inch pipe.
6. Clay slurries up to 50% solids by weight can be pumped through a 4 inch pipe. SSU viscosity tests are unreliable for these slurries. The apparent viscosity varies from 25 to 85 times that for water as shown on Fig. 32.
7. Bentonite slurries are stiff even when they contain only 25% solids by weight.
8. Thirty (30) percent solids by weight of some clays are too viscous to pump in a centrifugal pump.
9. It is possible to lift 60% solids by weight of iron and coke dusts or flue dirt.
10. It is notable that mining operations run solids as high as 70% by weight

This information indicates the great diversity of pumping applications and the necessity for careful analysis of the probable field conditions before the final selection of pumping equipment.

## TABLE 42. FALL VELOCITIES VARIOUS ABRASIVES

| Diameter Milli-meters | Mesh Size U.S. Fine | Fall Velocity Ft./Sec. | SOIL GRAIN SIZE IDENTIFICATION A.S.T.M. | U.S. Bur. Soils U.S.D.A. | M.I.T. | Inter-national |
|---|---|---|---|---|---|---|
| .0002 | | .000000098 | | | Med. Clay | Fine Clay |
| .0006 | | .00000092 | Clay | Clay | Coarse Clay | Coarse Clay |
| .001 | | .0000023 | | | | |
| .002 | | .0000092 | | | | |
| .005 | | .000056 | | | Fine Silt | Fine Silt |
| .006 | | .000082 | Silt | Silt | Med. Silt | Coarse Silt |
| .02 | | .00092 | | | | Fine Mo. |
| .05 | 270 | .0056 | | | Coarse Silt | |
| .06 | 230 | .0082 | | V. F. Sand | | Coarse Mo. |
| .10 | 150 | .024 | Fine Sand | | Fine Sand | Fine Sand |
| .20 | 70 | .069 | | Fine Sand | | |
| .25 | 60 | .085 | | | | Med. Sand |
| .30 | | .105 | | Sand | Med. Sand | |
| .50 | 35 | .173 | | | | |
| .60 | 30 | .206 | Coarse Sand | Coarse Sand | | Coarse Sand |
| 1.00 | 18 | .327 | | | Coarse Sand | |
| 2.00 | 10 | .556 | | Fine Gravel | | V. C. Sand |

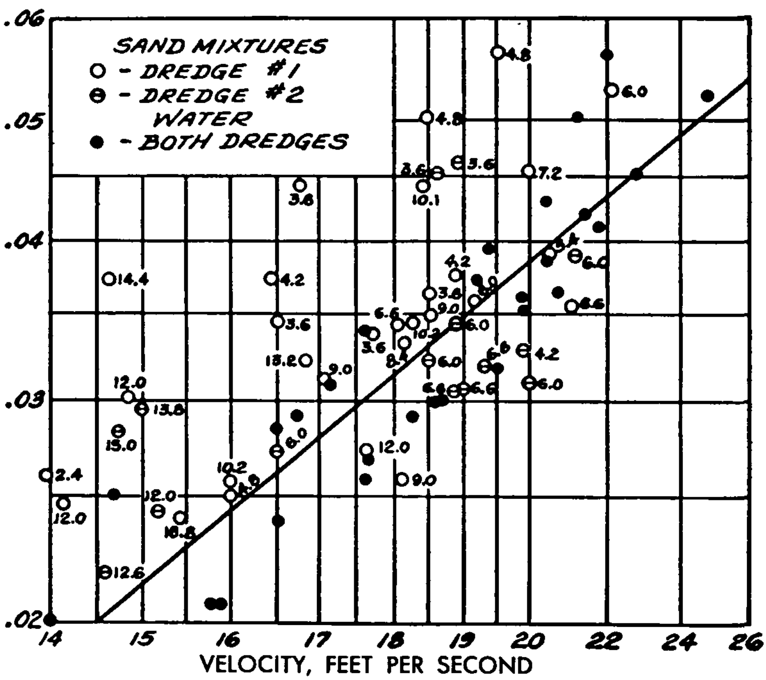


FIG. 43. Friction losses in 24" I.D. Dredge pipes when water and water sand mixtures are being pumped.

## FRICTION LOSS OF DIGESTED SLUDGE IN 6, 8, AND 10 INCH DIAMETER PIPE

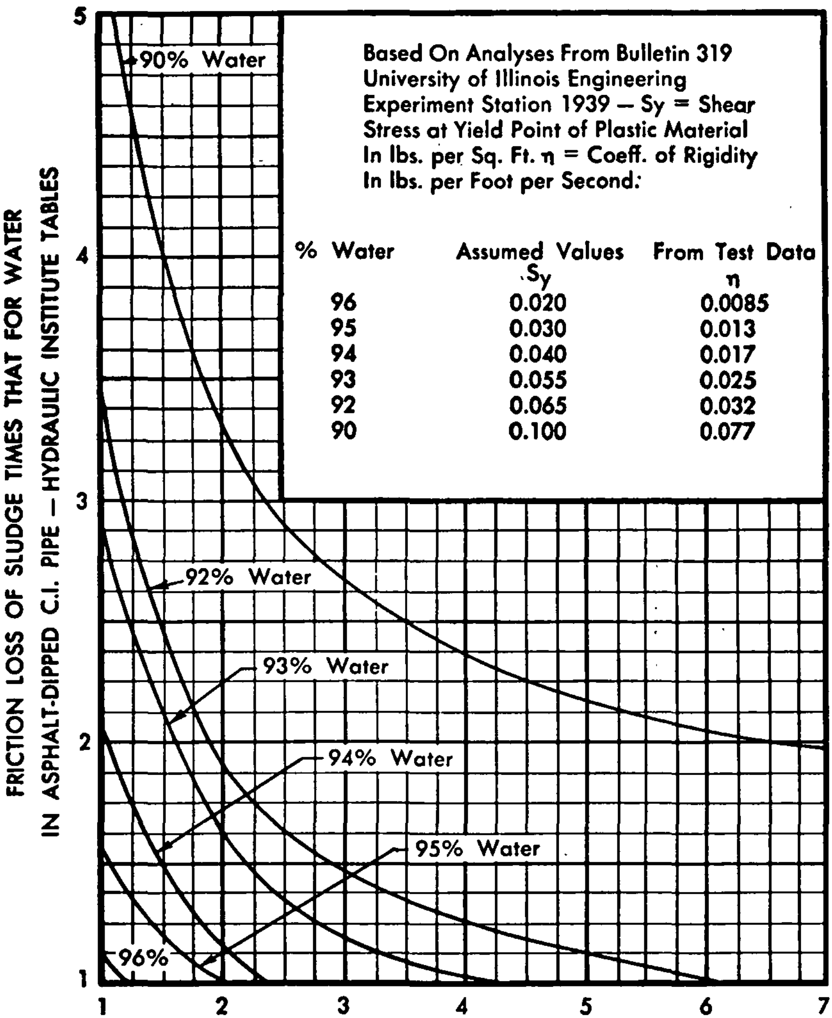


FIG. 44. Friction loss of digested sludge in 6, 8 and 10 in. diameter pipe.

VII

## PAPER STOCK

In the manufacture of paper of all kinds the underlying principle is to reduce all material to a pulp and, by adding necessary chemicals, obtain a homogeneous mass known as pulp or paper stock. This involves large volumes of water in the process work, all of which must be removed before the finished product is made. The types of stock encountered in connection with pumping are: reclaimed paper, ground wood stock, sulphite and soda stock, sulphate and kraft stock, and chemical pulp (cooked stock).

In most process work from the chippers and grinders to the stock chests the maximum consistency bone dry by weight is 3%. Experience has shown that where water is plentiful stock is more easily handled in lower percentages. Capacities or flow rates are usually given in terms of the number of tons of air dry stock per 24-hour day, at an average percentage. These figures must be reduced to a workable basis of gallons per minute. Table 44 for making such conversions is found in this Section. Pipe Friction Loss tables for various stock percentages and pipe sizes are also included and must be used when figuring total head.

The actual selection of a pump for this type of service requires additional data and experience in handling paper stock, together with a knowledge of the performance of a centrifugal pump. For instance, the pumping of dirty stock with fibrous and stringy material is best accomplished by use of a closed impeller stock pump with good solid handling ability. On the other hand, the handling of clean, homogeneous stock of a very heavy percentage requires a pump with a specially designed open impeller to keep down the entrance velocity and prevent the pump from "dewatering" the stock and causing it to pile up in the suction piping.

Rating charts are published on the basis of handling water, and curves are included in this section (Figs. 45 and 46 to enable calculation of reduction in design capacity and design head for a given percentage of stock for both closed and open impeller pumps.

*Example:* Given the characteristic and efficiency curves for a pump handling water, correct these curves for a closed impeller pump when pumping 3.15% ground wood paper stock.

Table 43 shows that 3.15% ground wood is equal to 3.0% sulfate stock. The characteristic curve is corrected by using Fig. 45 applying the head correction factors corresponding to various percentages of design capacity.

The efficiency curve is corrected by using Fig. 46 which shows that the efficiency at design point is reduced 28 points at a reduced capacity which is 67% of design capacity. The *efficiency correction applies only to the design point.*

TABLE 43. REQUIRED PERCENTAGE OF PAPER STOCKS TO EQUAL PERFORMANCE OF PUMP LIFTING KRAFT-SULPHATE

| Kraft-Sulfate | Reclaimed Paper | Jute | Ground Wood | Sulfite-Soda |
|---|---|---|---|---|
| 1.0 | 1.95 | 1.65 | 1.50 | 1.25 |
| 1.2 | 2.20 | 1.85 | 1.70 | 1.40 |
| 1.5 | 2.55 | 2.15 | 2.00 | 1.70 |
| 1.7 | 2.75 | 2.35 | 2.15 | 1.85 |
| 2.0 | 3.05 | 2.60 | 2.40 | 2.15 |
| 2.5 | 3.55 | 3.05 | 2.80 | 2.60 |
| 3.0 | 4.05 | 3.45 | 3.15 | 3.00 |
| 3.5 | 4.45 | 3.90 | 3.50 | |
| 4.0 | 4.90 | 4.30 | | |
| 4.5 | 5.25 | 4.75 | | |
| 5.0 | 5.65 | 5.15 | | |

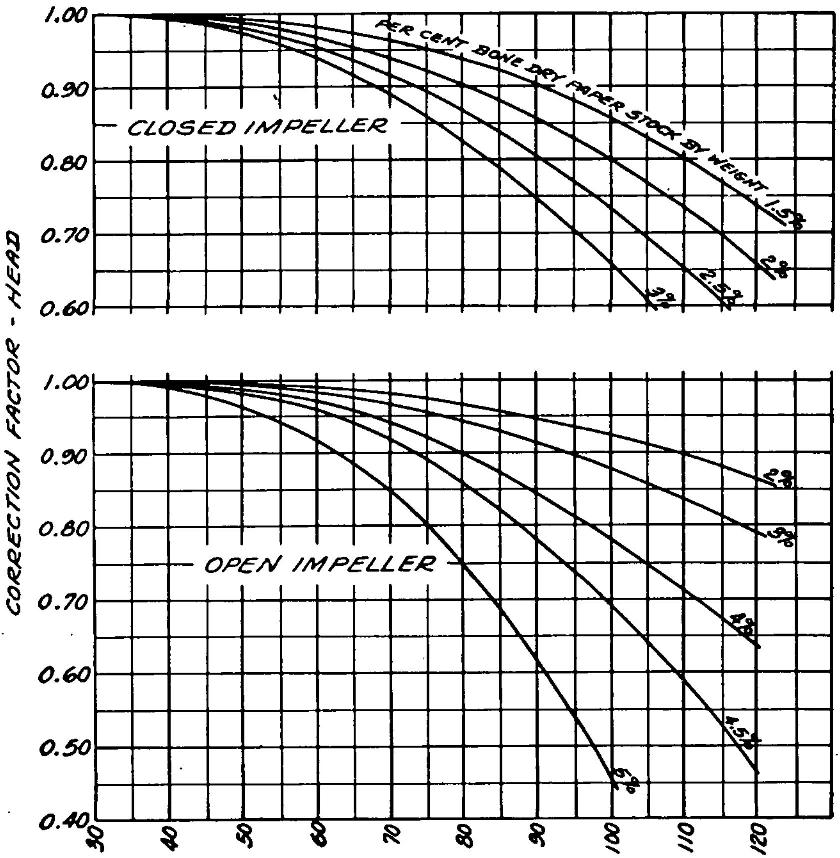


FIG. 45. Effect of Sulfate stock on centrifugal pump characteristic.

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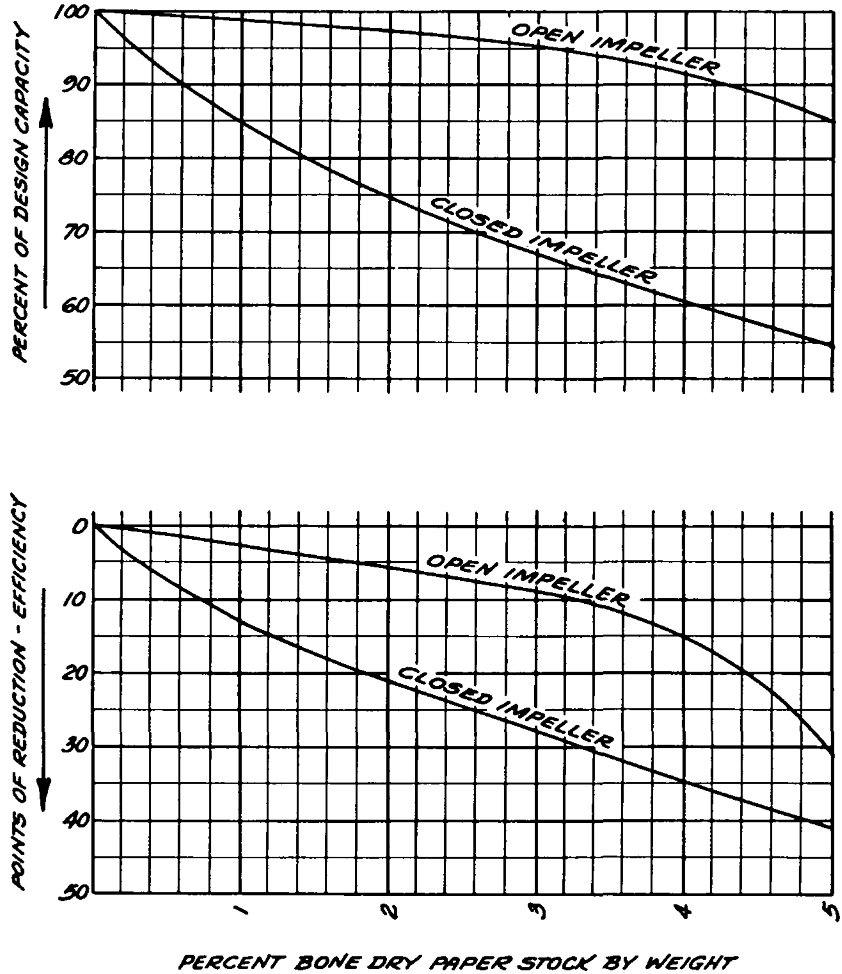


FIG. 46. Effect of Sulfate paper stock on centrifugal pump capacity and efficiency.

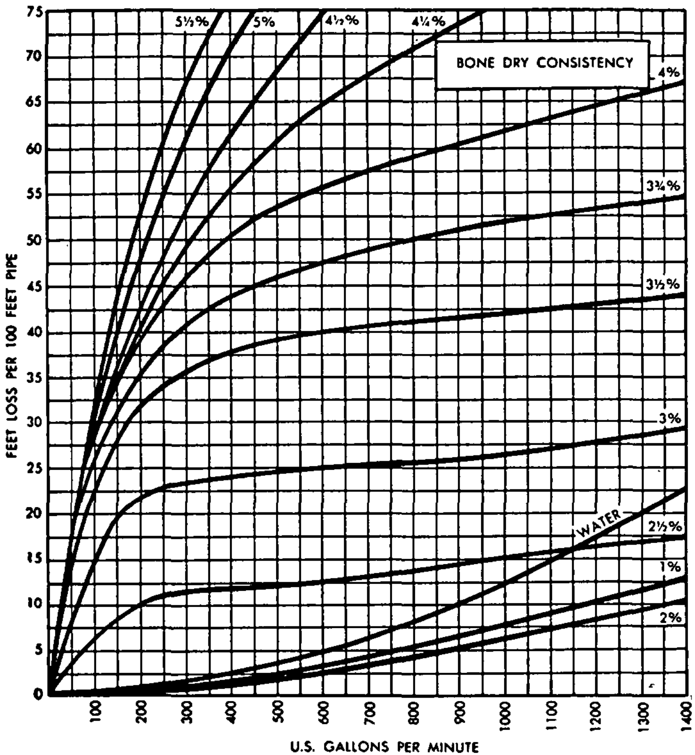


FIG. 47. Friction loss of groundwood paper stock through 6 inch cast iron pipe.†

†*Courtesy Hydraulic Institute. See page 6.*

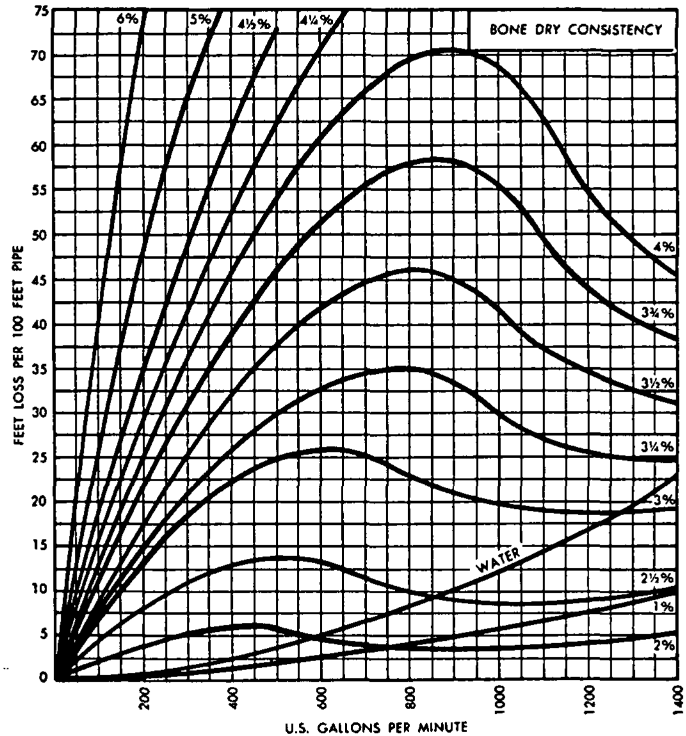


FIG. 48. Friction loss of sulphite paper stock through 6 inch cast iron pipe.

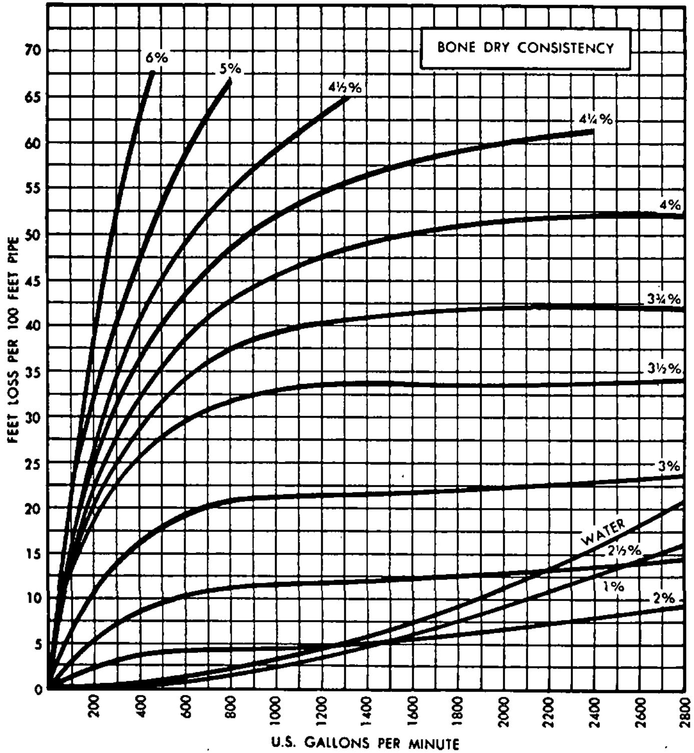


FIG. 49. Friction loss of groundwood paper stock through 8 inch cast iron pipe.

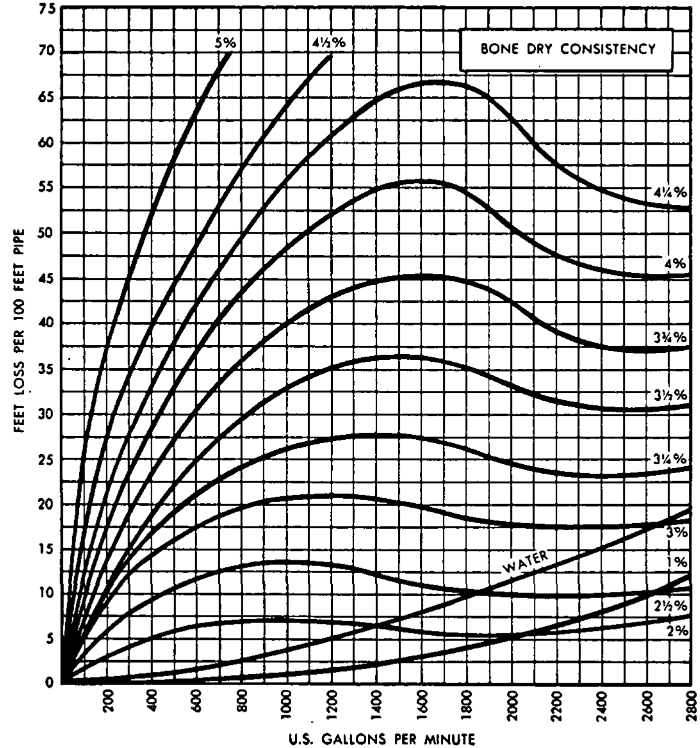


FIG. 50. Friction loss of sulphite paper stock through 8 inch cast iron pipe.

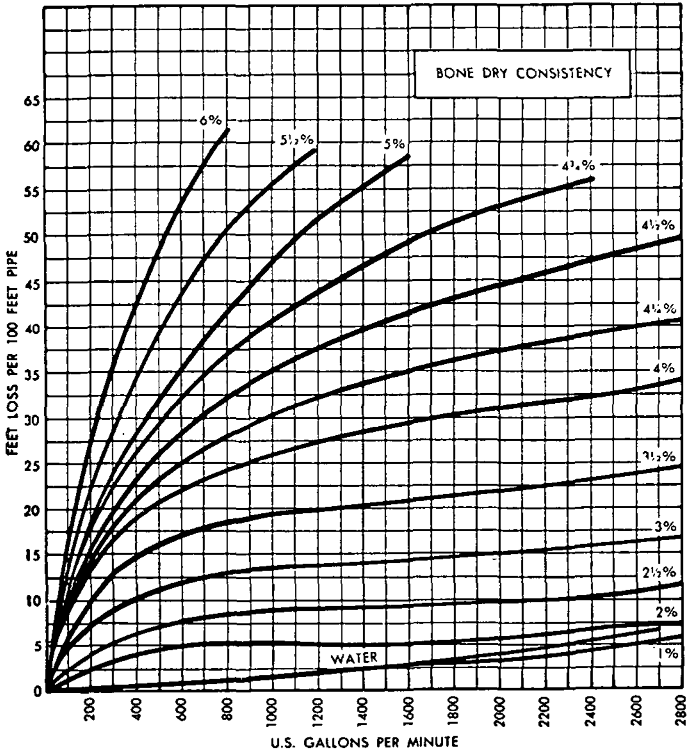


FIG. 51. Friction loss of groundwood paper stock through 10 inch cast iron pipe.

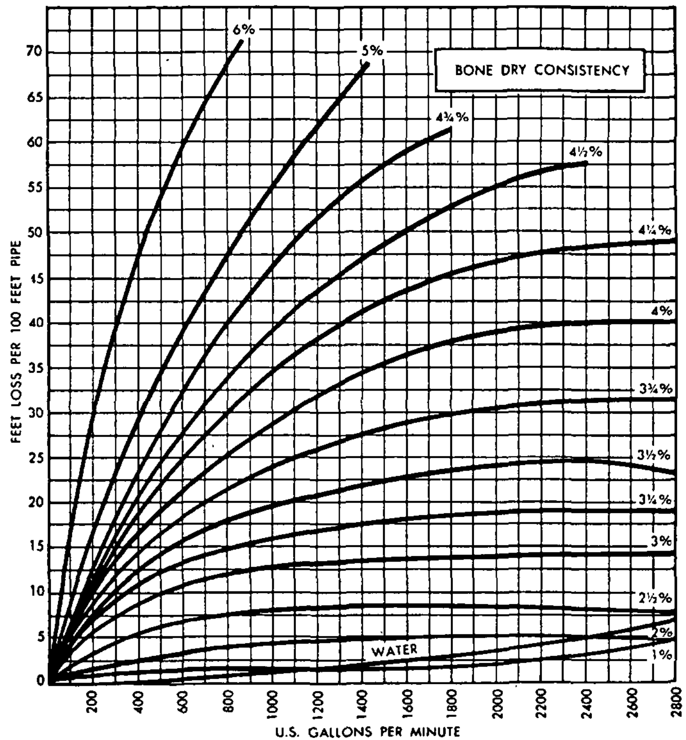


FIG. 52. Friction loss of sulphite paper stock through 10 inch cast iron pipe.

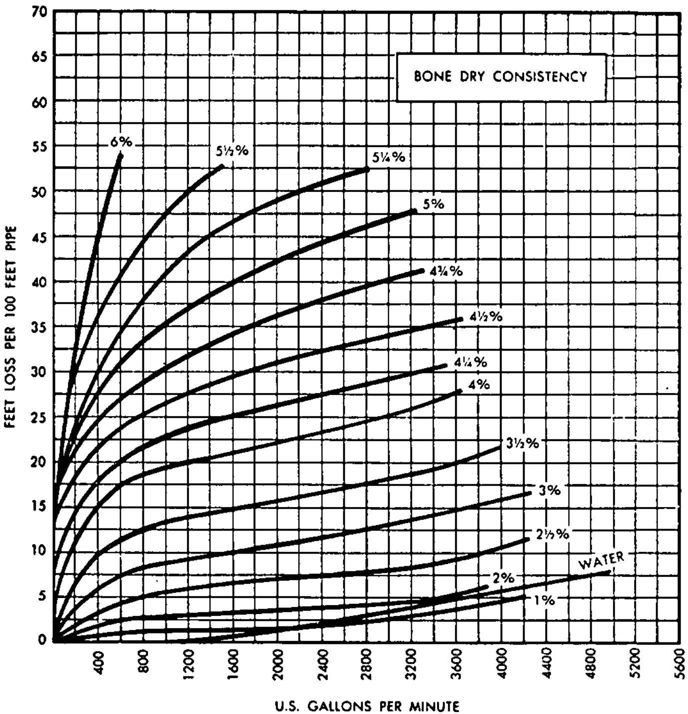


FIG. 53. Friction loss of groundwood paper stock through 12 inch cast iron pipe.

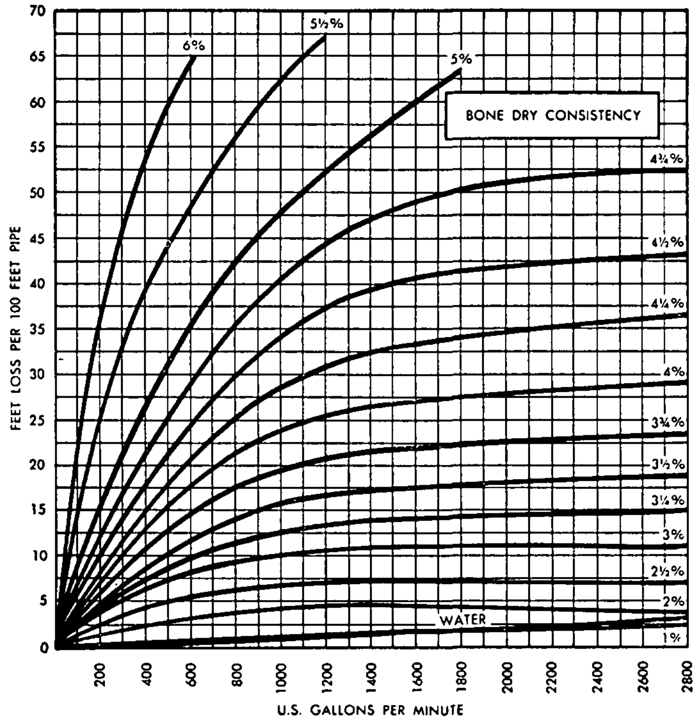


FIG. 54. Friction loss of sulphite paper stock through 12 inch cast iron pipe.

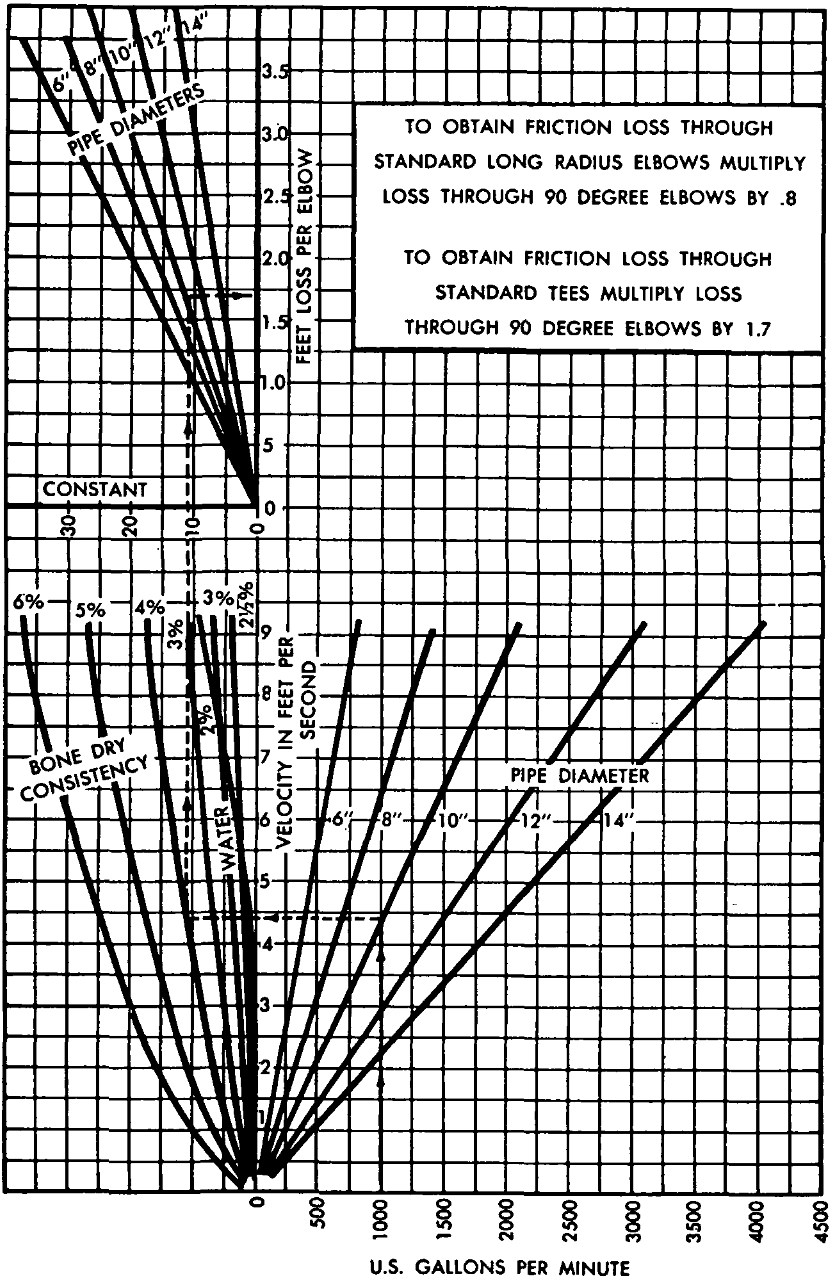


FIG. 55. Estimated friction loss for standard short radius 90 deg. elbows.

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## TABLE 44. WEIGHTS, VOLUMES, ETC., OF LIQUID PULP STOCK CARRYING VARIOUS PERCENTAGES OF AIR DRY STOCK.†

| % Dry stock in 100 lbs. of Liquid "K" | Lbs. dry stock in 1 cu. ft. of liquid 0.625x"K" | No. of Cu. ft. containing 1 Lb. of Stock $\frac{1.6}{\text{"K"}}$ | Lbs. of dry stock in 1 gal. of Liquid $\frac{\text{"K"}\,8.34}{100}$ | No. of gal. containing 1 Lb. of Stock $\frac{11.97}{\text{"K"}}$ | Cu. ft. of Liq. per Min. per ton of dry stock per 24 hrs. $\frac{2.22}{\text{"K"}}$ | Gals. of liquid per Min. per ton of Dry stock per 24 hrs. $\frac{16.62}{\text{"K"}}$ | Lbs. liquid per Min. per ton of Dry Stock per 24 hrs. $\frac{138.88}{\text{"K"}}$ | Lbs. of water per lb. of stock $\frac{100}{\text{"K"}}-1$ | Gallons water per lb. of stock $\left[\frac{100}{K}-1\right]\frac{1}{8.35}$ | Gallons water per ton of stock $\left[\frac{100}{K}-1\right]240$ | Gallons water per min. per ton of dry stock per 24 hrs. $\left[\frac{100}{K}-1\right]\frac{1}{6.02}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| .10 | .0625 | 16. | .008 | 119.55 | 22.22 | 166.20 | 1,388.88 | 999.00 | 119.36 | 238,710 | 165.78 |
| .20 | .1250 | 8. | .017 | 59.77 | 11.11 | 83.10 | 694.44 | 499.00 | 59.76 | 119,996 | 82.89 |
| .25 | .1562 | 6.40 | .021 | 47.87 | 8.88 | 66.49 | 555.55 | 399.00 | 47.75 | 95,511 | 66.32 |
| .30 | .1875 | 5.33 | .025 | 39.90 | 7.41 | 55.41 | 462.96 | 332.33 | 39.78 | 79,555 | 55.24 |
| .33 | .2063 | 4.80 | .028 | 36.27 | 6.72 | 50.32 | 420.84 | 302.10 | 36.17 | 72,487 | 50.17 |
| .35 | .2187 | 4.57 | .029 | 34.20 | 6.35 | 47.50 | 396.83 | 284.71 | 34.08 | 68,154 | 47.33 |
| .40 | .2500 | 4.00 | .033 | 29.92 | 5.55 | 41.56 | 347.20 | 249.00 | 29.80 | 59,605 | 41.39 |
| .45 | .2812 | 3.56 | .038 | 26.60 | 4.94 | 36.94 | 308.64 | 221.22 | 26.48 | 53,093 | 36.77 |
| .50 | .3125 | 3.20 | .042 | 23.92 | 4.44 | 33.25 | 277.77 | 199.00 | 23.82 | 47,760 | 33.08 |
| .55 | .3437 | 2.91 | .046 | 21.76 | 4.04 | 30.22 | 252.52 | 180.82 | 21.64 | 43,490 | 30.05 |
| .60 | .3750 | 2.66 | .050 | 19.95 | 3.70 | 27.71 | 231.48 | 165.66 | 19.83 | 39,758 | 27.54 |
| .65 | .4062 | 2.46 | .054 | 18.41 | 3.42 | 25.57 | 213.68 | 152.85 | 18.29 | 36,681 | 25.40 |
| .70 | .4375 | 2.28 | .058 | 17.10 | 3.17 | 23.75 | 198.42 | 141.86 | 17.00 | 34,284 | 23.58 |
| .75 | .4687 | 2.13 | .063 | 15.96 | 2.96 | 22.16 | 185.18 | 132.33 | 15.84 | 31,678 | 21.99 |
| .80 | .5000 | 2.00 | .067 | 14.96 | 2.78 | 20.78 | 173.61 | 124.00 | 14.84 | 29,683 | 20.61 |
| .85 | .5312 | 1.88 | .071 | 14.06 | 2.61 | 19.56 | 163.40 | 116.65 | 13.98 | 28,024 | 19.39 |
| .90 | .5624 | 1.78 | .075 | 13.30 | 2.47 | 18.47 | 154.32 | 110.11 | 13.18 | 26,426 | 18.30 |
| .95 | .5937 | 1.68 | .079 | 12.61 | 2.34 | 17.50 | 146.19 | 104.26 | 12.48 | 25,022 | 17.33 |

†*Courtesy Paper & Pulp Mill Catalog.*

Note: For conversion—1% Bone Dry Stock=1.1% Air Dry Stock.

TABLE 44. (Cont.) WEIGHTS, VOLUME, ETC. OF LIQUID PULP STOCK CARRYING VARIOUS PERCENTAGES OF AIR DRY STOCK

| % Dry stock in 100 lbs. of Liquid<br>"K" | Lbs. dry stock in 1 cu. ft. of liquid<br>0.625x"K" | No. of Cu. ft. containing 1 Lb. of Stock<br>$\frac{1.6}{\text{"K"}}$ | Lbs. of dry stock in 1 gal. of Liquid<br>$\frac{\text{"K"}8.34}{100}$ | No. of gal. containing 1 Lb. of Stock<br>$\frac{11.97}{\text{"K"}}$ | Cu. ft. of liquid per Min. per ton of dry stock per 24 hrs.<br>$\frac{2.22}{\text{"K"}}$ | Gals. of liquid per Min. per ton of dry stock per 24 hrs.<br>$\frac{16.62}{\text{"K"}}$ | Lbs. liquid per Min. per ton of Dry Stock per 24 hrs.<br>$\frac{138.8}{\text{"K"}}$ | Lbs. of water per lb. of stock<br>$\frac{100}{\text{"K"}}-1$ | Gallons water per lb. of stock<br>$\left[\frac{100}{K}-1\right]\frac{1}{8.35}$ | Gallons water per ton of stock<br>$\left[\frac{100}{K}-1\right]240$ | Gallons water per min. per ton of dry stock per 24 hrs.<br>$\left[\frac{100}{K}-1\right]\frac{1}{6.02}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | .6250 | 1.60 | .084 | 11.97 | 2.22 | 16.62 | 138.88 | 99.00 | 11.85 | 23,698 | 16.49 |
| 1.25 | .7812 | 1.28 | .104 | 9.57 | 1.78 | 13.30 | 111.11 | 79.00 | 9.45 | 18,911 | 13.13 |
| 1.50 | .9375 | 1.07 | .125 | 7.98 | 1.48 | 11.08 | 92.59 | 65.66 | 7.86 | 15,712 | 10.91 |
| 1.75 | 1.0937 | .91 | .146 | 6.84 | 1.27 | 9.50 | 79.37 | 56.14 | 6.72 | 13,439 | 9.33 |
| 2.00 | 1.2500 | .80 | .167 | 5.97 | 1.11 | 8.31 | 69.44 | 49.00 | 5.86 | 11,760 | 8.15 |
| 2.25 | 1.4062 | .71 | .188 | 5.32 | .99 | 7.39 | 61.73 | 43.44 | 5.20 | 10,437 | 7.23 |
| 2.50 | 1.5625 | .64 | .209 | 4.79 | .89 | 6.65 | 55.55 | 39.00 | 4.67 | 9,360 | 6.48 |
| 2.75 | 1.7187 | .58 | .230 | 4.35 | .81 | 6.04 | 50.50 | 35.36 | 4.23 | 8,465 | 5.88 |
| 3.00 | 1.8750 | .53 | .251 | 3.99 | .74 | 5.54 | 46.29 | 32.33 | 3.87 | 7,759 | 5.37 |
| 3.50 | 2.1875 | .46 | .292 | 3.42 | .63 | 4.75 | 39.68 | 27.57 | 3.30 | 6,616 | 4.58 |
| 4.00 | 2.5000 | .40 | .334 | 2.99 | .55 | 4.15 | 34.72 | 24.00 | 2.87 | 5,750 | 3.99 |
| 4.50 | 2.8125 | .36 | .376 | 2.74 | .49 | 3.69 | 30.86 | 21.22 | 2.54 | 5,100 | 3.53 |
| 5.00 | 3.1250 | .32 | .418 | 2.39 | .44 | 3.32 | 27.77 | 19.00 | 2.27 | 4,560 | 3.16 |
| 5.50 | 3.4375 | .29 | .459 | 2.18 | .40 | 3.02 | 25.25 | 17.18 | 2.06 | 4,115 | 2.85 |
| 6.00 | 3.7500 | .27 | .501 | 1.99 | .37 | 2.77 | 23.15 | 15.66 | 1.87 | 3,750 | 2.61 |
| 6.50 | 4.0625 | .25 | .542 | 1.84 | .34 | 2.56 | 21.36 | 14.38 | 1.72 | 3,450 | 2.37 |
| 7.00 | 4.3750 | .23 | .584 | 1.71 | .32 | 2.38 | 19.84 | 13.29 | 1.59 | 3,180 | 2.21 |
| 7.50 | 4.6875 | .21 | .626 | 1.60 | .29 | 2.22 | 18.51 | 12.33 | 1.48 | 2,960 | 2.04 |
| 8.00 | 5.0000 | .20 | .667 | 1.50 | .28 | 2.08 | 17.36 | 11.50 | 1.38 | 2,760 | 1.91 |

## FOOD HANDLING PUMPS

Commercial canners have long desired to convey foods hydraulically for this method represents a much less expensive means than mechanical conveyors. The problem is, of course, to handle the foods without clogging the pump or piping system and without damaging the foods. This is a manifold problem that involves not only the pump but also a satisfactory means of mixing the food with the liquid vehicle and finally separating the food and the liquid without damage to the product.

Hydraulic elevators that could handle such products as peas and cut beans have been on the market for many years, but new equipment is on the market that will handle the food so gently that the following foods have been successfully conveyed: apples, apricots, artichokes, cut asparagus, beans (green, lima, shelled, string, sprouts, dried or soaked), beets (peeled, diced, sugar), blueberries, brussel sprouts, carrots, cauliflower rosettes, cherries (marachino), chili-sauce, collard, corn (kernel), cranberries, dressings, boiled eggs, egg yolks, liquid eggs, grapes (crushed as pumped to pressing room), grits, mash, mushrooms, olives (green and ripe), onions, oranges, peas (black-eyed, field and sweet), peppers, pickles, pimientos, pineapple pulp from cores and fruit meat, white potatoes, rice (prior to soaking), soy beans (with oil extracted while pumping), soups, strawberries (except Marshall variety), sugar (raw cane juice, cachaza, syrups, molasses), tomato catsup, tomato juice, sea foods, such as fingerlings with only 2% loss, oysters, shrimp.

Fig. 56 shows a sketch of a typical installation using pump, rod reel washer and scavenger reel with water supply tank. This installation provides for vortexing of food in the hopper to the pump. This vortex is very important for it causes very light foods that normally float on top of the liquid to sink and be drawn uniformly into the pump suction. It also causes long foods like string beans to enter the stream with their length parallel to the stream flow. The forced vortex is limited so air is not drawn into the pump.

There are only six parts of a pump in contact with foods, namely; the housing or volute, back-head, removable drive shaft, packing, impeller and front-head. The interior of a pump for food handling service should be smoothly finished with no sharp corners, holes, pits, crevices, cracks or threads. Contact surfaces should be either ground to form a tight seal or to accommodate a rubber or single-service gasket.

Pump construction can be made to resist attack by foods, soaps, detergents and the germicidal agents used in cleaning. Stainless steel is satisfactory except for salt brines. Monel metal can be used for brines but not for corn, lima beans or peas where copper may produce darkening. Aluminum is corroded by alkalis and certain acids. Bronze is fairly corrosion resistant, but is not good for *conveying brines in which foods are canned* because of possible discoloration of the end product. Experience shows that for most applications the iron fitted pump with stainless steel sleeves has been doing a creditable job. Contamination by lubricants is impossible with well designed pumps.

The following suggestions, based on field experience, are offered as a guide in pump selection and application.

1. The solids should be mixed with the liquid at a uniform rate and vortexed into the pump suction. The vortex should be limited so that air is not drawn into the pump.

2. Although the pump capacity required will depend upon the tonnage to be handled, the pump preferably should be selected so that it will operate at its point of peak efficiency or slightly to the right of this point on the characteristic curve.

3. The speed of the pump should be selected to meet the head requirements of the system. Heads up to 110 ft. have been successful with some foods. The system should be designed to keep the head as low as possible.

4. The ratio of water to food solids should be as great as is practicable or economical. For peas one gallon per pound and for string beans 3 gallons per pound has been found practical.

5. With most foods a pump with a bladed impeller will damage the food. A pump with a "Bladeless" impeller is recommended.

6. Food solids should be carefully separated from the liquid as this is a common point of product damage.

For new uses it is recommended that the first pumping unit be installed with a provision for variable speed operation and observation of condition of the product after passing through the pump be made at the top of a riser prior to a bend. There is evidence that short radius ells, rough pipe joints or beads inside of welded pipe can cause more damage to foods than the pump itself. A velocity in the pipe of 5 fps should be tried first as this velocity appears to be above the critical for movement of food suspensions without clogging.

When pumping foods with hot water, write to the manufacturer for the required minimum suction head to obtain performance comparable with cold water. (See fundamentals concerning NPSH in Section I of this Handbook).

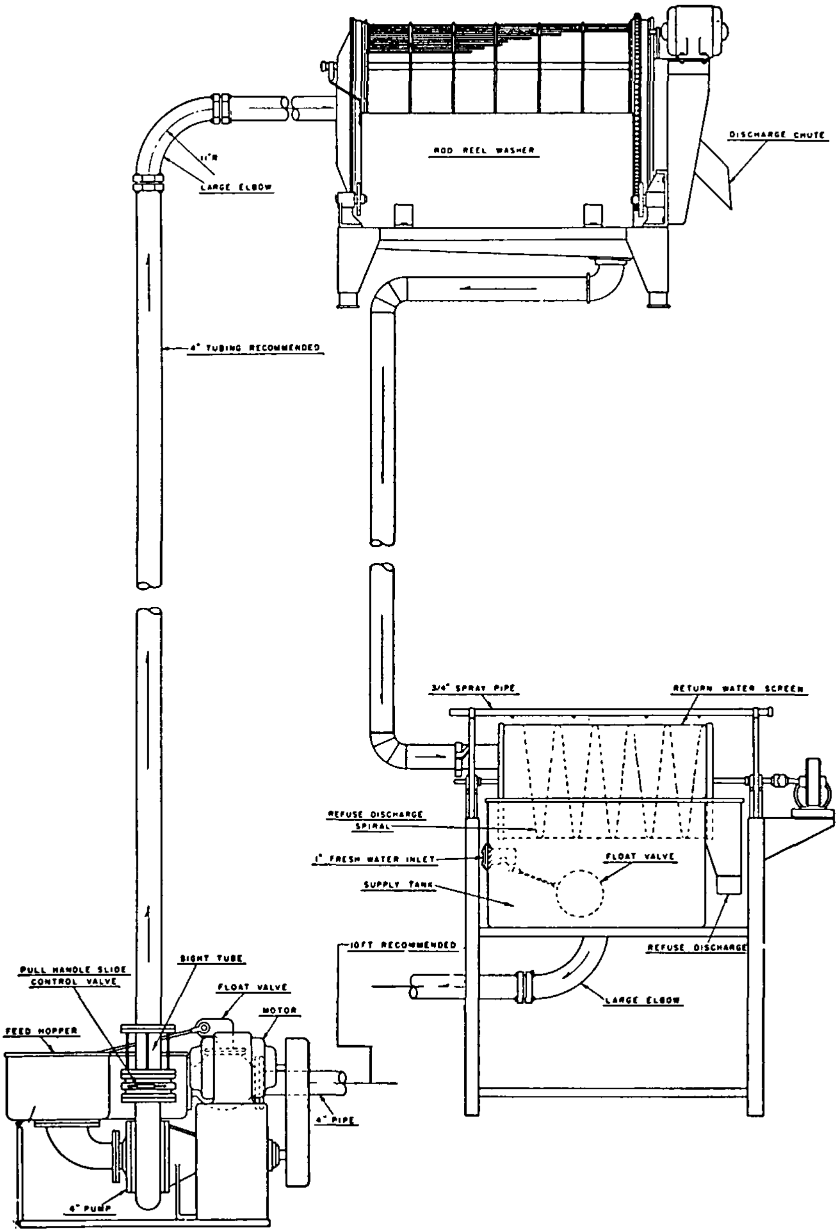


FIG. 56. Line drawing of typical installation including pump, rod reel washer and scavenger reel with supply tank.†

*Chisholm Ryder Corp. See page 6.*

# SECTION VIII—CHEMICAL LIQUIDS

## CONTENTS

# SECTION VIII—CHEMICAL LIQUIDS

## MATERIALS OF CONSTRUCTION FOR PUMPING VARIOUS LIQUIDS†

Although pumps produced by various manufacturers will differ in design and performance detail, they follow the same general pattern in the utilization of materials for handling specific liquids. This is natural since the manufacturer has little control over the corrosive reaction between the materials and the liquids handled and, hence, must use those types which experience has indicated as being most satisfactory for the particular application under consideration.

Because of the many variables which influence the rate at which corrosion may occur, it is not possible to make positive predictions which will cover every application. However, for the guidance of both pump manufacturers and users, the Materials Specifications Committee of the Hydraulic Institute has compiled a list of the liquids more commonly encountered in industry, along with the materials generally associated with their use. This data is shown in Table 46.

## DATA ON VARIOUS LIQUIDS

The liquids are assumed to be of commercial quality and of the degree of purity usually encountered. However, one must recognize that the presence of a foreign substance, even in small percentages, may, and frequently does, have a profound effect upon the corrosiveness of the solution and, hence, upon the choice of materials. For instance, the presence of a small percentage of soluble chloride or other halide in many of the liquids included in the table may greatly intensify their corrosive properties. Conversely, certain substances, such as the chromates and dichromates, may inhibit the corrosive action of many solutions on ferrous metals. Further, some liquids, noticeably the vegetable oils, while relatively inactive when fresh, may, upon exposure to heat and/or the atmosphere, turn rancid and become quite corrosive. While cast iron might be used safely with such oils when sweet, it would not necessarily be satisfactory after they had soured. In the latter case, other, more resistant materials would probably be required.

In some cases the satisfactory use of a particular material is restricted to a definite temperature and/or concentration range, and where this is known to occur, the limitations are so noted in the tabulation. As the corrosion rate usually increases with tem-

†Abridged from Standards of Hydraulic Institute. See page 6.

perature, the latter becomes an important factor in making a material selection. Where the space is left blank in the appropriate column, it is assumed the materials listed are suitable over the ranges of concentration and temperature normally encountered.

## PUMP CONSTRUCTION MATERIALS

The materials listed are those most commonly used in the principal parts of the pump, such as casings, impellers, cylinders, and, hence, are primarily castings. Wrought materials, such as shafts, should, where practical, be of similar composition to the castings used, and, in the case of ferrous materials, would carry the designation of the American Iron and Steel Institute. Cross-reference is made to such materials in the listings.

Since it is not possible in any generalization to say with certainty that any one material will best withstand the corrosive attack of a given liquid, more than one type is usually included. However, the order of listing does not necessarily indicate relative superiority, as certain factors predominating in one instance may be sufficiently overshadowed in others to reverse the arrangement.

When the liquid to be handled is an electrolyte, combinations of dissimilar metals which may promote galvanic reactions should, where practical, be avoided. The rate of corrosion, where metals widely separated in the galvanic series are used, will depend upon such things as the nature of the electrolyte, temperature, velocity, and particularly, the relative cathode-anode surface area. Although bronze fittings in an iron pump handling sea water may initially accelerate the corrosion of the surface of the iron, the overall rate is sometimes sufficiently low to make the use of large pumps, so fitted, economically sound.

VIII

## SELECTION OF MATERIALS

The pump construction and materials selected as suitable for each application are tabulated opposite the corresponding liquids in Table 46. To simplify identification, each construction and materials selection is designated by descriptive letters or a number as follows:

| | |
|---|---|
| (1) Iron or Bronze Fitted....SF | (3) All Bronze ....................AB |
| (2) All Iron...........................AI | (4) Types 8, 9, 10, 11............SS |

To simplify recording, the symbol SS is used in those cases where types 8, 9, 10, 11 would normally be listed. This does not necessarily mean, however, that all are equally effective in all environments. It merely means that each type has been satisfactorily applied in handling that liquid under some, possibly all, conditions.

Other materials, including corrosion resisting steels, are listed by number in accordance with Table 45.

## TABLE 45 MATERIAL SELECTION CHART†

| Institute Selection | ASTM A48 Class | ACI | AISI | Class | Tensile Strength | Transverse Loading—Pounds .875" Diam. | Transverse Loading—Pounds 1.20" Diam. | Transverse Loading—Pounds 2.00" Diam. |
|---|---|---|---|---|---|---|---|---|
| 1 | 20 | .. | .. | 20 | 20,000 | 900 | 1,800 | 6,000 |
| | 25 | .. | .. | 25 | 25,000 | 1,025 | 2,000 | 6,800 |
| | 30 | .. | .. | 30 | 30,000 | 1,150 | 2,200 | 7,600 |
| | 35 | .. | .. | 35 | 35,000 | .... | .... | .... |
| | 40 | .. | .. | 40 | 40,000 | .... | .... | .... |
| | 50 | .. | .. | 50 | 50,000 | .... | .... | .... |

| Institute Selection | ASTM | ACI | AISI | Grade | Cu. | Sn. | Pb. | Zn. | P. | Tensile | Elong. % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | .... | .. | .. | CB1 | 89.00 | 11.00 | .... | ... | 0.20 | 35,000 | 10 |
| | B143, 1B | .. | .. | CB2 | 88.00 | 8.00 | .... | 4.00 | ... | 40,000 | 20 |
| | B143, 2A | .. | .. | CB3 | 88.00 | 6.00 | .... | 4.50 | ... | 34,000 | 22 |
| | B145, 4A | .. | .. | CB4 | 85.00 | 5.00 | 1.50 | 5.00 | ... | 30,000 | 20 |
| | .... | .. | .. | CB5 | 88.00 | 10.00 | 2.00 | ... | ... | 35,000 | 10 |
| | B144, 3A | .. | .. | CB6 | 80.00 | 10.00 | 10.00 | ... | ... | 25,000 | 8 |

| Institute Selection | ASTM | ACI | AISI | C. | Mn. | Si. | Ni. | Cr. | Mo. | Tensile | Yield | Elong. % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | A216, WCB | .. | 1030 | 0.35 | 0.70 | 0.60 | ... | ... | ... | 70,000 | 36,000 | 22 |
| 4 | A217, C5-8 | .. | 501 | 0.20 | ... | ... | ... | 5.00 | 0.50 | 90,000 | 60,000 | 18 |
| 5 | A296, CA15 | CA15 | 410 | 0.15 | ... | ... | ... | 13.00 | ... | 90,000 | 65,000 | 18 |
| 6 | A296, CB30 | CB30 | .. | 0.30 | ... | ... | 1.00 | 20.00 | ... | 65,000 | 30,000 | .. |
| 7 | A296, CC50 | CC50 | 446 | 0.50 | ... | ... | 2.00 | 28.00 | ... | 55,000 | ..... | .. |

| Institute Selection | ASTM | ACI | AISI | C. | Mn. | P. | S. | Si. | Ni. | Cr. | Mo. | Cu. | Elong. % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | A296, CF-8 | CF-8 | 304 | 0.08 | 1.50 | 0.05 | 0.05 | 2.00 | 8.00 11.00 | 18.00 21.00 | ... | ... | 35 |
| | | | | Tensile Strength 70,000—Yield 28,000 | | | | | | | | | |
| 9 | A296, CF-8M | CF-8M | 316 | 0.08 | 1.50 | 0.05 | 0.05 | 2.00 | 9.00 12.00 | 18.00 21.00 | 2.00 3.00 | ... | 30 |
| | | | | Tensile Strength 70,000—Yield 30,000 | | | | | | | | | |
| 10 | .... | CN-7M | .. | 0.07 | 1.50 | 0.04 | 0.04 | 4.00 | 20.00 30.00 | 18.00 22.00 | 3.50 | 4.50 | 30 |
| | | | | Tensile Strength 65,000—Yield 30,000 | | | | | | | | | |

| Institute Selection | ASTM | ACI | AISI | Remarks |
|---|---|---|---|---|
| 11 | .... | .. | .. | A series of proprietary, nickel-base alloys containing chromium, molybdenum, and other elements, with less than 20% iron. |
| 12 | .... | .. | .. | A special 14.25% silicon cast iron, which is not effected by most corrodents. It is hard and extremely brittle. |

| Institute Selection | ASTM | ACI | AISI | Ni-Resist | C. | Si. | Mn. | Ni. | Cu. | Cr. |
|---|---|---|---|---|---|---|---|---|---|---|
| 13 | .... | .. | .. | Type I | 3.00 | 1.00 | 1.00-1.50 | 17.50 | 7.50 | 1.75-2.50 |
| | | | | Type II | 3.00 | 2.80 | .80-1.50 | 22.00 | .50 | 1.75-2.50 |
| | | | | Tensile Strength 25,000 | | | | | | |

| Institute Selection | ASTM | ACI | AISI | | Ni. | Fe. | Mn. | Si. | Cu. | Elong. % |
|---|---|---|---|---|---|---|---|---|---|---|
| 14 | .... | .. | .. | Monel Metal | 60.00 | 3.50 | 3.50 | 1.00 2.00 | 23.00 | 22 |
| | | | | Tensile Strength 65,000—Yield 30,000 | | | | | | |

| Institute Selection | ASTM | ACI | AISI | Remarks |
|---|---|---|---|---|
| 15 | .... | .. | .. | Commercial nickel castings for handling strong, hot alkalies, where pure white product is desired. |

ASTM—American Society for Testing Materials
ACI—Alloy Casting Institute
AISI—American Iron & Steel Institute

Cu = Copper, Sn = Tin, Pb = Lead, Zn = Zinc
C = Carbon, Mn = Manganese, Si = Silicon, Ni = Nickel
Mo = Molybdenum, S = Sulphur, Cr = Chromium, Fe = Iron

†Courtesy Hydraulic Institute See Page 6.

# TABLE 46. MATERIALS OF CONSTRUCTION & PACKING SUGGESTED WHEN PUMPING VARIOUS MATERIALS.†

| Liquid and Condition | Sg. at 60°F | Material Recommended[1] | Packing Recommended By:‡ Durametallic[2] | Crane | Anchor[4] |
|---|---|---|---|---|---|
| Acetaldehyde | 0.78 | AI | D-110 & 777-NMT | C-06 | 317-3687 |
| Acetate Solvents | | SF, AI, AB, SS | D-110 & 777-NMT | C-06 | 851 TT AB 808 A |
| Acetone | 0.79 | SF, AI | D-110 & 777-NMT | C-06 | 808 A |
| Acetic Anhydride | 1.08 | SS, 12 | D-110 & 777-NMT | C-06 | 811 XX |
| **Acids:** | | | | | |
| Acetic (Cold Conc.) | 1.05 | SS, 12 | D-110 | 111M-SS5 | 811 XX |
| Acetic (Cold Dil.) | | AB, SS, 12 | D-110 | 111M-SS5 | AB-808 A-811 XX |
| Acetic (Boiling Conc.) | | 9, 10, 11, 12 | 999-NM | 111M-SS5 | 811 XX |
| Acetic (Boiling Dil.) | | 9, 10, 11, 12 | 999-NM | 111M-SS5 | 811 XX |
| Arsenic (Ortho) | 2.0-2.5 | SS, 12 | 999-NM | C-06 | 851 TT |
| Benzoic | 1.27 | SS | 110-D-222 | C-06 | 851 TT |
| *Boric (Aqueous)* | | *AB, SS, 12* | *110-B-777* | *C-06* | *820 NJ* |
| Butyric (Conc.) | 0.96 | SS | D-110 | C-06 | 851 TT |
| Carbolic (Conc.) | 1.07 | AI, SS | D-110 | C-98 | 851 TT |
| Carbolic (Aqueous) | | SF, SS | D-110 | C-98 | SP-820 NJ-SS-851 TT |
| Carbonic (Aqueous) | | AB | 777-NMT | C-06 | 820 NJ |
| *Chromic (Aqueous)* | | *SS, 12* | *110 BLA-B-999* | *C-98* | *820 NJ* |
| Citric (Aqueous) | | AB, SS, 12 | 777 NM & D-110 | C-06 | AB-820 NJ-811 XX |
| Fatty (Oleic, Palmitic, etc.) | | AB, SS | D-110 & D-220 | C-06 | AB-820 NJ-811 XX |
| Formic | 1.22 | 9, 10, 11 | 999 NMT | C-98 | 851 TT |
| Fruit | | AB, SS, 14 | 777 NM & D-110 | C-06 | AB-820 NJ-851 TT |
| Hydrochloric (Coml. Conc.) | 1.16‡ | 11, 12 | 666-F[5] | C-98 | 842 |
| *Hydrochloric (10% Cold)* | *1.05‡* | *10, 11, 12, 14, 15* | *666-F[5]* | *C-98* | *842* |
| Hydrochloric (10% Hot) | 1.05‡ | 11, 12 | 666-F[5] | C-98 | 842 |
| Hydrocyanic | 0.70 | AI, SS | 777 NM | C-98 | 842 |
| Hydroflouric (Anhydrous with Hydrocarbon) | | 3, 14 | 666-F[5] | C-1045 | 888 |
| Hydroflouric (Aqueous) | | AB, 14 | 666-F[5] | C-1045 | 888 |
| *Hydrofluosilicic* | *1.30* | *AB, 14* | *B-999* | *C-1045* | *888* |
| Lactic | 1.25 | AB, SS, 12 | 777-NM | C-06 | 909 |
| Mine Water | | AB, SS | 777-NM | 111M-SS1 | 386 |
| Mixed (Sulfuric & Nitric) | | AI, 3, SS, 12 | | C-1045 | 317 |
| Muriatic (See Acid, Hydrochloric) | | | | | |
| Napthenic | | AI, 5, SS | | C-06 | 909 |
| Nitric (Conc. Boiling) | 1.4‡ | 6, 7, 10, 12 | 666-F[5] | C-98 | 842 |
| Nitric (Dil.) | | 5, 6, 7, 8, 9, 10, 12 | 666-F[5] | C-98 | 842 |
| Oxalic (Cold) | 1.65 | SS, 12 | 777-NM | C-06 | 851 TT |
| Oxalic (Hot) | | 10, 11, 12 | 999-NM | C-06 | Anklon |
| Ortho-Phosphoric | 1.36-1.4‡ | 9, 10, 11 | B-110 BLA & B-999 | C-98 | 850 |
| Picric | 1.76 | SS, 12 | | C-98 | 851 TT |
| Pyrogallic | 1.45 | SS | | C-98 | 851 TT |
| Pyroligneous | 1.02-1.03‡ | AB, SS | | C-98 | AB-820 NJ-811 XX |
| Sulphuric (>77% Cold) | 1.69-1.84 | AI, 10, 11, 12 | B-110 BLA & B-999 | C-98 | 842 |
| Sulphuric (65/93% > 175 deg. F.) | 1.60-1.84‡ | 11, 12 | B-110 BLA & B-999 | C-98 | 842 |

See footnotes at end of table.

# TABLE 46. (Cont.)

| Liquid and Condition | Sg. at 60°F | Material Recommended[1] | Packing Recommended By:‡ Durametallic[2] | Crane | Anchor[4] |
|---|---|---|---|---|---|
| Acids (Continued) | | | | | |
| Sulphuric (65/93% <175 deg. F.) | 1.60-1.84‡ | 10, 11, 12 | B-110 BLA & B-999 | C-98 | 842 |
| Sulphuric (10-65%) | 1.07-1.56‡ | 10, 11, 12 | B-110 BLA & B-999 | C-98 | 842 |
| Sulphuric (<10%) | 1.00-1.07‡ | AB, 10, 11, 12, 14 | B-110 BLA & B-999 | C-98 | 842 |
| Sulphuric (Fuming) | 1.92-1.94 | 3, 10, 11 | B-110 BLA | C-98 | 842 |
| Sulphurous | | AB, SS | B-110 BLA | C-98 | 842 |
| Tannic | | AB, SS, 14 | 777-NM | C-98 | 842 |
| Tartaric (Aqueous) | | AB, SS, 14 | 110-B-777 | C-06 | 888 |
| Alcohols | | AB, SF | 710-B-777 | C-06 | 820 NJ |
| Alum (See Aluminum Sulphate and Potash Alum) | | | | | |
| Aluminum Sulphate (Aqueous) | | 10, 11, 12, 14 | B-110 BLA & B-999 | C-06 | 842 |
| Ammonia, Aqua | | AI | B-110 & B777 | 111M-SS6 | 850-858 |
| Ammonium Bicarbonate (Aqueous) | | AI | B-110 & B777 | 111M-SS6 | 850-858 |
| Ammonium Chloride (Aqueous) | | 9, 10, 11, 12, 14 | B-110 BLA & B-999 | C-06 | 851 TT |
| Ammonium Nitrate (Aqueous) | | AI, SS, 14 | 999-NM | C-06 | 851 TT |
| Ammonium Phosphate (Aqueous) | | AI, SS, 14 | B-110 BLA & B-999 | C-06 | 851 TT |
| Ammonium Sulphate (Aqueous) | | AI, SS | B-110 BLA & B-999 | C-06 | 850-858 |
| Ammonium Sulphate (with $H_2SO_4$) | | AB, 9, 10, 11, 12 | B-110 BLA & B-999 | C-98 | 227 |
| Aniline | 1.02 | SF, AI | 710-B-777 | 111M-SS3 | 804 |
| Aniline Hydrochl. (Aqueous) | | 11, 12 | 710-B-777 | C-06 | 850 |
| Asphalts: (See Sect. V) | | | | | |
| Blended or Virgin | 0.98-1.4 | AI, 5 | D-110 | 805MD | 199 |
| Barium Chloride (Aqueous) | | AI, SS | 999-NMT | C-06 | 888 |
| Barium Nitrate (Aqueous) | | AI, SS | 999-NMT | C-06 | 888 |
| Beer | 1.01‡ | AB, 8 | 777-NM & D-110 | C-06 | 909 |
| Beer Wort | | AB, 8 | 777-NM & D-110 | C-06 | 909 |
| Beet Juice | | AB, 8 | 777-NM & D-110 | C-06 | 909 |
| Beet Pulp | | AB, SF, SS | 777-NM & D-110 | C-06 | 909 |
| Benzene (See Benzol) | | | | | |
| Benzine (See Petroleum Ether) | | | | | |
| Benzol | 0.88 | SF, AI | 710-B-777 | 111M-SS3 | 905 |
| Black Liquor (See Liquors, Pulp Mill) | | | | | |
| Blood | | AB, SF | D-110 | C-06 | Anklon |
| Brines: | | | | | |
| Calcium Chloride (pH>8) | | AI | 999-NMT | 811-SS1 | 851 TT |
| Calcium Chloride (pH<8) | | AB, 10, 11, 13, 14 | 999-NMT | 811-SS1 | 820 NJ |
| Calcium-Magnesium Chlorides (Aqueous) | | AB, 10, 11, 13, 14 | 999-NMT | 811-SS1 | 820 NJ |
| Calcium-Sodium Chloride (Aqueous) | | AB, 10, 11, 13, 14 | 999-NMT | 811-SS1 | 820 NJ |
| Sodium Chloride (<3%, Cold) | 1.02 | AB, AI, 13 | 110-B-777 | 811-SS1 | 820 NJ |
| Sodium Chloride (>3%, Cold) | 1.02-1.20 | AB, SS, 13, 14 | 110-B-777 | 811-SS1 | 820 NJ |
| Sodium Chloride (>3%, Hot) | | 9, 10, 11,12, 14 | 110-B-777 | 811-SS1 | 851 TT |

See footnotes at end of table.

## TABLE 46. (Cont.)

| Liquid and Condition | Sg. at 60°F | Material Recommended[1] | Packing Recommended By:‡ Durametallic[2] | Crane | Anchor[4] |
|---|---|---|---|---|---|
| Brines: (Continued) | | | | | |
| Sea Water | 1.03 | AB, SF, AI | 110-B-777 | 811-SS1 | 387 F |
| Butane | 0.59‡ | SF, AI, 3 | 710-B-777 | 111M-SS3 | 905 |
| Calcium Bisulfite (Paper Mill) | 1.06 | 9, 10, 11 | B-110 BLA & B-999 | C-06 | 811 XX |
| Calcium Chlorate (Aqueous) | | 10, 11, 12 | 999-NMT | C-06 | 820 NJ |
| Calcium Hypochlorite | | AI, 10, 11, 12 | 999-NMT | C-06 | 820 NJ |
| Calcium-Magnesium Chloride (See Brines) | | | | | |
| Cane Juice | | AB, SF, 13 | 110-D-222 | C-06 | 909 |
| Carbon Bisulfide | 1.26 | AI | D-110 | C-06 | 851 TT |
| Carbonate of Soda (See Soda Ash) | | | 110-B-777 | C-06 | |
| Carbon Tetrachloride (Anhydrous) | 1.50 | SF, AI | 710-B-777 | C-06 | 820 NJ |
| Carbon Tetrachloride (Plus Water) | | AB, 8 | 710-B-777 | C-06 | 820 NJ |
| Catsup | | AB, SS | D-110 | C-06 | 909 |
| Caustic Potash (See Potassium Hydroxide) | | | | | |
| Caustic Soda (See Sodium Hydroxide) | | | | | |
| *Cellulose Acetate* | | 9, 10, 11 | D-110 & 777-NMT | C-06 | 851 TT |
| Chlorate of Lime (See Calcium Chlorate) | | | | | |
| Chloride of Lime (See Calcium Hypochlorite) | | | | | |
| Chlorine Water (Depends on Concentration) | | 9, 10, 11, 12 | 999-NMT | 111M-SS1 | 851 TT |
| Chlorobenzene | 1.1 | AB, SF, 8 | 710-B-777 | C-06 | 820 NJ |
| Chloroform | 1.5 | AB, SS, 14 | 710-B-777 | C-06 | 804 |
| Chrome Alum (Aqueous) | | 10, 11, 12 | 999-NM | C-98 | 808 A |
| Condensate (See Water, Distilled) | | | | | |
| Copperas, Green (See Ferrous Sulfate) | | | | | |
| Copper Ammonium Acetate (Aqueous) | | AI, SS | B-999 | C-98 | 842 |
| Copper Chloride (Cupric) (Aqueous) | | 11, 12 | B-999 | C-98 | 842 |
| Copper Nitrate | | SS | 666-F[5] | C-98 | 842 |
| Copper Sulfate (Blue Vitriol) (Aqueous) | | SS, 12 | B-999 | C-98 | 842 |
| Creosote (See Oil, Creosote) | | | D-110 | 805MD | |
| Cresol, Meta | 1.03 | AI, 5 | D-110 | 805MD | 820 NJ |
| Cyanide (See Sodium or Potassium Cyanide) | | | | | |
| Cyanogen (in water) | | AI | 999-NM | C-98 | 804 |
| Diphenyl | 0.99 | AI, 3 | 110-D-222 | 111M-SS2 | 820 NJ |
| Enamel | | AI | D-110 & 777-NM | C-06 | Teflon |
| Ethanol (See Alcohols) | | | | | |
| Ethane‡ | 0.37‡ | SF, AI, 3‡ | 710-B-777 | 111M-SS2 | |
| Ethylene Chloride (Cold) | 1.28 | AB, SS, 14 | 710-B-777 | C-06 | 317-3687 |
| Ferric Chloride (Aqueous) | | 11, 12 | 666-F[5] | C-06 | 820 NJ |
| Ferric Sulphate (Aqueous) | | SS, 12 | 666-F[5] | C-06 | 820 NJ |
| Ferrous Chloride (Cold-Aqueous) | | 11, 12 | 666-F[5] | C-06 | 820 NJ |
| Ferrous Sulphate (Aqueous) | | 9, 10, 11, 12, 14 | 666-F[5] | C-06 | 820 NJ |
| Formaldehyde | 1.08 | AB, SS | 777-NMT | C-06 | 804 |
| Fruit Juices | | AB, SS, 14 | 110-D-222 | C-06 | 909 |
| Furfural | 1.16 | AB, AI, SS | D-110 & B-777 | C-06 | 820 NJ |

See footnotes at end of table.

VIII

## TABLE 46. (Cont.)

| Liquid and Condition | Sg. at 60°F | Material Recommended[1] | Packing Recommended By:‡ Durametallic[2] | Crane | Anchor[4] |
|---|---|---|---|---|---|
| Gasolines: | | | | | |
| Pentane | 0.63‡ | AI, SF | 710-B-777 | 111M-SS3 | 317-3687 |
| Hexane | 0.66‡ | AI, SF | 710-B-777 | 111M-SS3 | 317-3687 |
| Heptane | 0.69‡ | AI, SF | 710-B-777 | 111M-SS3 | 317-3687 |
| Octane | 0.71‡ | AI, SF | 710-B-777 | 111M-SS3 | 317-3687 |
| Nonane | 0.72‡ | AI, SF | 710-B-777 | 111M-SS3 | 317-3687 |
| Decane | 0.73‡ | AI, SF | 710-B-777 | 111M-SS3 | 317-3687 |
| Undecane | 0.74‡ | AI, SF | 710-B-777 | 111M-SS3 | 317-3687 |
| Dodecane | 0.75‡ | AI, SF | 710-B-777 | 111M-SS3 | 317-3687 |
| Glaubers Salt (See Sodium Sulfate) | | | | | |
| Glucose | 1.35-1.44‡ | AB, SF | 777-NM | C-06 | 1108 |
| Glue (Hot) | 1.20-1.25‡ | SF, AI | 110-D-222 | 810W | 317 W |
| Glue Sizing | | AB | 110-D-222 | 810W | 317 W |
| Glycerol (Glycerin) | 1.26 | AB, SF, AI | 777-NMT | C-06 | 820 NJ |
| Green Liquor (See Liquors, Pulp Mill) | | | | | |
| Heptane (See Gasolines) | | SF, AI | | | |
| Hydrogen Peroxide (Aqueous) | | SS | 666-F[5] | C-1045 | 820 NJ |
| Hydrogen Sulfide (Aqueous) | | SS | 110-D-222 | C-98 | 820 NJ |
| Kaolin Slip (In Water) | | AI, 3 | B-777 | 111M-SS1 | 851 TT |
| Kaolin Slip (In Acid) | | 10, 11, 12 | B-999 | C-98 | 851 TT |
| Kerosene (See Oil, Kerosene) | | | 710-B-777 | 111M-SS3 | |
| Lard (Hot) | | SF, AI | D-110 | C-06 | 909 |
| Lead Acetate (Aqueous) (Sugar of Lead) | | 9, 10, 11, 14 | 110-D-222 | C-98 | 842 |
| Lead (Molten) | | AI, 3 | | C-98 | 842 |
| Lime Water (Milk of Lime) | | AI | 777-NMT | SS6J | 820 NJ |
| Liquors, Pulp Mill: | | | | | |
| Black | | AI, 3, 9, 10, 11, 12, 14 | 666-F[5] | C-06 | 811 XX |
| Green | | AI, 3, 9, 10, 11, 12, 14 | 666-F[5] | C-06 | 811 XX |
| White | | AI, 3, 9, 10, 11, 12, 14 | 666-F[5] | C-06 | 811 XX |
| Pink | | AI, 3, 9, 10, 11, 12, 14 | 666-F[5] | C-06 | 811 XX |
| Sulfite | | 9, 10, 11 | B-110-BLA | C-06 | 811 XX |
| Lithium Chloride (Aqueous) | | AI | 110-B-777 | 111M-SS1 | 811 XX |
| Lye, Caustic (See Potassium & Sodium Hydroxide) | | | | | |
| Magnesium Chloride (Aqueous) | | 10, 11, 12 | 999-NM | C-06 | 851 TT |
| Magnesium Sulfate (Aqueous) (Epsom Salts) | | AI, SS | 999-NM | C-06 | 851 TT |
| Manganese Chloride (Aqueous) | | AI, SS, 12 | 999-NM | C-06 | 820 NJ |
| Manganous Sulfate (Aqueous) | | AB, AI, SS | 999-NM | C-06 | 820 NJ |
| Mash | | AB, SF, 8 | 110-D-222 | C-06 | 909 |
| Mercuric Chloride (Very dil. Aqueous) | | 9, 10, 11, 12 | 999-NM | C-06 | 851 TT |
| Mercuric Chloride (Coml. Conc. Aqueous) | | 11, 12 | 999-NM | C-06 | 851 TT |
| Mercuric Sulfate (in $H_2SO_4$) | | 10, 11, 12 | 999-NM | C-98 | 820 NJ |
| Mercurous Sulfate (in $H_2SO_4$) | | 10, 11, 12 | 999-NM | C-98 | 820 NJ |
| Methyl Chloride | 0.92‡ | AI | 710-B-777 | C-06 | 856 |
| Methylene Chloride | 1.34 | AI, 8 | 710-B-777 | C-06 | 856 |
| Milk | 1.03-1.04 | 8 | D-110 or 777-NM | C-06 | 909 |

See footnotes at end of table.

TABLE 46. (Cont.)

| Liquid and Condition | Sg. at 60°F | Material Recommended[1] | Packing Recommended By:‡ Durametallic[2] | Crane | Anchor[3] |
|---|---|---|---|---|---|
| Mine Water (See Acid, Mine Water) | | | | | |
| Miscella (20% Soyabean Oil and Solvent | .075 | AI | 110-D-222 | 111M-SS1 | 851 TT |
| Molasses | | AB, SF | 110-D-222 | C-06 | 909 |
| Mustard | | AB, SS, 12 | 110-D-222 | C-06 | 909 |
| Naphtha | 0.78-0.88 | SF, AI | 710-B-777 | 111M-SS3 | 820 NJ |
| Naphtha (Crude) | 0.92-0.95 | SF, AI | 710-B-777 | 111M-SS3 | 820 NJ |
| Nicotine Sulfate | | 10, 11, 12, 14 | B-110 BLA & B-999 | 896 | 851 TT |
| Nitre (See Potassium Nitrate) | | | | | |
| Nitre Cake (See Sodium Bisulfate) | | | | | |
| Nitro Ethane | 1.04 | SF, AI | 710-B-777 | 896 | 804 |
| Nitro Methane | 1.14 | SF, AI | 710-B-777 | 896 | 804 |
| Oils: | | | | | |
| Coal Tar | | SF, AI, SS | D-110 | 101AL | 820 NJ |
| Coconut | 0.91 | AB, SF, SS, AI,14 | 110-D-222 | C-06 | 820 NJ |
| Creosote | 1.04-1.10 | SF, AI | D-110 | 805MD | 317 |
| Crude (Cold) | | SF, AI | 710-B-777 | 111M-SS2 | 317 |
| Crude (Hot) | | 3 | D-110 | 101AL | 811 |
| Essential | | AB, SF, AI | 110-D-222 | 101AL | 317 |
| Fuel | 0.82-1.00‡ | SF, AI | 710-B-777 | 111M-SS2 | 317 |
| Kerosene | 0.78-0.82‡ | SF, AI | 710-B-777 | 111M-SS2 | 317-3687 |
| Linseed | 0.94 | AB, SF, AI, SS, 14 | 710-B-777 | 111M-SS2 | 317 |
| Lubricating | 0.88-0.94‡ | SF, AI | 710-B-777 | 111M-SS2 | 317 |
| Mineral | 0.88-0.94‡ | SF, AI | 710-B-777 | 111M-SS2 | 317 |
| Olive | 0 90 | SF, AI | 710-B-777 | 111M-SS2 | 317 |
| Palm | 0.90 | AB, SF, AI, SS, 14 | 710-B-777 | 111M-SS2 | 317 |
| Quenching | 0.91 | SF, AI | 710-B-777 | 111M-SS2 | 317 |
| Rapeseed | 0.92 | AB, SS, 14 | 710-B-777 | 111M-SS2 | 317 |
| Soya Bean | 0.93-0.98‡ | AB, SF, AI, SS, 14 | 710-B-777 | 111M-SS2 | 820 |
| Turpentine | 0.87 | SF, AI | 710-B-777 | 111M-SS2 | 820 NJ |
| Paraffin (Hot) | 0.90‡ | SF, AI | 110-D-222 | C-06 | 317-3687 |
| Perhydrol (See Hydrogen Peroxide) | | | | | |
| Petroleum Ether | | SF, AI | 710-B-777 | 111M-SS2 | 804 |
| Phenol (See Acid, Carbolic) | | | | | |
| Photographic Developers | | SS | 110-B-777 | 111M-SS2 | 888 |
| Potash (Plant Liquor) | | AB, SS, 13, 14 | 110-B-777 | 111M-SS2 | 888 |
| Potash Alum (Aqueous) | | AB, 9, 10, 11, 12, 13, 14 | B-110 BLA & B-999 | 111M-SS5 | 386 |
| Potassium Bichromate (Aqueous) | | AI | 666-F[5] | C-98 | 851 TT |
| Potassium Carbonate (Aqueous) | | AI | 110-B-777 | 111M-SS1 | 851 TT |
| Potassium Chlorate (Aqueous) | | SS, 12 | 666-F[5] | C-98 | 851 TT |
| Potassium Chloride (Aqueous) | | AB, SS, 14 | 110-B-777 | 111M-SS1 | 820 |
| Potassium Cyanide (Aqueous) | | AI | 777-NM | C-06 | 851 TT |
| Potassium Hydroxide (Aqueous) | | AI, 5, SS, 13, 14, 15 | 666-F[5] | SS6J | 853 |
| Potassium Nitrate (Aqueous) | | AI, 5, SS | B-110-BLA | SS6J | 851 TT |
| Potassium Sulfate (Aqueous) | | AB, SS | 110-B-777 | 111M-SS1 | 820 |
| Propane ($C^3H^8$) | 0.51‡ | SF, AI, 3 | 710-B-777 | 111M-SS3 | 317-3687 |
| Pyridine | 0.98 | AI | 710-B-777 | 111M-SS3 | 851 TT |
| Pyridine Sulphate | | 10, 12 | B-110 BLA & B-999 | 111M-SS5 | 851 TT |

See footnotes at end of table.

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## TABLE 46. (Cont.)

| Liquid and Condition | Sg. at 60°F | Material Recommended[1] | Packing Recommended By:‡ Durametallic[2] | Crane | Anchor[4] |
|---|---|---|---|---|---|
| Rhidolene | | SF | 710-B-777 | 810 | 317-3687 |
| Rosin (Colophony) (Paper Mill) | | AI | 110-D-222 | 100AL | 851 TT |
| Sal Ammoniac (See Ammonium Chloride) | | | | | |
| Salt Lake (Aqueous) | | AB, SS, 12 | 110-B-777 | 111M-SS1 | 808 A |
| Salt Water (See Brines) | | | | | |
| Sea Water (See Brines) | | | | | |
| Sewage | | AB, SF, AI | 110-B-777 | 111M-SS1 | 386 |
| Shellac | | AB | 110-B-777 | 111M-SS1 | 842 |
| Silver Nitrate (Aqueous) | | SS, 12 | 666-F[5] | C-06 | 811 XX |
| Slop, Brewery | | AB, SF, AI | 110-D-222 | 810(MICA) | 317 |
| Slop, Distillers | 1.05 | AB, SS | 110-D-222 | 810(MICA) | 317 |
| Soap Liquor | | AI | 110-B-777 | SS6J | 851 TT |
| Soda Ash (Cold Aqueous) | | AI | 110-B-777 | SS6J | 851 TT |
| Soda Ash (Hot Aqueous) | | SS, 13, 14 | 110-B-777 | SS6J | 888 |
| Sodium Bicarbonate (Aqueous) | | AI, SS, 13 | 110-B-777 | SS6J | 851 TT |
| Sodium Bisulfate (Aqueous) | | 10, 11, 12 | 110-B-777 | SS6J | 851 TT |
| Sodium Carbonate (See Soda Ash) | | | | | |
| Sodium Chlorate (Aqueous) | | SS, 12 | 666-F[5] | SS6J | 851 TT |
| Sodium Chloride (See Brines) | | | | | |
| Sodium Cyanide (Aqueous) | | AI | 777-NM | SS6J | 851 TT |
| Sodium Hydroxide (Aqueous) | | AI, 5, SS, 13, 14, 15 | 666-F[5] | SS6J | 851 TT |
| Sodium Hydrosulfite (Aqueous) | | SS | B-110-BLA | SS6J | 851 TI |
| Sodium Hypochlorite | | 10, 11, 12 | 666-F[5] | SS6J | 851 TT |
| Sodium Hyposulfite (See Sodium Thiosulfate) | | | | | |
| Sodium Meta Silicate | | AI | 777-NM | SS6J | 851 TT |
| Sodium Nitrate (Aqueous) | | AI, 5, SS | B-110 BLA | SS6J | 851 TT |
| Sodium Phosphate: | | | | | |
| Monobasic (Aqueous) | | AB, SS | 999-NM | 810S | 386 |
| Dibasic (Aqueous) | | AB, AI, SS | 777-NM | 810S | 386 |
| Tribasic (Aqueous) | | AI | 110-B-777 | 111M-SS1 | 851 TT |
| Meta (Aqueous) | | AB, SS | 110-B-777 | 111M-SS1 | 386 |
| Hexameta (Aqueous) | | SS | 110-B-777 | 111M-SS1 | 851 TT |
| Sodium Plumbite (Aqueous) | | AI | 666-F[5] | 810S | 851 TT |
| Sodium Silicate (Aqueous)‡ | 1.38‡ | AI‡ | 777-NM | 810S | |
| | 1.41‡ | | 999-NM | | |
| Sodium Sulfate (Aqueous) | | AB, SS | 110-B-777 | 111M-SS1 | 820 |
| Sodium Sulfide (Aqueous) | | AI, SS | 110-B-777 | 111M-SS1 | 851 TT |
| Sodium Sulfite (Aqueous) | | AB, SS | 110-B-777 | 111M-SS1 | 820 |
| Sodium Thiosulfate (Aqueous) | | SS | 110-B-777 | 111M-SS1 | 851 TT |
| Stannic Chloride (Aqueous) | | 11, 12 | 666-F[5] | SS6J | 851 TT |
| Stannous Chloride (Aqueous) | | 11, 12 | 666-F[5] | SS6J | 851 TT |
| Starch | | AB, SF | B-777 | 810(MICA) | 909 |
| Strontium Nitrate (Aqueous) | | AI, 8 | 999-NM | SS5 | 853 |
| Sugar (Aqueous) | | AB, SS, 13 | 110-D-222 | C-06 | 909 |
| Sulfite Liquors (See Liquors, Pulp Mill) | | | | | |
| Sulfur (In Water) | | AB, AI, SS | 110-D-222 | C-06 | 842 |
| Sulfur (Molten) | | AI | 110-D-222 | 101AL-SS2 | 851 TT |

See footnotes at end of table.

## TABLE 46. (Cont.)

| Liquid and Condition | Sg. at 60°F | Material Recommended[1] | Packing Recommended By:‡ Durametallic[2] | Crane | Anchor[4] |
|---|---|---|---|---|---|
| Sulfur Chloride (Cold) | | AI | 110 BLA-B-999 | 896 | 851 TT |
| Syrup (See Sugar) | | | | | |
| Tallow (Hot) | 0.90 | AI | 110-D-222 | 810 | 862 |
| Tanning Liquors | | AB, SS, 12, 14 | 777-NM | SS6J | 842 |
| Tar (Hot) | | AI, 3 | B-110 | 805MD | 842 |
| Tar & Ammonia (In Water) | | AI | B-110 | 805MD | 856 |
| Tetrachloride of Tin (See Stannic Chloride) | | | | | |
| Tetraethyl Lead | 1.66 | SF, AI | 710-B-777 | 810S(11) | 317-3687 |
| Toluene (Toluol) | 0.87 | SF, AI | 710-B-777 | 810S(11) | 905 |
| Trichloroethylene | 1.47 | AB, SF, AI, 8 | 710-B-777 | 810S(11) | 905 |
| Urine | | AB, SS | 110-B-777 | 810 | 317 |
| Varnish | | AB, SF, AI, 8, 14 | 710-B-777 | 810S(11) | 820 NJ |
| Vegetable Juices | | AB, SS,14 | 110-D-222 | C-06 | 820 |
| Vinegar | | AB, SS, 12 | 110-D-222 | C-06 | 820 NJ |
| Vitriol, Blue (See Copper Sulfate) | | | | | |
| Vitriol, Green (See Ferrous Sulfate) | | | | | |
| Vitriol, Oil of (See Acid Sulfuric) | | | | | |
| Vitriol, White (See Zinc Sulfate) | | | | | |
| Water, Boiler Feed: | | | | | |
| Not Evaported pH>8.5 | 1.0 | AI | 110-B-777 | 111M-SS1 | 808A |
| High Makeup pH>8.5 | 1.0 | SF | 110-B-777 | 111M-SS1 | 808A |
| Low Makeup Evaporated, any pH | 1.0 | 4, 5, 8, 14 | 110-B-777 | 111M-SS1 | 808A |
| Water Distilled: | | | 110-B-777 | | |
| High Purity | 1.0 | AB, 8 | 110-B-777 | C-06 | 808A |
| Condensate | 1.0 | AB, SF | 110-B-777 | 111M-SS1 | 386 |
| Water, Fresh | 1.0 | SF | 110-B-777 | 111M-SS1 | 386 |
| Water, Mine (See Acid, Mine Water) | | | | | |
| Water, Salt & Sea (See Brines) | | | | | |
| Whiskey | | AB, 8 | 110-D-222 | C-06 | 909 |
| White Liquor (See Liquors, Pulp Mill) | | | | | |
| White Water (Paper Mill) | | AB, SF, AI | 110-B-777 | C-64 | 909 |
| Wine | | AB, 8 | 110-D-222 | C-06 | 909 |
| Wood Pulp (Stock) | | AB, SF, AI | 110-B-777 | C-64 | 808 A |
| Wood Vinegar (See Acid, Pyroligneous) | | | | | |
| Wort (See Beer Wort) | | | | | |
| Xylol (Xylene) | 0.87 | SF, AI, SS | 710-B-777 | C-06 | 804 |
| Yeast | | AB, SF | 110-D-222 | C-06 | 909 |
| Zinc Chloride (Aqueous) | | 9, 10, 11, 12 | 100-BLA & B-999 | 810 | 842 |
| Zinc Sulfate (Aqueous) | | AB, 9, 10,11 | 999-NM | SS5 | 842 |

† Data from Standards of Hydraulic Institute 10th Edition except as noted:

‡ Data added from other sources.

[1] For meaning of symbols see Table 45 and preceding text.

[2] Symbol number of packing recommended by Durametallic Corp., Kalamazoo, Mich.

[3] Symbol number of packing recommended by Crane Packing Co., Morton Grove, Ill.

[4] Symbol number of packing recommended by Anchor Packing Co., 401 N. Broad St., Philadelphia, Pa.

[5] In non-oxidizing applications use A-666-S.

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## MECHANICAL SEALS

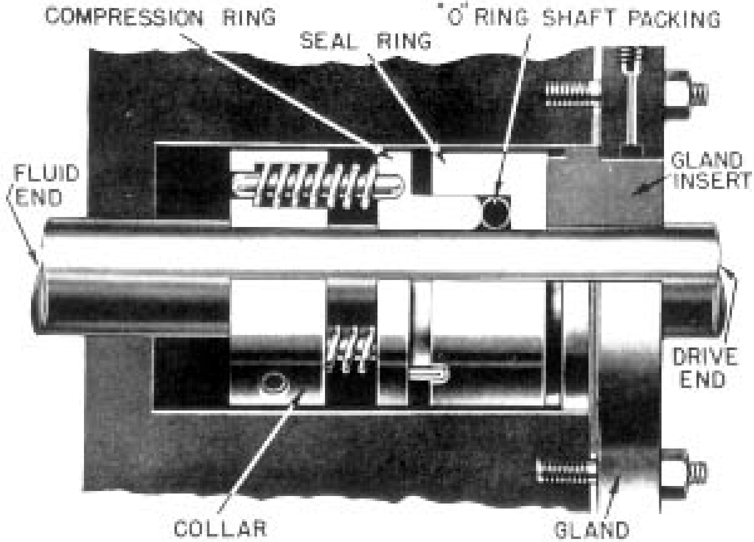


FIG. 57. Typical mechanical seal. Single inside type illustrated.†

When stuffing box packing is used some of the liquid being pumped or a separate sealing fluid must be permitted to drip from the packing box. This drip is the only means of lubricating and cooling the packing box. To meet the needs of industry for a dripless box, mechanical seals were developed and are especially applicable when sealing a pump handling corrosive, costly, volatile, toxic or gritty fluids. Their use results in lowered maintenance costs, fewer shut-downs, greater safety and more economical operation. They are particularly suitable for use in pumps handling light hydrocarbons, corrosive crude stocks, caustics, acids, solvents and other fluids difficult to seal with conventional packing.

To prevent leakage two essential anti-frictional mating rings lapped together are used. The rotating ring is sealed against leakage to and rotates with the shaft. The stationary member is generally fixed in the stuffing box or gland and leakage prevented by sealing with "O" rings or gaskets. In Fig. 57 gaskets are illustrated. The two mating rings are held together by spring and hydraulic pressure.

Mechanical seals can be built for a wide range of pressures and temperatures using in their construction any machineable material including steel or its alloys, carbon, ceramics or fibre.

†*Courtesy Durametallic Corp. See page 6.*

## pH VALUES

The acidity or alkalinity of a solution is expressed by its pH value. A neutral solution such as water has a pH value of 7.0. Decreasing pH values from 7.0 to 0.0 indicate increasing acidity and increasing pH values from 7.0 to 14.0 indicate increasing alkalinity. Since the pH value denotes the acidity or alkalinity of a liquid it gives some indication of the materials required in constructing a pump to handle the liquid. The pH value alone, however, is not conclusive. Many other factors must be considered. However, as an approximate guide, Table 47a may be found helpful.

TABLE 47a. MATERIALS OF CONSTRUCTION INDICATED BY pH VALUE.

| pH Value | Material of Construction |
|---|---|
| 0 to 4 | Corrosion Resistant Alloy Steels. |
| 4 to 6 | All Bronze. |
| 6 to 8 | Bronze Fitted or Standard Fitted. |
| 8 to 10 | All Iron. |
| 10 to 14 | Corrosion Resistant Alloys. |

The following tables give approximately pH values. From "modern pH and Chlorine Control", W. A. Taylor & Co., by permission.

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TABLE 47. APPROXIMATE pH VALUES.

ACIDS

| | | | |
|---|---|---|---|
| Hydrochloric, N | 0.1 | Formic, 0.1N | 2.3 |
| Hydrochloric, 0.1N | 1.1 | Lactic, 0.1N | 2.4 |
| Hydrochloric, 0.01N | 2.0 | Acetic, N | 2.4 |
| Sulfuric, N | 0.3 | Acetic, 0.1N | 2.9 |
| Sulfuric, 0.1N | 1.2 | Acetic, 0.01N | 3.4 |
| Sulfuric, 0.01N | 2.1 | Benzoic, 0.01N | 3.1 |
| Orthophosphoric, 0.1N | 1.5 | Alum, 0.1N | 3.2 |
| Sulfurous, 0.1N | 1.5 | Carbonic (saturated) | 3.8 |
| Oxalic, 0.1N | 1.6 | Hydrogen sulfide, 0.1N | 4.1 |
| Tartaric, 0.1N | 2.2 | Arsenious (saturated) | 5.0 |
| Malic, 0.1N | 2.2 | Hydrocyanic, 0.1N | 5.1 |
| Citric, 0.1N | 2.2 | Boric, 0.1N | 5.2 |

# TABLE 47. (Cont.) APPROXIMATE pH VALUES.

## BASES

| | | | |
|---|---|---|---|
| Sodium hydroxide, N | 14.0 | Ammonia, N | 11.6 |
| Sodium hydroxide, 0.1N | 13.0 | Ammonia, 0.1N | 11.1 |
| Sodium hydroxide, 0.01N | 12.0 | Ammonia, 0.01N | 10.6 |
| Potassium hydroxide, N | 14.0 | Potassium cyanide, 0.1N | 11.0 |
| Potassium hydroxide, 0.1N | 13.0 | Magnesia (saturated) | 10.5 |
| Potassium hydroxide, 0.01N | 12.0 | Sodium sesquicarbonate, 0.1N | 10.1 |
| Sodium metasilicate, 0.1N | 12.6 | Ferrous hydroxide (saturated) | 9.5 |
| Lime (saturated) | 12.4 | Calcium carbonate (saturated) | 9.4 |
| Trisodium phosphate, 0.1N | 12.0 | Borax, 0.1N | 9.2 |
| Sodium carbonate, 0.1N | 11.6 | Sodium bicarbonate, 0.1N | 8.4 |

## BIOLOGIC MATERIALS

| | | | |
|---|---|---|---|
| Blood, plasma, human | 7.3-7.5 | Duodenal contents, human | 4.8-8.2 |
| Spinal fluid, human | 7.3-7.5 | Feces, human | 4.6-8.4 |
| Blood, whole, dog | 6.9-7.2 | Urine, human | 4.8-8.4 |
| Saliva, human | 6.5-7.5 | Milk, human | 6.6-7.6 |
| Gastric contents, human | 1.0-3.0 | Bile, human | 6.8-7.0 |

## FOODS

| | | | |
|---|---|---|---|
| Apples | 2.9-3.3 | Milk, cows | 6.3-6.6 |
| Apricots | 3.6-4.0 | Olives | 3.6-3.8 |
| Asparagus | 5.4-5.8 | Oranges | 3.0-4.0 |
| Bananas | 4.5-4.7 | Oysters | 6.1-6.6 |
| Beans | 5.0-6.0 | Peaches | 3.4-3.6 |
| Beers | 4.0-5.0 | Pears | 3.6-4.0 |
| Blackberries | 4.9-5.5 | Peas | 5.8-6.4 |
| Bread, white | 5.0-6.0 | Pickles, sour | 3.0-3.4 |
| Beets | 4.9-5.5 | Pickles, dill | 3.2-3.6 |
| Butter | 6.1-6.4 | Pimento | 4.6-5.2 |
| Cabbage | 5.2-5.4 | Plums | 2.8-3.0 |
| Carrots | 4.9-5.3 | Potatoes | 5.6-6.0 |
| Cheese | 4.8-6.4 | Pumpkin | 4.8-5.2 |
| Cherries | 3.2-4.0 | Raspberries | 3.2-3.6 |
| Cider | 2.9-3.3 | Rhubarb | 3.1-3.2 |
| Corn | 6.0-6.5 | Salmon | 6.1-6.3 |
| Crackers | 6.5-8.5 | Sauerkraut | 3.4-3.6 |
| Dates | 6.5-8.5 | Shrimp | 6.8-7.0 |
| Eggs, fresh white | 7.6-8.0 | Soft drinks | 2.0-4.0 |
| Flour, wheat | 5.5-6.5 | Spinach | 5.1-5.7 |
| Gooseberries | 2.8-3.0 | Squash | 5.0-5.4 |
| Grapefruit | 3.0-3.3 | Strawberries | 3.0-3.5 |
| Grapes | 3.5-4.5 | Sweet potatoes | 5.3-5.6 |
| Hominy (lye) | 6.8-8.0 | Tomatoes | 4.0-4.4 |
| Jams, fruit | 3.5-4.0 | Tuna | 5.9-6.1 |
| Jellies, fruit | 2.8-3.4 | Turnips | 5.2-5.6 |
| Lemons | 2.2-2.4 | Vinegar | 2.4-3.4 |
| Limes | 1.8-2.0 | Water, drinking | 6.5-8.0 |
| Maple syrup | 6.5-7.0 | Wines | 2.8-3.8 |

# TABLE 48. PHYSICAL PROPERTIES OF CALCIUM CHLORIDE AND SODIUM CHLORIDE†

## CALCIUM CHLORIDE

| Degrees Baume 60°F | Specific gravity 60°/60°F | Degrees Salometer 60°F | % $CaCl_2$ by weight | Lb. $CaCl_2$ per gallon of solution (approx.) | Freezing point °F |
|---|---|---|---|---|---|
| 0 | 1.000 | 0 | 0 | 0 | 32. |
| 1. | 1.007 | 4 | 1 | ...... | 31.1 |
| 2.1 | 1.015 | 8 | 2 | ...... | 30.4 |
| 3.4 | 1.024 | 12 | 3 | ½ | 29.5 |
| 4.5 | 1.032 | 16 | 4 | ...... | 28.6 |
| 5.7 | 1.041 | 22 | 5 | ...... | 27.7 |
| 6.8 | 1.049 | 26 | 6 | 1 | 26.6 |
| 8. | 1.058 | 32 | 7 | ...... | 25.5 |
| 9.1 | 1.067 | 36 | 8 | ...... | 24.3 |
| 10.2 | 1.076 | 40 | 9 | 1½ | 22.8 |
| 11.4 | 1.085 | 44 | 10 | ...... | 21.3 |
| 12.5 | 1.094 | 48 | 11 | ...... | 19.7 |
| 13.5 | 1.103 | 52 | 12 | 2 | 18.1 |
| 14.6 | 1.112 | 58 | 13 | ...... | 16.3 |
| 15.6 | 1.121 | 62 | 14 | ...... | 14.3 |
| 16.8 | 1.131 | 68 | 15 | 2½ | 12.2 |
| 17.8 | 1.140 | 72 | 16 | ...... | 10. |
| 19. | 1.151 | 76 | 17 | ...... | 7.5 |
| 20. | 1.160 | 80 | 18 | 3 | 4.6 |
| 21. | 1.169 | 84 | 19 | ...... | 1.7 |
| 22. | 1.179 | 88 | 20 | ...... | —1.4 |
| 23. | 1.188 | 92 | 21 | 3½ | —4.9 |
| 24. | 1.198 | 96 | 22 | ...... | —8.6 |
| 25. | 1.208 | 100 | 23 | ...... | —11.6 |
| 26. | 1.218 | 104 | 24 | 4 | —17.1 |
| 27. | 1.229 | 108 | 25 | ...... | —21.8 |
| 28. | 1.239 | 112 | 26 | ...... | —27. |
| 29. | 1.250 | 116 | 27 | 4½ | —32.6 |
| 30. | 1.261 | 120 | 28 | ...... | —39.2 |
| 31. | 1.272 | 124 | 29 | ...... | —46.2 |
| 32. | 1.283 | 128 | 30 | 5 | —54.4 |

$CaCl_2$ is the most commonly used brine.

†*Courtesy Ingersoll-Rand Co.* *See page 6.*

## SODIUM CHLORIDE

| Specific gravity 60°/60°F | Degrees Baume 60°F | Degrees Salometer 60°F | % NaCl by weight | Lb. NaCl per gallon solution | Freezing point °F |
|---|---|---|---|---|---|
| 1.000 | 0 | 0 | 0 | 0 | 32.0 |
| 1.007 | 1.04 | 3.8 | 1 | 0.084 | 30.5 |
| 1.015 | 2.07 | 7.6 | 2 | 0.169 | 29.3 |
| 1.022 | 3.08 | 11.4 | 3 | 0.256 | 27.8 |
| *1.029 | 4.08 | 15.2 | 4 | 0.344 | 26.6 |
| 1.036 | 5.07 | 18.9 | 5 | 0.433 | 25.2 |
| 1.044 | 6.07 | 22.7 | 6 | 0.523 | 23.9 |
| 1.051 | 7.06 | 26.5 | 7 | 0.617 | 22.5 |
| 1.059 | 8.01 | 30.3 | 8 | 0.708 | 21.2 |
| 1.066 | 8.97 | 33.9 | 9 | 0.802 | 19.9 |
| 1.073 | 9.90 | 37.5 | 10 | 0.897 | 18.7 |
| 1.081 | 10.86 | 41.3 | 11 | 0.994 | 17.4 |
| 1.089 | 11.80 | 45.2 | 12 | 1.092 | 16.0 |
| 1.096 | 12.73 | 49.2 | 13 | 1.190 | 14.7 |
| 1.104 | 13.64 | 53.0 | 14 | 1.289 | 13. |
| 1.111 | 14.54 | 56.8 | 15 | 1.389 | 12.2 |
| 1.119 | 15.46 | 60.6 | 16 | 1.495 | 11.0 |
| 1.127 | 16.37 | 64.4 | 17 | 1.602 | 9.8 |
| 1.135 | 17.27 | 68.2 | 18 | 1.710 | 8.5 |
| 1.143 | 18.16 | 71.9 | 19 | 1.819 | 7.3 |
| 1.151 | 19.03 | 75.5 | 20 | 1.928 | 6.1 |
| 1.159 | 19.92 | 79.1 | 21 | 2.037 | 5.0 |
| 1.168 | 20.80 | 83.0 | 22 | 2.147 | 3.9 |
| 1.176 | 21.68 | 86.9 | 23 | 2.266 | 2.8 |
| 1.184 | 22.54 | 90.9 | 24 | 2.376 | 1.7 |
| 1.192 | 23.39 | 94.7 | 25 | 2.488 | +0.5 |
| 1.201 | 24.27 | 98.5 | 26 | 2.610 | —1.1 |
| 1.204 | 24.60 | 100. | 26.395 | 2.661 | —1.6 |

Temperature correction 1° Salometer for every 7½°F added to reading for temperatures above 60°F; subtracted below.

*Specific gravity of sea water.

## TABLE 49. SPECIFIC GRAVITY OF CAUSTIC SODA SOLUTIONS 15°C (59°F) BY LUNGE.†

| | | | | | One gallon contains | |
|---|---|---|---|---|---|---|
| Specific gravity | Degrees Baume | Degrees Twaddell | Per cent NaOH | Per cent $Na_2O$ | pounds NaOH | pounds $Na_2O$ |
| 1.007 | 1.0 | 1.4 | 0.61 | 0.47 | 0.051 | 0.039 |
| 1.014 | 2.0 | 2.8 | 1.20 | 0.93 | 0.101 | 0.079 |
| 1.022 | 3.1 | 4.4 | 2.00 | 1.55 | 0.170 | 0.132 |
| 1.029 | 4.1 | 5.8 | 2.70 | 2.10 | 0.232 | 0.180 |
| 1.036 | 5.1 | 7.2 | 3.35 | 2.60 | 0.289 | 0.225 |
| 1.045 | 6.2 | 9.0 | 4.00 | 3.10 | 0.345 | 0.268 |
| 1.052 | 7.2 | 10.4 | 4.64 | 3.60 | 0.407 | 0.316 |
| 1.060 | 8.2 | 12.0 | 5.29 | 4.10 | 0.467 | 0.362 |
| 1.067 | 9.1 | 13.4 | 5.87 | 4.55 | 0.522 | 0.405 |
| 1.075 | 10.1 | 15.0 | 6.55 | 5.08 | 0.587 | 0.455 |
| 1.083 | 11.1 | 16.6 | 7.31 | 5.67 | 0.660 | 0.512 |
| 1.091 | 12.1 | 18.2 | 8.00 | 6.20 | 0.728 | 0.564 |
| 1.100 | 13.2 | 20.0 | 8.68 | 6.73 | 0.796 | 0.617 |
| 1.108 | 14.1 | 21.6 | 9.42 | 7.30 | 0.870 | 0.674 |
| 1.116 | 15.1 | 23.2 | 10.06 | 7.80 | 0.936 | 0.726 |
| 1.125 | 16.1 | 25.0 | 10.97 | 8.50 | 1.029 | 0.797 |
| 1.134 | 17.1 | 26.8 | 11.84 | 9.18 | 1.119 | 0.868 |
| 1.142 | 18.0 | 28.4 | 12.64 | 9.80 | 1.203 | 0.933 |
| 1.152 | 19.1 | 30.4 | 13.55 | 10.50 | 1.301 | 1.008 |
| 1.162 | 20.2 | 32.4 | 14.37 | 11.14 | 1.392 | 1.079 |
| 1.171 | 21.2 | 34.2 | 15.13 | 11.73 | 1.477 | 1.145 |
| 1.180 | 22.1 | 36.0 | 15.91 | 12.33 | 1.565 | 1.213 |
| 1.190 | 23.1 | 38.0 | 16.77 | 13.00 | 1.664 | 1.290 |
| 1.200 | 24.2 | 40.0 | 17.67 | 13.70 | 1.768 | 1.371 |
| 1.210 | 25.2 | 42.0 | 18.58 | 14.40 | 1.874 | 1.453 |
| 1.220 | 26.1 | 44.0 | 19.58 | 15.18 | 1.992 | 1.554 |
| 1.231 | 27.2 | 46.2 | 20.59 | 15.96 | 2.113 | 1.638 |
| 1.241 | 28.2 | 48.2 | 21.42 | 16.76 | 2.216 | 1.734 |
| 1.252 | 29.2 | 50.4 | 22.64 | 17.55 | 2.363 | 1.832 |
| 1.263 | 30.2 | 52.6 | 23.67 | 18.35 | 2.492 | 1.932 |
| 1.274 | 31.2 | 54.8 | 24.81 | 19.23 | 2.635 | 2.042 |
| 1.285 | 32.2 | 57.0 | 25.80 | 20.00 | 2.764 | 2.143 |
| 1.297 | 33.2 | 59.4 | 26.83 | 20.80 | 2.901 | 2.249 |
| 1.308 | 34.1 | 61.6 | 27.80 | 21.55 | 3.032 | 2.350 |
| 1.320 | 35.2 | 64.0 | 28.83 | 22.35 | 3.173 | 2.460 |
| 1.332 | 36.1 | 66.4 | 29.93 | 23.20 | 3.324 | 2.576 |
| 1.345 | 37.2 | 69.0 | 31.22 | 24.20 | 3.501 | 2.714 |
| 1.357 | 38.1 | 71.4 | 32.47 | 25.17 | 3.673 | 2.848 |
| 1.370 | 39.2 | 74.0 | 33.69 | 26.12 | 3.848 | 2.983 |
| 1.383 | 40.2 | 76.6 | 34.96 | 27.10 | 4.031 | 3.125 |
| 1.397 | 41.2 | 79.4 | 36.25 | 28.10 | 4.222 | 3.273 |
| 1.410 | 42.2 | 82.0 | 37.47 | 29.05 | 4.405 | 3.415 |
| 1.424 | 43.2 | 84.8 | 38.80 | 30.08 | 4.606 | 3.571 |
| 1.438 | 44.2 | 87.6 | 39.99 | 31.00 | 4.794 | 3.716 |
| 1.453 | 45.2 | 90.6 | 41.41 | 32.10 | 5.016 | 3.888 |
| 1.468 | 46.2 | 93.6 | 42.83 | 33.20 | 5.242 | 4.063 |
| 1.483 | 47.2 | 96.6 | 44.38 | 34.40 | 5.487 | 4.253 |
| 1.498 | 48.2 | 99.6 | 46.15 | 35.70 | 5.764 | 4.459 |
| 1.514 | 49.2 | 102.8 | 47.60 | 36.90 | 6.008 | 4.658 |
| 1.530 | 50.2 | 106.0 | 49.02 | 38.00 | 6.253 | 4.847 |

†*Courtesy Ingersoll-Rand Co. See page 6.*

# SECTION IX—MECHANICAL DATA

## CONTENTS



IX

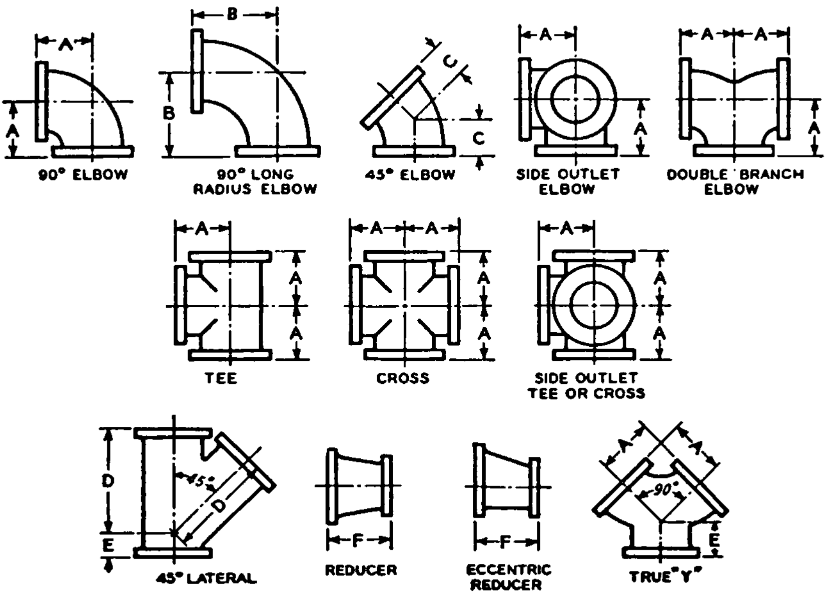
# TABLE 50. CAST IRON PIPE DIMENSIONS.†

| Nominal Diameter | CLASS A 100 Foot Head 43 Pounds Pressure | | | CLASS B 200 Foot Head 86 Pounds Pressure | | | CLASS C 300 Foot Head 130 Pounds Pressure | | | CLASS D 400 Foot Head 173 Pounds Pressure | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Outside Diameter | Wall Thickness | Inside Diameter | Outside Diameter | Wall Thickness | Inside Diameter | Outside Diameter | Wall Thickness | Inside Diameter | Outside Diameter | Wall Thickness | Inside Diameter |
| Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches |
| 3 | 3.80 | 0.39 | 3.02 | 3.96 | 0.42 | 3.12 | 3.96 | 0.45 | 3.06 | 3.96 | 0.48 | 3.00 |
| 4 | 4.80 | 0.42 | 3.96 | 5.00 | 0.45 | 4.10 | 5.00 | 0.48 | 4.04 | 5.00 | 0.52 | 3.96 |
| 6 | 6.90 | 0.44 | 6.02 | 7.10 | 0.48 | 6.14 | 7.10 | 0.51 | 6.08 | 7.10 | 0.55 | 6.00 |
| 8 | 9.05 | 0.46 | 8.13 | 9.05 | 0.51 | 8.03 | 9.30 | 0.56 | 8.18 | 9.30 | 0.60 | 8.10 |
| 10 | 11.10 | 0.50 | 10.10 | 11.10 | 0.57 | 9.96 | 11.40 | 0.62 | 10.16 | 11.40 | 0.68 | 10.04 |
| 12 | 13.20 | 0.54 | 12.12 | 13.20 | 0.62 | 11.96 | 13.50 | 0.68 | 12.14 | 13.50 | 0.76 | 12.00 |
| 14 | 15.30 | 0.57 | 14.16 | 15.30 | 0.66 | 13.98 | 15.65 | 0.74 | 14.17 | 15.65 | 0.82 | 14.01 |
| 16 | 17.40 | 0.60 | 16.20 | 17.40 | 0.70 | 16.00 | 17.80 | 0.80 | 16.20 | 17.80 | 0.89 | 16.02 |
| 18 | 19.50 | 0.64 | 18.22 | 19.50 | 0.75 | 18.00 | 19.92 | 0.87 | 18.18 | 19.92 | 0.96 | 18.00 |
| 20 | 21.60 | 0.67 | 20.26 | 21.60 | 0.80 | 20.00 | 22.06 | 0.92 | 20.22 | 22.06 | 1.03 | 20.00 |
| 24 | 25.80 | 0.76 | 24.28 | 25.80 | 0.89 | 24.02 | 26.32 | 1.04 | 24.22 | 26.32 | 1.16 | 24.00 |
| 30 | 31.74 | 0.88 | 29.98 | 32.00 | 1.03 | 29.94 | 32.40 | 1.20 | 30.00 | 32.74 | 1.37 | 30.00 |
| 36 | 37.96 | 0.99 | 35.98 | 38.30 | 1.15 | 36.00 | 38.70 | 1.36 | 39.98 | 39.16 | 1.58 | 36.00 |
| 42 | 44.20 | 1.10 | 42.00 | 44.50 | 1.28 | 41.94 | 45.10 | 1.54 | 42.02 | 45.58 | 1.78 | 42.02 |
| 48 | 50.50 | 1.26 | 47.98 | 50.80 | 1.42 | 47.96 | 51.40 | 1.71 | 47.98 | 51.98 | 1.96 | 48.06 |
| 54 | 56.66 | 1.35 | 53.96 | 57.10 | 1.55 | 54.00 | 57.80 | 1.90 | 54.00 | 58.40 | 2.23 | 53.94 |
| 60 | 62.80 | 1.39 | 60.02 | 63.40 | 1.67 | 60.06 | 64.20 | 2.00 | 60.20 | 64.82 | 2.38 | 60.06 |
| 72 | 75.34 | 1.62 | 72.10 | 76.00 | 1.95 | 72.10 | 76.88 | 2.39 | 72.10 | | | |
| 84 | 87.54 | 1.72 | 84.10 | 88.54 | 2.22 | 84.10 | | | | | | |

| Nominal Diameter | CLASS E 500 Foot Head 217 Pounds Pressure | | | CLASS F 600 Foot Head 260 Pounds Pressure | | | CLASS G 700 Foot Head 304 Pounds Pressure | | | CLASS H 800 Foot Head 347 Pounds Pressure | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Outside Diameter | Wall Thickness | Inside Diameter | Outside Diameter | Wall Thickness | Inside Diameter | Outside Diameter | Wall Thickness | Inside Diameter | Outside Diameter | Wall Thickness | Inside Diameter |
| Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches |
| 6 | 7.22 | 0.58 | 6.06 | 7.22 | 0.61 | 6.00 | 7.38 | 0.65 | 6.08 | 7.38 | 0.69 | 6.00 |
| 8 | 9.42 | 0.66 | 8.10 | 9.42 | 0.71 | 8.00 | 9.60 | 0.75 | 8.10 | 9.60 | 0.80 | 8.00 |
| 10 | 11.60 | 0.74 | 10.12 | 11.60 | 0.80 | 10.00 | 11.84 | 0.86 | 10.12 | 11.84 | 0.92 | 10.00 |
| 12 | 13.78 | 0.82 | 12.14 | 13.78 | 0.89 | 12.00 | 14.08 | 0.97 | 12.14 | 14.08 | 1.04 | 12.00 |
| 14 | 15.98 | 0.90 | 14.18 | 15.98 | 0.99 | 14.00 | 16.32 | 1.07 | 14.18 | 16.32 | 1.16 | 14.00 |
| 16 | 18.16 | 0.98 | 16.20 | 18.16 | 1.08 | 16.00 | 18.54 | 1.18 | 16.18 | 18.54 | 1.27 | 16.00 |
| 18 | 20.34 | 1.07 | 18.20 | 20.34 | 1.17 | 18.00 | 20.78 | 1.28 | 18.22 | 20.78 | 1.39 | 18.00 |
| 20 | 22.54 | 1.15 | 20.24 | 22.54 | 1.27 | 20.00 | 23.02 | 1.39 | 20.24 | 23.02 | 1.51 | 20.00 |
| 24 | 26.90 | 1.31 | 24.28 | 26.90 | 1.45 | 24.00 | 27.76 | 1.75 | 24.26 | 27.76 | 1.88 | 24.00 |
| 30 | 33.10 | 1.55 | 30.00 | 33.46 | 1.73 | 30.00 | | | | | | |
| 36 | 39.60 | 1.80 | 36.00 | 40.04 | 2.02 | 36.00 | | | | | | |

The A.W.W.A. Standard Specifications, Section 3 states: "For pipes whose standard thickness is less than 1 inch, the thickness of metal in the body of the pipe shall not be more than 0.08 of an inch less than the standard thickness, and for pipes whose standard thickness is 1 inch or more, the variation shall not exceed 0.10 of an inch, except that for spaces not exceeding 8 inches in length in any direction, variations from the standard thickness of 0.02 of an inch in excess of the allowance above given shall be permitted."

*Courtesy Cast Iron Pipe Research Association. See page 6.*




# TABLE 51. CLASS 125 CAST IRON FLANGES AND FITTINGS.†

| | | A | B | C | D | E | F | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Nominal Pipe Size | Inside Diam. of Fittings | Center to Face 90 Deg. Elbow Tees, Crosses True "Y" and Double Branch Elbow | Center to Face 90 Deg. Long Radius Elbow | Center to Face 45 Deg. Elbow | Center to Face Lateral | Short Center to Face True "Y" and Lateral | Face to Face Reducer | Diam. of Flange | Thickness of Flange | Wall Thickness |
| 1 | 1 | 3½ | 5 | 1¾ | 5¾ | 1¾ | .... | 4¼ | 7/16 | 5/16 |
| 1¼ | 1¼ | 3¾ | 5½ | 2 | 6¼ | 1¾ | .... | 4⅝ | ½ | 5/16 |
| 1½ | 1½ | 4 | 6 | 2¼ | 7 | 2 | .... | 5 | 9/16 | 5/16 |
| 2 | 2 | 4½ | 6½ | 2½ | 8 | 2½ | 5 | 6 | ⅝ | 5/16 |
| 2½ | 2½ | 5 | 7 | 3 | 9½ | 2½ | 5½ | 7 | 11/16 | 5/16 |
| 3 | 3 | 5½ | 7¾ | 3 | 10 | 3 | 6 | 7½ | ¾ | ⅜ |
| 3½ | 3½ | 6 | 8½ | 3½ | 11½ | 3 | 6½ | 8½ | 13/16 | 7/16 |
| 4 | 4 | 6½ | 9 | 4 | 12 | 3 | 7 | 9 | 15/16 | ½ |
| 5 | 5 | 7½ | 10¼ | 4½ | 13½ | 3½ | 8 | 10 | 15/16 | ½ |
| 6 | 6 | 8 | 11½ | 5 | 14½ | 3½ | 9 | 11 | 1 | 9/16 |
| 8 | 8 | 9 | 14 | 5½ | 17½ | 4½ | 11 | 13½ | 1⅛ | ⅝ |
| 10 | 10 | 11 | 16½ | 6½ | 20½ | 5 | 12 | 16 | 1 3/16 | ¾ |
| 12 | 12 | 12 | 19 | 7½ | 24½ | 5½ | 14 | 19 | 1¼ | 13/16 |
| 14 OD | 14 | 14 | 21½ | 7½ | 27 | 6 | 16 | 21 | 1⅜ | ⅞ |
| 16 OD | 16 | 15 | 24 | 8 | 30 | 6½ | 18 | 23½ | 1 7/16 | 1 |
| 18 OD | 18 | 16½ | 26½ | 8½ | 32 | 7 | 19 | 25 | 1 9/16 | 1 1/16 |
| 20 OD | 20 | 18 | 29 | 9½ | 35 | 8 | 20 | 27½ | 1 11/16 | 1⅛ |
| 24 OD | 24 | 22 | 34 | 11 | 40½ | 9 | 24 | 32 | 1⅞ | 1¼ |
| 30 OD | 30 | 25 | 41½ | 15 | 49 | 10 | 30 | 38¾ | 2⅛ | 1 7/16 |
| 36 OD | 36 | 28* | 49 | 18 | .... | .... | 36 | 46 | 2⅜ | 1⅝ |
| 42 OD | 42 | 31* | 56½ | 21 | .... | .... | 42 | 53 | 2⅝ | 1 13/16 |
| 48 OD | 48 | 34* | 64 | 24 | .... | .... | 48 | 59½ | 2¾ | 2 |

All dimensions given in inches.

*Does not apply to true Y's or double branch elbows.

†*Courtesy American Society of Mechanical Engineers.* *See page 6.*

# TABLE 52. AMERICAN STANDARD C.I. PIPE FLANGES.†††

| Nominal Pipe Size Inches | Dia. of Flange | Dia. of Bolt Circle | No. of Bolts | *25 lb. Standard | | | *125 lb. Standard | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Flange Thickness | Size Bolts | Lgth. Bolts | Flange Thickness | Size Bolts | Lgth. Bolts |
| 1 | 4¼ | 3⅛ | 4 | | | | 7/16 | ½ | 1¾ |
| 1¼ | 4⅝ | 3½ | 4 | | | | ½ | ½ | 2 |
| 1½ | 5 | 3⅞ | 4 | | | | 9/16 | ½ | 2 |
| 2 | 6 | 4¾ | 4 | | | | ⅝ | ⅝ | 2¼ |
| 2½ | 7 | 5½ | 4 | | | | 11/16 | ⅝ | 2½ |
| 3 | 7½ | 6 | 4 | | | | ¾ | ⅝ | 2½ |
| 3½ | 8½ | 7 | 8 | | | | 13/16 | ⅝ | 2¾ |
| 4 | 9 | 7½ | 8 | ¾ | ⅝ | 2¼ | 15/16 | ⅝ | 3 |
| 5 | 10 | 8½ | 8 | ¾ | ⅝ | 2¼ | 15/16 | ¾ | 3 |
| 6 | 11 | 9½ | 8 | ¾ | ⅝ | 2¼ | 1 | ¾ | 3¼ |
| 8 | 13½ | 11¾ | 8 | ¾ | ⅝ | 2¼ | 1⅛ | ¾ | 3½ |
| 10 | 16 | 14¼ | 12 | ⅞ | ⅝ | 2½ | 1 3/16 | ⅞ | 3¾ |
| 12 | 19 | 17 | 12 | 1 | ⅝ | 2¾ | 1¼ | ⅞ | 3¾ |
| 14 OD | 21 | 18¾ | 12 | 1⅛ | ¾ | 3¼ | 1⅜ | 1 | 4¼ |
| 16 OD | 23½ | 21¼ | 16 | 1⅛ | ¾ | 3¼ | 1 7/16 | 1 | 4½ |
| 18 OD | 25 | 22¾ | 16 | 1¼ | ¾ | 3½ | 1 9/16 | 1⅛ | 4¾ |
| 20 OD | 27½ | 25 | 20 | 1¼ | ¾ | 3½ | 1 11/16 | 1⅛ | 5 |
| 24 OD | 32 | 29½ | 20 | 1⅜ | ¾ | 3¾ | 1⅞ | 1¼ | 5½ |
| 30 OD | 38¾ | 36 | 28 | 1½ | ⅞ | 4¼ | 2⅛ | 1¼ | 6¼ |
| 36 OD | 46 | 42¾ | 32 | 1⅝ | ⅞ | 5 | 2⅜ | 1½ | 7 |
| 42 OD | 53 | 49½ | 36 | 1¾ | 1 | 5¼ | 2⅝ | 1½ | 7½ |
| 48 OD | 59½ | 56 | 44 | 2 | 1 | 5½ | 2¾ | 1½ | 7¾ |
| 54 OD | 66¼ | 62¾ | 44 | 2¼ | 1 | 5¾ | 3 | 1¾ | 8½ |
| 60 OD | 73 | 69¼ | 52 | 2¼ | 1⅛ | 6 | 3⅛ | 1¾ | 8¾ |
| 72 OD | 86½ | 82½ | 60 | 2½ | 1⅛ | 6¼ | 3½ | 1¾ | 9½ |
| 84 OD | 99¾ | 95½ | 64 | 2¾ | 1¼ | 7¼ | 3⅞ | 2 | 10½ |
| 96 OD | 113¼ | 108½ | 68 | 3 | 1¼ | 7¾ | 4¼ | 2¼ | 11½ |

These flanges are all with plain face.
†250 lb. std. flanges have 1/16 in. raised face. This is included in flange thickness.
††800 lb. std. flanges are of two types; raised face and male-female. Raised face and male side of male-female have 1/4 in. raised face which is not included in flange thickness. Female side is faced 3/16 in. deep within a raised face not included in flange thickness.

| Nominal pipe size | *250 lb. Standard | | | | | *800 lb. Standard | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Flange | | Bolt circle dia. | Bolt | | Flange | | Bolt circle dia. | Bolts | |
| | dia. | thickness† | | No. | size | dia. | thickness†† | | No. | size |
| 1 | 4⅞ | 11/16 | 3½ | 4 | ⅝ | | | | | |
| 1¼ | 5¼ | ¾ | 3⅞ | 4 | ⅝ | | | | | |
| 1½ | 6⅛ | 13/16 | 4½ | 4 | ¾ | | | | | |
| 2 | 6½ | ⅞ | 5 | 8 | ⅝ | 6½ | 1¼ | 5 | 8 | ⅝ |
| 2½ | 7½ | 1 | 5⅞ | 8 | ¾ | 7½ | 1⅜ | 5⅞ | 8 | ¾ |
| 3 | 8¼ | 1⅛ | 6⅝ | 8 | ¾ | 8¼ | 1½ | 6⅝ | 8 | ¾ |
| 3½ | 9 | 1 3/16 | 7¼ | 8 | ¾ | 9 | 1⅝ | 7¼ | 8 | ⅞ |
| 4 | 10 | 1¼ | 7⅞ | 8 | ¾ | 10¾ | 1⅞ | 8½ | 8 | ⅞ |
| 5 | 11 | 1⅜ | 9¼ | 8 | ¾ | 13 | 2⅛ | 10½ | 8 | 1 |
| 6 | 12½ | 1 7/16 | 10⅝ | 12 | ¾ | 14 | 2¼ | 11½ | 12 | 1 |
| 8 | 15 | 1⅝ | 13 | 12 | ⅞ | 16½ | 2½ | 13¾ | 12 | 1⅛ |
| 10 | 17½ | 1⅞ | 15¼ | 16 | 1 | 20 | 2⅞ | 17 | 16 | 1¼ |
| 12 | 20½ | 2 | 17¾ | 16 | 1⅛ | 22 | 3 | 19¼ | 20 | 1¼ |
| 14 OD | 23 | 2⅛ | 20¼ | 20 | 1⅛ | | | | | |
| 16 OD | 25½ | 2¼ | 22½ | 20 | 1¼ | | | | | |
| 18 OD | 28 | 2⅜ | 24¾ | 24 | 1¼ | | | | | |
| 20 OD | 30½ | 2½ | 27 | 24 | 1¼ | | | | | |
| 24 OD | 36 | 2¾ | 32 | 24 | 1½ | | | | | |
| 30 OD | 43 | 3 | 39¼ | 28 | 1¾ | | | | | |
| 36 OD | 50 | 3⅜ | 46 | 32 | 2 | | | | | |
| 42 OD | 57 | 3 11/16 | 52¾ | 36 | 2 | | | | | |
| 48 OD | 65 | 4 | 60¾ | 40 | 2 | | | | | |

*Pressure ratings at ordinary room temperatures

| Standard, lb. | Size, in. | Max. rating, psi |
|---|---|---|
| 25 | 4-36 | 43 |
| 25 | 42-96 | 25 |
| 125 | 1-12 | 175 |
| 125 | 14-48 | 150 |
| 125 | 54-96 | No established rating |
| 250 | 1-12 | 400 |
| 250 | 14-48 | 300 |
| 800 | 2-12 | 800 |

Authority: ASA B16 b2—1931 (25 lb) ASA B16b—1944 (250 lb)
ASA B16.1—1948 (125 lb) ASA B16b1—1931 (800 lb)

†††*Courtesy American Society Mechanical Engineers. See page 6.*

## TABLE 53. PROPERTIES OF STEEL AND WROUGHT IRON PIPE.†

| Nominal Diameter | Schedule | Outside Diameter | Wall Thickness | Internal Diameter | Internal Area | $\epsilon/D$ $\epsilon = 0.00015$ ft. |
|---|---|---|---|---|---|---|
| Inches | | Inches | Inches | Inches | Sq. Inches | |
| ⅛ | 40 (S) | 0.405 | 0.068 | 0.269 | 0.0568 | 0.00669 |
| | 80 (X) | | 0.095 | 0.215 | 0.0363 | 0.00837 |
| ¼ | 40 (S) | 0.540 | 0.088 | 0.364 | 0.1041 | 0.00495 |
| | 80 (X) | | 0.119 | 0.302 | 0.0716 | 0.00596 |
| ⅜ | 40 (S) | 0.675 | 0.091 | 0.493 | 0.1909 | 0.00365 |
| | 80 (X) | | 0.126 | 0.423 | 0.1405 | 0.00426 |
| ½ | 40 (S) | 0.840 | 0.109 | 0.622 | 0.3039 | 0.00289 |
| | 80 (X) | | 0.147 | 0.546 | 0.2341 | 0.00330 |
| | 160 | | 0.187 | 0.466 | 0.1706 | 0.00386 |
| | (XX) | | 0.294 | 0.252 | 0.0499 | 0.00714 |
| ¾ | 40 (S) | 1.050 | 0.113 | 0.824 | 0.5333 | 0.00218 |
| | 80 (X) | | 0.154 | 0.742 | 0.4324 | 0.00243 |
| | 160 | | 0.218 | 0.614 | 0.2961 | 0.00293 |
| | (XX) | | 0.308 | 0.434 | 0.1479 | 0.00415 |
| 1 | 40 (S) | 1.315 | 0.133 | 1.049 | 0.8643 | 0.00172 |
| | 80 (X) | | 0.179 | 0.957 | 0.7193 | 0.00188 |
| | 160 | | 0.250 | 0.815 | 0.5217 | 0.00221 |
| | (XX) | | 0.358 | 0.599 | 0.2818 | 0.00301 |
| 1¼ | 40 (S) | 1.660 | 0.140 | 1.380 | 1.496 | 0.00130 |
| | 80 (X) | | 0.191 | 1.278 | 1.283 | 0.00141 |
| | 160 | | 0.250 | 1.160 | 1.057 | 0.00155 |
| | (XX) | | 0.382 | 0.896 | 0.6305 | 0.00201 |
| 1½ | 40 (S) | 1.900 | 0.145 | 1.610 | 2.036 | 0.00112 |
| | 80 (X) | | 0.200 | 1.500 | 1.767 | 0.00120 |
| | 160 | | 0.281 | 1.338 | 1.406 | 0.00135 |
| | (XX) | | 0.400 | 1.100 | 0.9503 | 0.00164 |
| 2 | 40 (S) | 2.375 | 0.154 | 2.067 | 3.356 | 0.00087 |
| | 80 (X) | | 0.218 | 1.939 | 2.953 | 0.00093 |
| | 160 | | 0.343 | 1.689 | 2.241 | 0.00107 |
| | (XX) | | 0.436 | 1.503 | 1.774 | 0.00120 |
| 2½ | 40 (S) | 2.875 | 0.203 | 2.469 | 4.788 | 0.000729 |
| | 80 (X) | | 0.276 | 2.323 | 4.238 | 0.000775 |
| | 160 | | 0.375 | 2.125 | 3.547 | 0.000847 |
| | (XX) | | 0.552 | 1.771 | 2.464 | 0.00102 |
| 3 | 40 (S) | 3.500 | 0.216 | 3.068 | 7.393 | 0.000587 |
| | 80 (X) | | 0.300 | 2.900 | 6.605 | 0.000621 |
| | 160 | | 0.437 | 2.626 | 5.416 | 0.000685 |
| | (XX) | | 0.600 | 2.300 | 4.155 | 0.000783 |
| 3½ | 40 (S) | 4.000 | 0.226 | 3.548 | 9.887 | 0.000507 |
| | 80 (X) | | 0.318 | 3.364 | 8.888 | 0.000535 |
| | (XX) | | 0.636 | 2.728 | 5.845 | 0.000660 |
| 4 | 40 (S) | 4.500 | 0.237 | 4.026 | 12.73 | 0.000447 |
| | 80 (X) | | 0.337 | 3.826 | 11.50 | 0.000470 |
| | 120 | | 0.437 | 3.626 | 10.33 | 0.000496 |
| | 160 | | 0.531 | 3.438 | 9.283 | 0.000524 |
| | (XX) | | 0.674 | 3.152 | 7.803 | 0.000571 |

S = Wall thickness formerly designated "standard weight". X = Wall thickness formerly designated "extra heavy." XX = Wall thickness formerly designated "double extra heavy".

†*Courtesy Hydraulic Institute. See page 6.*

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## TABLE 53. (Cont.) PROPERTIES OF STEEL AND WROUGHT IRON PIPE.

| Nominal Diameter Inches | Schedule | Outside Diameter Inches | Wall Thickness Inches | Internal Diameter Inches | Internal Area Sq. Inches | $\epsilon/D$ $\epsilon=0.00015$ ft. |
|---|---|---|---|---|---|---|
| 5 | 40 (S) | 5.563 | 0.258 | 5.047 | 20.01 | 0.000357 |
| | 80 (X) | | 0.375 | 4.813 | 18.19 | 0.000374 |
| | 120 | | 0.500 | 4.563 | 16.35 | 0.000394 |
| | 160 | | 0.625 | 4.313 | 14.61 | 0.000417 |
| | (XX) | | 0.750 | 4.063 | 12.97 | 0.000443 |
| 6 | 40 (S) | 6.625 | 0.280 | 6.065 | 28.89 | 0.000293 |
| | 80 (X) | | 0.432 | 5.761 | 26.07 | 0.000312 |
| | 120 | | 0.562 | 5.501 | 23.77 | 0.000327 |
| | 160 | | 0.718 | 5.189 | 21.15 | 0.000347 |
| | (XX) | | 0.864 | 4.897 | 18.83 | 0.000368 |
| 8 | 20 | 8.625 | 0.250 | 8.125 | 51.85 | 0.000222 |
| | 30 (S) | | 0.277 | 8.071 | 51.16 | 0.000223 |
| | 40 (S) | | 0.322 | 7.981 | 50.03 | 0.000226 |
| | 60 | | 0.406 | 7.813 | 47.94 | 0.000230 |
| | 80 (X) | | 0.500 | 7.625 | 45.66 | 0.000236 |
| | 100 | | 0.593 | 7.439 | 43.46 | 0.000242 |
| | 120 | | 0.718 | 7.189 | 40.59 | 0.000250 |
| | 140 | | 0.812 | 7.001 | 38.50 | 0.000257 |
| | (XX) | | 0.875 | 6.875 | 37.12 | 0.000262 |
| | 160 | | 0.906 | 6.813 | 36.46 | 0.000264 |
| 10 | 20 | 10.75 | 0.250 | 10.250 | 82.52 | 0.000176 |
| | (S) | | 0.279 | 10.192 | 81.58 | 0.000177 |
| | 30 (S) | | 0.307 | 10.136 | 80.69 | 0.000178 |
| | 40 (S) | | 0.365 | 10.020 | 78.85 | 0.000180 |
| | 60 (X) | | 0.500 | 9.750 | 74.66 | 0.000185 |
| | 80 | | 0.593 | 9.564 | 71.84 | 0.000188 |
| | 100 | | 0.718 | 9.314 | 68.13 | 0.000193 |
| | 120 | | 0.843 | 9.064 | 64.53 | 0.000199 |
| | 140 | | 1.000 | 8.750 | 60.13 | 0.000206 |
| | 160 | | 1.125 | 8.500 | 56.75 | 0.000212 |
| 12 | 20 | 12.75 | 0.250 | 12.250 | 117.86 | 0.000147 |
| | 30 | | 0.330 | 12.090 | 114.80 | 0.000149 |
| | (S) | | 0.375 | 12.000 | 113.10 | 0.000150 |
| | 40 | | 0.406 | 11.938 | 111.93 | 0.000151 |
| | (X) | | 0.500 | 11.750 | 108.43 | 0.000153 |
| | 60 | | 0.562 | 11.626 | 106.16 | 0.000155 |
| | 80 | | 0.687 | 11.376 | 101.64 | 0.000158 |
| | 100 | | 0.843 | 11.064 | 96.14 | 0.000163 |
| | 120 | | 1.000 | 10.750 | 90.76 | 0.000167 |
| | 140 | | 1.125 | 10.500 | 86.59 | 0.000171 |
| | 160 | | 1.312 | 10.126 | 80.53 | 0.000178 |
| 14 OD | 10 | 14.00 | 0.250 | 13.500 | 143.14 | 0.000133 |
| | 20 | | 0.312 | 13.376 | 140.52 | 0.000135 |
| | 30 | | 0.375 | 13.250 | 137.89 | 0.000136 |
| | 40 | | 0.437 | 13.126 | 135.32 | 0.000137 |
| | 60 | | 0.593 | 12.814 | 128.96 | 0.000140 |
| | 80 | | 0.750 | 12.500 | 122.72 | 0.000144 |
| | 100 | | 0.937 | 12.126 | 115.49 | 0.000148 |
| | 120 | | 1.062 | 11.876 | 110.77 | 0.000152 |
| | 140 | | 1.250 | 11.500 | 103.87 | 0.000157 |
| | 160 | | 1.406 | 11.188 | 98.31 | 0.000161 |

S = Wall thickness formerly designated "standard weight". X = Wall thickness formerly designated "extra heavy"
XX = Wall thickness formerly designated "double extra heavy".

## TABLE 53. (Cont.) PROPERTIES OF STEEL AND WROUGHT IRON PIPE.

| Nominal Diameter | Schedule | Outside Diameter | Wall Thickness | Internal Diameter | Internal Area | $\epsilon/D$ $\epsilon=0.00015$ ft. |
|---|---|---|---|---|---|---|
| Inches | | Inches | Inches | Inches | Sq. Inches | |
| 16 OD | 10 | 16.00 | 0.250 | 15.500 | 188.69 | 0.000116 |
| | 20 | | 0.312 | 15.376 | 185.69 | 0.000117 |
| | 30 | | 0.375 | 15.250 | 182.65 | 0.000118 |
| | 40 | | 0.500 | 15.000 | 176.72 | 0.000120 |
| | 60 | | 0.656 | 14.688 | 169.44 | 0.000121 |
| | 80 | | 0.843 | 14.314 | 160.92 | 0.000126 |
| | 100 | | 1.031 | 13.938 | 152.58 | 0.000129 |
| | 120 | | 1.218 | 13.564 | 144.50 | 0.000133 |
| | 140 | | 1.437 | 13.126 | 135.32 | 0.000137 |
| | 160 | | 1.562 | 12.876 | 130.21 | 0.000140 |
| 18 OD | 10 | 18.00 | 0.250 | 17.500 | 240.53 | 0.000103 |
| | 20 | | 0.312 | 17.376 | 237.13 | 0.000104 |
| | (S) | | 0.375 | 17.250 | 233.71 | 0.000104 |
| | 30 | | 0.437 | 17.126 | 230.36 | 0.000105 |
| | (X) | | 0.500 | 17.000 | 226.98 | 0.000106 |
| | 40 | | 0.562 | 16.876 | 223.68 | 0.000107 |
| | 60 | | 0.718 | 16.564 | 215.49 | 0.000109 |
| | 80 | | 0.937 | 16.126 | 204.24 | 0.000112 |
| | 100 | | 1.156 | 15.688 | 193.30 | 0.000115 |
| | 120 | | 1.343 | 15.314 | 184.19 | 0.000118 |
| | 140 | | 1.562 | 14.876 | 173.81 | 0.000121 |
| | 160 | | 1.750 | 14.500 | 165.13 | 0.000124 |
| 20 OD | 10 | 20.00 | 0.250 | 19.500 | 298.65 | 0.0000923 |
| | 20 | | 0.375 | 19.250 | 291.04 | 0.0000935 |
| | 30 | | 0.500 | 19.000 | 283.53 | 0.0000947 |
| | 40 | | 0.593 | 18.814 | 278.01 | 0.0000957 |
| | 60 | | 0.812 | 18.376 | 265.21 | 0.0000980 |
| | 80 | | 1.031 | 17.938 | 252.72 | 0.000100 |
| | 100 | | 1.250 | 17.500 | 240.53 | 0.000103 |
| | 120 | | 1.500 | 17.000 | 226.98 | 0.000106 |
| | 140 | | 1.750 | 16.500 | 213.83 | 0.000109 |
| | 160 | | 1.937 | 16.126 | 204.24 | 0.000112 |
| 24 OD | 10 | 24.00 | 0.250 | 23.500 | 433.74 | 0.0000766 |
| | 20 | | 0.375 | 23.250 | 424.56 | 0.0000774 |
| | (S) | | 0.500 | 23.000 | 415.48 | 0.0000783 |
| | 30 | | 0.562 | 22.876 | 411.01 | 0.0000787 |
| | 40 | | 0.687 | 22.626 | 402.07 | 0.0000796 |
| | 60 | | 0.937 | 22.126 | 384.50 | 0.0000814 |
| | 80 | | 1.218 | 21.564 | 365.22 | 0.0000835 |
| | 100 | | 1.500 | 21.000 | 346.36 | 0.0000857 |
| | 120 | | 1.750 | 20.500 | 330.06 | 0.0000878 |
| | 140 | | 2.062 | 19.876 | 310.28 | 0.0000906 |
| | 160 | | 2.312 | 19.376 | 294.86 | 0.0000929 |
| 30 OD | 10 | 30.00 | 0.312 | 29.376 | 677.76 | 0.0000613 |
| | 20 | | 0.500 | 29.000 | 660.52 | 0.0000621 |
| | 30 | | 0.625 | 28.750 | 649.18 | 0.0000626 |

S = Wall thickness formerly designated "standard weight." X = Wall thickness formerly designated "extra heavy. XX = Wall thickness formerly designated "double extra heavy".

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## TABLE 54. WEIGHTS AND DIMENSIONS OF COPPER AND BRASS PIPE AND TUBES.†

| Nominal Size Inches | Copper Tubing | | | | | | | Copper and Brass Pipe—Regular Wt. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Outside Diameter Inches | Type K | | Type L | | Type M | | Outside Diameter Inches | Inside Diameter Inches | Weight per Ft.—Lb. | | |
| | | Inside Diameter Inches | Weight per Ft. Lb. | Inside Diameter Inches | Weight per Ft. Lb. | Inside Diameter Inches | Weight per Ft. Lb. | | | 67% Copper | 85% Copper | 100% Copper |
| ⅛ | .250 | .186 | .085 | .200 | .068 | .20 | .068 | .405 | .281 | .246 | .253 | .259 |
| ¼ | .375 | .311 | .134 | .315 | .126 | .325 | .106 | .540 | .375 | .437 | .450 | .460 |
| ⅜ | .500 | .402 | .269 | .430 | .198 | .450 | .144 | .675 | .494 | .612 | .630 | .643 |
| ½ | .625 | .527 | .344 | .545 | .284 | .569 | .203 | .840 | .625 | .911 | .938 | .957 |
| ⅝ | .750 | .652 | .418 | .666 | .362 | .690 | .263 | .. | .. | .. | .. | .. |
| ¾ | .875 | .745 | .641 | .785 | .454 | .811 | .328 | 1.050 | .822 | 1.24 | 1.27 | 1.30 |
| 1 | 1.125 | .995 | .839 | 1.025 | .653 | 1.055 | .464 | 1.315 | 1.062 | 1.74 | 1.79 | 1.83 |
| 1¼ | 1.375 | 1.245 | 1.04 | 1.265 | .882 | 1.291 | .681 | 1.660 | 1.368 | 2.56 | 2.63 | 2.69 |
| 1½ | 1.625 | 1.481 | 1.36 | 1.505 | 1.14 | 1.571 | .940 | 1.900 | 1.600 | 3.04 | 3.13 | 3.20 |
| 2 | 2.125 | 1.959 | 2.06 | 1.985 | 1.75 | 2.009 | 1.46 | 2.375 | 2.062 | 4.02 | 4.14 | 4.23 |
| 2½ | 2.625 | 2.435 | 2.92 | 2.465 | 2.48 | 2.495 | 2.03 | 2.875 | 2.500 | 5.83 | 6.00 | 6.14 |
| 3 | 3.125 | 2.907 | 4.00 | 2.945 | 3.33 | 2.981 | 2.68 | 3.500 | 3.062 | 8.31 | 8.56 | 8.75 |
| 3½ | 3.625 | 3.385 | 5.12 | 3.425 | 4.29 | 3.459 | 3.58 | 4.000 | 3.500 | 10.85 | 11.17 | 11.41 |
| 4 | 4.125 | 3.857 | 6.51 | 3.905 | 5.38 | 3.935 | 4.66 | 4.500 | 4.000 | 12.29 | 12.66 | 12.94 |
| 4½ | .. | .. | .. | .. | .. | .. | .. | 5.000 | 4.500 | 13.74 | 14.15 | 14.46 |
| 5 | 5.125 | 4.805 | 9.67 | 4.875 | 7.61 | 4.907 | 6.66 | 5.563 | 5.063 | 15.40 | 15.85 | 16.21 |
| 6 | 6.125 | 5.741 | 13.87 | 5.845 | 10.20 | 5.881 | 8.91 | 6.625 | 6.125 | 18.44 | 18.99 | 19.41 |
| 7 | .. | .. | .. | .. | .. | .. | .. | 7.625 | 7.062 | 23.92 | 24.63 | 25.17 |
| 8 | 8.125 | 7.583 | 25.90 | 7.725 | 19.29 | 7.785 | 16.46 | 8.625 | 8.000 | 30.05 | 30.95 | 31.63 |

The National Bureau of Standards has recommended the elimination of the 3½″ and 4½″ pipe sizes.

†*Courtesy Ingersoll-Rand Company.* *See page 6.*

# TABLE 55. CYLINDRICAL TANKS SET VERTICALLY.

## CAPACITY IN U. S. GALLONS PER FOOT OF DEPTH.

| Dia. of Tank | Cap. U S. Gals. | Dia. of Tank | Cap. U.S. Gals. | Dia. of Tank | Cap. U.S. Gals. | Dia. of Tank | Cap. U.S. Gals. | Dia. of Tank | Cap. U.S. Gals. | Dia. of Tank | Cap. U.S. Gals. | Dia. of Tank | Cap. U.S. Gals. | Dia. of Tank | Cap U.S. Gals. | Dia. of Tank | Cap. U.S. Gals. | Dia. of Tank | Cap. U.S. Gals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1' ... | 5.87 | 2' 3" | 29.74 | 3' 6" | 71.97 | 4' 9" | 132.56 | 6' ... | 211.51 | 9' 6" | 530.24 | 13' ... | 992.91 | 16' 6" | 1599.5 | 20' ... | 2350.1 | 23' 6" | 3244.6 |
| 1' 1" | 6.89 | 2' 4" | 31.99 | 3' 7" | 75.44 | 4' 10" | 137.25 | 6' 3" | 229.50 | 9' 9" | 558.51 | 13' 3" | 1031.5 | 16' 9" | 1648.4 | 20' 3" | 2409.2 | 23' 9" | 3314. |
| 1' 2" | 8. | 2' 5" | 34.31 | 3' 8" | 78.99 | 4' 11" | 142.02 | 6' 6" | 248.23 | 10' ... | 587.52 | 13' 6" | 1070.8 | 17' ... | 1697.9 | 20' 6" | 2469.1 | 24' ... | 3384.1 |
| 1' 3" | 9.18 | 2' 6" | 36.72 | 3' 9" | 82.62 | 5' ... | 146.88 | 6' 9" | 267.69 | 10' 3" | 617.26 | 13' 9" | 1110.8 | 17' 3" | 1748.2 | 20' 9" | 2529.6 | 24' 3" | 3455. |
| 1' 4" | 10.44 | 2' 7" | 39.21 | 3' 10" | 86.33 | 5' 1" | 151.82 | 7' ... | 287.88 | 10' 6" | 640.74 | 14' ... | 1151.5 | 17' 6" | 1799.3 | 21' ... | 2591. | 24' 6" | 3526.6 |
| 1' 5" | 11.79 | 2' 8" | 41.78 | 3' 11" | 90.13 | 5' 2" | 156.83 | 7' 3" | 308.81 | 10' 9" | 678.95 | 14' 3" | 1193.0 | 17' 9" | 1851.1 | 21' 3" | 2653. | 24' 9" | 3598.9 |
| 1' 6" | 13.22 | 2' 9" | 44.43 | 4' ... | 94. | 5' 3" | 161.93 | 7' 6" | 330.48 | 11' ... | 710.90 | 14' 6" | 1235.3 | 18' ... | 1903.6 | 21' 6" | 2715.8 | 25' ... | 3672. |
| 1' 7" | 14.73 | 2' 10" | 47.16 | 4' 1" | 97.96 | 5' 4" | 167.12 | 7' 9" | 352.88 | 11' 3" | 743.58 | 14' 9" | 1278.2 | 18' 3" | 1956.8 | 21' 9" | 2779.3 | 25' 3" | 3745.8 |
| 1' 8" | 16.32 | 2' 11" | 49.98 | 4' 2" | 102. | 5' 5" | 172.38 | 8' ... | 376.01 | 11' 6" | 776.99 | 15' ... | 1321.9 | 18' 6" | 2010.8 | 22' ... | 2843.6 | 25' 6" | 3820.3 |
| 1' 9" | 17.99 | 3' ... | 52.88 | 4' 3" | 106.12 | 5' 6" | 177.72 | 8' 3" | 399.88 | 11' 9" | 811.14 | 15' 3" | 1366.4 | 18' 9" | 2065.5 | 22' 3" | 2908.6 | 25' 9" | 3895.6 |
| 1' 10" | 19.75 | 3' 1" | 55.86 | 4' 4" | 110.32 | 5' 7" | 183.15 | 8' 6" | 424.48 | 12' ... | 846.03 | 15' 6" | 1411.5 | 19' ... | 2120.9 | 22' 6" | 2974.3 | 26' ... | 3971.6 |
| 1' 11" | 21.58 | 3' 2" | 58.92 | 4' 5" | 114.61 | 5' 8" | 188.66 | 8' 9" | 449.82 | 12' 3" | 881.65 | 15' 9" | 1457.4 | 19' 3" | 2177.1 | 22' 9" | 3040.8 | 26' 3" | 4048.4 |
| 2' ... | 23.50 | 3' 3" | 62.06 | 4' 6" | 118.97 | 5' 9" | 194.25 | 9' ... | 475.89 | 12' 6" | 918. | 16' ... | 1504.1 | 19' 6" | 2234. | 23' ... | 3108. | 26' 6" | 4125.9 |
| 2' 1" | 25.50 | 3' 4" | 65.28 | 4' 7" | 123.42 | 5' 10" | 199.92 | 9' 3" | 502.70 | 12' 9" | 955.09 | 16' 3" | 1551.4 | 19' 9" | 2291.7 | 23' 3" | 3175.9 | 26' 9" | 4204.1 |
| 2' 2" | 27.58 | 3' 5" | 68.58 | 4' 8" | 127.95 | 5' 11" | 205.67 | | | | | | | | | | | | |

To find the capacity of tanks of larger diameter than shown in the table select a tank of ½ the desired size and multiply the capacity given in the table by 4, or one of 1/3 size and multiply by 9, etc.
The capacity of a square tank where the length of one side equals the diameter of a round tank is equal to the capacity of the round tank divided by 0.7854.

# TABLE. 56. CYLINDRICAL TANKS SET HORIZONTALLY AND PARTIALLY FILLED.

| | GALLONS PER FOOT OF LENGTH WHEN TANK IS FILLED | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DIAMETER | 1/10 | 1/5 | 3/10 | 2/5 | 1/2 | 3/5 | 7/10 | 4/5 | 9/10 |
| 1 ft. | .3 | .8 | 1.4 | 2.1 | 2.9 | 3.6 | 4.3 | 4.9 | 5.5 |
| 2 ft. | 1.2 | 3.3 | 5.9 | 8.8 | 11.7 | 14.7 | 17.5 | 20.6 | 22.2 |
| 3 ft. | 2.7 | 7.5 | 13.6 | 19.8 | 26.4 | 33.0 | 39.4 | 45.2 | 50.1 |
| 4 ft. | 4.9 | 13.4 | 23.8 | 35.0 | 47.0 | 59.0 | 70.2 | 80.5 | 89.0 |
| 5 ft. | 7.6 | 20.0 | 37.0 | 55.0 | 73.0 | 92.0 | 110.0 | 126.0 | 139.0 |
| 6 ft. | 11.0 | 30.0 | 53.0 | 78.0 | 106.0 | 133.0 | 158.0 | 182.0 | 201.0 |
| 7 ft. | 15.0 | 41.0 | 73.0 | 107.0 | 144.0 | 181.0 | 215.0 | 247.0 | 272.0 |
| 8 ft. | 19.0 | 52.0 | 96.0 | 140.0 | 188.0 | 235.0 | 281.0 | 322.0 | 356.0 |
| 9 ft. | 25.0 | 67.0 | 112.0 | 178.0 | 238.0 | 298.0 | 352.0 | 408.0 | 450.0 |
| 10 ft. | 30.0 | 83.0 | 149.0 | 219.0 | 294.0 | 368.0 | 440.0 | 504.0 | 556.0 |
| 11 ft. | 37.0 | 101.0 | 179.0 | 265.0 | 356.0 | 445.0 | 531.0 | 610.0 | 672.0 |
| 12 ft. | 44.0 | 120.0 | 214.0 | 315.0 | 423.0 | 530.0 | 632.0 | 741.0 | 800.0 |
| 13 ft. | 51.0 | 141.0 | 250.0 | 370.0 | 496.0 | 621.0 | 740.0 | 850.0 | 940.0 |
| 14 ft. | 60.0 | 164.0 | 291.0 | 430.0 | 576.0 | 722.0 | 862.0 | 989.0 | 1084.0 |
| 15 ft. | 68.0 | 188.0 | 334.0 | 494.0 | 661.0 | 829.0 | 988.0 | 1134.0 | 1253.0 |

# TABLE 57. V-BELT DRIVES.†

## RECOMMENDED V-BELT CROSS-SECTIONS FOR VARIOUS HP. AND SPEEDS

| Horsepower | MOTOR SPEED—RPM | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1750 | 1160 | 870 | 690 | 575 | 490 | 435 |
| ½ | A | A | A | ........... | ........... | ........... | ........... |
| ¾ | A | A | A | ........... | ........... | ........... | ........... |
| 1 | A | A | A | ........... | ........... | ........... | ........... |
| 1½ | A | A | A | ........... | ........... | ........... | ........... |
| 2 | A | A | A | ........... | ........... | ........... | ........... |
| 3 | A | A | B (or A) | ........... | ........... | ........... | ........... |
| 5 | B (or A) | B (or A) | B | ........... | ........... | ........... | ........... |
| 7½ | B | B | B | ........... | ........... | ........... | ........... |
| 10 | B | B | B or C | ........... | ........... | ........... | ........... |
| 15 | B | B or C | C (or B) | ........... | ........... | ........... | ........... |
| 20 | B or C | C (or B) | C | D | D | ........... | ........... |
| 25 | C (or B) | C | C | D | D | ........... | ........... |
| 30 | C | C | C | D | D | ........... | ........... |
| 40 | C | C or D | C or D | D | D | ........... | ........... |
| 50 | C | C or D | C or D | D | D | ........... | ........... |
| 60 | C | C or D | D (or C) | D | D | E | E |
| 75 | C | D (or C) | D | D | D (or E) | E | E |
| 100 | C | D | D | D or E | E (or D) | E | E |
| 125 | ........... | D | D | D or E | E (or D) | E | E |
| 150 | ........... | D | D | E (or D) | E | E | E |
| 200 | ........... | D | D | E | E | E | E |
| 250 | ........... | D | D | E | E | E | E |
| 300 and above | ........... | D | D | E | E | E | E |

## HP. TRANSMITTED BY V-BELTS BASED ON 180° ARC OF CONTACT

| Velocity in Feet Per Minute | Cross-Section A | Cross-Section B | Cross-Section C | Cross-Section D | Cross-Section E | Velocity in Feet Per Minute | Cross-Section A | Cross-Section B | Cross-Section C | Cross-Section D | Cross-Section E |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | width ½" thick ⅜" | width ²¹⁄₃₂" thick ½" | width ⅞" thick ⅝" | width 1¼" thick ¾" | width 1½" thick 1" | | width ½" thick ⅜" | width ²¹⁄₃₂" thick ½" | width ⅞" thick ⅝" | width 1¼" thick ¾" | width 1½" thick 1" |
| 1000 | .9 | 1.2 | 3.0 | 5.5 | 7.5 | 2600 | 2.2 | 2.8 | 6.7 | 12.9 | 17.5 |
| 1100 | 1.0 | 1.3 | 3.2 | 6.0 | 8.2 | 2700 | 2.2 | 2.9 | 6.9 | 13.3 | 18.0 |
| 1200 | 1.0 | 1.4 | 3.4 | 6.5 | 8.9 | 2800 | 2.3 | 3.0 | 7.1 | 13.7 | 18.5 |
| 1300 | 1.1 | 1.5 | 3.6 | 7.0 | 9.6 | 2900 | 2.3 | 3.1 | 7.3 | 14.1 | 19.3 |
| 1400 | 1.2 | 1.6 | 3.8 | 7.5 | 10.3 | 3000 | 2.4 | 3.2 | 7.5 | 14.5 | 19.8 |
| 1500 | 1.3 | 1.7 | 4.0 | 8.0 | 11.0 | | | | | | |
| 1600 | | | | | | 3100 | 2.5 | 3.3 | 7.7 | 14.8 | 20.0 |
| 1700 | 1.4 | 1.8 | 4.3 | 8.4 | 11.6 | 3200 | 2.5 | 3.4 | 7.9 | 15.1 | 20.5 |
| 1800 | 1.5 | 1.9 | 4.6 | 8.8 | 12.2 | 3300 | 2.5 | 3.5 | 8.1 | 15.4 | 21.0 |
| 1900 | 1.6 | 2.1 | 4.9 | 9.2 | 12.8 | 3400 | 2.6 | 3.6 | 8.3 | 15.7 | 21.3 |
| 2000 | 1.6 | 2.2 | 5.2 | 9.6 | 13.4 | 3500 | 2.6 | 3.7 | 8.5 | 16.0 | 21.8 |
| | 1.7 | 2.3 | 5.5 | 10.0 | 14.0 | | | | | | |
| 2100 | | | | | | 3600 | 2.7 | 3.8 | 8.6 | 16.3 | 22.0 |
| 2200 | 1.8 | 2.4 | 5.7 | 10.5 | 14.8 | 3700 | 2.7 | 3.9 | 8.7 | 16.6 | 22.8 |
| 2300 | 1.9 | 2.5 | 5.9 | 11.0 | 15.2 | 3800 | 2.8 | 4.0 | 8.8 | 16.9 | 23.0 |
| 2400 | 1.9 | 2.6 | 6.1 | 11.5 | 15.8 | 3900 | 2.8 | 4.1 | 8.9 | 17.2 | 23.3 |
| 2500 | 2.0 | 2.7 | 6.3 | 12.0 | 16.4 | 4000 | 2.8 | 4.2 | 9.0 | 17.5 | 23.5 |
| | 2.1 | 2.8 | 6.5 | 12.5 | 17.0 | 5000 | 2.8 | 4.2 | 9.0 | 17.5 | 23.5 |

$$\text{No. of belts required} = \frac{\text{hp of drive}}{\left(\text{hp per belt}\right)\left(1 - \dfrac{.175\,(D-d)}{C}\right)}$$

D = pitch diam. of large pulley, inches.
d = pitch diam. of small pulley, inches.
C = center distance, inches.
For pump, compressor and blower drives 40% more belting than shown by above formula should be used.

†*Courtesy Dayton Rubber Manufacturing Co.* *See page 6.*

# TABLE 58. FUNCTIONS OF NUMBERS.

| No. | Square | Cube | Sq. Rt. | Cu. Rt. | Reciprocal | Circum. | Area |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1.0000 | 1.0000 | 1.000000000 | 3.1416 | 0.7854 |
| 2 | 4 | 8 | 1.4142 | 1.2599 | .500000000 | 6.2832 | 3.1416 |
| 3 | 9 | 27 | 1.7321 | 1.4423 | .333333333 | 9.4248 | 7.0686 |
| 4 | 16 | 64 | 2.0000 | 1.5874 | .250000000 | 12.5664 | 12.5664 |
| 5 | 25 | 125 | 2.2361 | 1.7100 | .200000000 | 15.7080 | 19.635 |
| 6 | 36 | 216 | 2.4495 | 1.8171 | .166666667 | 18.850 | 28.274 |
| 7 | 49 | 343 | 2.6458 | 1.9129 | .142857143 | 21.991 | 38.485 |
| 8 | 64 | 512 | 2.8284 | 2.0900 | .125000000 | 25.133 | 50.266 |
| 9 | 81 | 729 | 3.0000 | 2.0801 | .111111111 | 28.274 | 63.617 |
| 10 | 100 | 1,000 | 3.1623 | 2.1544 | .100000000 | 31.416 | 78.540 |
| 11 | 121 | 1,331 | 3.3166 | 2.2240 | .090909091 | 34.558 | 95.033 |
| 12 | 144 | 1,728 | 3.4641 | 2.2894 | .083333333 | 37.699 | 113.10 |
| 13 | 169 | 2,197 | 3.6056 | 2.3513 | .076923077 | 40.841 | 132.73 |
| 14 | 196 | 2,744 | 3.7417 | 2.4101 | .071428571 | 43.982 | 153.94 |
| 15 | 225 | 3,375 | 3.8730 | 2.4662 | .066666667 | 47.124 | 176.71 |
| 16 | 256 | 4,096 | 4.0000 | 2.5198 | .062500000 | 50.265 | 201.06 |
| 17 | 289 | 4,913 | 4.1231 | 2.5713 | .058823529 | 53.407 | 226.98 |
| 18 | 324 | 5,832 | 4.2426 | 2.6207 | .055555556 | 56.549 | 254.47 |
| 19 | 361 | 6,859 | 4.3589 | 2.6684 | .052631579 | 59.690 | 283.53 |
| 20 | 400 | 8,000 | 4.4721 | 2.7144 | .050000000 | 62.832 | 314.16 |
| 21 | 441 | 9,261 | 4.5826 | 2.7589 | .047619048 | 65.973 | 346.36 |
| 22 | 484 | 10,648 | 4.6904 | 2.8020 | .045454545 | 69.115 | 380.13 |
| 23 | 529 | 12,167 | 4.7958 | 2.8439 | .043478261 | 72.257 | 415.48 |
| 24 | 576 | 13,824 | 4.8990 | 2.8845 | .041666667 | 75.398 | 452.39 |
| 25 | 625 | 15,625 | 5.0000 | 2.9240 | .040000000 | 78.540 | 490.87 |
| 26 | 676 | 17,576 | 5.0990 | 2.9625 | .038461538 | 81.681 | 530.93 |
| 27 | 729 | 19,683 | 5.1962 | 3.0000 | .037037037 | 84.823 | 572.56 |
| 28 | 784 | 21,952 | 5.2915 | 3.0366 | .035714286 | 87.965 | 615.75 |
| 29 | 841 | 24,389 | 5.3852 | 3.0723 | .034482759 | 91.106 | 660.52 |
| 30 | 900 | 27,000 | 5.4772 | 3.1072 | .033333333 | 94.248 | 706.86 |
| 31 | 961 | 29,791 | 5.5678 | 3.1414 | .032258065 | 97.389 | 754.77 |
| 32 | 1,024 | 32,768 | 5.6569 | 3.1748 | .031250000 | 100.53 | 804.25 |
| 33 | 1,089 | 35,937 | 5.7446 | 3.2075 | .030303030 | 103.67 | 855.30 |
| 34 | 1,156 | 39,304 | 5.8310 | 3.2396 | .029411765 | 106.81 | 907.92 |
| 35 | 1,225 | 42,875 | 5.9161 | 3.2711 | .028571429 | 109.96 | 962.11 |
| 36 | 1,296 | 46,656 | 6.0000 | 3.3019 | .027777778 | 113.10 | 1,017.88 |
| 37 | 1,369 | 50,653 | 6.0828 | 3.3322 | .027027027 | 116.24 | 1,075.21 |
| 38 | 1,444 | 54,872 | 6.1644 | 3.3620 | .026315789 | 119.38 | 1,134.11 |
| 39 | 1,521 | 59,319 | 6.2450 | 3.3912 | .025641026 | 122.52 | 1,194.59 |
| 40 | 1,600 | 64,000 | 6.3246 | 3.4200 | .025000000 | 125.66 | 1,256.64 |
| 41 | 1,681 | 68,921 | 6.4031 | 3.4482 | .024390244 | 128.81 | 1,320.25 |
| 42 | 1,764 | 74,088 | 6.4807 | 3.4760 | .023809524 | 131.95 | 1,385.44 |
| 43 | 1,849 | 79,507 | 6.5574 | 3.5034 | .023255814 | 135.09 | 1,452.20 |
| 44 | 1,936 | 85,184 | 6.6332 | 3.5304 | .022727273 | 138.23 | 1,520.53 |
| 45 | 2,025 | 91,125 | 6.7082 | 3.5569 | .022222222 | 141.37 | 1,590.43 |
| 46 | 2,116 | 97,336 | 6.7823 | 3.5830 | .021739130 | 144.51 | 1,661.90 |
| 47 | 2,209 | 103,823 | 6.8557 | 3.6088 | .021276600 | 147.65 | 1,734.94 |
| 48 | 2,304 | 110,592 | 6.9282 | 3.6342 | .020833333 | 150.80 | 1,809.56 |
| 49 | 2,401 | 117,649 | 7.0000 | 3.6593 | .020408163 | 153.94 | 1,885.74 |
| 50 | 2,500 | 125,000 | 7.0711 | 3.6840 | .020000000 | 157.08 | 1,963.50 |

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## TABLE 58. (Cont.) FUNCTIONS OF NUMBERS.

| No. | Square | Cube | Sq. Rt. | Cu. Rt. | Reciprocal | Circum. | Area |
|---|---|---|---|---|---|---|---|
| 51 | 2,601 | 132,651 | 7.1414 | 3.7084 | .019607843 | 160.22 | 2,042.82 |
| 52 | 2,704 | 140,608 | 7.2111 | 3.7325 | .019230769 | 163.36 | 2,123.72 |
| 53 | 2,809 | 148,877 | 7.2801 | 3.7563 | .018867925 | 166.50 | 2,206.18 |
| 54 | 2,916 | 157,464 | 7.3485 | 3.7798 | .018518519 | 169.65 | 2,290.22 |
| 55 | 3,025 | 166,375 | 7.4162 | 3.8030 | .018181818 | 172.79 | 2,375.83 |
| 56 | 3,136 | 175,616 | 7.4833 | 3.8259 | .017857143 | 175.93 | 2,463.01 |
| 57 | 3,249 | 185,193 | 7.5498 | 3.8485 | .017543860 | 179.07 | 2,551.76 |
| 58 | 3,364 | 195,112 | 7.6158 | 3.8709 | .017241379 | 182.21 | 2,642.08 |
| 59 | 3,481 | 205,379 | 7.6811 | 3.8930 | .016949153 | 185.35 | 2,733.97 |
| 60 | 3,600 | 216,000 | 7.7460 | 3.9149 | .016666667 | 188.50 | 2,827.43 |
| 61 | 3,721 | 226,981 | 7.8102 | 3.9365 | .016393443 | 191.64 | 2,922.47 |
| 62 | 3,844 | 238,328 | 7.8740 | 3.9579 | .016129032 | 194.78 | 3,019.07 |
| 63 | 3,969 | 250,047 | 7.9373 | 3.9791 | .015873016 | 197.92 | 3,117.25 |
| 64 | 4,096 | 262,144 | 8.0000 | 4.0000 | .015625000 | 201.06 | 3,216.99 |
| 65 | 4,225 | 274,625 | 8.0623 | 4.0207 | .015384615 | 204.20 | 3,318.31 |
| 66 | 4,356 | 287,496 | 8.1240 | 4.0412 | .015151515 | 207.34 | 3,421.19 |
| 67 | 4,489 | 300,763 | 8.1854 | 4.0616 | .014925373 | 210.49 | 3,525.65 |
| 68 | 4,624 | 314,432 | 8.2462 | 4.0817 | .014705882 | 213.63 | 3,631.68 |
| 69 | 4,761 | 328,509 | 8.3066 | 4.1016 | .014492754 | 216.77 | 3,739.28 |
| 70 | 4,900 | 343,000 | 8.3666 | 4.1213 | .014285714 | 219.91 | 3,848.45 |
| 71 | 5,041 | 357,911 | 8.4261 | 4.1408 | .014084517 | 223.05 | 3,959.19 |
| 72 | 5,184 | 373,248 | 8.4853 | 4.1602 | .013888889 | 226.19 | 4,071.50 |
| 73 | 5,329 | 389,017 | 8.5440 | 4.1793 | .013698630 | 229.34 | 4,185.39 |
| 74 | 5,476 | 405,224 | 8.6023 | 4.1983 | .013513514 | 232.48 | 4,300.84 |
| 75 | 5,625 | 421,875 | 8.6603 | 4.2172 | .013333333 | 235.62 | 4,417.86 |
| 76 | 5,776 | 438,976 | 8.7178 | 4.2358 | .013157895 | 238.76 | 4,536.46 |
| 77 | 5,929 | 456,533 | 8.7750 | 4.2543 | .012987013 | 241.90 | 4,656.63 |
| 78 | 6,084 | 474,552 | 8.8318 | 4.2727 | .012820513 | 245.04 | 4,778.36 |
| 79 | 6,241 | 493,039 | 8.8882 | 4.2908 | .012658228 | 248.19 | 4,901.67 |
| 80 | 6,400 | 512,000 | 8.9443 | 4.3089 | .012500000 | 251.33 | 5,026.55 |
| 81 | 6,561 | 531,441 | 9.0000 | 4.3268 | .012345679 | 254.47 | 5,153.00 |
| 82 | 6,724 | 551,368 | 9.0554 | 4.3445 | .012195122 | 257.61 | 5,281.02 |
| 83 | 6,889 | 571,787 | 9.1104 | 4.3621 | .012048193 | 260.75 | 5,410.61 |
| 84 | 7,056 | 592,704 | 9.1652 | 4.3795 | .011904762 | 263.89 | 5,541.77 |
| 85 | 7,225 | 614,125 | 9.2195 | 4.3968 | .011764706 | 267.04 | 5,674.50 |
| 86 | 7,396 | 636,056 | 9.2736 | 4.4140 | .011627907 | 270.18 | 5,808.80 |
| 87 | 7,569 | 658,503 | 9.3274 | 4.4310 | .011494253 | 273.32 | 5,944.68 |
| 88 | 7,744 | 681,472 | 9.3808 | 4.4480 | .011363636 | 276.46 | 6,082.12 |
| 89 | 7,921 | 704,969 | 9.4340 | 4.4647 | .011235955 | 279.60 | 6,221.14 |
| 90 | 8,100 | 729,000 | 9.4868 | 4.4814 | .011111111 | 282.74 | 6,361.73 |
| 91 | 8,281 | 753,571 | 9.5394 | 4.4979 | .010989011 | 285.88 | 6,503.88 |
| 92 | 8,464 | 778,688 | 9.5917 | 4.5144 | .010869565 | 289.03 | 6,647.61 |
| 93 | 8,649 | 804,357 | 9.6437 | 4.5307 | .010752688 | 292.17 | 6,792.91 |
| 94 | 8,836 | 830,584 | 9.6954 | 4.5468 | .010638298 | 295.31 | 6,939.78 |
| 95 | 9,025 | 857,375 | 9.7468 | 4.5629 | .010526316 | 298.45 | 7,088.22 |
| 96 | 9,216 | 884,736 | 9.7980 | 4.5789 | .010416667 | 301.59 | 7,238.23 |
| 97 | 9,409 | 912,673 | 9.8489 | 4.5947 | .010309278 | 304.73 | 7,389.81 |
| 98 | 9,604 | 941,192 | 9.8995 | 4.6104 | .010204082 | 307.88 | 7,542.96 |
| 99 | 9,801 | 970,299 | 9.9499 | 4.6261 | .010101010 | 311.02 | 7,697.69 |
| 100 | 10,000 | 1,000,000 | 10.0000 | 4.6416 | .010000000 | 314.16 | 7,853.98 |

# SECTION X—ELECTRICAL DATA

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X

# SECTION X—ELECTRICAL DATA

## ELECTRIC MOTORS—SERVICE CONDITIONS

Electric motors are manufactured in several types of frame enclosures. This makes it possible to install motors in a variety of atmospheric environments some of which are normally unfriendly to the efficient operation of electrical apparatus. The table following gives the normal temperature rating and overload rating or service factor for each type.

### NORMAL TEMPERATURE RISE BY THERMOMETER, AND SERVICE FACTOR, 40 C AMBIENT

| Enclosure | Class A Insulation | | Class B Insulation | | Class H Insulation | |
|---|---|---|---|---|---|---|
| Dripproof<br>Dripproof, guarded<br>Dripproof with moisture-sealed features<br>Forced-ventilated (pipe- or base-) | 40 C | 1.15 | 60 C | 1.15 | 90 C | 1.15 |
| Self-ventilated (base- and pipe-, where ducts are attached)<br>Splashproof | 50 C | 1.00 | 70 C | 1.00 | 110 C | 1.00 |
| Totally enclosed fan-cooled (std and exp-proof)<br>TEFC with air-to-water heat exchanger<br>Waterproof, totally enclosed fan-cooled | 55 C | 1.00 | 75 C | 1.00 | 115 C | 1.00 |
| Weather-protected, NEMA Type I<br>Weather-protected, NEMA Type II | 40 C | 1.15 | 60 C | 1.15 | 90 C | 1.15 |

These ratings apply where:

1. Temperature of the surrounding air does not exceed 40 deg. C. (104 deg. F.).

2. Voltage does not vary more than 10% above or below the nameplate rating.

3. Frequency does not vary more than 5% above or below the nameplate rating

4. Both voltage and frequency do not vary the maximum amount given in (2) and (3) simultaneously. Keeping the limit of 5% on frequency the combined variation is limited to 10%.

5. Altitude does not exceed 1000 meters (3300 ft.)

# TABLE 59. MOTOR CHARACTERISTICS

| Type of Driven Machinery | Motor Type Designation | Speed R.P.M. | Approx. Starting Torque in % of Full Load Torque | Approx. Max. Torque in % of Full Load Torque | Approx. Starting Current in % of Full Load Current | Approx. Speed Regulation % Slip | Load Conditions |
|---|---|---|---|---|---|---|---|
| Pumps, Centrifugals, Westco Peripheral, Rotary, Propeller | NEMA Design A & B | 1800 | 125 To 275 | 200 To 300 | 450 To 550 | 2 To 4 | Require normal starting torque for continuous duty. Infrequent load fluctuations. Motor provides service factor for overload conditions. Constant speed. No special conditions. |
| | | 1200 | 125 To 180 | 200 To 275 | 450 To 550 | 2 To 4 | |
| | | 900 | 115 To 150 | 200 To 250 | 450 To 550 | 2 To 4 | |
| Pumps, Positive Displacement | Ratings 3 H.P. & Larger NEMA Design C | 1800 | 225 To 275 | 200 To 300 | 450 To 550 | 3 To 5 | Compressors and pumps requiring less than 7½Hp. under certain conditions may be successfully handled by type KZK Motors. |
| | | 1200 | 200 To 250 | 200 To 275 | 450 To 550 | 3 To 5 | |
| | | 900 | 190 To 225 | 190 To 250 | 450 To 550 | 3 To 5 | Heavy starting, continuous or intermittent duty; service factor for overload conditions. |
| Pump, Centrifugal Propeller | 30 H.P. & Larger NEMA Design F | 1800 | 75-100 | 150-160 | 350-400 | 3-5 | Low starting and maximum torque. Low starting current. Continuous duty, service factor 1.0 and no overload capacity. |
| | | 1200 | 75-100 | 150-160 | 350-400 | 3-5 | |
| | | 900 | 75-100 | 150-160 | 350-400 | 3-5 | |
| Pumps, Positive Displacement | Multi-Speed Constant Torque | 1800/900 | 125-180 | 200-250 | 450-550 | 2-4 | Require normal starting torque for continuous duty. Infrequent load fluctuations. Motor provides service factor for overload conditions. Constant speed. No special conditions. |
| | | 1800/1200/900/600 | 125-180 | 200-250 | 450-550 | 2-4 | |
| Pumps, Centrifugal | Multi Speed Variable Torque | 1800/900 | 125-180 | 200-250 | 450-550 | 2-4 | Require normal starting torque for continuous duty. Infrequent load fluctuations. Motor provides service factor for overload conditions. Constant speed. No special conditions. |
| | | 1800/1200/900/600 | 125-180 | 200-250 | 450-550 | 2-4 | |

# TABLE 60. SYNCHRONOUS AND APPROXIMATE FULL LOAD SPEEDS OF STANDARD A. C. INDUCTION MOTORS

| No. of Poles | 60 Cycle R. P. M. Sync. | 60 Cycle F. L. | 50 Cycle R. P. M. Sync. | 50 Cycle F. L. | 40 Cycle R. P. M. Sync. | 40 Cycle F. L. | 30 Cycle R. P. M. Sync. | 30 Cycle F. L. | 25 Cycle R. P. M. Sync. | 25 Cycle F. L. |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 3600 | 3500 | 3000 | 2900 | 2400 | 2310 | 1800 | 1750 | 1500 | 1450 |
| 4 | 1800 | 1770 | 1500 | 1450 | 1200 | 1150 | 900 | 860 | 750 | 720 |
| 6 | 1200 | 1170 | 1000 | 960 | 800 | 770 | 600 | 575 | 500 | 480 |
| 8 | 900 | 870 | 750 | 720 | 600 | 575 | 450 | 375 | 375 | 360 |
| 10 | 720 | 690 | 600 | 575 | 480 | 460 | 360 | 340 | 300 | 285 |
| 12 | 600 | 575 | 500 | 480 | 400 | 385 | 300 | 285 | 250 | 240 |
| 14 | 514 | 490 | 428 | 410 | 343 | 330 | 257 | 247 | 215 | 205 |
| 16 | 450 | 430 | 375 | 360 | 300 | 288 | 225 | 215 | 187 | 180 |
| 18 | 400 | 380 | 333 | 319 | 266 | 256 | .... | .... | .... | .... |
| 20 | 360 | 340 | 300 | 285 | 240 | 230 | .... | .... | .... | .... |
| 22 | 326 | 310 | 273 | 260 | 218 | 208 | .... | .... | .... | .... |
| 24 | 300 | 285 | 240 | 230 | 200 | 192 | .... | .... | .... | .... |
| 30 | 240 | 230 | 200 | 192 | 160 | 153 | .... | .... | .... | .... |

THE SPEED OF THE A.C. SQUIRREL CAGE INDUCTION MOTOR IS DETERMINED BY THE FREQUENCY OF THE SUPPLY SYSTEM AND THE NUMBER OF POLES FOR WHICH THE MOTOR IS WOUND:

$$\text{SYNC. R.P.M.} = \frac{F \times 60}{P}$$

WHERE: R.P.M. = REVOLUTIONS PER MINUTE; F = FREQUENCY OF SUPPLY IN CYCLES PER SECOND; P = NUMBER OF PAIRS OF POLES

## TABLE 61. ELECTRICAL CONVERSION FORMULAS

| TO FIND | DIRECT CURRENT | ALTERNATING CURRENT: Single Phase | ALTERNATING CURRENT: † Three Phase |
|---|---|---|---|
| Amperes When Horse Power (Input) is Known | $\frac{\text{H.P.} \times 746}{\text{Volts} \times \text{Efficiency}}$ | $\frac{\text{H.P.} \times 746}{\text{Volts} \times \text{Efficiency} \times \text{P.F.}}$ | $\frac{\text{H.P.} \times 746}{\text{Volts} \times 1.73 \times \text{Efficiency} \times \text{P.F.}}$ |
| Amperes When Kilowatts is Known | $\frac{\text{KW} \times 1000}{\text{Volts}}$ | $\frac{\text{KW} \times 1000}{\text{Volts} \times \text{P.F.}}$ | $\frac{\text{KW} \times 1000}{\text{Volts} \times 1.73 \times \text{P.F.}}$ |
| Amperes When kva is Known | | $\frac{\text{kva} \times 1000}{\text{Volts}}$ | $\frac{\text{kva} \times 1000}{\text{Volts} \times 1.73}$ |
| Kilowatts | $\frac{\text{Amperes} \times \text{Volts}}{1000}$ | $\frac{\text{Amps.} \times \text{Volts} \times \text{P.F.}}{1000}$ | $\frac{\text{Amps.} \times \text{Volts} \times 1.73 \times \text{P.F.}}{1000}$ |
| kva | | $\frac{\text{Amps.} \times \text{Volts}}{1000}$ | $\frac{\text{Amps} \times \text{Volts} \times 1.73}{1000}$ |
| Power Factor | | $\frac{\text{Kilowatts} \times 1000}{\text{Amps.} \times \text{Volts}}$ or $\frac{\text{KW}}{\text{kva}}$ | $\frac{\text{KW} \times 1000}{\text{Amps.} \times \text{Volts} \times 1.73}$ or $\frac{\text{KW}}{\text{kva}}$ |
| Horse Power (Output) | $\frac{\text{Amps} \times \text{Volts} \times \text{Efficiency}}{746}$ | $\frac{\text{Amps.} \times \text{Volts} \times \text{Efficiency} \times \text{P.F.}}{746}$ | $\frac{\text{Amps.} \times \text{Volts} \times 1.73 \times \text{Efficiency} \times \text{P.F.}}{746}$ |

**Power Factor and Efficiency when used in above formulas should be expressed as decimals.**

† For 2-phase, 4-wire substitute 2 instead of 1.73.

† For 2-phase, 3-wire substitute 1.41 instead of 1.73.

# TABLE 62. FULL-LOAD CURRENTS OF MOTORS

The following data are approximate full-load currents for motors of various types, frequencies, and speeds. They have been compiled from average values for representative motors of their respective classes. Variations of 10 per cent above or below the values given may be expected.

| Hp. of Motor | Amperes—Full-load Current | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Direct-current Motors | | | Alternating-current Motors | | | | | | | | | | | | | | | | | | | | | |
| | | | | Single-phase Motors | | Squirrel-cage Induction Motors | | | | | | | | | | Slip-ring Induction Motors | | | | | | | | | |
| | | | | | | Two-phase | | | | | Three-phase | | | | | Two-phase | | | | | Three-phase | | | | |
| | 115-volt | 230-volt | 550-volt | 110-volt | 220-volt | 110-volt | 220-volt | 440-volt | 550-volt | 2300-volt | 110-volt | 220-volt | 440-volt | 550-volt | 2300-volt | 110-volt | 220-volt | 440-volt | 550-volt | 2300-volt | 110-volt | 220-volt | 440-volt | 550-volt | 2300-volt |
| ¼ | .... | .... | .... | 4.8 | 2.4 | ... | .... | .... | .... | .. | ... | .... | .... | .... | ... | ... | .... | .... | .... | ... | ... | .... | .... | .... | ... |
| ½ | 4.5 | 2.3 | .... | 7 | 3.5 | 4.3 | 2.2 | 1.1 | .9 | .. | 5.0 | 2.5 | 1.3 | 1.0 | ... | ... | .... | .... | .... | ... | ... | .... | .... | .... | ... |
| ¾ | 6.5 | 3.3 | 1.4 | 9.4 | 4.7 | 4.7 | 2.4 | 1.2 | 1.0 | .. | 5.4 | 2.8 | 1.4 | 1.1 | ... | 6.2 | 3.1 | 1.6 | 1.3 | ... | 7.2 | 3.6 | 1.8 | 1.5 | ... |
| 1 | 8.4 | 4.2 | 1.7 | 11 | 5.5 | 5.7 | 2.9 | 1.4 | 1.2 | .. | 6.6 | 3.3 | 1.7 | 1.3 | ... | 6.7 | 3.4 | 1.7 | 1.4 | ... | 7.8 | 3.9 | 2.0 | 1.6 | ... |
| 1½ | 12.5 | 6.3 | 2.6 | 15.2 | 7.6 | 7.7 | 4.0 | 2 | 1.6 | .. | 9.4 | 4.7 | 2.4 | 2.0 | ... | 11.7 | 5.9 | 3.0 | 2.3 | ... | ... | .... | .... | .... | ... |
| 2 | 16.1 | 8.3 | 3.4 | 20 | 10 | 10.4 | 5 | 3 | 2.0 | .. | 12.0 | 6 | 3.0 | 2.4 | ... | 12.5 | 6.3 | 3.1 | 2.5 | ... | 14 4 | 7.2 | 3.6 | 2.9 | ... |
| 3 | 23 | 12.3 | 5.0 | 28 | 14 | ... | 8 | 4 | 3.0 | .. | ... | 9 | 4.5 | 4.0 | ... | ... | 8.7 | 4.3 | 3.5 | ... | 20.2 | 10 | 5.0 | 4 | ... |
| 5 | 40 | 19.8 | 8.2 | 46 | 23 | ... | 13 | 7 | 6 | .. | ... | 15 | 7.5 | 6.0 | ... | ... | 13.0 | 6.5 | 5.2 | ... | ... | 15 | 7.5 | 6 | ... |
| 7½ | 58 | 28.7 | 12 | 68 | 34 | ... | 19 | 9 | 7 | .. | ... | 22 | 11 | 9.0 | ... | ... | 20.0 | 10.0 | 7.6 | ... | ... | 25 | 13 | 10 | ... |
| 10 | 75 | 38 | 16 | 86 | 43 | ... | 24 | 12 | 10 | .. | ... | 27 | 14 | 11 | ... | ... | 24.3 | 12.1 | 10.0 | ... | ... | 28 | 14 | 11 | ... |
| 15 | 112 | 56 | 23 | ... | ... | ... | 33 | 16 | 13 | .. | ... | 38 | 19 | 15 | ... | ... | 39 | 19.5 | 15.6 | ... | ... | 45 | 23 | 18 | ... |
| 20 | 140 | 74 | 30 | ... | ... | ... | 45 | 23 | 19 | .. | ... | 52 | 26 | 21 | 5.7 | ... | 49 | 24.7 | 19.8 | ... | ... | 56 | 28 | 22 | ... |
| 25 | 185 | 92 | 38 | ... | ... | ... | 55 | 28 | 22 | .. | ... | 64 | 32 | 26 | 7 | ... | 60 | 30.0 | 24.0 | 6.4 | ... | 67 | 34 | 27 | 7.5 |
| 30 | 220 | 110 | 45 | ... | ... | ... | 67 | 34 | 27 | 7 | ... | 77 | 39 | 31 | 8 | ... | 72 | 36.0 | 28.8 | 7.8 | ... | 82 | 41 | 33 | 9 |
| 40 | 294 | 146 | 61 | ... | ... | ... | 88 | 44 | 35 | 9 | ... | 101 | 51 | 40 | 10 | ... | 93 | 46.5 | 37.3 | 9.5 | ... | 106 | 53 | 42 | 11 |
| 50 | 364 | 180 | 75 | ... | ... | ... | 108 | 54 | 43 | 11 | ... | 125 | 63 | 50 | 13 | ... | 113 | 57 | 45 | 12.1 | ... | 128 | 64 | 51 | 14 |
| 60 | 436 | 215 | 90 | ... | ... | ... | 129 | 65 | 52 | 13 | ... | 149 | 75 | 60 | 15 | ... | 135 | 68 | 54 | 14.0 | ... | 150 | 75 | 60 | 16 |
| 75 | 540 | 268 | 111 | ... | ... | ... | 156 | 78 | 62 | 16 | ... | 180 | 90 | 72 | 19 | ... | 164 | 82 | 65 | 17.3 | ... | 188 | 94 | 75 | 19 |
| 100 | .... | 357 | 146 | ... | ... | ... | 212 | 106 | 85 | 22 | ... | 246 | 123 | 98 | 25 | ... | 214 | 108 | 87 | 21.7 | ... | 246 | 123 | 99 | 25 |
| 125 | .... | 443 | 184 | ... | ... | ... | 268 | 134 | 108 | 27 | ... | 310 | 155 | 124 | 32 | ... | 267 | 134 | 108 | 27 | ... | 310 | 155 | 124 | 31 |
| 150 | .... | .... | 220 | ... | ... | ... | 311 | 155 | 124 | 31 | ... | 360 | 180 | 144 | 36 | ... | 315 | 158 | 127 | 32 | ... | 364 | 182 | 145 | 37 |
| 175 | .... | .... | .... | ... | ... | ... | .... | .... | .... | .. | ... | .... | .... | .... | ... | ... | .... | .... | .... | ... | ... | .... | .... | .... | ... |
| 200 | .... | .... | 295 | ... | ... | ... | 415 | 208 | 166 | 43 | ... | 480 | 240 | 195 | 49 | ... | 430 | 216 | 173 | 44 | ... | 490 | 245 | 196 | 52 |

## POWER MEASUREMENT BY WATT-HOUR METERS.

If the watt-hour meter is in correct adjustment it can be used as a convenient means of measuring electrical power. By measuring with a stop watch the exact time for a definite number of revolutions of the disk, the average speed of the disk can be determined accurately. The speed of the disk is directly proportional to the power being used, as expressed in the formulas:

$$\text{Watts} = K \times M \times \text{Revolutions per Hour}$$

$$\text{Kilowatts} = \frac{60 \times 60}{1000} K \times M \times \textit{Rev. per Sec.}$$

$$= 3.6\, K \times M \times \frac{R}{t}$$

$$\text{H.P. Input to Motor} = 4.826\, K \times M \times \frac{R}{t}$$

$K$ = disk constant, representing watt-hours per revolution, found on the meter nameplate or painted on the disk.
$M$ = product of current transformer ratio and potential transformer ratio. (When either transformer is not used the equivalent ratio is one.)
$R$ = total revolutions of watt-hour meter disk.
$t$ = time for total revolutions of disk in seconds.

For convenient reference the disk constants of a number of commonly used meters are listed below and on the following page.

### TABLE 63. DISK CONSTANTS FOR SINGLE-PHASE METERS
(Watt-Hours per Revolution of Disk)

| METER RATING | | GENERAL ELECTRIC | | | WESTINGHOUSE | SANGAMO | | DUNCAN | |
|---|---|---|---|---|---|---|---|---|---|
| | | Types | | | Types | Types | | Types | |
| Volts | Amp | I-14 | I-16 I-20 I-30 | I-60S I-18 V-2 | B, C, OA, OB, OC, CA, CB, CS, DS-3 | H | J35 HC HF | M2 | MQS MD MF |
| | 5 | 0.3 | 0.6 | 1.2 | 1/3 | 5/24 | 1/3 | 0.25 | 1/3 |
| | 10 | 0.6 | 1.2 | 2.4 | 2/3 | 5/12 | 2/3 | 0.5 | 2/3 |
| | 15 | 0.9 | †1.8 | 3.6 | 1 | 5/8 | 1 | 0.75 | 1 |
| 100 to 120 | 25 | 1.5 | 3. | 6. | 1-2/3 | 1-1/24 | 1-2/3 | 1.25 | 1-2/3 |
| | 50 | 3. | 6. | 12. | 3-1/3 | 2-1/12 | 3-1/3 | 2.5 | 3-1/3 |
| | 75 | 4.5 | | | 5 | 3-1/8 | 5 | 3.5 | 5 |
| | 100 | 6. | 12. | | 6-2/3 | 4-1/6 | 6-2/3 | 5.0 | 6-2/3 |
| | 150 | 9. | | | 10 | 6-1/4 | 10 | 7.5 | 10 |
| | 5 | 0.6 | 1.2 | 2.4 | 2/3 | 5/12 | 2/3 | 0.5 | 2/3 |
| | 10 | 1.2 | 2.4 | 4.8 | 1-1/3 | 5/6 | 1-1/3 | 1.0 | 1-1/3 |
| | 15 | 1.8 | Δ3.6 | 7.2 | 2 | 1-1/4 | 2 | 1.5 | 2 |
| 200 to 240 | 25 | 3. | 6. | 12. | 3-1/3 | 2-1/12 | 3-1/3 | 2.5 | 3-1/3 |
| | 50 | 6. | 12. | 24. | 6-2/3 | 4-1/6 | 6-2/3 | 5. | 6-2/3 |
| | 75 | 9. | | | 10 | 6-1/4 | 10 | 7.5 | 10 |
| | 100 | 12. | 24. | | 13-1/3 | 8-1/3 | 13-1/3 | 10. | 13-1/3 |
| | 150 | 18. | | | 20 | 12-1/2 | 20 | 15. | 20 |

† I-30 Meters have K = 1.5 in the 15 amp. size.
Δ I-30 Meters have K = 3.0 in the 15 amp. size.

# TABLE 63A. DISK CONSTANTS FOR POLYPHASE METERS

## (Watt-Hours per Revolution of Disk)

| METER READING | | GENERAL ELECTRIC Types | | | WESTINGHOUSE Types | | SANGAMO Types | | DUNCAN Types | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 2 element | | |
| Volts | Amp. | D-6, D-7 | D-14, V-3 | D-15, V-4 | CS-2, CA-2, C, C-2, R-2, OA, OB, RA, RB, RO | R-3, C-3, CA-3, CS-3 | H | HC, HF, L2-P | M2 | MD, MF, MG | 3 element MD, MF, MG |
| | 5 | 0.6 | †1.2 | 1.8 | 2/3 | 1 | 5/12 | 2/3 | 0.5 | 2/3 | 1 |
| | 10 | 1.2 | 2.4 | 3.6 | 1-1/3 | 2 | 5/6 | 1-1/3 | 1.0 | 1-1/3 | 2 |
| | 15 | 1.8 | 3.6 | 5.4 | 2 | 3 | 1-1/4 | 2 | 1.5 | 2 | 3 |
| 100 to 120 | 25 | 3. | 6. | 9. | 3-1/3 | 5 | 2-1/12 | 3-1/3 | 2.5 | 3-1/3 | 5 |
| | 50 | 6. | 12. | 18. | 6-2/3 | 10 | 4-1/6 | 6-2/3 | 5. | 6-2/3 | 10 |
| | 75 | 9. | | | 10 | 15 | 6-1/4 | 10 | 7.5 | 10 | 15 |
| | 100 | 12. | | | 13-1/3 | 20 | 8-1/3 | 13-1/3 | 10. | 13-1/3 | 20 |
| | 150 | 18. | | | 20 | 30 | 12-1/2 | 20 | 15.2 | 20 | 30 |
| | 5 | 1.2 | †2.4 | 3.6 | 1-1/3 | 2 | 5/6 | 1-1/3 | 1. | 1-1/3 | 2 |
| | 10 | 2.4 | 4.8 | 7.2 | 2-2/3 | 4 | 1-2/3 | 2-2/3 | 2. | 2-2/3 | 4 |
| | 15 | 3.6 | 7.2 | 10.8 | 4 | 6 | 2-1/2 | 4 | 3. | 4 | 6 |
| 200 to 240 | 25 | 6. | 12. | 18. | 6-2/3 | 10 | 4-1/6 | 6-2/3 | 5. | 6-2/3 | 10 |
| | 50 | 12. | 24. | 36. | 13-1/3 | 20 | 8-1/3 | 13-1/3 | 10. | 13-1/3 | 20 |
| | 75 | 18. | | | 20 | 30 | 12-1/2 | 20 | 15. | 20 | 30 |
| | 100 | 24. | | | 26-2/3 | 40 | 16-2/3 | 26-2/3 | 20. | 26-2/3 | 40 |
| | 150 | 36. | | | 40 | 60 | 25 | 40 | 30. | 40 | 60 |
| | 5 | 2.4 | †4.8 | 7.2 | 2-2/3 | 4 | 1-2/3 | 2-2/3 | 2. | 2-2/3 | 4 |
| | 10 | 4.8 | 9.6 | 14.4 | 5-1/3 | 8 | 3-1/3 | 5-1/3 | 4. | 5-1/3 | 8 |
| | 15 | 7.2 | 14.4 | 21.6 | 8 | 12 | 5 | 8 | 6. | 8 | 12 |
| 400 to 480 | 25 | 12. | 24. | 36. | 13-1/3 | 20 | 8-1/3 | 3-1/3 | 10. | 13-1/3 | 20 |
| | 50 | 24. | 48. | 72. | 26-2/3 | 40 | 16-2/3 | 26-2/3 | 20. | 26-2/3 | 40 |
| | 75 | 36. | | | 40 | 60 | 25 | 40 | 30. | 40 | 60 |
| | 100 | 48. | | | 53-1/3 | 80 | 33-1/3 | 53-1/3 | 40. | 53-1/3 | 60 |
| | 150 | 72. | | | 80 | 120 | 50 | 80 | 60. | 80 | 120 |
| | 5 | 3. | †6. | 9. | 3-1/3 | 5 | 2-1/12 | 3-1/3 | 2.5 | 3-1/3 | 5 |
| | 10 | 6. | 12. | 18. | 6-2/3 | 10 | 4-1/6 | 6-2/3 | 5. | 6-2/3 | 10 |
| | 15 | 9. | 18. | 27. | 10 | 15 | 6-1/4 | 10 | 7.5 | 10 | 15 |
| 500 to 600 | 25 | 15. | 30. | 45. | 16-2/3 | 25 | 10-5/12 | 16-2/3 | 12.5 | 16-2/3 | 25 |
| | 50 | 30. | 60. | 90. | 33-1/3 | 50 | 20-5/6 | 33-1/3 | 25. | 33-1/3 | 50 |
| | 75 | 45. | 90. | 135. | 50 | 75 | 31-1/4 | 50 | 37.5 | 50 | 75 |
| | 100 | 60. | 120. | 180. | 66-2/3 | 100 | 41-2/3 | 66-2/3 | 50. | 66-2/3 | 100 |
| | 150 | 90. | 180. | 270. | 100 | 150 | 62-1/2 | 100 | 75. | 100 | 150 |

†Most modern meters with current transformers have 2½ amp. current coils which would make the constant one half of that shown above. This constant is marked on edge of disc.

X

# TABLE 64. TABLE FOR SELECTING WIRE AND FUSE SIZES FOR MOTOR BRANCH CIRCUITS

(Based on Room Temperature 30°C. 86°F.)

| | Minimum Allowable Size of Copper Wire, A. W. G. or MCM National Electric Code | | | For Running Protection of Motors | | Maximum Allowable Rating of Branch-Circuit Fuses with Code Letters | | | |
|---|---|---|---|---|---|---|---|---|---|
| Full-load Current Rating of Motor—Amps. | Rubber Types R, RW, RU (14-6) | Type RH Heat-Resistant Grade Rubber | Types TA V. AVB | Max. Rating of N.E.C. Fuses—Amps. | Max. Setting of Time-Limit Protective Device—Amps. | Single-phase and Squirrel-cage Full Voltage, Resistor or Reactor Starting Code Letters F to R, Incl. | Single-phase and Squirrel-cage Full Voltage, Resistor or Reactor Starting Code Letters B to E, Incl. Autotransformer Starting F to R | Squirrel-cage, Auto-transformer Starting. Code Letters B to E, Incl. | All Motors Code Letter A. D.C. and Wound-rotor Motors |
| 1 | 14 | 14 | 14 | 2 | 1.25 | 15 | 15 | 15 | 15 |
| 2 | 14 | 14 | 14 | 3 | 2.50 | 15 | 15 | 15 | 15 |
| 3 | 14 | 14 | 14 | 4 | 3.75 | 15 | 15 | 15 | 15 |
| 4 | 14 | 14 | 14 | 6 | 5.0 | 15 | 15 | 15 | 15 |
| 5 | 14 | 14 | 14 | 8 | 6.25 | 15 | 15 | 15 | 15 |
| 6 | 14 | 14 | 14 | 8 | 7.50 | 20 | 15 | 15 | 15 |
| 8 | 14 | 14 | 14 | 10 | 10.0 | 25 | 20 | 20 | 15 |
| 10 | 14 | 14 | 14 | 15 | 12.50 | 30 | 25 | 20 | 15 |
| 12 | 14 | 14 | 14 | 15 | 15.00 | 40 | 30 | 25 | 20 |
| 14 | 14 | 12 | 14 | 20 | 17.50 | 45 | 35 | 30 | 25 |
| 16 | 12 | 12 | 14 | 20 | 20.00 | 50 | 40 | 35 | 25 |
| 18 | 12 | 12 | 14 | 25 | 22.50 | 60 | 45 | 40 | 30 |
| 20 | 12 | 12 | 14 | 25 | 25.0 | 60 | 50 | 40 | 30 |
| 24 | 10 | 10 | 14 | 30 | 30.0 | 80 | 60 | 50 | 40 |
| 28 | 10 | 10 | 12 | 35 | 35.0 | 90 | 70 | 60 | 45 |
| 32 | 8 | 8 | 10 | 40 | 40.0 | 100 | 80 | 70 | 50 |
| 36 | 8 | 8 | 10 | 45 | 45.0 | 100 | 90 | 80 | 60 |
| 40 | 8 | 8 | 10 | 50 | 50.0 | 125 | 100 | 80 | 60 |
| 44 | 6 | 8 | 8 | 60 | 55.0 | 125 | 110 | 90 | 70 |
| 48 | 6 | 6 | 8 | 60 | 60.0 | 150 | 125 | 100 | 80 |
| 52 | 6 | 6 | 6 | 70 | 65.0 | 175 | 150 | 110 | 80 |
| 56 | 4 | 6 | 6 | 70 | 70.0 | 175 | 150 | 120 | 90 |
| 60 | 4 | 6 | 6 | 80 | 75.0 | 200 | 150 | 120 | 90 |
| 64 | 4 | 6 | 6 | 80 | 80.0 | 200 | 175 | 150 | 100 |
| 68 | 4 | 4 | 6 | 90 | 85.0 | 225 | 175 | 150 | 110 |
| 72 | 3 | 4 | 4 | 90 | 90.0 | 225 | 200 | 150 | 110 |
| 76 | 3 | 4 | 4 | 100 | 95.0 | 250 | 200 | 175 | 125 |
| 80 | 3 | 4 | 4 | 100 | 100.0 | 250 | 200 | 175 | 125 |
| 84 | 2 | 4 | 4 | 110 | 105.0 | 250 | 225 | 175 | 150 |
| 88 | 2 | 3 | 4 | 110 | 110.0 | 300 | 225 | 200 | 150 |
| 92 | 2 | 3 | 3 | 125 | 115.0 | 300 | 250 | 200 | 150 |
| 96 | 1 | 3 | 3 | 125 | 120.0 | 300 | 250 | 200 | 150 |
| 100 | 1 | 3 | 3 | 125 | 125.0 | 300 | 250 | 200 | 150 |
| 110 | 1 | 2 | 2 | 150 | 137.5 | 350 | 300 | 225 | 175 |
| 120 | 0 | 1 | 2 | 150 | 150.0 | 400 | 300 | 250 | 200 |
| 130 | 00 | 1 | 1 | 175 | 162.5 | 400 | 350 | 300 | 200 |
| 140 | 00 | 0 | 1 | 175 | 175.0 | 450 | 350 | 300 | 225 |
| 150 | 000 | 0 | 0 | 200 | 187.5 | 450 | 400 | 300 | 225 |
| 160 | 000 | 00 | 00 | 200 | 200.0 | 500 | 400 | 350 | 250 |
| 170 | 0000 | 00 | 00 | 225 | 213.0 | 500 | 450 | 350 | 300 |
| 180 | 0000 | 000 | 00 | 225 | 225.0 | 600 | 450 | 400 | 300 |
| 190 | 0000 | 000 | 000 | 250 | 238.0 | 600 | 500 | 400 | 300 |
| 200 | 250 | 0000 | 000 | 250 | 250.0 | 600 | 500 | 400 | 300 |
| 220 | 300 | 0000 | 0000 | 300 | 275.0 | ... | 600 | 500 | 400 |
| 240 | 300 | 250 | 250 | 300 | 300.0 | ... | 600 | 500 | 400 |

Wire sizes shown in this table are for single motor, for short distances from feeder center to motor, therefore the wire sizes are tabulated as minimum. Where a group of motors is involved, special consideration must be given in selecting proper wire size.

Wire sizes are based on not more than three conductors in raceway or cable.

FROM NATIONAL ELECTRIC CODE 1947

# SECTION XI—PUMP TESTING

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# SECTION XI — PUMP TESTING

## MEASUREMENT OF PRESSURE

Pressures are usually measured by means of Bourdon tube type gauges although for pressures less than approximately 10 psi water or mercury manometers are often used. Any type of instrument used should be so located that it can reflect the true pressure inside the pipe line. To do so the pressure (or vacuum) connection should be located in a pipe, straight and smooth on the inside, of unvarying cross-section and preferably five to ten pipe diameters down stream from any elbow, valve or other similar turn or obstruction that might cause turbulence at the gauging section.

The pressure tap should be ⅛″ to ¼″ diameter, drilled at right angles to the wall of the water passage, perfectly smooth and flush with the inside of the pipe and any burrs carefully removed. Two pressure taps approved by the Hydraulic Institute are shown in Fig. 58.

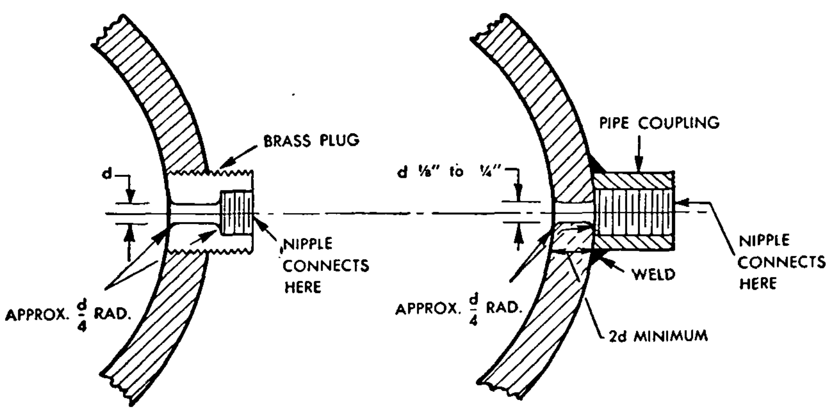


FIG. 58. Approved pressure taps.

The pressure gauge is constructed as shown in Fig. 59. Being a mechanical device and adjustable the gauge must always be calibrated before use. Very few gauges will be found to be accurate over their entire scale range. On important tests or where considerable heat is present the gauge should be calibrated both before and after the test. This may be done by means of a standard dead weight gauge tester. Whenever the pressure of hot water or steam is being measured, a syphon should always be used with the gauge. The water trapped in the syphon loses heat and the temperature of the water forced into the Bourdon tube is, therefore, relatively cool. The elastic qualities of the Bourdon tube will be destroyed if overheated.

FIG. 60.
Pressure gauge.†

FIG. 62.
Vacuum gauge.†

FIG. 59.
Gauge mechanism.†

FIG. 61.
Altitude gauge.†

FIG. 63.
Compound gauge.†

Gauges are available in most any dial graduation desired, but the units the gauge indicates is not always given on the face of the gauge. Custom in the industry has, however, made gauge users familiar with these units. The gauge illustrated in Fig. 60 reads from 0 to 100. When no indication is present on the face of the gauge to indicate the units, it is always understood in the industry to indicate the pressures in psi. When the word ALTITUDE appears on the face as in Fig. 61 the gauge reads head in feet of water. The word VACUUM on the face of the gauge as illustrated in Fig. 62 indicates negative pressures (vacuum) in in.hg. and the compound gauge illustrated in Fig. 63 reads vacuum in in. hg. and pressure in psi. Any gauge reading in inches of water, ounces/sq.ft. or in any other units, will be clearly marked on the face of the gauge.

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In using gauges when the pressure is positive or above atmospheric pressure any air in the gauge line should be vented off by

†*Courtesy American Machine & Metals, Inc. See page 6.*

loosening the gauge until liquid appears. When this is done it can be assumed that the gauge is reading the pressure at the elevation of the center line of the gauge. However, in measuring vacuum the gauge line will be empty of liquid and the gauge will be reading the vacuum at the elevation of the point of attachment of the gauge line to the pipe line.

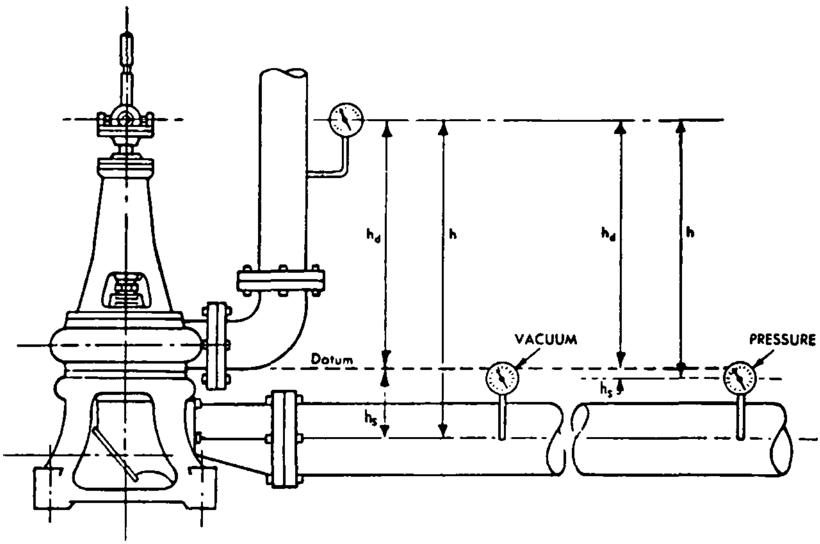


FIG. 64. Determination of total head from gauge readings.

In pump tests the total head can be determined by gauges as illustrated in Fig. 64. In this illustration the total Head would be determined as follows.

$H =$ Discharge gauge reading, corrected, Ft. liquid + Vacuum gauge reading, corrected, ft. liquid + distance between point of attachment of vacuum gauge to the center line of discharge gauge, $h$, ft. + $\left(\frac{V_d^2}{2g} - \frac{V_s^2}{2g}\right)$

or $H =$ Discharge gauge reading, corrected, Ft. liquid − pressure gauge reading in suction line, corrected, ft. liquid + distance between center of discharge and center of suction gauges, $h$, Ft. + $\left(\frac{V_d^2}{2g} - \frac{V_s^2}{2g}\right)$

The method of head determination above applies specifically to pumping units installed so that both suction and discharge flanges of the pump and adjacent piping are located so as to be accessible for installation of gauges for testing the pump. In such an installation it is possible to determine the head losses in both the suction and discharge piping and, therefore, the test will determine the true efficiency of the pump. In this case the pump is charged only with the head losses in the pump itself and all other head losses are rightfully charged against the piping system.

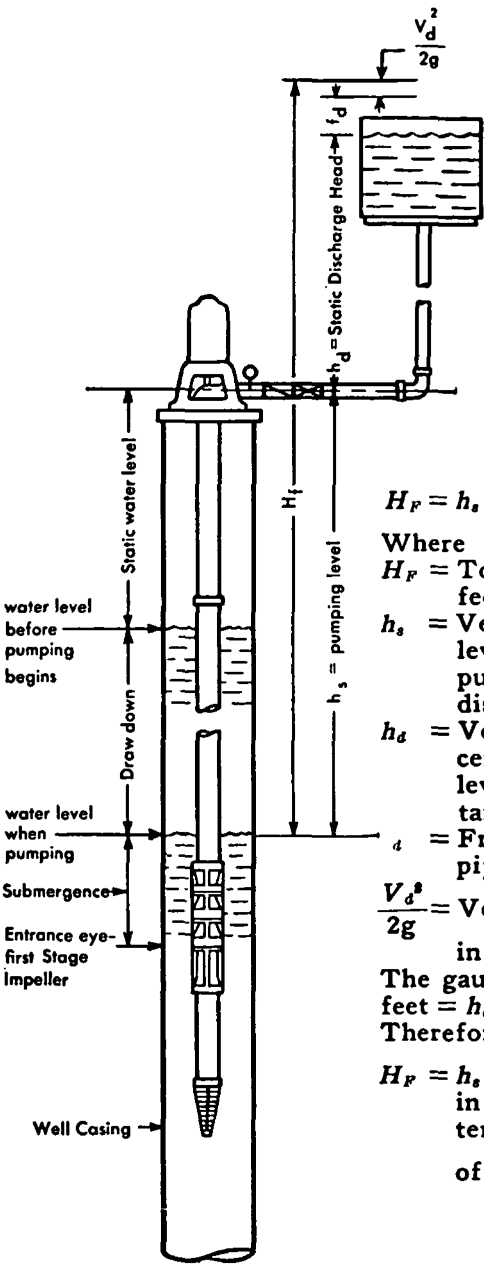


FIG. 64a. Total Head—Deep well turbine or propeller pump.

$$H_F = h_s + h_d + f_d + \frac{V_d^2}{2g}$$

Where

$H_F$ = Total Head or Field Head, in feet.

$h_s$ = Vertical distance in feet from level of water in well when pumping to the center-line of discharge.

$h_d$ = Vertical distance in feet from center-line of discharge to level of water in elevated tank = Static discharge head.

$f_d$ = Friction head in discharge piping, in feet.

$\frac{V_d^2}{2g}$ = Velocity head at discharge, in feet.

The gauge reading at discharge in feet = $h_d + f_d$

Therefore $H_F$ also equals—

$H_F$ = $h_s$ + discharge gauge reading in feet + distance from center line of gage to center line of discharge pipe + $\frac{V_d^2}{2g}$

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The installation of vertical Propeller and Turbine Pumps is invariably such that it is not possible to obtain pressures at the suction and discharge of the submerged basic pumping unit. Therefore, the method of head determination and testing must necessarily vary from the practice used on horizontal pumps. The only fair method of head determination to the user of the pump is one that will permit checking of pump performance in the field. Such a method will be described here. The Total Head determined by this method will be called "Field Head", $H_f$, for it can be obtained by field measurements. Please refer to Figure 64a.

Notice in this method of figuring that all velocity, entrance and friction losses at the suction of the pump are charged against the pump. Also all exit losses from pump discharge as well as all column friction losses are charged against the pump. This makes the efficiency of the pump appear lower than it really is. These losses exist whether charged to the pump or not. When not charged to the pump it makes field checking of pump performance impractical.

In the illustrations and text relating to calculations of total head the simplest type of pumping has been used—i.e. from one open vessel to another. Often closed vessels under pressure or vacuum are involved. To avoid error convert all elements of total head i.e., pressure or vacuum, static, friction and velocity to head in feet of the liquid pumped and proceed algebraically as described and illustrated in the preceding text.

Pressures may also be measured by manometers. The liquid used in the manometer is generally water or mercury. However, any liquid of known specific gravity may be used. Manometers are most often used for low pressures for the instrument becomes too long when used on the higher pressures. About 10 psi is the practical limit, for this would be equivalent to a water column 23 ft. high or a mercury column about 24 in. high. The advantage of using the manometer is, of course, that they do not need to be calibrated and since the deflection is greater they can be read more accurately.

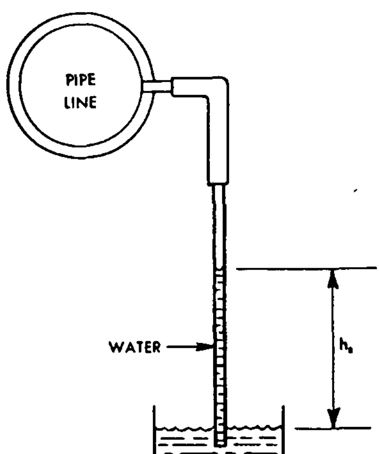


FIG. 65. Manometer indicating vacuum.

For field tests water manometers are quite convenient for they can often be fabricated out of readily obtainable materials. Fig. 65 shows a simple manometer installed on a suction pipe where $h_s$ = the vacuum in the pipe line at the point of attachment of the manometer to the pipe. Mercury could also be used in this simple manometer but great care should be used to see that the space between the pipe and the mercury meniscus is completely filled with air or completely filled with liquid.

To illustrate this point refer to Fig. 66 showing a mercury manometer measuring pressure in a water pipe line. If the space above the mercury in both legs of the manometer is filled with air the pressure in the pine line,

$$H\text{, ft. water} = h_d\text{, in. hg.} \times \frac{13.6}{12}$$
$$= h_d \times 1.133$$

where
13.6 = specific gravity of mercury.

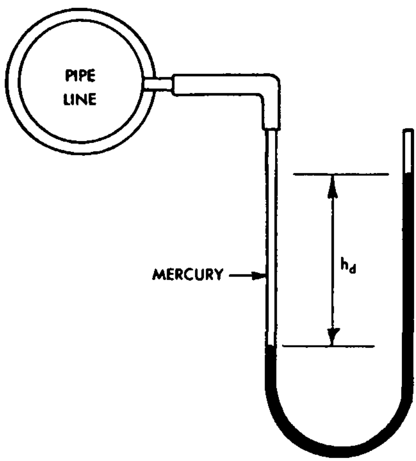



FIG. 66. Manometer indicating pressure.

However if the left hand leg above the mercury is filled with water the weight of the water, $h_d$, causes extra deflection of the mercury. In this case, therefore, it is necessary to subtract the specific gravity of water from the specific gravity of mercury in arriving at the head in the pipe, thus:

$$H\text{, ft. water} = h_d\text{, in. hg} \times \frac{13.6 - 1}{12} = h_d \times 1.05$$

XI

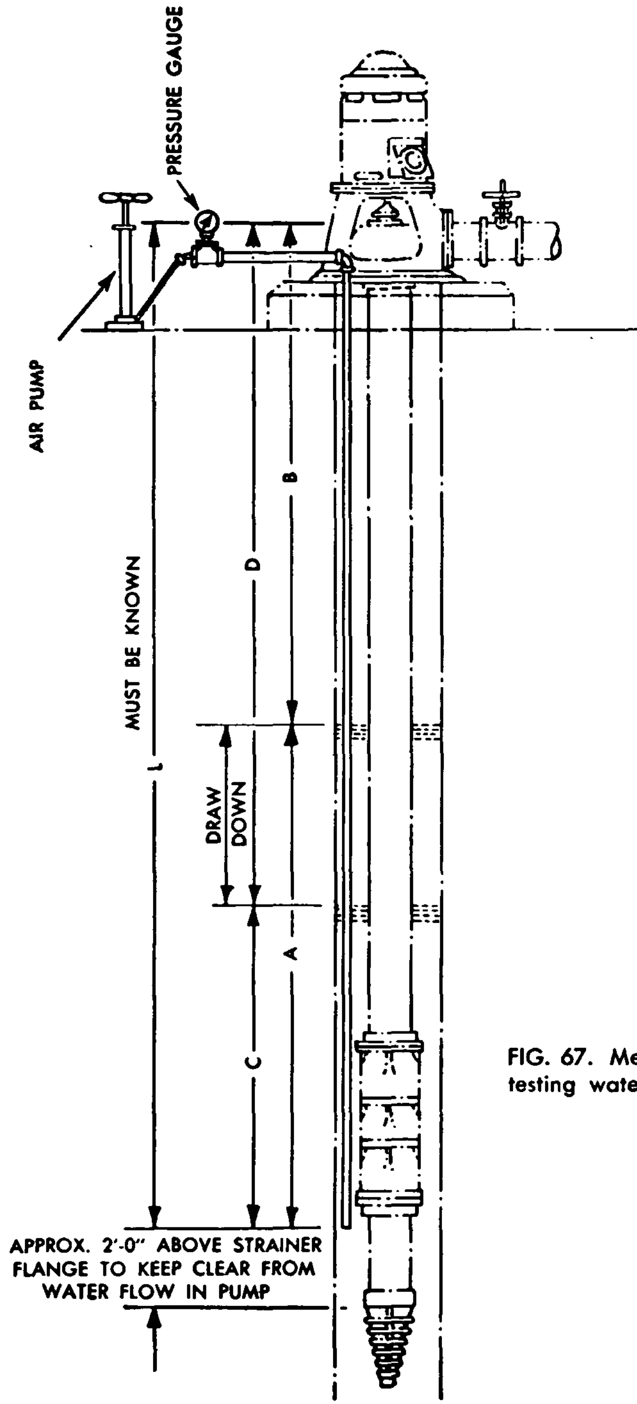



FIG. 67. Method of testing water level.

## DETERMINING THE DEPTH TO WATER LEVEL IN A DEEP WELL

In testing a vertical submerged pump such as a Deep Well Turbine it is necessary to determine the water level in the well when pumping.

The most satisfactory method of determining the water level involves the use of a ¼ in. air line of known vertical length, a pressure gauge and an ordinary bicycle or automobile pump installed as shown in Fig. 67. If possible the air line pipe should reach at least twenty feet beyond the lowest anticipated water level in the well in order to assure more reliable gauge readings and preferably should not be attached to the column or bowls as this would hinder the removal of the pipe should any leaks develop. As noted in Fig. 67 an air pressure gauge is used to indicate the pressure in the air line.

The ¼ in. air line pipe is lowered into the well, a tee is placed in the line above the ground, and a pressure gauge is screwed into one connection and the other is fitted with an ordinary bicycle valve to which a bicycle pump is attached. All joints must be made carefully and must be air tight to obtain correct information. When air is forced into the line by means of the tire pump the gauge pressure increases until all the water has been expelled. When this point is reached the gauge reading becomes constant. The maximum maintained air pressure recorded by the gauge is equivalent to that necessary to support a column of water of the same height as that forced out of the air line. The length of this water column is equal to the amount of air line submerged.

Deducting this pressure converted to feet (pounds pressure × 2.31 equals feet) from the known length of the ¼ in. air line pipe, will give the amount of submergence. The following examples will serve to clarify the above explanation.

Assume a length $L$ of 150 ft.

Pressure gauge reading before starting pump $= P_1 = 25$ lb. per sq. in. Then $A = 25 \times 2.31 = 57.7$ ft., therefore the water level in the well before starting the pump would be $B = L - A = 150 - 57.7 = 92.3$ feet.

Pressure gauge reading when pumping $= P_2 = 18$ lb. per sq. in. Then $C = 18 \times 2.31 = 41.6$ feet, therefore the water level in the well when pumping would be $D = L - C = 150 - 41.6$ ft. $= 108.4$ ft.

The drawdown is determined by the following equation:

$D - B = 108.4 - 92.3 = 16.1$ feet.

## MEASUREMENT OF CAPACITY

XI

The most accurate method of measuring the capacity of a pumping unit is by weighing the liquid pumped or measuring its volume in a calibrated vessel. For obvious reasons either method is practical only for small capacities. It has been necessary therefore, to devise other means, some of which are quite accurate, others only approximations. Some are suitable for measuring flow in a pipe line under pressure—others can be used only in open channels. Typical methods of measuring flow will be described here.

## VENTURI METER

The Venturi Meter is a common device for accurately measuring the discharge of pumps, particularly when a permanent meter installation is required. When the coefficient for the meter has been determined by actual calibration, and the meter is correctly installed and accurately read, the probable error in computing the discharge should be less than one per cent.

As usually constructed the meter consists of a converging portion, a throat having a diameter of approximately one third the main pipe diameter, and a diverging portion to reduce loss of energy from turbulence, see Fig. 68. The length of the converging portion is usually 2 to 2½ times the diameter of the main pipe, while the best angle of divergence is about 10 degrees included angle.

For accurate results the distance from the nearest elbow or fitting to the entrance of the meter should be at least 10 times the diameter of the pipe. Otherwise straightening vanes should be used to prevent spiral flow at entrance.

From a consideration of Bernoulli's Theorem:

$$\text{Gallons per Minute} = 3.118\ c\ a \sqrt{\frac{2\,gh}{R^4 - 1}}$$

$c$ = coefficient of discharge from calibration data. While this coefficient may vary from about 0.94 to more than unity it is usually about 0.98.

$a$ = area of entrance section where the upstream manometer connection is made, in square inches.

$R$ = ratio of entrance to throat diameter $= \dfrac{d}{d_1}$

$g$ = acceleration of gravity (32.2 ft./sec.²).

$h$ = $h_1 - h_2$ = difference in pressure between the entrance section and throat, as indicated by a manometer, in feet.

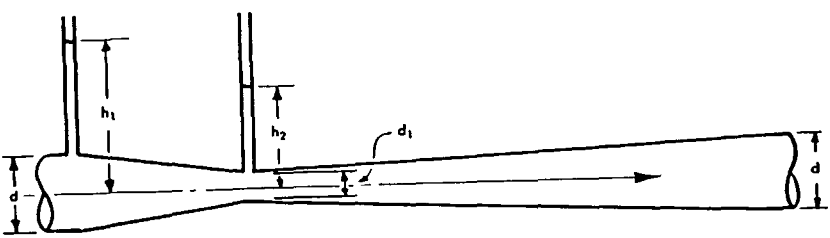



FIG. 68. Venturi meter.

In the illustration Fig. 68 the pressures $h_1$ and $h_2$ may be taken by manometer as illustrated when the pressures are low. When pressures are high a differential mercury manometer which indicates the difference in pressure $h_1 - h_2$ directly, is most often used. Gauges can also be used, but they can be read less accurately than a manometer and do require calibration. In commercial installations of venturi meters instruments are often installed that will continuously indicate, record and/or integrate the flow. They also require calibration so, when conducting a test, it is best to use a differential manometer connected directly to the meter to measure $h_1 - h_2$.

## NOZZLES

A nozzle is, in effect, the converging portion of a venturi tube. The water issues from the nozzle throat into the atmosphere. The pressure $h_2$, therefore, is atmospheric pressure. To calculate the flow from a nozzle use the same formula as for the venturi meter. The head, $h$, in the formula will be the gauge reading $h_1$.

## ORIFICES

Approximate discharge through orifice

$$Q = 19.636\ Kd^2\sqrt{h}\sqrt{\frac{1}{1-\left(\frac{d}{D}\right)^4}} \qquad \text{where } \frac{d}{D} \text{ is greater than .3}$$

$$Q = 19.636\ Kd^2\sqrt{h} \qquad \text{where } \frac{d}{D} \text{ is less than .3}$$

$Q$ = flow, in Gpm

$d$ = dia. of orifice or nozzle opening, in.

$h$ = head at orifice, in feet of liquid.

$D$ = dia. of pipe in which orifice is placed.

$K$ = discharge coefficient

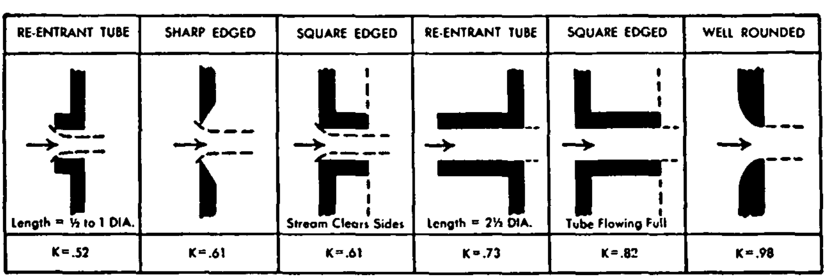



FIG. 69. Typical orifice coefficients.†

†*Courtesy Ingersoll-Rand Co. See page 6.*

# TABLE 65. THEORETICAL DISCHARGE OF ORIFICES, U.S. GPM.

| Head Lbs. | Head Feet | Velocity of Discharge Feet per Second | Diameter of Orifice in Inches 1/16 | 1/8 | 3/16 | 1/4 | 3/8 | 1/2 | 5/8 | 3/4 | 7/8 | 1 | 1 1/8 | 1 1/4 | 1 3/8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 23.1 | 38.6 | 0.37 | 1.48 | 3.32 | 5.91 | 13.3 | 23.6 | 36.9 | 53.1 | 72.4 | 94.5 | 120 | 148 | 179 |
| 15 | 34.6 | 47.25 | 0.45 | 1.81 | 4.06 | 7.24 | 16.3 | 28.9 | 45.2 | 65.0 | 88.5 | 116. | 147 | 181 | 219 |
| 20 | 46.2 | 54.55 | 0.52 | 2.09 | 4.69 | 8.35 | 18.8 | 33.4 | 52.2 | 75.1 | 102. | 134. | 169 | 209 | 253 |
| 25 | 57.7 | 61.0 | 0.58 | 2.34 | 5.25 | 9.34 | 21.0 | 37.3 | 58.3 | 84.0 | 114. | 149. | 189 | 234 | 283 |
| 30 | 69.3 | 66.85 | 0.64 | 2.56 | 5.75 | 10.2 | 23.0 | 40.9 | 63.9 | 92.0 | 125. | 164. | 207 | 256 | 309 |
| 35 | 80.8 | 72.2 | 0.69 | 2.77 | 6.21 | 11.1 | 24.8 | 44.2 | 69.0 | 99.5 | 135. | 177. | 224 | 277 | 334 |
| 40 | 92.4 | 77.2 | 0.74 | 2.96 | 6.64 | 11.8 | 26.6 | 47.3 | 73.8 | 106. | 145. | 189. | 239 | 296 | 357 |
| 45 | 103.9 | 81.8 | 0.78 | 3.13 | 7.03 | 12.5 | 28.2 | 50.1 | 78.2 | 113. | 153. | 200. | 253 | 313 | 379 |
| 50 | 115.5 | 86.25 | 0.83 | 3.30 | 7.41 | 13.2 | 29.7 | 52.8 | 82.5 | 119. | 162. | 211. | 267 | 330 | 399 |
| 55 | 127.0 | 90.4 | 0.87 | 3.46 | 7.77 | 13.8 | 31.1 | 55.3 | 86.4 | 125. | 169. | 221. | 280 | 346 | 418 |
| 60 | 138.6 | 94.5 | 0.90 | 3.62 | 8.12 | 14.5 | 32.5 | 57.8 | 90.4 | 130. | 177. | 231. | 293 | 362 | 438 |
| 65 | 150.1 | 98.3 | 0.94 | 3.77 | 8.45 | 15.1 | 33.8 | 60.2 | 94.0 | 136. | 184. | 241. | 305 | 376 | 455 |
| 70 | 161.7 | 102.1 | 0.98 | 3.91 | 8.78 | 15.7 | 35.2 | 62.5 | 97.7 | 141. | 191. | 250. | 317 | 391 | 473 |
| 75 | 173.2 | 105.7 | 1.01 | 4.05 | 9.08 | 16.2 | 36.4 | 64.7 | 101. | 146. | 198. | 259. | 327 | 404 | 489 |
| 80 | 184.8 | 109.1 | 1.05 | 4.18 | 9.39 | 16.7 | 37.6 | 66.8 | 104. | 150. | 205. | 267. | 338 | 418 | 505 |
| 85 | 196.3 | 112.5 | 1.08 | 4.31 | 9.67 | 17.3 | 38.8 | 68.9 | 108. | 155. | 211. | 276. | 349 | 431 | 521 |
| 90 | 207.9 | 115.8 | 1.11 | 4.43 | 9.95 | 17.7 | 39.9 | 70.8 | 111. | 160. | 217. | 284. | 359 | 443 | 536 |
| 95 | 219.4 | 119.0 | 1.14 | 4.56 | 10.2 | 18.2 | 41.0 | 72.8 | 114. | 164. | 223. | 292. | 369 | 456 | 551 |
| 100 | 230.9 | 122.0 | 1.17 | 4.67 | 10.5 | 18.7 | 42.1 | 74.7 | 117. | 168. | 229. | 299. | 378 | 467 | 565 |
| 105 | 242.4 | 125.0 | 1.20 | 4.79 | 10.8 | 19.2 | 43.1 | 76.5 | 120. | 172. | 234. | 306. | 388 | 479 | 579 |
| 110 | 254.0 | 128.0 | 1.23 | 4.90 | 11.0 | 19.6 | 44.1 | 78.4 | 122. | 176. | 240. | 314. | 397 | 490 | 593 |
| 115 | 265.5 | 130.9 | 1.25 | 5.01 | 11.2 | 20.0 | 45.1 | 80.1 | 125. | 180. | 245. | 320. | 406 | 501 | 606 |
| 120 | 277.1 | 133.7 | 1.28 | 5.12 | 11.5 | 20.5 | 46.0 | 81.8 | 128. | 184. | 251. | 327. | 414 | 512 | 619 |
| 125 | 288.6 | 136.4 | 1.31 | 5.22 | 11.7 | 20.9 | 47.0 | 83.5 | 130. | 188. | 256. | 334. | 423 | 522 | 632 |
| 130 | 200.2 | 139.1 | 1.33 | 5.33 | 12.0 | 21.3 | 48.0 | 85.2 | 133. | 192. | 261. | 341. | 432 | 533 | 645 |
| 135 | 311.7 | 141.8 | 1.36 | 5.43 | 12.2 | 21.7 | 48.9 | 86.7 | 136. | 195. | 266. | 347. | 439 | 543 | 656 |
| 140 | 323.3 | 144.3 | 1.38 | 5.53 | 12.4 | 22.1 | 49.8 | 88.4 | 138. | 199. | 271. | 354. | 448 | 553 | 668 |
| 145 | 334.8 | 146.9 | 1.41 | 5.62 | 12.6 | 22.5 | 50.6 | 89.9 | 140. | 202. | 275. | 360. | 455 | 562 | 680 |
| 150 | 346.4 | 149.5 | 1.43 | 5.72 | 12.9 | 22.9 | 51.5 | 91.5 | 143. | 206. | 280. | 366. | 463 | 572 | 692 |
| 175 | 404.1 | 161.4 | 1.55 | 6.18 | 13.9 | 24.7 | 55.6 | 98.8 | 154. | 222. | 302. | 395. | 500 | 618 | 747 |
| 200 | 461.9 | 172.6 | 1.65 | 6.61 | 14.8 | 26.4 | 59.5 | 106. | 165. | 238. | 323. | 423. | 535 | 660 | 799 |
| 250 | 577.4 | 193.0 | 1.85 | 7.39 | 16.6 | 29.6 | 66.5 | 118. | 185. | 266. | 362. | 473. | 598 | 739 | 894 |
| 300 | 692.8 | 211.2 | 2.02 | 8.08 | 18.2 | 32.4 | 72.8 | 129. | 202. | 291. | 396. | 517. | 655 | 808 | 977 |

NOTE—To determine actual discharge multiply values from table by coefficient of discharge.

## TABLE 65. (Cont.) THEORETICAL DISCHARGE OF ORIFICES, U. S. GPM.

| Head | | Velocity of Discharge Feet Per Second | Diameter of Orifice in Inches | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lbs. | Feet | | 1½ | 1¾ | 2 | 2¼ | 2½ | 2¾ | 3 | 3½ | 4 | 4½ | 5 | 5½ | 6 |
| 10 | 23.1 | 38.6 | 213 | 289 | 378 | 479 | 591 | 714 | 851 | 1158 | 1510 | 1915 | 2365 | 2855 | 3405 |
| 15 | 34.6 | 47.25 | 260 | 354 | 463 | 585 | 723 | 874 | 1041 | 1418 | 1850 | 2345 | 2890 | 3490 | 4165 |
| 20 | 46.2 | 54.55 | 301 | 409 | 535 | 676 | 835 | 1009 | 1203 | 1638 | 2135 | 2710 | 3340 | 4040 | 4819 |
| 25 | 57.7 | 61.0 | 336 | 458 | 598 | 756 | 934 | 1128 | 1345 | 1830 | 2385 | 3025 | 3730 | 4510 | 5380 |
| 30 | 69.3 | 66.85 | 368 | 501 | 655 | 828 | 1023 | 1236 | 1473 | 2005 | 2615 | 3315 | 4090 | 4940 | 5895 |
| 35 | 80.8 | 72.2 | 398 | 541 | 708 | 895 | 1106 | 1335 | 1591 | 2168 | 2825 | 3580 | 4415 | 5340 | 6370 |
| 40 | 92.4 | 77.2 | 425 | 578 | 756 | 957 | 1182 | 1428 | 1701 | 2315 | 3020 | 3830 | 4725 | 5710 | 6810 |
| 45 | 103.9 | 81.8 | 451 | 613 | 801 | 1015 | 1252 | 1512 | 1802 | 2455 | 3200 | 4055 | 5000 | 6050 | 7210 |
| 50 | 115.5 | 86.25 | 475 | 647 | 845 | 1070 | 1320 | 1595 | 1900 | 2590 | 3375 | 4275 | 5280 | 6380 | 7600 |
| 55 | 127.0 | 90.4 | 498 | 678 | 886 | 1121 | 1385 | 1671 | 1991 | 2710 | 3540 | 4480 | 5530 | 6690 | 7970 |
| 60 | 138.6 | 94.5 | 521 | 708 | 926 | 1172 | 1447 | 1748 | 2085 | 2835 | 3700 | 4685 | 5790 | 6980 | 8330 |
| 65 | 150.1 | 98.3 | 542 | 737 | 964 | 1220 | 1506 | 1819 | 2165 | 2950 | 3850 | 4875 | 6020 | 7270 | 8670 |
| 70 | 161.7 | 102.1 | 563 | 765 | 1001 | 1267 | 1565 | 1888 | 2250 | 3065 | 4000 | 5060 | 6250 | 7560 | 9000 |
| 75 | 173.2 | 105.7 | 582 | 792 | 1037 | 1310 | 1619 | 1955 | 2330 | 3170 | 4135 | 5240 | 6475 | 7820 | 9320 |
| 80 | 184.8 | 109.1 | 602 | 818 | 1070 | 1354 | 1672 | 2020 | 2405 | 3280 | 4270 | 5410 | 6690 | 8080 | 9630 |
| 85 | 196.3 | 112.5 | 620 | 844 | 1103 | 1395 | 1723 | 2080 | 2480 | 3375 | 4400 | 5575 | 6890 | 8320 | 9920 |
| 90 | 207.9 | 115.8 | 638 | 868 | 1136 | 1436 | 1773 | 2140 | 2550 | 3475 | 4530 | 5740 | 7090 | 8560 | 10210 |
| 95 | 219.4 | 119.0 | 565 | 892 | 1168 | 1476 | 1824 | 2200 | 2625 | 3570 | 4655 | 5900 | 7290 | 8800 | 10500 |
| 100 | 230.9 | 122.0 | 672 | 915 | 1196 | 1512 | 1870 | 2255 | 2690 | 3660 | 4775 | 6050 | 7470 | 9030 | 10770 |
| 105 | 242.4 | 125.0 | 689 | 937 | 1226 | 1550 | 1916 | 2312 | 2755 | 3750 | 4890 | 6200 | 7650 | 9250 | 11020 |
| 110 | 254.0 | 128.0 | 705 | 960 | 1255 | 1588 | 1961 | 2366 | 2820 | 3840 | 5010 | 6350 | 7840 | 9470 | 11300 |
| 115 | 265.5 | 130.9 | 720 | 980 | 1282 | 1621 | 2005 | 2420 | 2885 | 3930 | 5120 | 6490 | 8010 | 9680 | 11550 |
| 120 | 277.1 | 133.7 | 736 | 1002 | 1310 | 1659 | 2050 | 2470 | 2945 | 4015 | 5225 | 6630 | 8180 | 9900 | 11800 |
| 125 | 288.6 | 136.4 | 751 | 1022 | 1338 | 1690 | 2090 | 2520 | 3005 | 4090 | 5340 | 6760 | 8350 | 10100 | 12030 |
| 130 | 300.2 | 139.1 | 767 | 1043 | 1365 | 1726 | 2132 | 2575 | 3070 | 4175 | 5450 | 6900 | 8530 | 10300 | 12290 |
| 135 | 311.7 | 141.8 | 780 | 1063 | 1390 | 1759 | 2173 | 2620 | 3125 | 4250 | 5550 | 7030 | 8680 | 10400 | 12510 |
| 140 | 323.3 | 144.3 | 795 | 1082 | 1415 | 1790 | 2212 | 2670 | 3180 | 4330 | 5650 | 7160 | 8850 | 10600 | 12730 |
| 145 | 334.8 | 146.9 | 809 | 1100 | 1440 | 1820 | 2250 | 2715 | 3235 | 4410 | 5740 | 7280 | 8990 | 10880 | 12960 |
| 150 | 346.4 | 149.5 | 824 | 1120 | 1466 | 1853 | 2290 | 2760 | 3295 | 4485 | 5850 | 7410 | 9150 | 11070 | 13200 |
| 175 | 404.1 | 161.4 | 890 | 1210 | 1582 | 2000 | 2473 | 2985 | 3560 | 4840 | 6310 | 8000 | 9890 | 11940 | 14250 |
| 200 | 461.9 | 172.6 | 950 | 1294 | 1691 | 2140 | 2645 | 3190 | 3800 | 5175 | 6750 | 8550 | 10580 | 12770 | 15220 |
| 250 | 577.4 | 193.0 | 1063 | 1447 | 1891 | 2392 | 2955 | 3570 | 4250 | 5795 | 7550 | 9570 | 11820 | 14290 | 17020 |
| 300 | 692.8 | 211.2 | 1163 | 1582 | 2070 | 2615 | 3235 | 3900 | 4650 | 6330 | 8260 | 10480 | 12940 | 15620 | 18610 |

NOTE—To determine actual discharge multiply values from table by coefficient of discharge.

## CONSTRUCTION AND USE OF PIPE CAP ORIFICE

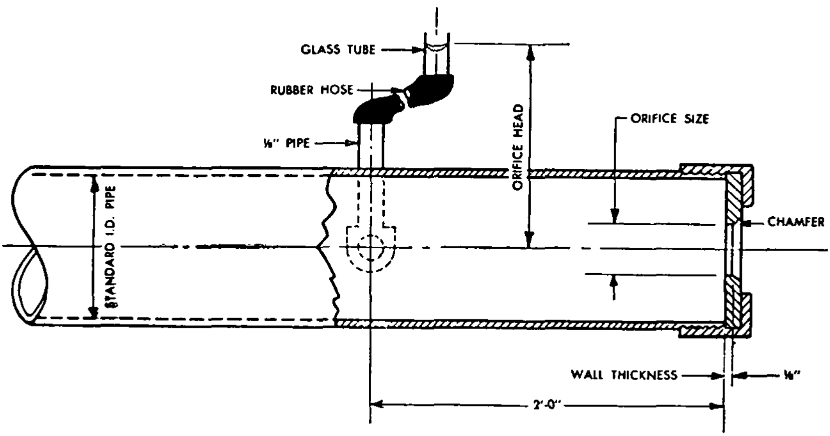



FIG. 70. Pipe cap orifice.

A pipe cap orifice is a form of sharp-edged orifice and is free flowing, since it is placed on the end of a pipe and allows the water to discharge into the atmosphere.

A number of precautions must be taken to insure accuracy of measurement.

1. Approach pipe must be smooth inside, straight and horizontal.

2. The distance between the orifice and any valves or fittings in the approach pipe must be greater than 8 pipe diameters.

3. The 1/8" pressure opening should be two feet back of, and in the centerline plane of, the orifice. It should be fitted with a standard nipple, at right angles to the approach pipe and flush on the inside. A rubber tube and a piece of glass pipe complete the arrangement for easy reading of the head on the orifice. The rubber tube may be used as shown, or may be connected directly to the horizontal nipple.

4. The orifice must be a true bore, smooth, diameter accurate to ± 0.001", inside wall flush and smooth, edges square and sharp and 1/8" thick, excess material chamfered at an angle of 45 deg. on outside as illustrated in Fig. 70.

Capacities may be read directly in GPM from Fig. 71.

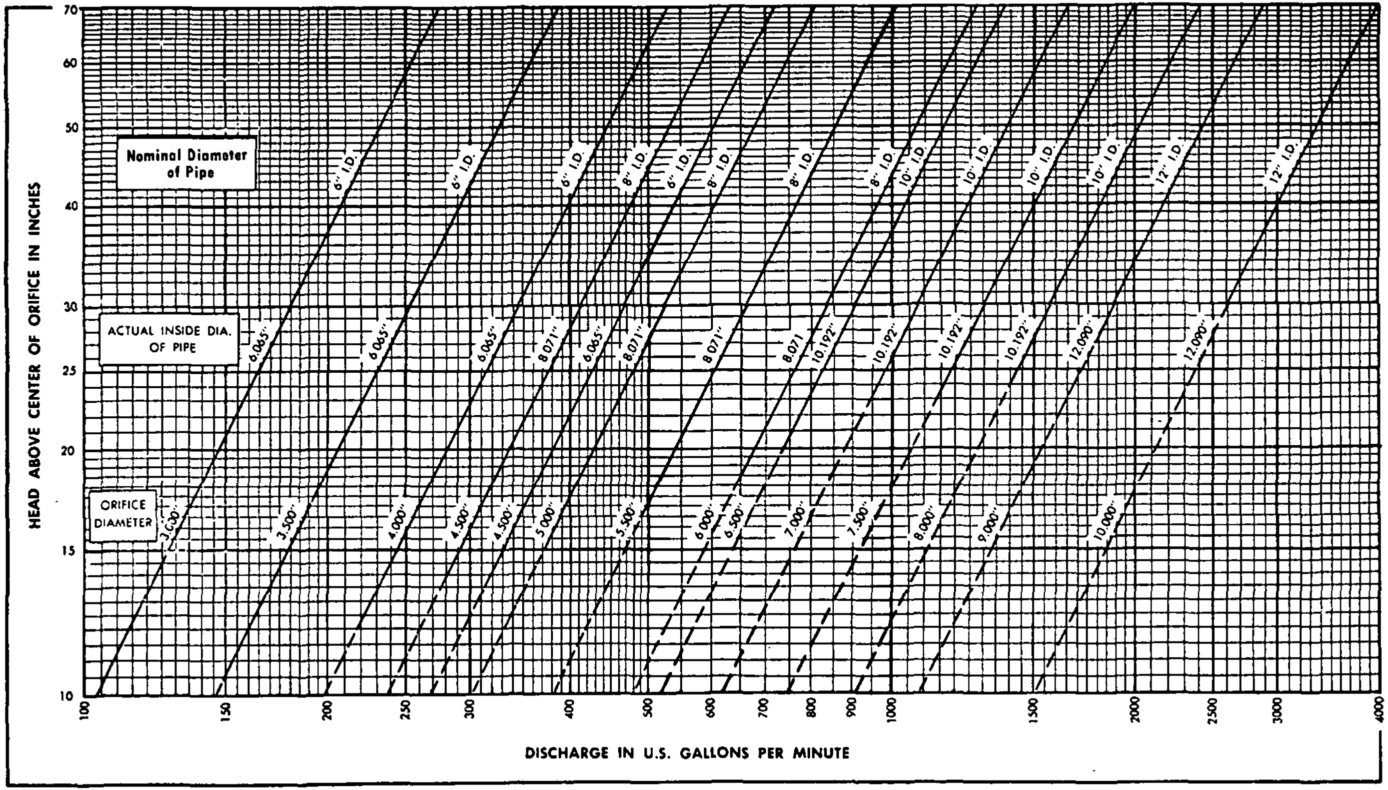



FIG. 71. Pipe cap orifice chart.

## WEIRS

There are a number of forms of the weir in use as capacity measuring devices, but this discussion concerns itself primarily with the rectangular suppressed weir, the only form approved in the Standards of the Hydraulic Institute.

This is the rectangular sharp crested weir with smooth vertical crest wall, complete crest contraction, free overfall and with end contraction suppressed. It is often called, simply, a full width rectangular weir. This weir is of the specific proportions of weirs that have been calibrated by precision methods and proper coefficient determined and these data are applicable to this specific form only.

When a weir is constructed, certain dimensional relationships should be incorporated to insure accuracy of flow measurement. See Fig. 72.

When using an existing weir, a tolerance of plus or minus two percent may be expected when the Head, $h$, is accurately read and the following flow limitations obtain:

a. Head, $h$, not less than 0.2 feet.

b. Head, $h$, not greater than ½ height of weir crest, (½ of $Z$).

c. Head, $h$, not greater than ½ length of weir crest, (½ of $B$).

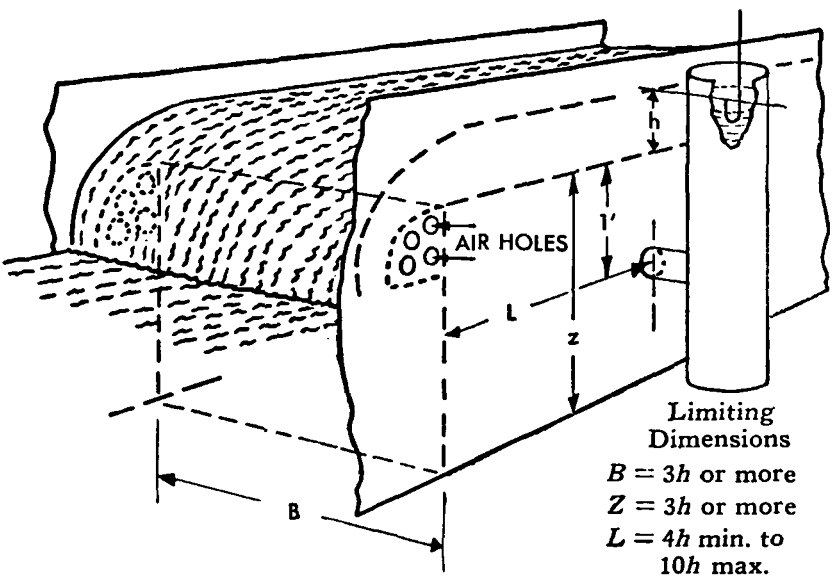



FIG. 72. Rectangular suppressed weir.

The weir plate shall be constructed of non-corrosive metal about ¼″ thick, sharp right angle corner on upstream edge, actual crest width $\frac{1}{8}''$, with plate beveled at 45° angle from crest on the downstream face. The crest shall be smooth and free from rust, grease, algae, etc., during testing. The plate must be mounted in a vertical plane at right angles to the line of flow, with the crest absolutely level. The channel walls shall be smooth and parallel and shall extend downstream beyond the overfall, and above the crest level. Complete aeration of the nappe is required, and observations before and during test are necessary to provide evidence of complete freedom from adhering nappe, disturbed or turbulent flow, or surging. The weir shall be located sufficiently downstream from the source to insure that smooth flow, free from eddies, surface disturbance, or excessive air in suspension, is maintained at all flow rates. Since slight deviation from proper conditions can cause appreciable variation in the indicated quantity, proper baffling is very important in order to give approximately uniform velocity across the approach channel. This channel must be of uniform cross section, straight and free from stilling racks or other obstructions for a length equal to at least fifteen times the maximum head on the weir. If out of doors, protection should be provided against surface disturbance from wind.

The head on the weir shall be measured by hook gages, securely placed in stilling boxes located at the side of the approach channel, upstream from the crest a distance, $L$, of between four and ten times the maximum head, $h$, on the weir. The stilling boxes shall communicate with the channel by a pipe about $1\frac{1}{2}''$ in diameter, flush with the side of the channel and approximately one foot below the level of the crest. If located out of doors, protection against wind pressure and entrance of foreign material shall be provided.

Table 66 gives the flow over this type of weir, based on the Francis formula, $Q = 3.33Bh^{3/2}$, where $Q =$ flow in cu. ft./second, $B =$ crest length in feet, and $h =$ head on the weir in feet. While this is an approximation, it is a close one, and is accurate enough for many field tests.

However, where accurate field testing is desired and precise instruments are available to measure the head, $h$, the Rehbock formula should be used as follows:

$$Q = \left(3.228 + 0.435\frac{h_e}{z}\right)Bh_e^{3/2}$$

where:

$Q =$ quantity in Cu. ft./sec.

$h_e = h + 0.0036$

$h =$ observed head on crest, in feet, without correction for velocity of approach.

$z =$ height of weir crest above bottom of channel of approach, in feet.

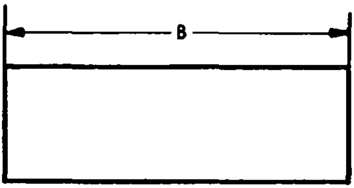
$B =$ length of weir crest, in feet.

TABLE 66. FLOW OVER RECTANGULAR SUPPRESSED WEIR IN CU. FT. PER SECOND. $Q = 3.33Bh^{3/2}$

| | Crest Length in Feet | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Head Ft. | 1.0 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 |
| 0.1 | 0.11 | 0.16 | 0.21 | 0.32 | 0.42 | 0.53 | 0.63 | 0.74 | 0.84 |
| 0.2 | 0.30 | 0.45 | 0.60 | 0.89 | 1.19 | 1.49 | 1.79 | 2.08 | 2.38 |
| 0.3 | 0.55 | 0.82 | 1.09 | 1.64 | 2.19 | 2.74 | 3.28 | 3.83 | 4.38 |
| 0.4 | 0.84 | 1.26 | 1.68 | 2.53 | 3.37 | 4.21 | 5.05 | 5.90 | 6.74 |
| 0.5 | 1.18 | 1.77 | 2.35 | 3.53 | 4.71 | 5.89 | 7.06 | 8.24 | 9.42 |
| 0.6 | 1.55 | 2.32 | 3.10 | 4.64 | 6.19 | 7.74 | 9.29 | 10.83 | 12.38 |
| 0.7 | 1.95 | 2.93 | 3.90 | 5.85 | 7.80 | 9.75 | 11.70 | 13.65 | 15.60 |
| 0.8 | 2.38 | 3.57 | 4.77 | 7.15 | 9.53 | 11.91 | 14.30 | 16.68 | 19.06 |
| 0.9 | 2.84 | 4.26 | 5.69 | 8.53 | 11.37 | 14.22 | 17.06 | 19.90 | 22.75 |
| 1.0 | 3.33 | 5.00 | 6.66 | 9.99 | 13.32 | 16.65 | 19.98 | 23.31 | 26.64 |
| 1.1 | 3.84 | 5.76 | 7.68 | 11.53 | 15.37 | 19.21 | 23.05 | 26.89 | 30.73 |
| 1.2 | 4.38 | 6.57 | 8.75 | 13.13 | 17.51 | 21.89 | 26.26 | 30.64 | 35.02 |
| 1.3 | 4.94 | 7.40 | 9.87 | 14.81 | 19.74 | 24.68 | 29.61 | 34.55 | 39.49 |
| 1.4 | 5.52 | 8.27 | 11.03 | 16.55 | 22.06 | 27.58 | 33.10 | 38.61 | 44.13 |
| 1.5 | 6.12 | 9.18 | 12.24 | 18.35 | 24.47 | 30.59 | 36.71 | 42.82 | 48.94 |
| 1.6 | 6.74 | 10.11 | 13.48 | 20.22 | 26.96 | 33.70 | 40.44 | 47.18 | 53.92 |
| 1.7 | 7.38 | 11.08 | 14.76 | 22.14 | 29.52 | 36.91 | 44.29 | 51.67 | 59.05 |
| 1.8 | 8.04 | 12.06 | 16.08 | 24.13 | 32.17 | 40.21 | 48.25 | 56.29 | 64.33 |
| 1.9 | 8.72 | 13.08 | 17.44 | 26.16 | 34.89 | 43.61 | 52.33 | 61.05 | 69.77 |
| 2.0 | 9.42 | 14.13 | 18.84 | 28.26 | 37.68 | 47.10 | 56.51 | 65.93 | 75.35 |
| 2.1 | 10.13 | 15.20 | 20.27 | 30.40 | 40.54 | 50.67 | 60.80 | 70.94 | 81.07 |
| 2.2 | 10.87 | 16.30 | 21.73 | 32.60 | 43.46 | 54.33 | 65.20 | 76.06 | 86.93 |
| 2.3 | 11.62 | 17.42 | 23.23 | 34.85 | 46.46 | 58.08 | 69.69 | 81.31 | 92.92 |
| 2.4 | 12.38 | 18.57 | 24.76 | 37.14 | 49.52 | 61.91 | 74.29 | 86.67 | 99.05 |
| 2.5 | 13.16 | 19.74 | 26.33 | 39.49 | 52.65 | 65.82 | 78.98 | 92.14 | 105.30 |
| 2.6 | 13.96 | 20.94 | 27.92 | 41.88 | 55.84 | 69.81 | 83.77 | 97.73 | 111.69 |
| 2.7 | 14.77 | 22.16 | 29.55 | 44.32 | 59.10 | 73.87 | 88.64 | 103.42 | 118.19 |
| 2.8 | 15.60 | 23.40 | 31.20 | 46.81 | 62.41 | 78.01 | 93.61 | 109.21 | 124.82 |
| 2.9 | 16.45 | 24.67 | 32.89 | 49.34 | 65.78 | 82.23 | 98.67 | 115.12 | 131.56 |
| 3.0 | 17.30 | 25.95 | 34.61 | 51.91 | 69.21 | 86.52 | 103.82 | 121.12 | 138.42 |

Following are sketches of various weir types, with formulas for calculation of flow over each:

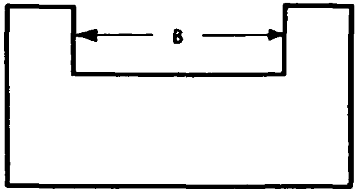
Rectangular Suppressed




Francis Formula, $Q = 3.33Bh^{3/2}$ or the more accurate Rehbock Formula,

$$Q = \left(3.228 + 0.435\frac{h_e}{z}\right) Bh_e^{3/2}$$

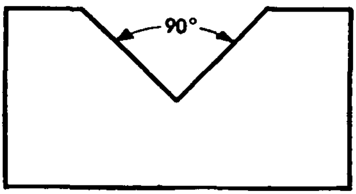
Rectangular Contracted




Francis Formula,

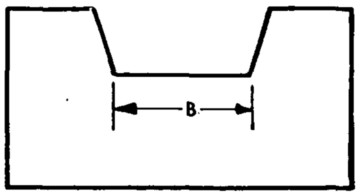
$$Q = 3.33h^{3/2}\,(B - 0.2h)$$

V-Notch




Thompson Formula,
$Q = 2.54h^{5/2}$

Cipolletti




Sides Slope 1 :4

Cipolletti Formula,
$Q = 3.367Bh^{3/2}$

FIG. 73. Various weir formula.

## PITOT TUBE

The Pitot Tube is a device used for measuring the velocity of flowing fluids. Many forms of Pitot Tube are used but the principle of all are the same. Two pressure readings are taken on the pipe interior—one receiving the full impact of the flowing stream reads a pressure equal to the static head plus the velocity head—the other reads the static head only. The difference between the two readings, therefore, is the velocity head. The velocity can be calculated by the equation $V = C\sqrt{2gh}$ where $C$ is a cofficient for the meter determined by calibration. The quantity of fluid flowing equals the pipe area × average velocity.

Since the velocity varies from a minimum at a point adjacent to the pipe wall to a maximum at the pipe center a traverse of the pipe must be made to determine the average velocity. This is not easily done. The use of a commercially manufactured Pitot Tube gives results accurate to approximately 97% when used by a carefully trained operator.

## TESTING FIRE PUMPS

A specialized type of Pitot Tube is used when testing Fire Pumps.

It is an instrument used manually by holding the tip of the Pitot Tube in the stream of water issuing from the hose nozzle. A gauge indicates the velocity pressure in Psi. Fire stream formula and tables have been prepared for use with these Pitot Tube measurements. The following data and tables are published by permission of Associated Factory Mutual Fire Insurance Companies.

## TABLE 67. NOZZLE DISCHARGE TABLES†

The following formulas may be used to determine the volume of discharge, hydrant pressure, or nozzle pressure for nozzles of varying size and with different lengths of 2½-inch cotton rubber-lined hose when one factor is unknown.

The use of these formulas will give the same result as Freeman's Fire Stream Tables, since the constants indicated have been derived from the tables. The detailed nozzle discharge tables are limited to the 1⅛- and 1¾-inch smooth nozzles as these are the most common sizes encountered in private fire protection. The discharge from nozzles of other sizes can be calculated from the following formulas and tables.

$$G = K\sqrt{p} \qquad P = p(AB+1) \qquad p = \frac{P}{AB+1}$$

$G$ = Discharge, gal. per min.
$p$ = Nozzle (pitot) pressure, lb. per sq. in.
$P$ = Hydrant pressure, lb. per sq. in.
$K$ = Constant for discharge
$A$ = Constant for size of nozzle
$B$ = Constant for length of hose

| Nozzle Size (inches) | K | A |
|---|---|---|
| 1 | 29.1 | .024 |
| 1-1/16 | 32.8 | .031 |
| 1-1/8 | 36.8 | .039 |
| 1-3/16 | 41.0 | .048 |
| 1-1/4 | 45.4 | .059 |
| 1-5/16 | 50.1 | .072 |
| 1-3/8 | 54.9 | .087 |
| 1-7/16 | 60.0 | .104 |
| 1-1/2 | 65.4 | .123 |
| 1-9/16 | 70.9 | .145 |
| 1-5/8 | 76.8 | .170 |
| 1-11/16 | 82.8 | .197 |
| 1-3/4 | 89.0 | .228 |
| 1-13/16 | 95.5 | .262 |
| 1-7/8 | 102.0 | .300 |
| 1-15/16 | 109.0 | .343 |
| 2 | 116.0 | .389 |

| Length of 2½-in. C.R.L. Hose (feet) | B |
|---|---|
| 50 | 4.9 |
| 100 | 8.8 |
| 150 | 12.8 |
| 200 | 16.7 |
| 250 | 20.6 |
| 300 | 24.5 |
| 350 | 28.4 |
| 400 | 32.4 |
| 450 | 35.3 |
| 500 | 40.2 |
| 550 | 44.1 |
| 600 | 48.1 |
| 650 | 52.1 |
| 700 | 55.9 |
| 750 | 58.8 |
| 800 | 63.8 |
| 850 | 67.7 |
| 900 | 71.6 |
| 950 | 75.5 |
| 1000 | 79.4 |

†*Courtesy of Associated Factory Mutual Fire Insurance Companies.* *See page 6.*

## TABLE 67 (Continued) NOZZLE DISCHARGE TABLES

### Showing Pressures Required at Hydrant or Fire Department Pumper, while Stream is Flowing, to Maintain Nozzle Pressure Indicated in First Column Through Various Lengths of Best Quality Cotton Rubber-Lined Hose

### 1⅛-INCH SMOOTH NOZZLE

| Nozzle Pressure psi. | Discharge (G.P.M.) | Hydrant Pressure, psi. Single 2½-Inch Lines (Feet) 50 | 100 | 150 | 200 |
|---|---|---|---|---|---|
| 2 | 52 | 2 | 3 | 3 | 3 |
| 4 | 74 | 5 | 6 | 6 | 7 |
| 6 | 90 | 7 | 8 | 9 | 10 |
| 8 | 104 | 9 | 11 | 12 | 13 |
| 10 | 116 | 12 | 13 | 14 | 16 |
| 12 | 127 | 14 | 16 | 17 | 19 |
| 14 | 137 | 17 | 18 | 20 | 23 |
| 16 | 146 | 19 | 21 | 23 | 26 |
| 18 | 155 | 21 | 24 | 26 | 29 |
| 20 | 164 | 24 | 27 | 29 | 33 |
| 22 | 172 | 26 | 29 | 32 | 36 |
| 24 | 180 | 29 | 32 | 35 | 39 |
| 26 | 187 | 31 | 35 | 38 | 43 |
| 28 | 194 | 33 | 38 | 41 | 46 |
| 30 | 201 | 36 | 40 | 44 | 50 |
| 32 | 208 | 38 | 43 | 47 | 53 |
| 34 | 213 | 40 | 45 | 50 | 56 |
| 36 | 220 | 42 | 48 | 53 | 59 |
| 38 | 226 | 45 | 51 | 56 | 63 |
| 40 | 232 | 47 | 54 | 59 | 66 |
| 42 | 238 | 50 | 56 | 62 | 69 |
| 44 | 243 | 52 | 59 | 65 | 73 |
| 46 | 248 | 54 | 61 | 68 | 76 |
| 48 | 254 | 57 | 64 | 71 | 80 |
| 50 | 259 | 59 | 66 | 74 | 83 |
| 52 | 264 | 62 | 69 | 77 | 86 |
| 54 | 269 | 64 | 72 | 80 | 89 |
| 56 | 274 | 66 | 75 | 83 | 92 |
| 58 | 279 | 68 | 78 | 86 | 95 |
| 60 | 283 | 71 | 80 | 89 | 98 |
| 62 | 288 | 73 | 83 | 92 | 101 |
| 64 | 293 | 76 | 86 | 95 | 104 |
| 66 | 298 | 78 | 89 | 98 | 107 |
| 68 | 302 | 81 | 91 | 101 | 110 |
| 70 | 307 | 83 | 94 | 104 | 113 |
| 72 | 311 | 85 | 97 | 107 | 116 |
| 74 | 315 | 88 | 99 | 110 | 120 |
| 76 | 319 | 90 | 102 | 113 | 123 |
| 78 | 323 | 92 | 105 | 116 | 126 |
| 80 | 328 | 95 | 108 | 119 | 130 |
| 82 | 332 | 97 | 111 | 122 | 133 |
| 84 | 336 | 100 | 113 | 125 | 136 |
| 86 | 340 | 103 | 116 | 128 | 140 |
| 88 | 343 | 105 | 118 | 131 | 143 |
| 90 | 347 | 107 | 121 | 133 | 146 |
| 92 | 351 | 110 | 124 | 136 | 150 |
| 94 | 355 | 113 | 127 | 139 | 153 |
| 96 | 359 | 115 | 129 | 142 | 156 |
| 98 | 363 | 117 | 132 | 145 | 160 |
| 100 | 367 | 119 | 135 | 148 | 164 |

Nozzle Pressure = Pitot Tube Pressure. Discharge Coef. = .97

XI

# TABLE 67. (Cont.) NOZZLE DISCHARGE TABLES.

## Showing Pressures Required at Hydrant or Fire Department Pumper, while Stream is Flowing, to Maintain Nozzle Pressure Indicated in First Column Through Various Lengths of Best Quality Cotton Rubber-Lined Hose

## 1¾-INCH SMOOTH NOZZLE

| Nozzle Pressure psi. | Discharge (G.P.M.) | Hydrant Pressure, psi. Single 2½-Inch Lines (Feet) 50 | 100 | 150 | 200 |
|---|---|---|---|---|---|
| 2 | 125 | 4 | 6 | 8 | 9 |
| 4 | 178 | 8 | 12 | 16 | 19 |
| 6 | 217 | 13 | 18 | 23 | 29 |
| 8 | 251 | 17 | 24 | 31 | 39 |
| 10 | 280 | 21 | 30 | 38 | 48 |
| 12 | 307 | 25 | 36 | 46 | 58 |
| 14 | 332 | 29 | 42 | 54 | 68 |
| 16 | 355 | 34 | 48 | 62 | 77 |
| 18 | 376 | 38 | 54 | 69 | 87 |
| 20 | 397 | 42 | 60 | 77 | 96 |
| 22 | 416 | 46 | 66 | 85 | 106 |
| 24 | 435 | 50 | 72 | 93 | 116 |
| 26 | 452 | 54 | 78 | 101 | 126 |
| 28 | 469 | 58 | 84 | 112 | 135 |
| 30 | 486 | 63 | 90 | 120 | 145 |
| 32 | 502 | 67 | 96 | 128 | 155 |
| 34 | 517 | 72 | 102 | 135 | 165 |
| 36 | 532 | 76 | 108 | 143 | 175 |
| 38 | 547 | 80 | 114 | 150 | ...... |
| 40 | 561 | 85 | 120 | 158 | ...... |
| 42 | 574 | 89 | 126 | 165 | ...... |
| 44 | 588 | 93 | 132 | 173 | ...... |
| 46 | 601 | 97 | 138 | 181 | ...... |
| 48 | 614 | 101 | 144 | ...... | ...... |
| 50 | 627 | 106 | 149 | ...... | ...... |
| 52 | 639 | 110 | 154 | ...... | ...... |
| 54 | 651 | 115 | 160 | ...... | ...... |
| 56 | 663 | 119 | 166 | ...... | ...... |
| 58 | 675 | 123 | 172 | ...... | ...... |
| 60 | 687 | 127 | ...... | ...... | ...... |
| 62 | 698 | 131 | ...... | ...... | ...... |
| 64 | 709 | 135 | ...... | ...... | ...... |
| 66 | 720 | 140 | ...... | ...... | ...... |
| 68 | 731 | 145 | ...... | ...... | ...... |
| 70 | 742 | 149 | ...... | ...... | ...... |
| 72 | 753 | 154 | ...... | ...... | ...... |
| 74 | 763 | 158 | ...... | ...... | ...... |
| 76 | 773 | 163 | ...... | ...... | ...... |
| 78 | 783 | 167 | ...... | ...... | ...... |
| 80 | 793 | 172 | ...... | ...... | ...... |
| 82 | 803 | 177 | ...... | ...... | ...... |
| 84 | 813 | ...... | ...... | ...... | ...... |
| 86 | 823 | ...... | ...... | ...... | ...... |
| 88 | 832 | ...... | ...... | ...... | ...... |
| 90 | 841 | ...... | ...... | ...... | ...... |
| 92 | 850 | ...... | ...... | ...... | ...... |
| 94 | 859 | ...... | ...... | ...... | ...... |
| 96 | 868 | ...... | ...... | ...... | ...... |
| 98 | 877 | ...... | ...... | ...... | ...... |
| 100 | 887 | ...... | ...... | ...... | ...... |

Nozzle Pressure = Pilot Tube Pressure. Discharge Coef. = .97

## THE PARSHALL MEASURING FLUME

The Parshall measuring flume, as shown in Fig. 74, is an excellent device for the measurement of irrigation water since it is relatively simple to build and operate. It will not easily get out of order, and is not likely to be affected by silt deposit because of the increased velocity of flow in the approach channel and the throat. As long as the depth of water at the lower gage, $H_b$, is less than 0.7 of the depth at the upper gage, $H_a$, for flumes with throat widths of one foot or more, or 0.6 for the smaller flumes, the flow can be determined from a single gage reading, $H_a$.

Discharge under these conditions is called free flow and the measurement is not affected by conditions in the channel downstream. This is the only condition for which information is given in the table in this Handbook.

When the depth at the lower gage, $H_b$, is more than 70% of the depth at the upper gage, the flow is considered to be submerged, and determination of flow requires readings at both gages plus application of necessary correction factors.

Information on submerged flow, plus complete formulae for both types of flow, may be found in Bulletin 423, Colorado State College, Fort Collins, Colorado.

Dimensions for building the Parshall flume, plus information on discharge capacities for the free flow condition, are included herewith.

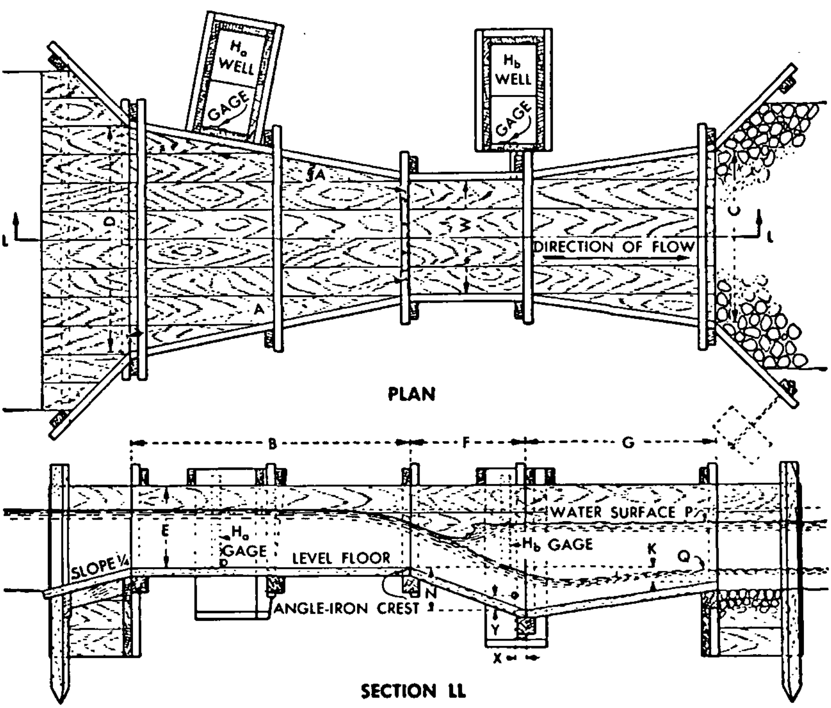



FIG. 74. Plan and elevation of the Parshall measuring flume.†

*From U.S.D.A. Farmers' Bulletin No. 1683.*

## TABLE 68. DIMENSIONS AND CAPACITIES—PARSHALL FLUMES.

### SEE FIGURE 74.

| Throat Width | A | ⅔ A | B | C | D | E | F | G | K | N | X | Y | Free Flow Cu.ft./Sec. Max. | Min. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0'3" | 1'6⅜" | 1'0¼" | 1'6" | 0'7" | 0'10 3/16" | 1'4" | ½' | 1' | 1" | 2¼" | 1" | 1½" | 1.1 | 0.03 |
| 0'6" | 2'0 7/16" | 1'4 5/16" | 2'0" | 1'3⅝" | 1'3⅝" | 2'0" | 1' | 2' | 3" | 4½" | 2" | 3" | 3.9 | 0.05 |
| 0'9" | 2'10⅝" | 1'11⅛" | 2'10" | 1'3" | 1'10⅝" | 2'6" | 1' | 1½' | 3" | 4½" | 2" | 3" | 8.8 | 0.09 |
| 1'0" | 4'6" | 3'0" | 4'4⅞" | 2'0" | 2'9¼" | 3'0" | 2' | 3' | 3" | 9" | 2" | 3" | 16.1 | 0.35 |
| 1'6" | 4'9" | 3'2" | 4'7⅞" | 2'6" | 3'4⅜" | 3'0" | 2' | 3' | 3" | 9" | 2" | 3" | 24.6 | 0.51 |
| 2'0" | 5'0" | 3'4" | 4'10⅞" | 3'0" | 3'11½" | 3'0" | 2' | 3' | 3" | 9" | 2" | 3" | 33.1 | 0.66 |
| 3'0" | 5'6" | 3'8" | 5'4¾" | 4'0" | 5'1⅞" | 3'0" | 2' | 3' | 3" | 9" | 2" | 3" | 50.4 | 0.97 |
| 4'0" | 6'0" | 4'0" | 5'10⅝" | 5'0" | 6'4¼" | 3'0" | 2' | 3' | 3" | 9" | 2" | 3" | 67.9 | 1.26 |
| 5'0" | 6'6" | 4'4" | 6'4½" | 6'0" | 7'6⅝" | 3'0" | 2' | 3' | 3" | 9" | 2" | 3" | 85.6 | 2.22 |
| 6'0" | 7'0" | 4'8" | 6'10⅜" | 7'0" | 8'9" | 3'0" | 2' | 3' | 3" | 9" | 2" | 3" | 103.5 | 2.63 |
| 7'0" | 7'6" | 5'0" | 7'4¼" | 8'0" | 9'11⅜" | 3'0" | 2' | 3' | 3" | 9" | 2" | 3" | 121.4 | 4.08 |
| 8'0" | 8'0" | 5'4" | 7'10⅛" | 9'0" | 11'1¾" | 3'0" | 2' | 3' | 3" | 9" | 2" | 3" | 139.5 | 4.62 |

## TABLE 69. FREE FLOW DISCHARGE—PARSHALL FLUME—CU. FT./SEC.

$$Q = 4\,W\,H_a^{1.522W^{0.026}}$$

| Head, $H_a$ Feet | Size of Flume, *W*. 3″ | 6″ | 9″ | 1′0″ | 1′6″ | 2′0″ | 3′0″ | 4′0″ | 5′0″ | 6′0″ | 7′0″ | 8′0″ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | .028 | .05 | .09 | .... | .... | .... | ...... | ...... | ...... | ...... | ...... | ...... |
| 0.2 | .082 | .16 | .26 | .35 | .51 | .66 | .97 | 1.26 | ...... | ...... | ...... | ...... |
| 0.3 | .154 | .31 | .49 | .64 | .94 | 1.24 | 1.82 | 2.39 | 2.96 | 3.52 | 4.08 | 4.62 |
| 0.4 | .241 | .48 | .76 | .99 | 1.47 | 1.93 | 2.86 | 3.77 | 4.68 | 5.57 | 6.46 | 7.34 |
| 0.5 | .339 | .69 | 1.06 | 1.39 | 2.06 | 2.73 | 4.05 | 5.36 | 6.66 | 7.94 | 9.23 | 10.51 |
| 0.6 | .450 | .92 | 1.40 | 1.84 | 2.73 | 3.62 | 5.39 | 7.15 | 8.89 | 10.63 | 12.36 | 14.08 |
| 0.7 | .571 | 1.17 | 1.78 | 2.33 | 3.46 | 4.60 | 6.86 | 9.11 | 11.36 | 13.59 | 15.82 | 18.04 |
| 0.8 | .702 | 1.45 | 2.18 | 2.85 | 4.26 | 5.66 | 8.46 | 11.25 | 14.04 | 16.81 | 19.59 | 22.36 |
| 0.9 | .843 | 1.74 | 2.61 | 3.41 | 5.10 | 6.80 | 10.17 | 13.55 | 16.92 | 20.29 | 23.66 | 27.02 |
| 1.0 | .992 | 2.06 | 3.07 | 4.00 | 6.00 | 8.00 | 12.00 | 16.00 | 20.00 | 24.00 | 28.00 | 32.00 |
| 1.1 | ...... | 2.40 | 3.55 | 4.62 | 6.95 | 9.27 | 13.93 | 18.60 | 23.26 | 27.94 | 32.62 | 37.30 |
| 1.2 | ...... | 2.75 | 4.06 | 5.28 | 7.94 | 10.61 | 15.96 | 21.33 | 26.71 | 32.10 | 37.50 | 42.89 |
| 1.3 | ...... | ...... | 4.59 | 5.96 | 8.99 | 12.01 | 18.10 | 24.21 | 30.33 | 36.47 | 42.62 | 48.78 |
| 1.4 | ...... | ...... | 5.14 | 6.68 | 10.10 | 13.48 | 20.32 | 27.21 | 34.11 | 41.05 | 47.99 | 54.95 |
| 1.5 | ...... | ...... | ...... | 7.41 | 11.20 | 15.00 | 22.64 | 30.34 | 38.06 | 45.82 | 53.59 | 61.40 |
| 1.6 | ...... | ...... | ...... | 8.18 | 12.40 | 16.58 | 25.05 | 33.59 | 42.17 | 50.79 | 59.42 | 68.10 |
| 1.7 | ...... | ...... | ...... | 8.97 | 13.60 | 18.21 | 27.55 | 36.96 | 46.43 | 55.95 | 65.48 | 75.08 |
| 1.8 | ...... | ...... | ...... | 9.79 | 14.80 | 19.90 | 30.13 | 40.45 | 50.83 | 61.29 | 71.75 | 82.29 |
| 1.9 | ...... | ...... | ...... | 10.62 | 16.10 | 21.63 | 32.79 | 44.05 | 55.39 | 66.81 | 78.24 | 89.76 |
| 2.0 | ...... | ...... | ...... | 11.49 | 17.40 | 23.43 | 35.53 | 47.77 | 60.08 | 72.50 | 84.94 | 97.48 |
| 2.1 | ...... | ...... | ...... | 12.37 | 18.80 | 25.27 | 38.35 | 51.59 | 64.92 | 78.37 | 91.84 | 105.40 |
| 2.2 | ...... | ...... | ...... | 13.28 | 20.20 | 27.15 | 41.25 | 55.52 | 69.90 | 84.41 | 98.94 | 113.60 |
| 2.3 | ...... | ...... | ...... | 14.21 | 21.60 | 29.09 | 44.22 | 59.56 | 75.01 | 90.61 | 106.20 | 122.00 |
| 2.4 | ...... | ...... | ...... | 15.16 | 23.00 | 31.09 | 47.27 | 63.69 | 80.25 | 96.97 | 113.70 | 130.70 |
| 2.5 | ...... | ...... | ...... | 16.13 | 24.60 | 33.11 | 50.39 | 67.93 | 85.62 | 103.50 | 121.40 | 139.50 |

NOTE: Approximate values of flow for heads other than those shown may be found by direct interpolation in the table.

## OTHER METHODS OF APPROXIMATING WATER FLOW

Often an approximation of water flow is required when it is not practical to use weirs, orifices, nozzles or other means of determination. This can be done by taking the coordinates of a point in the stream flow as indicated in Fig. 75. The accuracy of this method will vary from 90-100%. The pipe must be flowing full.

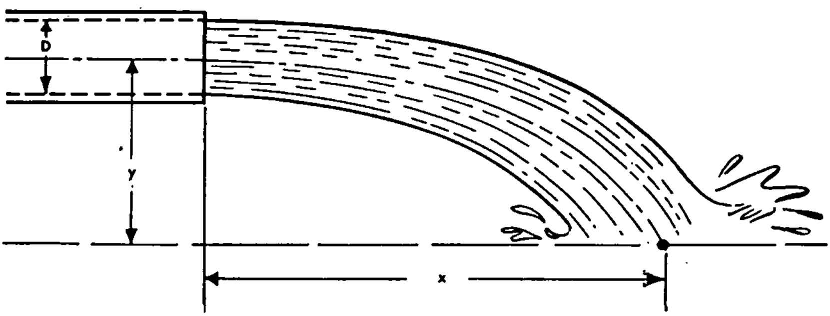



FIG. 75. Approximating flow from horizontal pipe.

$$\text{Capacity, Gpm} = \frac{2.45\, D^2 x}{\sqrt{\dfrac{2y}{32.16}}}$$

Where $D$ = Pipe diameter, in.
$x$ = Horizontal distance, ft.
$y$ = Vertical distance, ft.

This can be further simplified by measuring to the top of the flowing stream and always measuring so that $y$ will equal 12 inches and measuring the horizontal distance "$X$" in inches as illustrated in Fig. 76.

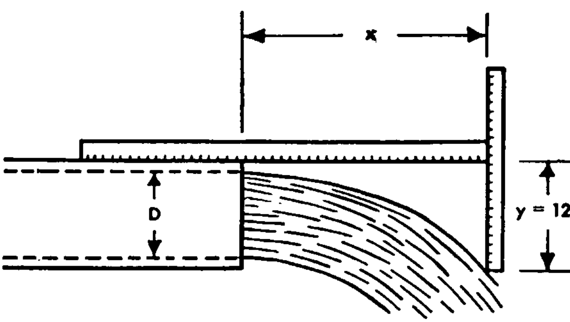


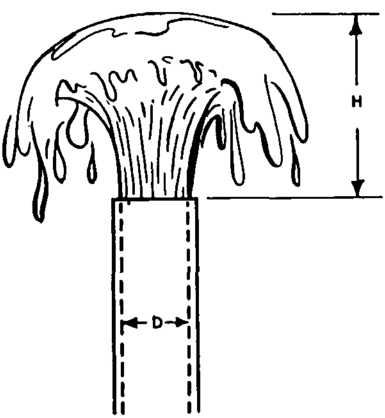

FIG. 76. Approximating flow from horizontal pipe.

Capacity, Gpm $= 0.818\, D^2X$

## TABLE 70. APPROXIMATE CAPACITY, GPM, FOR FULL FLOWING HORIZONTAL PIPES ILLUSTRATED IN FIG. 76.

| Std. Wt. Steel Pipe, Inside Dia., In. | | Distance x, in., when y = 12" | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nominal | Actual | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 |
| 2 | 2.067 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 91 | 98 | 105 | 112 |
| 2½ | 2.469 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 |
| 3 | 3.068 | 93 | 108 | 123 | 139 | 154 | 169 | 185 | 200 | 216 | 231 | 246 |
| 4 | 4.026 | 159 | 186 | 212 | 239 | 266 | 292 | 318 | 345 | 372 | 398 | 425 |
| 5 | 5.047 | 250 | 292 | 334 | 376 | 417 | 459 | 501 | 543 | 585 | 627 | 668 |
| 6 | 6.065 | 362 | 422 | 482 | 542 | 602 | 662 | 722 | 782 | 842 | 902 | 962 |
| 8 | 7.981 | 627 | 732 | 837 | 942 | 1047 | 1150 | 1255 | 1360 | 1465 | 1570 | 1675 |
| 10 | 10.020 | 980 | 1145 | 1310 | 1475 | 1635 | 1800 | 1965 | 2130 | 2290 | 2455 | 2620 |
| 12 | 12.000 | 1415 | 1650 | 1890 | 2125 | 2360 | 2595 | 2830 | 3065 | 3300 | 3540 | 3775 |

In like manner flow can be estimated from a vertical pipe as shown in Fig. 77 by measuring the vertical height $H$.




Capacity, Gpm. $= 5.68\ KD^2\ H^{1/2}$

$D$ = I.D. of Pipe, In.

$H$ = Vertical Height of water jets, in.

$K$ = a constant, varying from .87 to .97 for pipes 2 to 6 in. dia. and $H$ = 6 to 24 in.

FIG. 77. Approximating flow from vertical pipe.

## TABLE 71. FLOW FROM VERTICAL PIPES, GPM.

| Nominal | Vertical Height, $H$, of Water Jet, in. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I.D. Pipe, in. | 3 | 3.5 | 4 | 4.5 | 5 | 5.5 | 6 | 7 | 8 | 10 | 12 |
| 2 | 38 | 41 | 44 | 47 | 50 | 53 | 56 | 61 | 65 | 74 | 82 |
| 3 | 81 | 89 | 96 | 103 | 109 | 114 | 120 | 132 | 141 | 160 | 177 |
| 4 | 137 | 151 | 163 | 174 | 185 | 195 | 205 | 222 | 240 | 269 | 299 |
| 6 | 318 | 349 | 378 | 405 | 430 | 455 | 480 | 520 | 560 | 635 | 700 |
| 8 | 567 | 623 | 684 | 730 | 776 | 821 | 868 | 945 | 1020 | 1150 | 1270 |
| 10 | 950 | 1055 | 1115 | 1200 | 1280 | 1350 | 1415 | 1530 | 1640 | 1840 | 2010 |

# SECTION XII. FAIRBANKS MORSE PUMPS

## CONTENTS

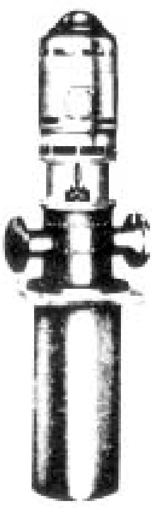


XII

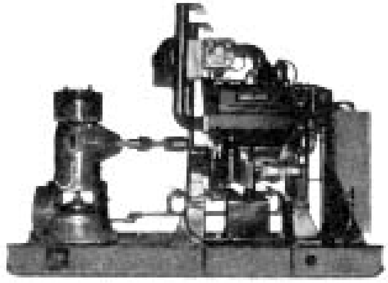
# TURBINE AND PROPELLER PUMPS

6920, 6970 & 7000
OIL AND WATER
LUBRICATED DEEP WELL &
SUMP TURBINE PUMPS

8211 & 8312
PROPELLER PUMPS



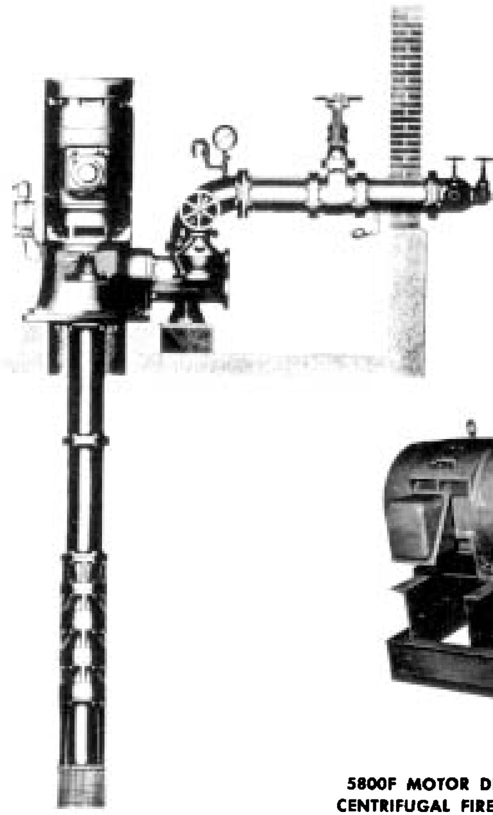
6930
POT PUMP

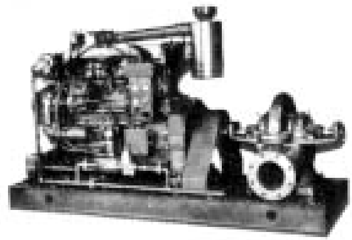


6900F & 7000F
SKID MOUNTED UNIT
FOR OFFSHORE
FIRE PROTECTION

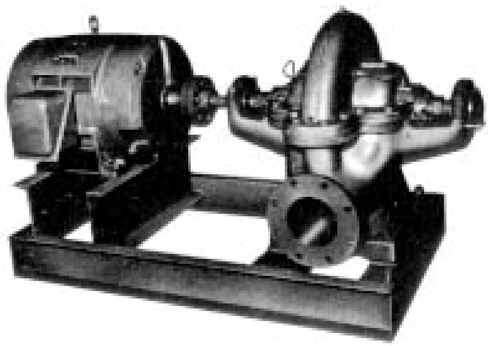
# FIRE PUMPS

6920F & 7000F
TURBINE FIRE PUMP





5800F
ENGINE DRIVEN
CENTRIFUGAL FIRE PUMP



5800F MOTOR DRIVEN
CENTRIFUGAL FIRE PUMP

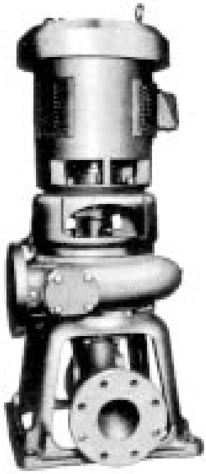
5876F
HI-SPEED CENTRIFUGAL FIRE PUMP

## *NON-CLOG PUMPS*

### *5400 with Bladed Impeller*
### *5400 K with Bladeless Impeller*

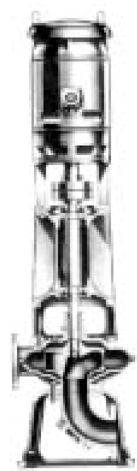
**5420P**
**HORIZONTAL SELF PRIMER PUMP**

**5410 & 5410K**
**VERTICAL PUMP**



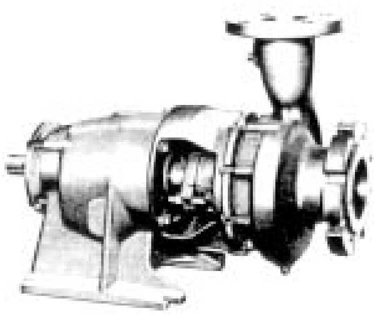
**5430**
**VERTICAL BILTOGETHER PUMP**

**5430M**
**PULL-UP**
**SUBMERSIBLE PUMP**



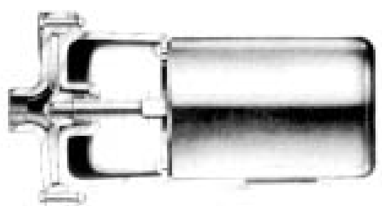
**5440**
**NON CLOG PUMP**

## *END SUCTION AND SUBMERSIBLE PUMPS*



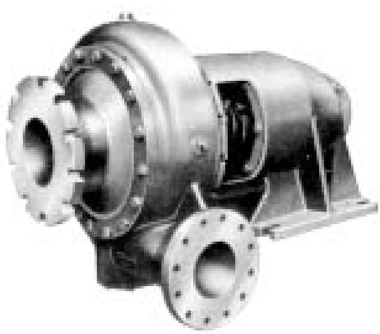
5520R
FRAME MOUNTED END SUCTION

5553ER
END SUCTION
HORIZONTAL BILTOGETHER



5553F
RADIAL VANE DIFFUSER

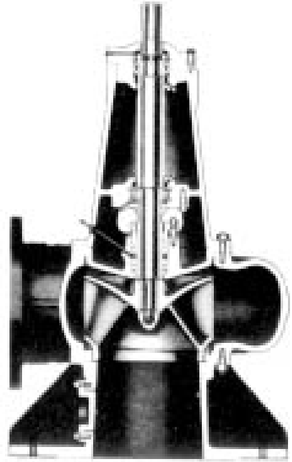
5430AW
SUBMERSIBLE-NONCLOG PUMP



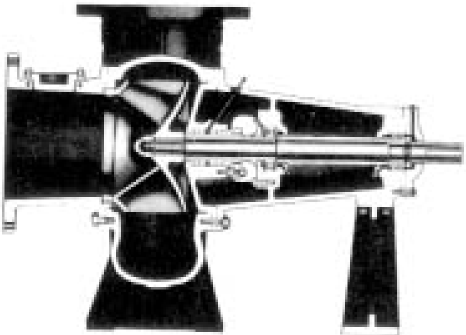
5426
NON-CLOG
HI-HEAD
PUMP

XII

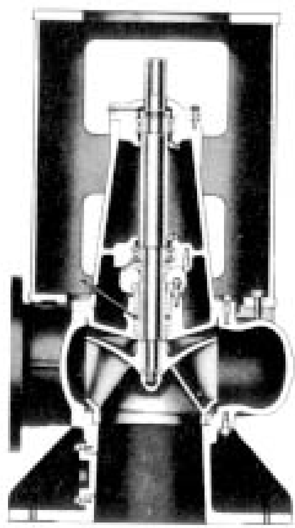
## *ANGLEFLOW & SPLIT CASE*



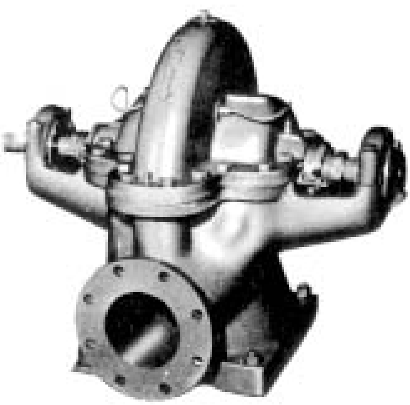
5710
ANGLEFLOW



5720
ANGLEFLOW



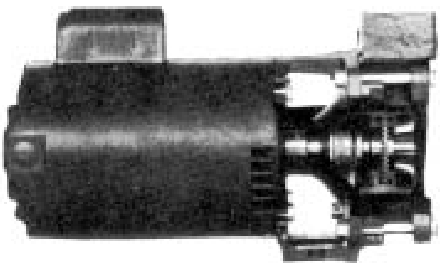
5740
ANGLEFLOW



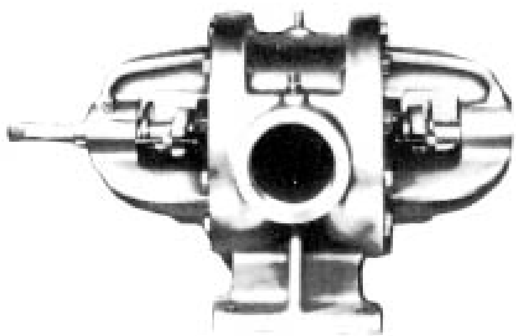
5800
SPLIT CASE

5900
MULTISTAGE SPLIT CASE

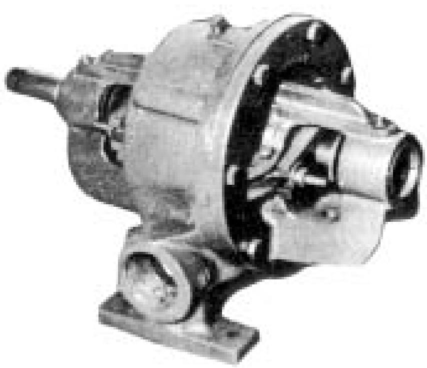
## *PERIPHERAL PUMPS*



TOP—SUCTION TYPE



CENTER—SUCTION TYPE



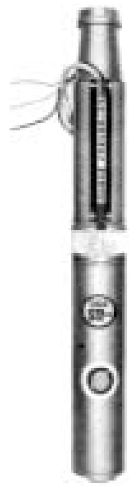
BOTTOM—SUCTION TYPE

# WATER SYSTEMS

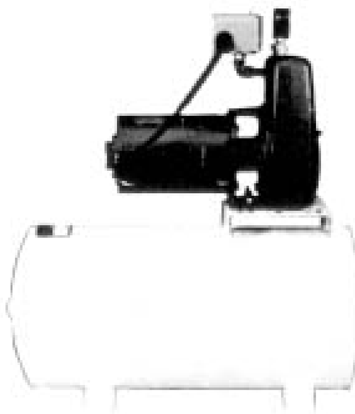
From nearly a century of service to the farm and the rural home, Fairbanks Morse continues to pioneer in the development of machinery which will bring prosperity, health and luxury to rural living.

**SD70 CELLAR DRAINER**

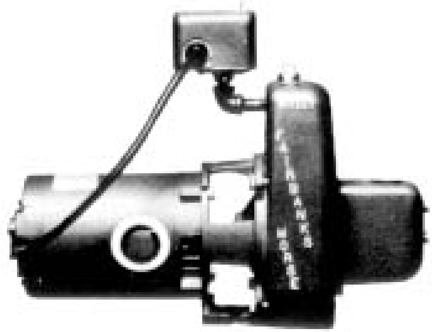
**MULTIPLE VERTICAL PUMP**



**SUBMERSIBLE DEEP WELL PUMP**



**CONVERTIBLE JET PUMP WITH 12 GAL. PRESSURE TANK**



**SHALLOW WELL JET PUMP**

## *UTILITY PUMPS*

"Rain Maker"
CENTRIFUGAL PUMP

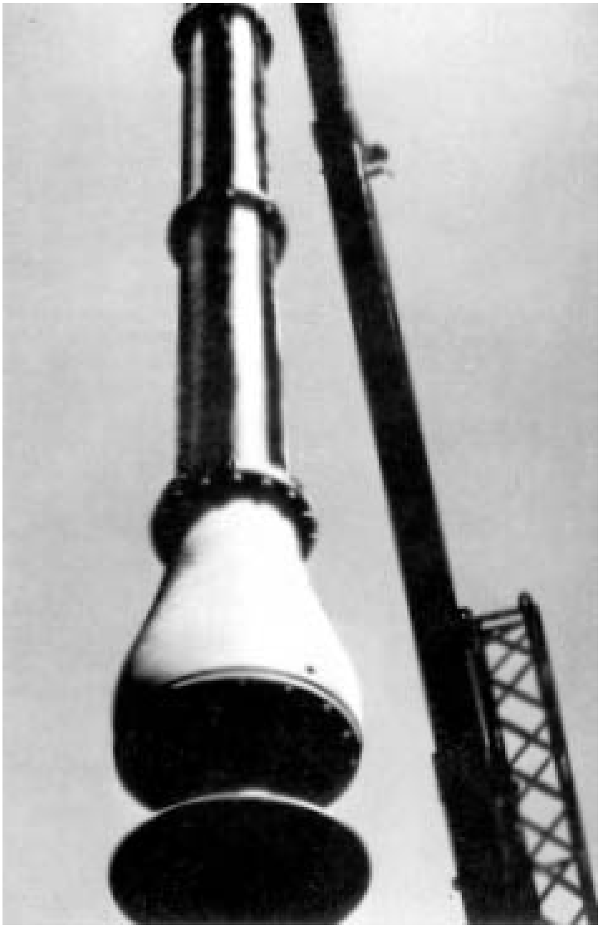
ESP 315-320 ENGINE DRIVEN
SELF-PRIMING CENTRIFUGAL PUMP

58 MAGNUM HIGH PRESSURE
UTILITY PUMP

1½ C1JE ENGINE DRIVEN
CENTRIFUGAL FERTILIZER PUMP

C1J CENTRIFUGAL PUMP

# VTSH Pump



The Vertical Turbine Solids Handling (VTSH) pump is a wet pit solids handling pump combining the advantages of the classic solids handling pump with the well-proven vertical pump. The design is patented by Fairbanks Morse.

# GENERAL INDEX



*Continued next page*

D



E



*Continued next page*

F



G



H



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Y

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# INDEX OF FIGURE NUMBERS

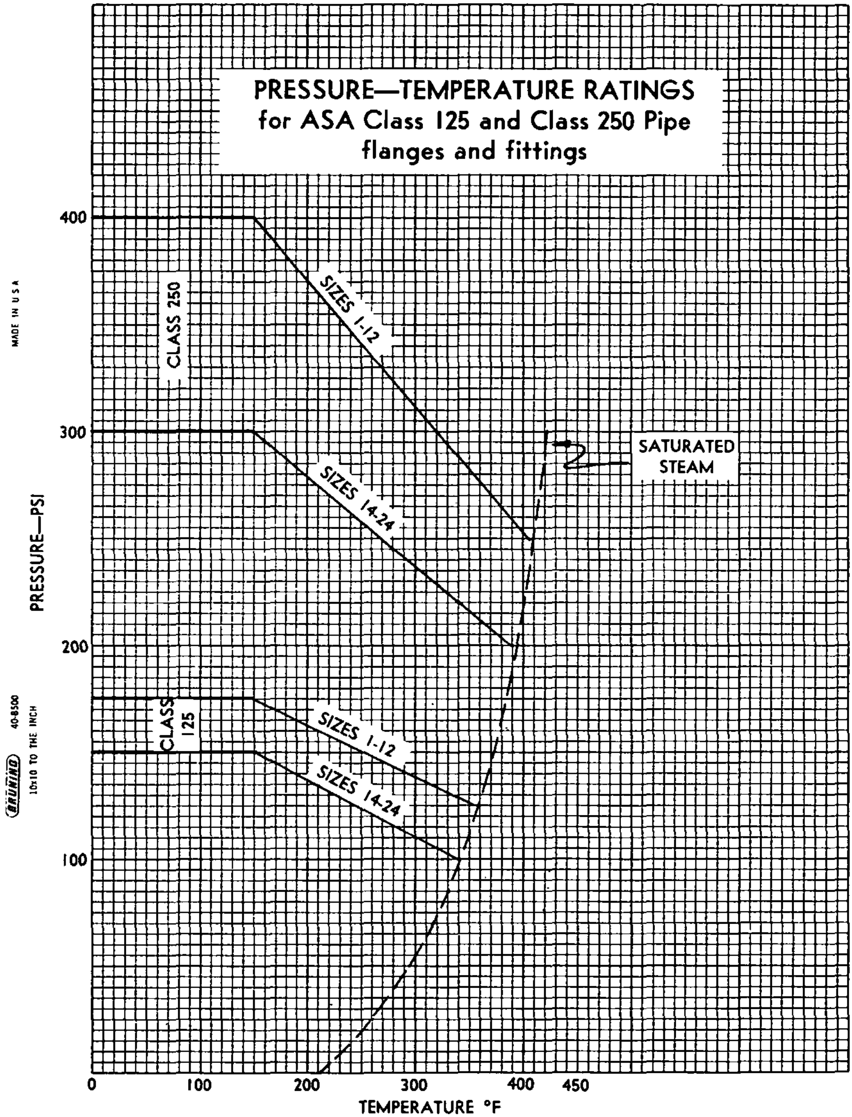
INDEX

TABLE 72.
TABLE FRICTION LOSS OF WATER PER 100 FEET OF FLEXIBLE PIPE

# FRICTION LOSS OF WATER PER 100 FEET OF FLEXIBLE PLASTIC PIPE

| SIZE | ½″ | | ¾″ | | 1″ | | 1¼″ | | 1½″ | | 2″ | | 3″ | | 4″ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GPM | Head in Feet | PSI | Head in Feet | PSI | Head in Feet | PSI | Head in Feet | PSI | Head in Feet | PSI | Head in Feet | PSI | Head in Feet | PSI | Head in Feet | PSI |
| 1 | 1.50 | .65 | .32 | .14 | .09 | .04 | | | | | | | | | | |
| 2 | 5.08 | 2.20 | 1.13 | .49 | .30 | .13 | .09 | .04 | | | | | | | | |
| 3 | 10.51 | 4.55 | 2.40 | 1.04 | .60 | .26 | .18 | .08 | .09 | .04 | | | | | | |
| 4 | 17.81 | 7.71 | 3.81 | 1.65 | 1.02 | .44 | .32 | .14 | .16 | .07 | | | | | | |
| 5 | 26.01 | 11.26 | 5.61 | 2.43 | 1.43 | .62 | .46 | .20 | .23 | .10 | | | | | | |
| 6 | 36.01 | 15.59 | 7.51 | 3.25 | 1.94 | .84 | .65 | .28 | .30 | .13 | .09 | .04 | | | | |
| 8 | 61.00 | 26.41 | 12.01 | 5.20 | 3.19 | 1.38 | 1.04 | .45 | .51 | .22 | .14 | .06 | | | | |
| 10 | 92.15 | 39.89 | 18.32 | 7.93 | 4.90 | 2.12 | 1.59 | .69 | .76 | .33 | .23 | .10 | | | | |
| 15 | | | 38.83 | 16.81 | 10.12 | 4.38 | 3.30 | 1.43 | 1.55 | .67 | .49 | .21 | | | | |
| 20 | | | | | 16.52 | 7.15 | 5.50 | 2.38 | 2.54 | 1.10 | .83 | .36 | .12 | .05 | | |
| 25 | | | | | | | 8.11 | 3.51 | 3.81 | 1.65 | 1.22 | .53 | .18 | .08 | | |
| 30 | | | | | | | 10.81 | 4.68 | 5.20 | 2.25 | 1.69 | .73 | .25 | .11 | .09 | .04 |
| 35 | | | | | | | 14.02 | 6.07 | 6.61 | 2.86 | 2.19 | .95 | .32 | .14 | .12 | .05 |
| 40 | | | | | | | | | 8.92 | 3.86 | 2.80 | 1.21 | .42 | .18 | .14 | .06 |
| 45 | | | | | | | | | 10.12 | 4.38 | 3.40 | 1.47 | .53 | .23 | .16 | .07 |
| 50 | | | | | | | | | 11.92 | 5.16 | 4.09 | 1.77 | .85 | .37 | .23 | .10 |
| 60 | | | | | | | | | | | 5.71 | 2.47 | 1.11 | .48 | .30 | .13 |
| 70 | | | | | | | | | | | 7.30 | 3.16 | 1.41 | .61 | .37 | .16 |
| 80 | | | | | | | | | | | 9.22 | 3.99 | 1.80 | .78 | .46 | .20 |
| 90 | | | | | | | | | | | 11.20 | 4.85 | 2.19 | .95 | .55 | .24 |
| 100 | | | | | | | | | | | 13.91 | 6.02 | 3.30 | 1.43 | .88 | .38 |

FIG. 78


PRESSURE—TEMPERATURE RATINGS
for ASA Class 125 and Class 250 Pipe
flanges and fittings
400
300
200
100
PRESSURE—PSI
CLASS 250
SIZES 1-12
SIZES 14-24
CLASS 125
SIZES 1-12
SIZES 14-24
SATURATED
STEAM
0
100
200
300
400
450
TEMPERATURE °F
MADE IN U S A
BRUNING 40-8500
10x10 TO THE INCH

# MEMORANDA

# MEMORANDA

# MEMORANDA

# Fairbanks Morse Pump

## CORPORATE HEADQUARTERS

Pentair, Inc.
Waters Edge Plaza
1500 County Road B2 West
St. Paul, MN 55113-3105
Phone: (612) 636-7920
Fax: (612) 639-5203

## MANUFACTURING FACILITY

Fairbanks Morse Pump
3601 Fairbanks Avenue
Kansas City, KS 66106
Phone: (913) 371-5000
Fax: (913) 371-2272

## PUMP SERVICES GROUP

Fairbanks Morse Pump
3601 Fairbanks Avenue
Kansas City, KS 66106
Phone: (913) 371-5000
Fax: (913) 371-0515

# NOTES