USEFUL PUMP & HYDRAULIC ENGINEERING DATA
DEFINITIONS, EQUATIONS, TESTING, TABLES, CHARTS DETERMINATIONS

Bulletin EM-77

DEFINITION OF PUMP TERMS

A2.1 *A line shaft vertical turbine* pump is a vertical-shaft centrifugal or mixed-flow pump with rotating impeller or impellers, and with discharge from the pumping element coaxial with the shaft. The pumping element is suspended by the conductor system which encloses a system of vertical shafting used to transmit power to the impellers, the prime mover being external to the flow stream. A basic pump consists of three elements, defined as follows:

A2.1.1 *The pump bowl assembly* is either a single or multistage, centrifugal or mixed- flow vertical pump with discharge coaxial with the shaft. It has open, semi open, or enclosed impellers. Assemblies are constructed for use with either open or enclosed line shafts.

A2. 1.2 *The column-and-shaft assembly* consists of the column pipe which suspends the pump bowl assembly from the head assembly and serves as a conductor for the fluid from the pump bowl assembly to the discharge head. Contained within the column pipe is the line shaft which transmits the power from the driver to the pump shaft. The line shaft is supported throughout its length by means of bearings and may be enclosed in a shaft-enclosing tube and generally lubricated with oil, or it may be open and lubricated with the fluid being pumped.

A2. 1.3 *The head assembly* consists of the base from which the column and shaft assembly and the bowl assembly are suspended, and may include the discharge head, which directs the fluid into the desired piping system, and the driver.

A2.3 *The datum* shall be taken as the elevation of that surface from which the weight of the pump is supported. This is normally the elevation of the underside of the discharge head or head base plate.

A2.4 *The setting* is the nominal vertical distance in feet from the datum to the column pipe connection at the bowl assembly.

A2.5 *The static water level* is the vertical distance in feet from the datum to the level of the free pool while no water is being drawn from the pool.

A2.6 The *pumping water level* is the vertical distance in feet from the datum to the level of the free pool while the specified fluid flow is being drawn from the pool.

A2.7 *Drawdown* is the difference in feet between the pumping water level and the static water level.

A2.9 *The capacity of the pump* is the volume rate of flow (*Q*), expressed in gpm, produced by the pump, calculated for specified conditions.

A2.10 *The pump speed of rotation* (*N*) is the rate of rotation of the pump shaft, expressed in rpm (revolutions per minute).

A2.11 *Head* is a quantity used to express the energy content of the liquid per unit weight of the liquid, referred to any arbitrary datum. In terms of foot- pounds of energy of per pound of liquid being pumped, all head quantities have the dimension of feet of liquid.

A2. 11.1 *Head below datum* (h_b) is the vertical distance in feet between the datum and the pumping level.

A2.11.2 *Head above datum* (h_a) is the head measured above the datum, expressed in feet of liquid, plus the velocity head (sec. A2.11.3) at the point of measurement.

A2.11.3 *Velocity head* (h_v) is the kinetic energy per unit weight of the liquid at a given section expressed in feet of liquid. Velocity head is specifically defined by the expression:

$$hv = \frac{v^2}{2g}$$

A2. 11.4 *Suction head* (h_8) (closed system) is the algebraic sum of the pressure in feet of fluid (measured at the pump suction connection) and the velocity head at that point. Pump suction connection is that point at which the suction piping is attached to the pump bowl assembly or its enclosing vessel.

A2.11.5 *Pump total head* (*H*) is the bowl assembly head (sec. A2.11.6) minus the column loss (sec. A2.12) and discharge head loss. This is the head generally called for in pump specifications.

A2. 11.5.1 *On open-suction installations*, it is the sum of the head below datum and the head above datum.

A2.11.5.2 *On closed-suction installations*, it is the algebraic difference of the suction head, the distance between the suction connection, and the datum and the head above the datum.

A2.11.6 *Bowl assembly head* (h_l) is the energy imparted to the liquid by the pump, expressed in feet of liquid. It is the head of a pump developed at the discharge connection of the bowl assembly.

A2.12 *The column loss* (h_c) is the value of the head loss (expressed in feet) due to the flow friction in the column pipe. This value, together with the discharge head loss, is subtracted from the bowl assembly head to predict the pump total head.

A2.13 *The line shaft loss* (hp_1) is the power (expressed in horsepower) required because of the rotation friction of the line shaft. This value is added to the bowl assembly input (sec. A2.14.3) to predict the pump input (sec. A2.14.1).

A2.14 *Power* is expressed in units of horsepower. One horsepower is equivalent to 550 ft-lb per second, 33,000 ft-lb per minute, 2,545 Btu per hour, or 0.746 kW.

A2.14.1 *Pump input* is the power delivered to the top shaft by the driver, expressed in horsepower.

A2.14.2 *Driver power input* is the power input to the driver, expressed in horsepower.

A2.14.3 *Bowl assembly input* is the power delivered to the pump shaft, expressed in horsepower.

A2.15 *Pump output* is defined as $\frac{QH}{3,960}$ for water having a specific weight of 62.4 lb per cubic foot. It is expressed in horsepower.

A2.16 *Bowl output* is defined as $\frac{Qh_1}{3,960}$ for water having a specific weight of 62.4 lb per cubic foot. It is expressed in horsepower.

A2.17 *Pump efficiency* (E_p) is the ratio of pump output to pump input, expressed in percent.

A2.18 *Overall efficiency* (*E*) is a ratio of pump output to the prime mover input, expressed in percent.

A2.19 *Driver efficiency* (E_g) is the ratio of the driver output to the driver input, expressed in percent.

A2.20 *Bowl assembly efficiency* (E_l), is the ratio of the bowl output to the bowl assembly input, expressed in percent.

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DETERMINATION OF PUMPING HEAD

The operating conditions of a pump should be determined as accurately as possible. If there is a variation in head, both maximum and minimum heads should be allowed for in the pump selection.

The total head developed by a pump, or total dynamic head, is made up of the following:

1. **Static Head**. The total change in elevation of the liquid, from suction level to discharge level, plus the pressure difference of suction and discharge reservoirs of different from atmospheric.
2. **Pipe Friction**. The friction head loss in the suction and discharge line, elbows and valves, and the suction pipe entrance loss.
3. **Velocity Head**. The velocity head at the end of the discharge pipe.

SYSTEM HEAD CURVES

In addition to knowing the head for the design capacity, it is, for many installations, desirable to know the piping system head-capacity characteristic. When operating conditions are variable, a plot of the system head curve imposed on the pump curves enables the best pump selection for the operating range.

In any piping system, the pipe friction and velocity head varies with capacity. Thus, for any fixed static head conditions, the system head increases from static head at zero flow for any increase in capacity. Also, the static head may be variable. Then, the pipe friction and velocity head losses can be added separately to the maximum and minimum static heads, respectively, and the maximum and minimum system head curves can be plotted.

When the system curve is superimposed on the pump curve, the operating points are the intersections of the system curve; the operating points are the intersections of the system curve with the pump curves. Thus, the operating range for the pump is established and its suitability for the application is determined.

PUMPING LIQUIDS OTHER THAN WATER

HEAD

The head of a pump is generally expressed in feet and is so plotted on pump curves. This head developed, expressed in feet, is the same irrespective of the fluid pumped. However, the head expressed in pounds per square inch (psi) will be different for fluids of different specific gravity. The heavier the fluid, the greater will be the head expressed in psi for a pump. The relation of feet head and psi are:

$$\frac{\text{ft x sp-gr}}{2.31} = \text{psi}$$

$$\frac{\text{psi x 2.31}}{\text{sp-gr}} = \text{ft}$$

HORSEPOWER

Pump horsepower is changed with any change in specific gravity. Pump horsepower curves, unless otherwise noted, are plotted for water, which has a specific gravity of 1.00 at normal temperatures. Any increase or decrease in specific gravity will proportionately increase or decrease the horsepower. The general formula for calculating horsepower is:

$$\text{bhp} = \frac{\text{gpm x total head in feet}}{\text{3960 x efficiency}}$$

is based upon water, i.e., a specific gravity of 1.00. When the sp-gr is other than 1.00, the formula should be:

$$\text{bhp} = \frac{\text{gpm x total head in feet}}{\text{3960 x efficiency}} \text{ x sp-gr}$$

VISCOUS LIQUIDS

Centrifugal pumps can satisfactorily handle many oils and other viscous liquids. Applications of pumps to viscous liquids should be referred to the factory. When pumping viscous liquids, centrifugal pump characteristics are radically altered. The pump head, capacity, and efficiency all decrease when pumping viscous liquids. The variation is more pronounced as the liquid becomes more viscous, and is not a linear function.

NPSH
(*NET POSITIVE SUCTION HEAD*)

A major problem encountered in many pumping applications, particularly those involving fluids at or near their boiling points, is a lack of net positive suction head (NPSH). Net positive suction head is the absolute pressure, above the vapor pressure of the fluid pumped, available at the entrance or eye of an impeller, to move and accelerate the fluid entering the eye. If the NPSH available in an installation is insufficient, the pump will cavitate and serious operational difficulties may develop. These troubles can include serious reduction in capacity and efficiency, excessive vibration, reduced life of pump parts due to cavitation erosion, and damage to the pump from possible vapor lock and running dry.

A centrifugal pump has a minimum required NPSH to prevent cavitation, which varies with capacity. This characteristic is inherent in the design of a pump and is just as much a performance characteristic as its head-capacity relationship. For a pump to operate cavitation free, the available NPSH of an installation must exceed the NPSH required by the pump for operating conditions.

The NPSH required by a pump can be supplied by the pump manufacturer. It is expressed in feet of fluid pumped as is total head developed.

The system NPSH available in a proposed installation can be calculated by the formula:

$H_{sv} = H_p \pm H_z - H_f - H_{vp}$

Where:

H_{sv} = NPSH expressed in feet of fluid
H_p = Absolute pressure on the surface of the liquid where the pump takes suction, expressed in feet of fluid.
H_z = Static elevation of the liquid above or below the centerline of the impeller (on vertical pumps, the correction should be made to the entrance eye of the impeller) expressed in feet.
H_f = Friction and entrance head losses in the suction piping expressed in feet.
H_{vp} = Absolute vapor pressure of fluid at the pumping temperature expressed in feet of fluid.

The system NPSH available in an existing installation can be measured as follows:

$$H_{sv} = P_a \pm P_s + \frac{V_s^2}{2g} - H_{vp}$$

Where:

P_a = Atmospheric pressure for the elevation of the installation expressed in feet of fluid.
P_s = Gage pressure at the suction flange of the pump corrected to the pump centerline and expressed in feet of fluid.
$\frac{V_s^2}{2g}$ = Velocity head at the point of measurement of Ps.
H_{vp} = Absolute vapor pressure expressed in feet of fluid.

NPSH as explained defines suction conditions of a pump installation and suction characteristic of a pump. Naturally, NPSH and suction lift are related for suction lift also indicates suction conditions. When the NPSH is known, the suction lift can be determined by the formula:

$H_s = H_p - H_{sv} - H_{vp} - H_f$

Where:

H_s = Total suction lift.

EFFECT ON CENTRIFUGAL PUMPS OF CHANGE OF SPEED OR SLIGHT CHANGE OF IMPELLER DIAMETER

H = Head in feet. d = Dia. of impeller.

Total head varies as the square of the speed or diameter:

$$H_2 = H_1 \left(\frac{rpm_2}{rpm_1}\right)^2 \text{ or } H_2 = H_1 \left(\frac{d_2}{d_1}\right)^2$$

Capacity varies directly as the speed or diameter:

$$gpm_2 = gpm_1 \text{ x } \frac{rpm^2}{rpm^1} \text{ or } gpm_2 = gpm_1 \text{ x } \frac{d_2}{d_1}$$

Brake horsepower varies as the cube of the speed or diameter:

$$bhp_2 = bhp_1 \text{ x } \left(\frac{rpm_2}{rpm_1}\right)^3 \text{ or } bhp_2 = bhp_1 \text{ x } \left(\frac{d_2}{d_1}\right)^3$$

With efficiency of pump and motor known, proportionate cost of power can be predetermined on a basis common to all pumps, regardless of size or capacity. By using units of capacity and head, comparisons can be made in pumps having different capacities.

Power cost of pumping varies inversely with overall plant efficiency (Eo). Thus, power cost per gallon for each foot head on a pump of 30% overall plant efficiency is double that of a pump of 60% overall plant efficiency. (Assuming power rate the same in both cases).

To pump one gallon of water in one minute (1 gpm) against one foot head with 100% overall plant efficiency, requires .0001 89 kilowatts. Pumping 1000 gallons per minute (1000 gpm) per foot head at 100% (Eo) requires .189 kilowatts.

The following formulae can be used for determining power costs of pumping under any conditions:

COST PER 1000 GALLONS

(not gallons per minute) for each foot of head

$$= \frac{.00315 \times R}{Eo} \quad \text{or} \quad \frac{.189 \times R}{Ep \times Em \times 60}$$

Where:
.189 = Theoretical kw as stated above.
R = Power cost per kwh.
Ep = Pump efficiency.
Em = Motor efficiency.
Eo = Overall plant efficiency.
60 = Minutes.

Example: Find the cost per 1000 gallons (not gpm) per foot head, of a pumping plant whose overall plant efficiency (Eo) is 60% (.60), power rate, five cents ($0.05) per kwh.
Substituting in formula:
Cost per 1000 gallons per foot head =

$$\frac{.00315 \times .05}{.60} = \frac{.0001575}{.60} = \$.0002625$$

If the pump is lifting water over a 120-foot head, then the cost per 1000 gallons (not gpm) delivered would be: $.0002625 x 120 = $.0315

Pumping costs per any given condition of capacity or head may be determined by using the following formula:

COST PER HOUR

$$= \frac{.000189 \times \text{gpm} \times \text{Total Head} \times \text{Power Rate}}{\text{Overall Plant Efficiency}}$$

Example: Find the cost per hour of a pump delivering 500 gpm against a 120-foot head, overall plant efficiency of pump 60% (.60), power rate five cents ($0.05) per kwh. Substituting in formula we have:

$$\text{Cost per hour} = \frac{.000189 \times 500 \times 120 \times .05}{.60}$$

$$= \$0945$$

COST PER ACRE-FOOT

$$= \frac{1.023 \times \text{Total Head} \times \text{Power Rate}}{Eo}$$

Example: Find the cost per acre-foot of a pump delivering 500 gpm against a 120-foot head, overall plant efficiency of pump 60% (.60), power rate five cents ($0.05) per kwh. Substituting in formula:

$$\text{Cost per acre-foot} = \frac{1.023 \times 120 \times .05}{.60}$$

$$= \$10.23$$

Formulae for Determining
COST OF ELECTRICAL PUMPING

Kilowatt Hours Required

$$\text{per 1000 gallons} = \frac{\text{kw} \times 16.66}{\text{gpm}}$$

kw = Kilowatts input to meter, based on plane efficiency (wire to water).
kw = hp to pump x .746, based on pump efficiency (water to water).

$$\text{Pump efficiency} = \frac{\text{gpm} \times \text{head}}{2960 \times \text{bhp (to pump)}}$$

$$\text{1 Horsepower} \begin{cases} = 33{,}000 \text{ ft lbs per minute} \\ = 550 \text{ ft lbs per second} \\ = 0.746 \text{ kw} \end{cases}$$

bhp to pump = motor efficiency x hp at meter.

H.P. AT METER
(DISK CONSTANT METHOD)

$$\text{hp (at meter)} = \frac{R \times K \times M}{.2072 \times t}$$

R= Rev. of disk.
K = Disk constant. Do not confuse disk constant with dial constant. Dial constant is not used to calculate meter horsepower. The disk constant is the watt hours per revolution of disk and can usually be found either on the nameplate or painted on the face of the disk.
M = Multiplier = Ratio of current transformers used to rating of mete. When current and potential transformers are used, M equals the product of the current transformer ratio times the potential transformer ratio. If neither type of transformer is used, there is no multiplier required in the above formula.
(M=1).
Example: (No current or potential transformers used). Generally, the meter nameplate states what the multiplier is if the size of the motor requires that a transformer be used. Disk K = 4.8 Turning 20 revolutions in 54.5 seconds.

$$\text{Hp at meter} = \frac{20 \times 4.8}{.2072 \times 54.5} = 8.5 \text{ hp}$$

Example: (Current transformers used).
Disk K = 4,8 Turning 20 revolutions in 54.5 seconds.
Multiplier = M = 10

$$\text{hp at meter} = \frac{20 \times 4.8 \times 10}{.2072 \times 54.5} = 85.0 \text{ hp}$$

The term “Efficiency” as used in pumping would be of no practical value if it could not be reduced to terms of actual pumping costs, expressed in dollars.

ELECTRICAL FORMULAE

REQUIRED	DIRECT CURRENT	ALTERNATING CURRENT Single-phase	ALTERNATING CURRENT 3-phase
Amperes when hp is known	$\frac{746\ (hp)}{(E)\ (eff)}$	$\frac{746\ (hp)}{(E)\ (eff)\ (pf)}$	$\frac{746\ (hp)}{1.73\ (E)\ (eff)\ (pf)}$
Amperes when kilowatts are known	$\frac{1000\ (kw)}{E}$	$\frac{1000\ (kw)}{(E)\ (pf)}$	$\frac{1000\ (kw)}{1.73\ (E)\ (pf)}$
Amperes when kva is known		$\frac{1000\ (kva)}{E}$	$\frac{1000\ (kva)}{1.73\ (E)}$
Kilowatts	$\frac{(I)\ (E)}{1000}$	$\frac{(E)\ (I)\ (pf)}{1000}$	$\frac{1.73\ (I)\ (E)\ (pf)}{1000}$
kva		$\frac{(I)\ (E)}{1000}$	$\frac{1.73\ (I)\ (E)}{1000}$
Horsepower Output	$\frac{(I)\ (E)\ (eff)}{746}$	$\frac{(I)\ (E)\ (pf)\ (eff)}{746}$	$\frac{1.73\ (I)\ (E)\ (pf)\ (eff)}{746}$

I = amperes
E = volts
eff = efficiency (as a decimal)
hp = horsepower
pf = power factor
kw = kilowatts
kva = kilovolt amperes

MOTOR CHARACTERISTICS

General purpose open motors (drip-proof) are designed to give the best operation at their normal voltage and frequency (this information included on motor name-plate).

Some variation from normal is allowable, the voltage limits being approximately plus or minus 10% and the frequency limits plus or minus 5%. The voltage and frequency should never be varied simultaneously in opposite directions, and both should not be varied at the same time to the extreme limits allowed.

These motors will operate with an ambient temperature of 40° C. (surrounding temperature 104° F.) with a temperature rise of 40° C. (rise of 72° F.) when carrying the rated load at an altitude of not over 3300 feet.

These same motors are capable of carrying a 15% overload continuously providing the total temperature rise does not exceed 50° C. (122° F.) However, the total temperature cannot exceed 90° C., and thus if the ambient temperature is 122° F. this 15% service factor cannot be used. When operating a motor above 3300 feet the motor temperature rise increases approximately 1% for each 330 feet rise and this must be allowed for in computing the total allowable temperature rise.

SYNCHRONOUS AND FULL LOAD SPEED OF INDUCTION MOTORS—230-460 VOLTS

Number of Poles	50 Cycle Synch. Speed	50 Cycle Full Load Speed	60 Cycle Synch. Speed	60 Cycle Full Load Speed
2	3000	2900	3600	3460
4	1500	1460	1800	1760
6	1000	970	1200	1160
8	750	730	900	870
10	600	585	720	700
12	500	485	600	580
14	428	420	514	500

The following tabulation shows the approximate effects of variations in voltage and frequency on motor characteristics. These values should in no way be considered as guarantees.

	Characteristic	Alternating-current (Induction) Motors			
		Voltage		Frequency	
		110%	90%	105%	95%
Torque*	Starting and Max Running	Increase 21%	Decrease 19%	Decrease 10%	Increase 11%
Speed†	Synchronous Full Load Per Cent Slip	No change Increase 1% Decrease 17%	No change Decrease 1.5% Increase 23%	Increase 5% Increase 5% Little change	Decrease 5% Decrease 5% Little change
Efficiency	Full Load ¾ Load ½ Load	Increase 0.5 to 1 Point Little change Decrease 1 to 2 Points	Decrease 2 Points Little change Increase 1 to 2 Points	Slight increase Slight increase Slight increase	Slight decrease Slight decrease Slight decrease
Power Factor	Full Load ¾ Load ½ Load	Decrease 3 Points Decrease 4 Points Decrease 5 to 6 Points	Increase 1 Point Increase 2 to 3 Points Increase 4 to 5 Points	Slight increase Slight increase Slight increase	Slight decrease Slight decrease Slight decrease
Current	Starting Full Load	Increase 10 to 12% Decrease 7%	Decrease 10 to 12% Increase 11%	Decrease 5 to 6% Slight decrease	Increase 5 to 6% Slight increase
Temperature Rise	ac Motors	Decrease 3 to 4° C	Increase 6 to 7° C	Slight decrease	Slight increase
	Maximum Overload Capacity Magnetic Noise	Increase 21% Slight increase	Decrease 19% Slight decrease	Slight decrease Slight decrease	Slight increase Slight increase

* The starting and maximum running torque of ac induction motors will vary as the square of the voltage.

† The speed of ac induction motors will vary directly with the frequency.

3 – PHASE SQUIRREL – CAGE INDUCTION MOTORS

	230 – Volt				460 – Volt			
hp	Full Load (amp)	† Min. Size Wire AWG	Size Conduit (inches)	# Max. Rating of Branch Circuit Fuses	Full Load (amp)	† Min. Size Wire AWG	Size Conduit (inches)	# Max. Rating of Branch Circuit Fuses
1.000	3.600	14	0.500	‡ 15	1.800	14	0.500	‡ 15
1.500	5.200	14	0.500	‡ 15	2.600	14	0.500	‡ 15
2.000	6.600	14	0.500	‡ 20	3.400	14	0.500	‡ 15
3.000	9.600	14	0.500	‡ 25	4.800	14	0.500	‡ 15
5.000	15.200	12	0.500	‡ 45	7.600	14	0.500	‡ 20
7.500	22.000	10	0.750	° 60	11.000	14	0.500	° 30
10.000	28.000	8	0.750	° 80	14.000	12	0.500	° 40
15.000	42.000	6	1.000	° 125	21.000	10	0.750	° 60
20.000	54.000	4	1.250	° 150	27.000	8	0.750	° 80
25.000	68.000	3	1.250	° 200	34.000	8	0.750	° 100
30.000	80.000	1	1.500	° 225	40.000	6	1.000	° 125
40.000	104.000	00	2.000	° 300	52.000	4	1.000	° 150
50.000	130.000	000	2.000	° 350	65.000	3	1.250	° 175
60.000	154.000	200,000CM	2.500	° 450	77.000	2	1.250	° 225

SINGLE-PHASE INDUCTION MOTORS

	115 – Volt				230 – Volt			
0.500	9.800	14.000	0.500	25.000	4.900	14.000	0.500	15.000
0.750	13.800	12.000	0.500	40.000	6.900	14.000	0.500	20.000
1.000	16.000	12.000	0.500	45.000	8.000	14.000	0.500	25.000
1.500	20.000	10.000	0.750	60.000	10.000	14.000	0.500	30.000
2.000	24.000	10.000	0.750	70.000	12.000	14.000	0.500	35.000
3.000	34.000	6.000	0.750	100.000	17.000	10.000	0.750	50.000
5.000	56.000	4.000	1.250	150.000	28.000	8.000	0.750	80.000

† In order to avoid excessive voltage drop where long runs are involved, it may be necessary to use conductors and conduit of sizes larger than the minimum sizes listed above.

Branch-circuit fuses must be large enough to carry the starting current, hence they protect against short-circuit only. Additional protection of an approved type must be provided to protect each motor against operating overloads.

‡ For full-voltage starting of normal torque, normal starting current motors.

° For reduced-voltage starting of normal torque, normal starting current-motors and full-voltage, starting of high-reactance, low starting current squirrel-cage motors.

METHOD OF DETERMINATION OF ELECTRICAL LINE LOSS

Used when meter is located an appreciable distance from the pump motor

Watts equals I^2 R per line.
Kilowatts or kw equals I^2 R, divided by 1,000. R equals the resistance of one line.
For 3-phase circuit kw equals 3 I^2 R, divided by 1,000.
R equals the resistance in ohms for wire size used.
I equals the full load current of the motor.
Full load current of the motor should be obtained from the name plate on the motor.
See tabulations at right for values of R.
For more accurate determination, use the same value of R and determine I by use of an ammeter in the circuit.
After determining the total kw loss, subtract this figure from the kw input to the motor.

DIAMETER AND RESISTANCE OF STANDARD ANNEALED COPPER WIRE
(Round Solid Conductor)
(Based on U.S. Bureau of Standards)

No.	Diameter Circ. Mils	Resistance at 25° C (77° F) Ohms per 1,000 Feet
A.W.D.	460	0.04998
0000	410	0.06302
000	365	0.07947
00	325	0.1002
0	289	01 264
2	258	0.1593
3	229	0.2009
4	204	0.2533
6	162	0.4028
8	129	0.6405
10	102	1.018
12	81	1.619
14	64	2.575

MECHANICAL AND ELECTRICAL EQUIVALENTS

FLOWING WATER

1 cubic foot per minute = 7.4805 gallons per minute.
1 second foot =
  1 cubic foot per second.
  448.83 gallons per minute.
1 second - foot - day = 2 acre feet.

WEIGHTS AND MEASURES

LENGTH

1 millimeter = .03937 inch.
1 centimeter = 3.937 inch.
1 meter =
  39.37 inches.
  3.2808 feet.
Circumference of a circle = 3.1416 x diameter.

1 mile =
  5280 feet.
  1.60935 kilometers.
  .868 knots
  8 furlongs

AREA

1 acre = 43560 square feet

Area of a circle = $3.1416 \times \frac{\text{diam}^2}{4}$

1 acre foot =
  43560 cubic feet.
  325900 gallons.

VOLUME

Volume of a sphere = $3.1416 \times \frac{\text{diam}^3}{6}$

1 barrel = 42 gallons.

WEIGHT

1 gram
  1 cubic centimeter of distilled water.
  15.43 grains troy.
  .0353 ounce.
1 kilogram = 2.20462 pounds avoirdupois.
1 metric ton 2204.6 pounds.
1 cubic foot of concrete (1:2:4) = 146 pounds
1 cubic foot of sea water = 63.9 pounds.
1 cubic inch of bronze = .32 pound.
1 cubic inch of cast iron = .26 pound.
1 cubic inch of steel = .28 pound.

TEMPERATURE

Degrees C = $\frac{5}{9}$ x (F - 32)   Degrees F= $\frac{9}{5}$ x C+32

PRESSURE

1 atmosphere =
  760 millimeters of mercury at 32° F.
  14.7 pounds per square inch.
  29.921 inches of mercury at 32° t.
  2116 pounds per square foot.
  1.033 kilograms per square centimeter.
  33.947 feet of water at 62° F.
  10.33 meters of water at 20° C.
  1.013 bar.
1 foot of air at 32° F and barometer 29.92 =
  .0761 pound per square foot.
  .0146 inch of water at 62° F.
1 foot of water at 62° F =
  .433 pound per square inch
  62.355 pounds per square foot.
  .883 inch of mercury at 62° F.
  821.2 feet of air at 62° F and barometer 29.92.
1 inch of water 62° F =
  .0361 pound per square inch.
  5.196 pounds per square foot
  .5776 ounce per square inch
  .073 5 inch of mercury at 62° F
  68.44 feet of air at 62° F and barometer 29.92.
1 pound per square inch =
  2.0355 inches of mercury at 32° F
  2.0416 inches of mercury at 62° F.
  2.309 feet of water at 62° F.
  .07031 kilograms per square centimeter
  .06804 atmosphere.
  51.7 millimeters of mercury at 32° F.

EQUIVALENTS OF CAPACITY OR VOLUME FACTORS

1-U.S. Gallon of Water	231	Cu. inches
1-U.S. Gallon of Water	.1337	Cu. foot
1-U.S. Gallon of Water	8.326	Lbs. at 39° F or 1.00 Sp. Gr.
1-U.S. Gallon of Water	.833	Imperial gallon
1-U.S. Gallon of Water	3.7853	Litres
1-Imperial Gallon of Water	1.201	U.S. Gallons
1-Imperial Gallon of Water	277.418	Cu. inches
1-Imperial Gallon of Water	9.988	Lbs. at 39° F or 1.00 Sp. Gr.
1-Cubic Foot of Water	7.48	U.S. Gallons
1-Cubic Foot of Water	62.428	Lbs. at 39° F
1-Cubic Foot of Water	28.316	Litres
1-Cubic Foot of Water	.0283	Cubic meter
1-Lb. of Water	27.71	Cu. inches
1-Lb. of Water	.12	U.S. Gallon
1-Lb	.4536	Kilogram
1-Litre	.2642	U.S. Gallon
1-Litre	.22	Imperial Gallon
1-Litre	61.025	Cu. inches
1-Litre	.0353	Cu. foot
1-Cubic Meter	264	U.S. Gallons
1-Cubic Meter	220	Imperial Gallons
1-Cubic Meter	1.308	Cu. yards
1-Cubic Meter	61,028	Cu. inches
1-Cubic Meter	35.31	Cu. feet
1-Ton of Water (2000 lbs.)	240 2	U.S. Gallons at 39° F
1-Ton of Water (2000 lbs.)	199.8	Imperial Gallons at 39° F
1-Second-foot	7.48	U.S. Gallons per Second
1-Second-foot	448.8	U.S Gallons per Minute
1-Second-foot	646,272	U.S. Gallons per Day
1-Second-foot	1	Acre inch per hour approximately
100-U.S. Gallons per Minute	223	Second-fool
1,000,000-US. Gallons per Day	1.547	Second-feet
1,000,000-U.S. Gallons	3.07	Acre feet
1,000,000-U.S. Gallons per Day	694.4	Gallons per Minute
1-Acre foot	325,851	Gallons
1-Inch deep on 1 sq. Mile	2,323,200	Cu. ft.
		Boiler HP x .072

MECHANICAL AND ELECTRICAL UNITS

1 btu =
  1054 joules.
  777.5 foot pounds.
  107.5 kilogram-meters.
  .0003927 horsepower hour.
1 foot pound =
  1.3558 joules.
  .13826 kilogram-meter.
  .001286 btu.
  .03241 gram calorie.
  .000000505 horsepower hour.
1 horsepower =
  745.7 watts.
  .736 Kw (metric)
  33,000 foot pounds per minute.
  641,700 gram calories per hour.
  273,743 kilogram-meters per hour.
  2,547 btu per hour.
  75 kg m/s
1 joule =
  1 Nm
  .10197 kilogram-meter.
  .73756 foot pound.
  .239 gram calorie.
  .0009486 btu.
1 kilogram-meter =
  7.233 foot pounds.
  9.806 joules.
  2.344 gram calories.
  .0093 btu.
1 kilowatt =
  1000 watts.
  1.341 horsepower.
  2,655,200 foot pounds per hour.
  860,500 gram calories per hour.
  367,000 kilogram-meters per hour.
  3,415 btu per hour.
  .102 boiler horsepower.

METRICATION

LENGTH

1 km	= 1000 m	1 m	= 1000mm = 100 cm
cm	= 0.3937 in	in	= 2.54 cm = 25.4 mm
m	= 3.28 ft	ft	= 0.3048 m
m	= 1.094 yd	yd	= 0.9144 mm
km	= 0.621mi	mi	= 1.61 km

CAPACITY

1L	= 1000 cc	1L	= 1000 mL
1L	= 0.0353 ft^3	cu ft	= 28.32 L
1L	= 0.2642 gal (U.S.)	gal	= 3.785 L
1L	= 61.023 in^3	cu in	= 0.0164

AREA

sq cm	= 0.155 sq in	sq in	= 6.45 sq cm
sq m	= 10.76 sq ft	sq ft	= .0929 sq m
sq m	= 1.196 sq yd	sq yd	= .836 sq m
ha	= 2.47 acres	acre	= .405 ha
sq km	= 0.386 sq mi	sq mi	= 259 sq km

PRESSURE

1 kg per sq cm	= 14.2233 psi
1 kg per cm^2	= .96784 std atm
1 kg per cm^2	= .98l bar
1 psi	= .0703l kg per cm^2
1 kg per m^2	= .20482 lbs/ft^2
1 lb per ft^2	= 4.8824 kg per m^2
1 std atm	= 1.033228 kg per cm^2
1 metric atm	= 1.033228 kg per cm^2
1 st atm	= 14.6959 psi
1 N/m^2	= 1.0194 x 10-6 kg/cm^2

CENTIGRADE/FAHRENHEIT CONVERSION FORMULAE

F = 9/5 x © + 32 = 1.8 (C + 17.8)
C=5/9(F—32)

WEIGHT

one kg	= 1000 g	one g	= 1000 mg
g	= 15.432 grains	oz	= 28.35 g
g	= .0353 oz	lb	= .454 kg
kg	= 2.2046 lbs.	ton (short)	= 907.18 kg
kg	= .0011 ton (short)	ton (short)	= .907 metric
		ton (short)	= 2000 lbs
metric ton	= 1.1025 ton (short)		
grain	= .0648 g		

VOLUME

one cu m	= $(100)^3$ cm	one L	= 1000 cc = 1000 mL
cu cm	= .061 cu in	cu in	= 16.38 cm^3
cu m	= 35.315 cu ft	cu ft	= .0283 m^3
cu m	= 1.308 cu yd	cu yd	= .7645 m^3

CONVERSION

CONVERT FROM	TO	MULTIPLY BY
gal (U.S.) per min	m^3/hr	.2272
m	ft	3.28
ft	m	.3048
m^3/hr	U.S. gpm	4.4021
m^3/hr	L/sec	.2278
hp (mech.)	hp (metric)	1.01387
hp (metric)	hp (mech.)	.986320
kg/cm^2	psi	14.2233
psi	kg/cm^2	.07031

HORSEPOWER* FORMULAE °1 hp = 33,000 ft lb/min

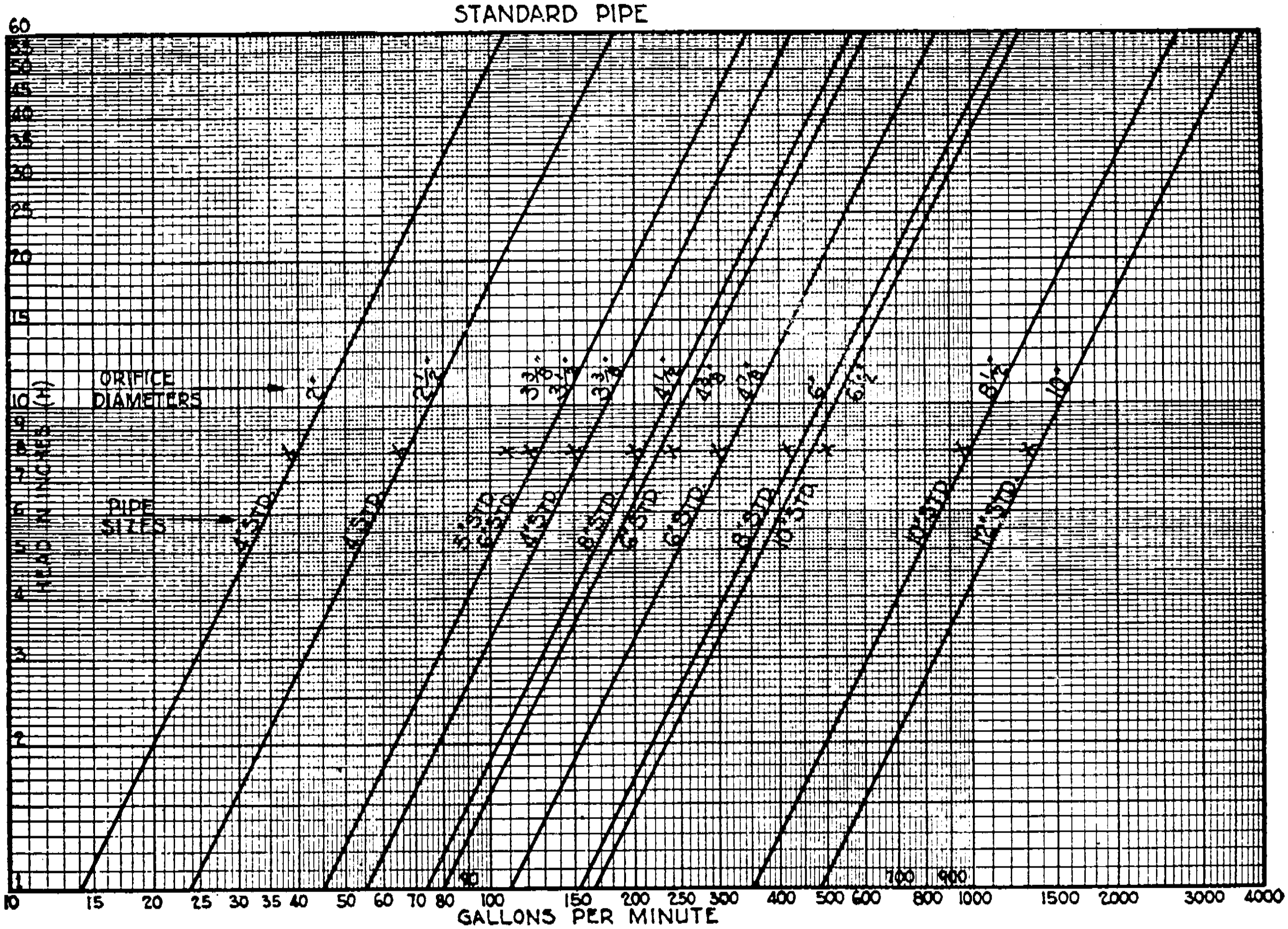
bhp = .7460 kw
= 550 ft lb/sec.
1 hp = .7355 kw (metric)
= 75 kg/m/sec.
mhp = .9863 x bhp

$$\text{bhp} = \frac{Q\ (\text{gpm}) \times H\ (\text{ft}) \times \text{Sp. Gr.}}{3960 \times E} = \frac{m^3/\text{hr} \times H\ (\text{m}) \times \text{Sp. Gr.}}{274.23217 \times E} = \frac{m^3/\text{hr} \times H\ (\text{m}) \times \text{Sp. Gr.}}{278.04134}$$

ABBREVIATIONS

acre-spell out	ft-foot	kPa-kilopascal	N-Newton
atm-atmosphere	g-gram	L-liter	oz-ounce
bar-spell out	gal-gallon	lb-pound	P-Pascal
bhp-brake horsepower C-Centigrade (Celsius)	gpm-gal per min	m-meter	psi-pounds per square inch
	grain-spell out	m^3-cubic meters	Sp. Gr.-Specific Gravity
cc-cm^3	ha-hectare	metric-spell out	ton-spell out
cm-centimeter	hp-horsepower	mhp-metric horsepower	yd-yard
cu-cubic	in-inch	mi-mile	
F-Fahrenheit	km-kilometer	mm-millimeter	

STANDARD PIPE



STANDARD PIPE

All weights and dimensions are nominal

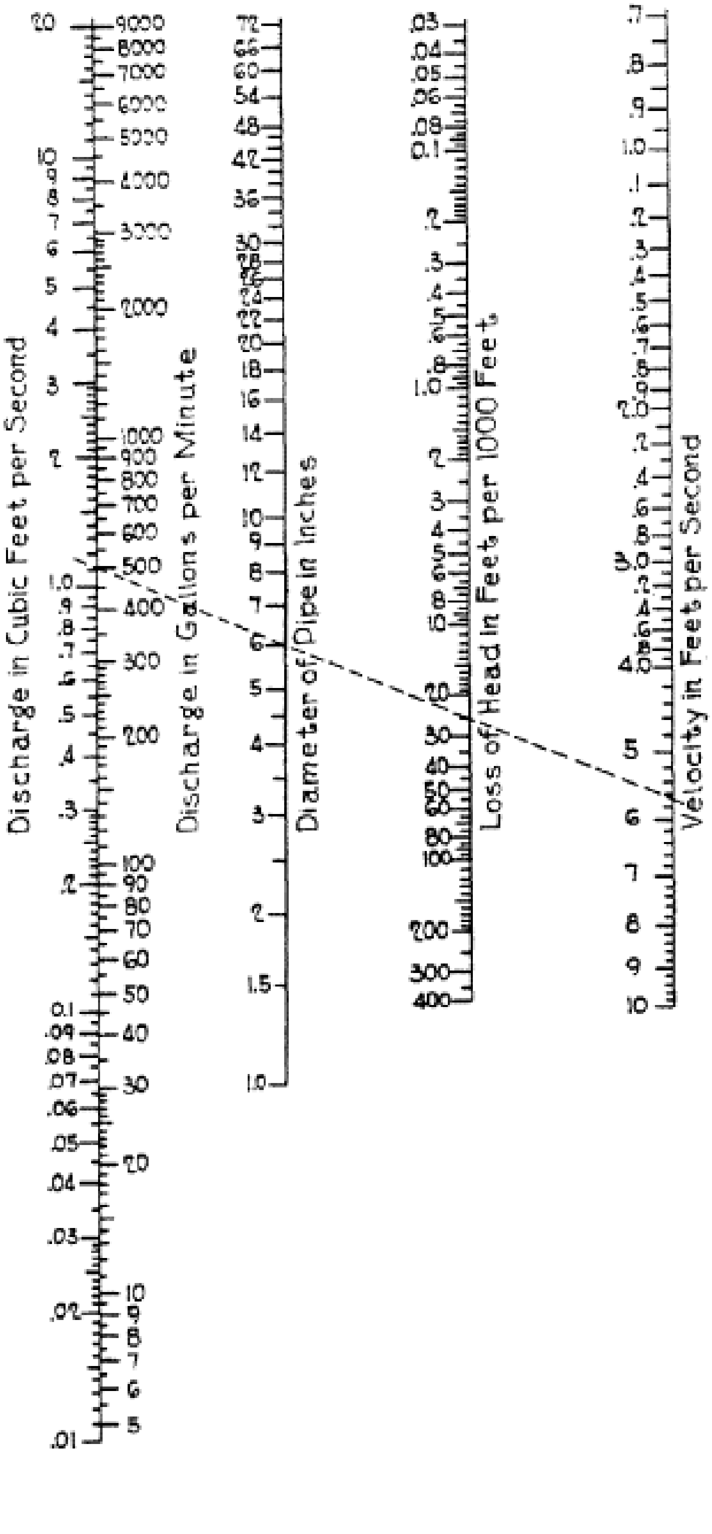
Size	Weight per foot		Pipe			Threads per inch	Couplings			Test pressure		
	Threads and couplings	Plain ends	Thickness	Diameters External	Diameters Internal		Length	External diameter	Weight	Butt-welded	Lap-welded	Seamless
Ins.	Lbs.	Lbs.	Ins.	Ins.	Ins.		Ins.	Ins.	Lbs.	Lbs. per sq. in.		
1/8	.24	.24	.068	.405	.269	27	13/16	.563	.03	700	....	1000
1/4	.42	.42	.088	.540	.364	18	1 3/16	.719	.07	700	....	1000
3/8	.57	.57	.091	.675	.493	18	1 3/16	.875	.09	700	....	1000
1/2	.85	.85	.109	.840	.622	14	1 9/16	1.063	.17	700	....	1000
3/4	1.13	1.13	.113	1.050	.824	14	1 5/8	1.313	.24	700	....	1000
1	1.68	1.68	.133	1.315	1.049	11 1/2	2	1.576	.38	700	....	1000
1 1/4	2.28	2.27	.140	1.660	1.380	11 1/2	2 1/16	1.900	.44	700	....	2500
1 1/2	2.73	2.72	.145	1.900	1.610	11 1/2	2 1/16	2.200	.60	700	....	2300
2	3.67	3.65	.154	2.375	2.067	11 1/2	2 1/8	2.750	.93	700	1000	1900
2 1/2	5.81	5.79	.203	2.875	2.469	8	3 1/8	3.250	1.82	800	1000	2100
3	7.61	7.58	.216	3.500	3.068	8	3 1/4	4.000	2.98	800	1000	1900
3 1/2	9.20	9.11	.226	4.000	3.548	8	3 3/8	4.625	4.20	...	1000	1700
4	10.88	10.79	.237	4.500	4.026	8	3 1/2	5.000	4.51	...	1000	1600
5	14.81	14.62	.258	5.563	5.047	8	3 3/4	6.296	8.25	...	1000	1500
6	19.18	18.97	.280	6.625	6.065	8	4	7.390	10.88	...	1000	1500
8	25.00	24.70	.277	8.625	8.071	8	5 1/4	9.625	23.46	...	800	1000
8	28.80	28.55	.322	8.625	7.981	8	5 1/4	9.625	23.46	...	1000	1200
10	32.00	31.20	.279	10.750	10.192	8	5 3/4	11.750	32.02	...	600	800
10	35.00	34.24	.307	10.750	10.136	8	5 3/4	11.750	32.02	...	800	900
10	41.13	40.48	.365	10.750	10.020	8	5 3/4	11.750	32.02	...	900	1000
12	45.00	43.77	.330	12.750	12.090	8	6 1/8	14.000	49.92	...	600	800
12	50.70	49.56	.375	12.750	12.000	8	6 1/8	14.000	49.92	...	800	900

The permissible variation in weight is 5 per cent above and 5 per cent below.

DIAGRAM FOR CALCULATING PIPE SIZES, DISCHARGE VELOCITIES AND LOSS OF HEAD IN STANDARD STEEL PIPE

PIPE FRICTION LOSS CHART

(For Cast Iron and Concrete Pipes See Note at Right)



Lay a straightedge on scales at the points for any two known quantities and the unknown quantities will lie at aitersection of the straightedge with the other scales.

Example: To discharge 500 gals. per minute through 6.000” pipe, following dotted line would show loss of head in a thousand feet of approximately 25 feet head and velocity of 5.7 feet per second.

Note: Loss of head in Cast Iron Pipe — loss of head in steel pipe multiplied by 1.5. Loss of head in Concrete Pipe loss of head in steel pipe multiplied by 2. When pipe is somewhat rough, add 10% to loss of head; when very rough add 25%.

FRICTION OF WATER IN SMALL PIPES

Loss of Head in Feet due to Friction
Per 100 Feet of Smooth Straight Pipe.

gpm	0.500 Inch Pipe	0.750 Inch Pipe	1.000 Inch Pipe
2	7.57	1.93	0.595
3	16.0	4.08	1.26
4	27.3	6.94	2.14
5	41.2	10.5	3.24

RESISTANCE OF VALVES AND FITTINGS TO FLOW OF FLUIDS

A simple way to account for the resistance offered to flow by valves and fittings is to add to the length of pipe in the line a length which will give a pressure drop equal to that which occurs in the valves and fittings in the line.

Example: The dotted line shows that the resistance of a 6-inch Standard Elbow is equivalent to approximately 16 feet of 6-inch Standard Steel Pipe.

Note: For sudden enlargements or sudden contractions, use the smaller diameter on the nominal pipe size scale.