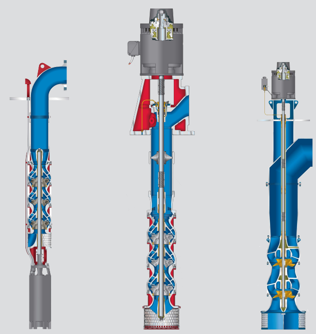
AMERICAN-MARSH PUMPS

*A WILO BRAND*



# 480 Series Vertical Turbine
# Open & Enclosed Lineshaft, Submersible, Axial & Mixed Flow Pumps

**Engineering Information**

# VERTICAL TURBINE PUMPS

## TURBINE TERMINOLOGY

ENGINEERING DATA

1. DATUM OR GRADE - The elevation of the surface from which the pump is supported.

2. STATIC WATER LEVEL - The vertical distance from grade to the water level when no water is being drawn from the well.

3. DRAWDOWN - The distance between the static water level and the water level when pumping at required capacity.

4. PUMPING WATER LEVEL - The vertical distance from grade to water level when pumping at required capacity. Pumping water level equals static Water Level plus Drawdown.

5. SETTING - The distance from grade to the top of the pump bowl assembly.

6. FIELD PUMPING HEAD - Lift below discharge plus head above discharge plus friction losses in discharge line. This is the head for which the customer is responsible and does not include any losses within the pump.

7 COLUMN FRICTION LOSS - Head loss in the pump due to friction in the column assembly. Friction loss is measured in feet and is dependent upon column and shaft size and setting. See Turbine Column Friction Loss Table in catalog.

8. TDH (LAB. HEAD) - Total head which the pump bowl assembly must deliver at the given capacity. TDH equals Field Pumping Head plus Column Friction Loss.

9 LABORATORY EFFICIENCY - The efficiency of the bowl unit only. This value is read directly from the performance curve.

10. LABORATORY HORSEPOWER - The horsepower required by the bowls only to deliver a given capacity against Laboratory Head.

$$\text{LAB. HP} = \frac{\text{Capacity x TDH}}{\text{3960 x Laboratory Efficiency}}$$

11. SHAFT FRICTION LOSS - The horsepower required to turn the lineshaft in the bearings. See Mechanical Friction in Turbine Pump Line Shafts in catalog.

12. FIELD HORSEPOWER OR BRAKE HORSEPOWER - Sum of laboratory horsepower plus shaft loss (and the driver thrust bearing loss under certain conditions.)

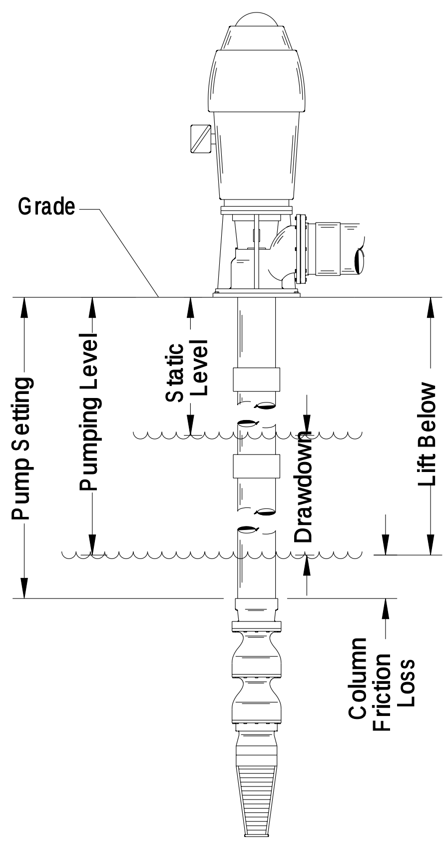
13. PUMP FIELD EFFICIENCY (WATER TO WATER) - The efficiency of the complete pump less the driver, with all losses between laboratory and field performance being taken into account.

$$\text{Field Efficiency} = \frac{\text{Capacity x Field Pumping Head}}{\text{3960 x Brake Horsepower}}$$

14. TOTAL PUMP THRUST - The sum of the weight of the shaft plus hydraulic thrust of the liquid being pumped. See Shaft Stretch Section in Catalog for shaft weight per foot. Performance curves give hydraulic "K" factor. Total thrust equals:

Shaft Wt. Per Foot x Setting in Feet + "K" x TDH

15. OVERALL EFFICIENCY (WIRE TO WATER) - The efficiency of the pump and motor complete. Overall efficiency = Pump Field Efficiency x Motor Efficiency.




NOT TO SCALE

# VERTICAL PUMP SELECTION GUIDE WELL OR SUMP PUMP

## WELL OR SUMP CONDITIONS

Pump application:
Inside diameter of surface casing or sump (in):
Total depth of well or sump (ft.):
Is casing stepped down?: Where? (ft.):
Smaller (in.): casing from (ft.): to (ft.):
Screen set (ft.): to (ft.):
and from (ft.): to (ft.):
Sump water level: Min.: Max.:
Well static water level (ft.):
Well pumping water level (ft.):

## FLUID CONDITIONS

Fluid to be pumped:
Ph value:
Specific Gravity: Temperature (°F):
Viscosity:
Foreign matter in fluid. (Describe):

## PUMPING HYDRAULIC CONDITIONS

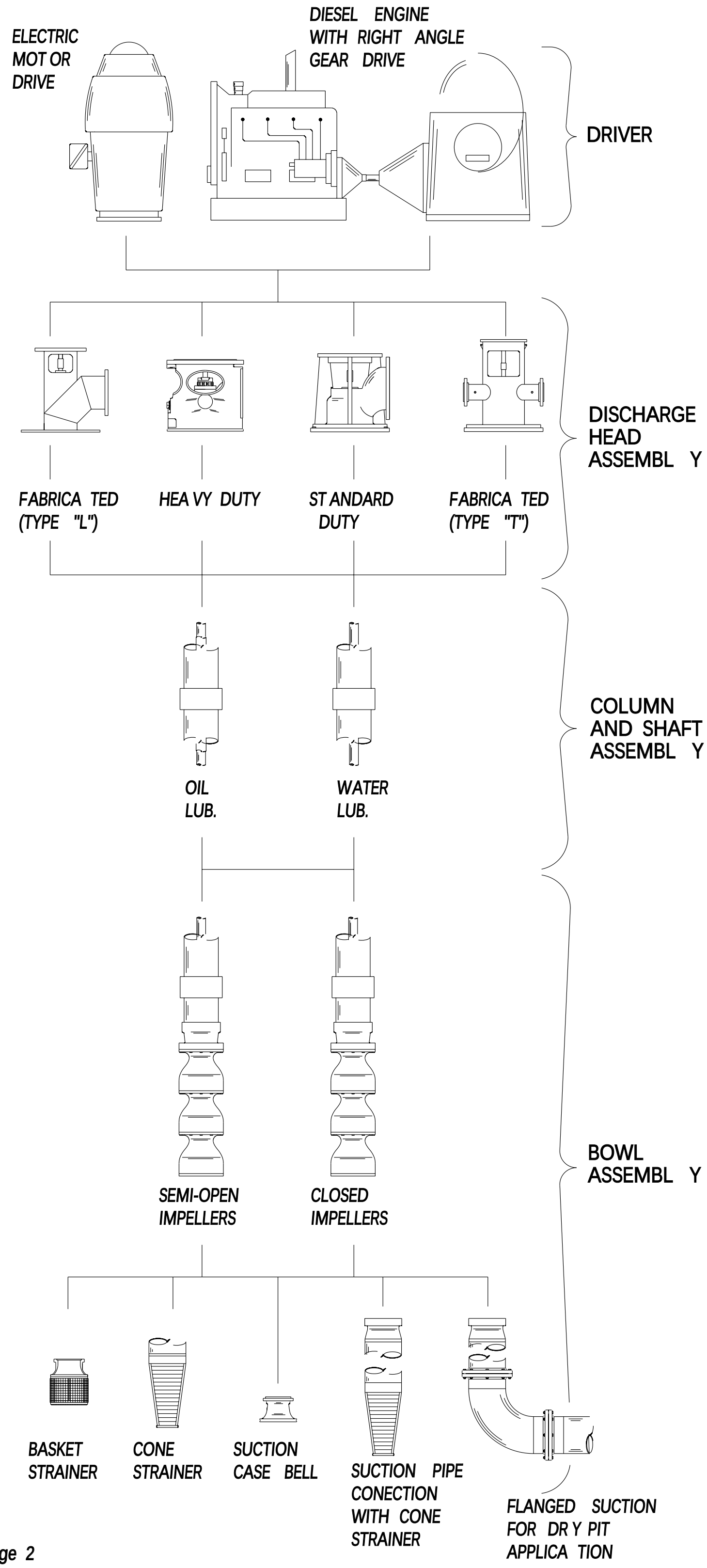
Capacity (USGPM):
Bowl head in feet (TDH):
Bowl setting (column length) (ft.):
Column lubrication required: (oil) or (water) .
Type impellers required: (semi-open) or (enclosed).
Bowl size: No. of stages:
NOTE: Bowl head = elevation difference in feet between pumping liquid level in well or sump and pump discharge connection plus friction losses in column and discharge head plus system head requirements.

## DRIVER

Size: HP: Type: (VHS) (VSS)
Speed of driver (RPM): Ratio (if gear):
Non-reverse ratchet desired:
Current characteristics (ph): (hz): (volts):
Other driver characteristics:

## SUCTION AND DISCHARGE COMPONENTS

Suction pipe size (in.): Length (ft.):
Strainer (type): (material):
Discharge flange size: Column pipe size:
Discharge head connection: (standard) or (special)
(If special, describe fully):
Seal arrangement: Stretch Nipple Kit (oil lube):
Packing Housing Kit (water lube):
Mechanical seal:



# VERTICAL PUMP SELECTION GUIDE CAN PUMP

## BARREL SIZING

Suction pipe size (in): ____________________
Outside diameter of barrel (in): ____________________
Suction type: (Flanged) (Plain end) (Victaulic)
Total length of barrel (ft.): ____________________

## FLUID CONDITIONS

Fluid to be pumped: ____________________
Ph value: ____________________
Specific Gravity: Temperature (°F): __________
Viscosity: ____________________
Foreign matter in fluid. (Describe): ____________________

## PUMPING HYDRAULIC CONDITIONS

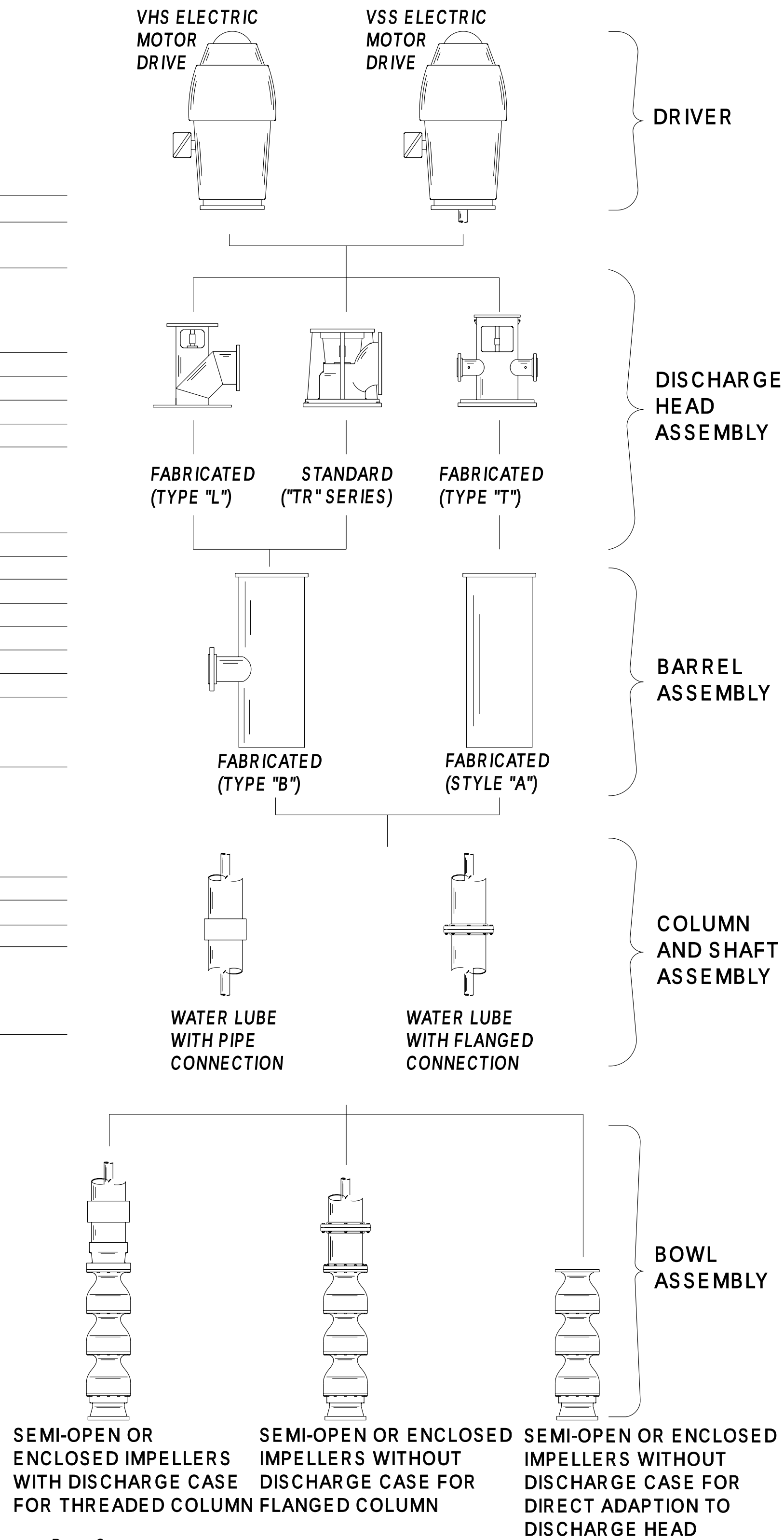
Discharge Pressure (ft.): ____________________
Suction Pressure (ft.): ____________________
Differential Pressure or Head (ft.): ____________________
Capacity (USGPM): ____________________
Pump differential head (ft.): ____________________
Column losses (ft.): ____________________
Suction barrel and discharge head losses (ft.): __________
Bowl head (differential head plus losses) (ft.): __________
Column lubrication: (product).
Type impellers required: (semi-open) or (enclosed) .
Bowl size: ______ No. of Stages: __________

## DRIVER

Size: _____ HP: _____ Type: (VHS) (VSS)
Speed of driver (RPM): Ratio (if gear): __________
Non-reverse ratchet desired: ____________________
Current characteristics (ph): (hz): _____ (volts): _____ __________
Other driver characteristics: ____________________

## SUCTION AND DISCHARGE COMPONENTS

Suction pipe size (in.): ____________________
Suction pipe type: (flanged) (plain end) (victaulic groove)
Discharge flange size (in.): _____ Rating: (150#) (300#)
Seal arrangement: (mechanical seal kit) (Packing Housing Kit)



# VERTICAL PUMP SELECTION GUIDE SUBMERSIBLE PUMP

## WELL OR SUMP CONDITIONS

Inside diameter of surface casing or sump (in.): ____________
Total depth of well or sump (ft.): ____________
Is casing stepped down?: Where? (ft.): ____________
Smaller (in.): casing from (ft.): ____ to (ft.): ____________
Screen set (ft.): to (ft.): ____________
and from (ft.): to (ft.): ____________
Sump water level (ft.): Min.: ________ Max.: ____________
Well static water level (ft.): ____________
Well pumping water level (ft.): ____________

## FLUID CONDITIONS

Fluid to be pumped: ____________
Ph value: ____________
Specific Gravity: Temperature (°F): ____________
Viscosity: ____________
Foreign matter in fluid. (Describe): ____________

## PUMPING HYDRAULIC CONDITIONS

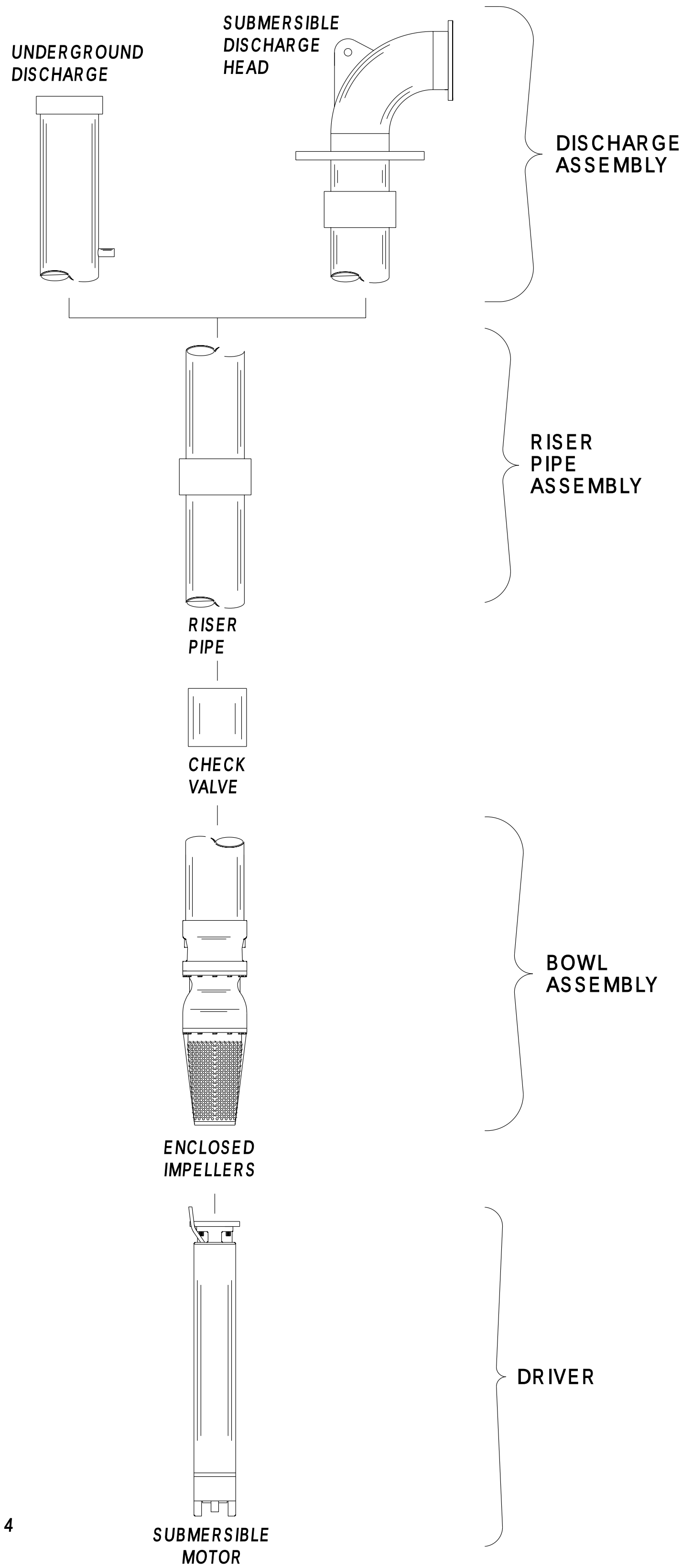
Capacity (USGPM): ____________
Bowl head in feet (TDH): ____________
Bowl setting (column length) (ft.): ____________
Type impellers required: (Enclosed only offered on Submersibles. Contact factory for semi-open impeller application.)
Bowl size: No. of stages: ____________
NOTE: Bowl head = elevation difference in feet between pumping level in well or sump and pump discharge connection plus friction losses in column and discharge head plus system head requirements.)

## DRIVER

Motor Diameter: HP: ____________
Speed of driver (RPM): Full load amps: ____________
Current characteristics (ph/): (hz): (volts): ____________
Min. velocity past motor for cooling (ft/sec): ____________
Other driver characteristics: ____________

## SUCTION AND DISCHARGE COMPONENTS

Discharge flange type: ____________
Riser pipe size: ____________
Column check valve: (yes) (no) Size: ____________
Electrical cable size: __________ Length: ____________



# VERTICAL PUMP SELECTION GUIDE
# LOW LIFT (Mixed Flow/Axial Flow) PUMP

## WELL OR SUMP CONDITIONS

Inside diameter of surface casing or sump (in): ______
Total depth of well or sump (ft.): ______
Sump water level: Min.: Max.: ______

## FLUID CONDITIONS

Fluid to be pumped: ______
If water, is it clear, raw, river, brackish?: ______
Specific Gravity: Temperature (°F): ______
Foreign matter in fluid. (Describe): ______
"Discharge Pressure" or head (ft.): ______

## PUMPING HYDRAULIC CONDITIONS

Capacity (USGPM): ______
Continuous flow: Min.: Max.: ______
Bowl head in feet (TDH): ______
Bowl setting (column length) (ft.): ______
Column lubrication preferred: (oil) or (water) .
Bowl size: Type: (mixed flow) (axial flow)

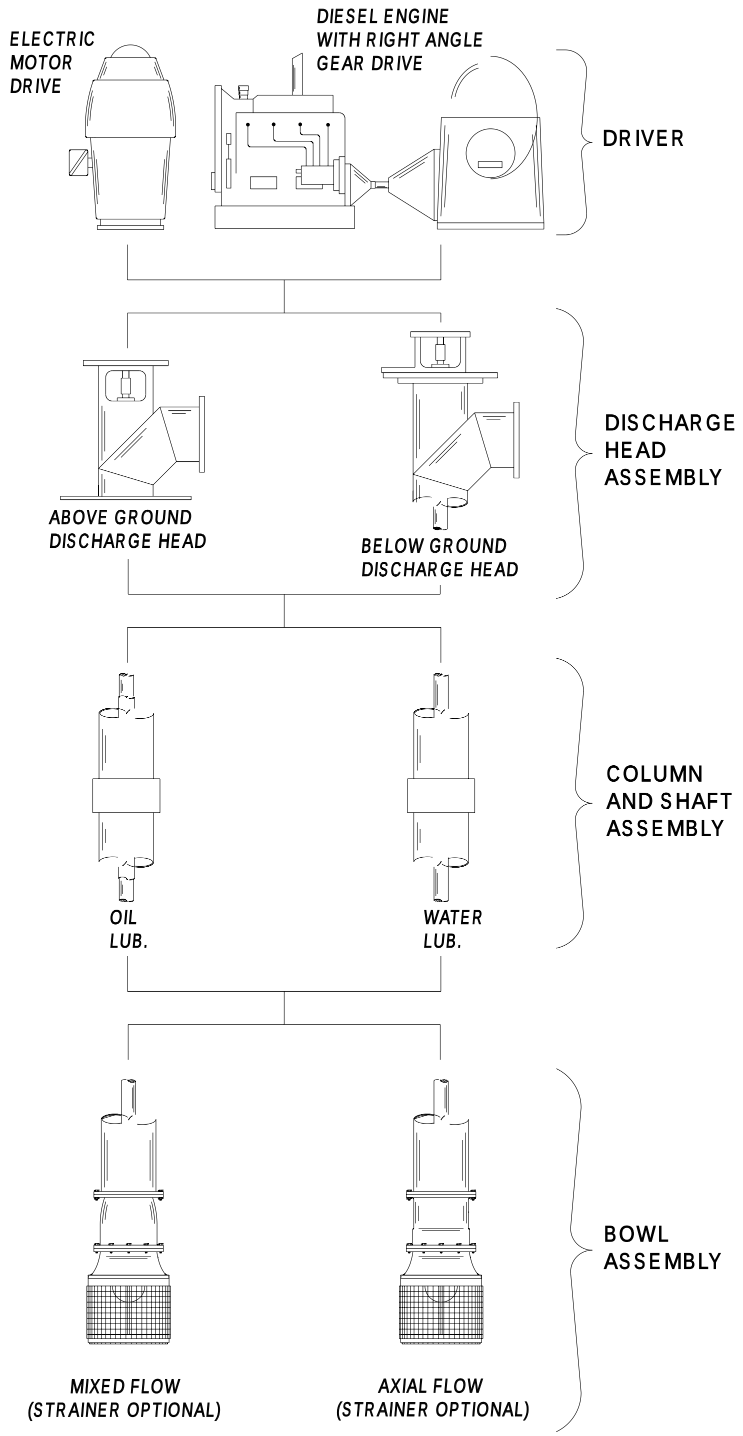
NOTE: Bowl head = elevation difference in feet between pumping liquid level in well or sump and pump discharge connection plus friction losses in column and discharge head plus system head requirements. Velocity head must be added by user to determine system total head.

## DRIVER

Type: ______
Speed of driver (RPM): Ratio (if gear): ______
Non-reverse ratchet desired: ______
Current characteristics (ph): (hz): (volts): ______
Other driver characteristics: ______

## SUCTION AND DISCHARGE COMPONENTS

Strainer (type): (material): ______
Discharge size: ______
Discharge type: (150# flange) (plain end) (victaulic groove)



# INTAKE DESIGN

NOTE:

The following sump design recommendations are based on the Hydraulic Institute Standards 14th Edition 1983. These recommendations are not to be considered exact as there are many design considerations to evaluate in arriving at a properly designed sump which do not appear in this section.

GENERAL

The function of the intake is to supply an evenly distributed flow of water to the pump suction bell or suction case. An uneven flow is characterized by strong local currents, favors the formation of vortices, and under certain submergence conditions will result in the introduction of air into the pump with a resulting loss of pump performance, accompanied by noise, also uneven distribution can increase or decrease the power consumption with a change in total dynamic head. There can be vortices which do not appear on the surface, and these also may have adverse effects.

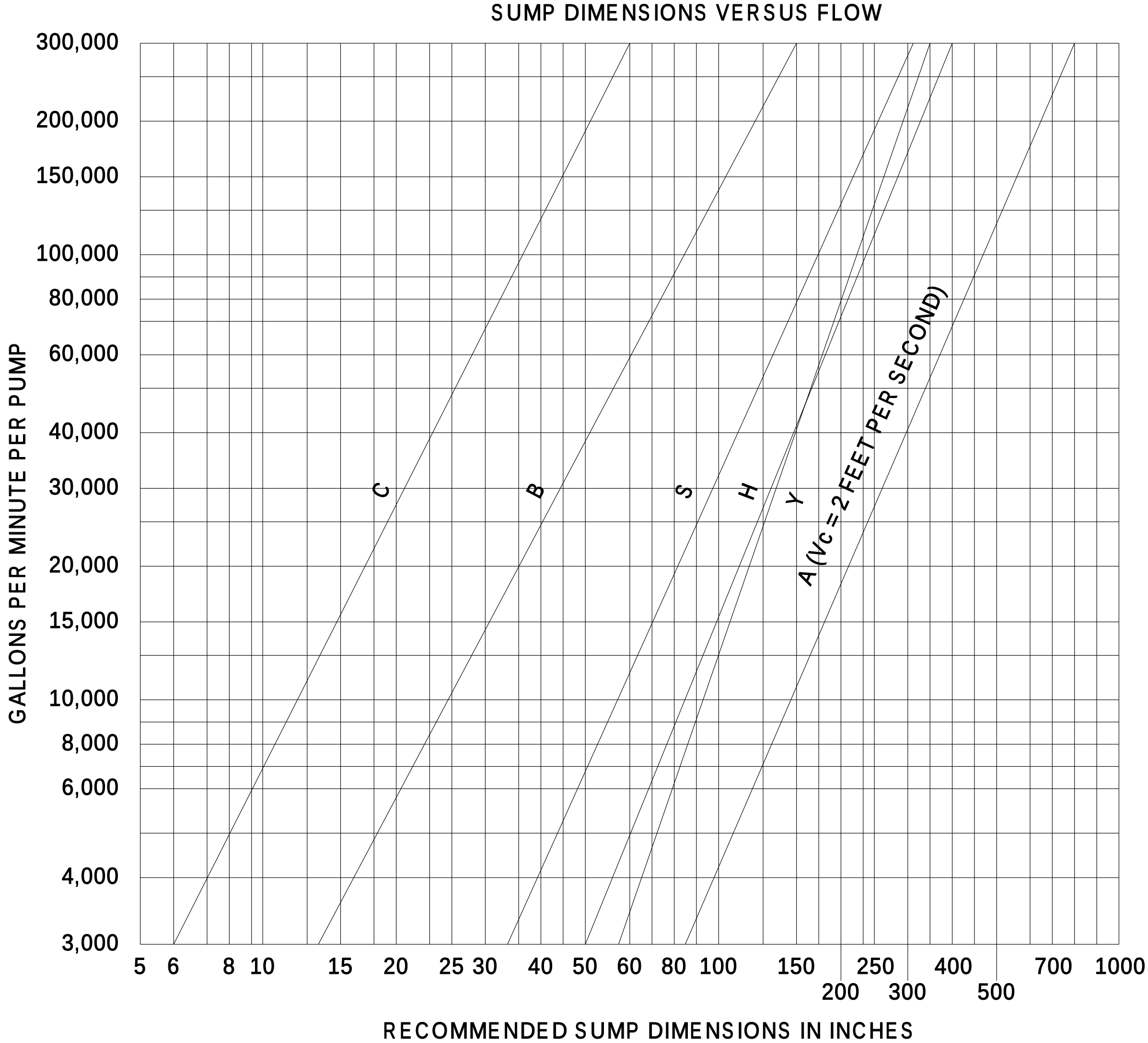
Uneven velocity distribution leads to rotation of portions of the mass of water about a centerline called vortex motion. This centerline may also be moving. Uneven distribution of flow is caused by the geometry of the intake and the manner in which water is introduced into the intake from the primary source.

Calculated low average velocity is not always a proper basis for judging the excellence of an intake. High local velocities in currents and in swirls may be present in intakes which have very low average velocity. Indeed, the uneven distribution which they represent occurs less in a higher velocity flow with sufficient turbulence to discourage the gradual built-up of a larger and larger vortex in any region. Numerous small surface eddies may be present without causing any trouble.

The ideal intake design is a direct channel going directly to the pump. Any turn or obstructions are detrimental since they may cause eddy currents and tend to initiate deep-cored vortices.

Water should not flow past one pump to reach another. If pumps must be placed in line of flow, it may be necessary to construct an open front cell around each pump or to put turning vanes under the pump to deflect the water upward. Streamlining should be used to reduce the trail of alternating vortices in the wake of the pump or of other obstructions in the stream flow.

FIGURE 1 SUMP DIMENSIONS VERSUS FLOW



# INTAKE DESIGN

The amount of submergence for a successful operation will depend greatly on the approaches to the intake and the size of the pump. While specific design is generally beyond the scope of the pump manufacture's responsibility, he may comment while the intake layout is still preliminary if he is provided with the necessary intake drawings reflecting the physical limitations of the site.

SUMP DIMENSIONS

Figures 1, 2 & 3 provide general sump dimension information for single and simple multiple pump arrangements. These guidelines cover pumps in the 3,000 to 300,000 GPM range. Additional information for smaller capacity pumps can be found at the end of this discussion. All of the dimensions in Figures 1, 2 & 3 are based on the rated capacity of the pump at design head. If the pump is to operate for significant periods at a higher capacity, the higher capacity should be used as the basis for determining dimensions.

Dimension C (distance from lip of suction bell to sump floor) is an average value based on the analysis of many pumps. The manufacturer should be consulted prior to determining a final value

Dimension B (distance between pump centerline and back wall) is a suggested maximum dimension. If the position of the back wall is dictated by other factors, it may be necessary to install a "false" wall for proper intake design.

Dimension S (minimum sump width for a single pump) can be increased, but if it is to be made smaller the manufacturer should be consulted or a model constructed to determine the adequacy of the design.

Dimension H (normal low water level) takes into account friction losses through the inlet screen and approach channel. The pump should be operated only momentarily or infrequently when the sump water level falls below this level.

NOTE: Minimum submergence (provided with bowl performance data) is normally specified as "Dimension H minus Dimension C".

Dimensions Y and A are recommended minimum values. These dimensions can be as large as desired but should be restricted to the limitations indicated on the curve. If the design does not include a screen, dimension A should be considerably longer. The screen or gate widths should not be substantially less than S, and heights should not be less than H. If the main stream velocity is more than two feet per second, it may be necessary to construct straightening vanes in the approach channel, increase dimension A, conduct a sump model test of the installation, or work out some combination of these factors.

On multiple pump installations the information presented in Figures 1, 2 & 3 applies, with the addition of the following factors:

Figure 4 (low velocity and straight line flow to all units) represents the recommended style of pit for multiple pump installations. Velocities in the pump area should approximate one foot per second, although with careful design velocities of two feet per second or higher may produce satisfactory results. Not recommended would be any design feature that would introduce eddying (such as an abrupt change in size of inlet pipe to sump or inlet on one side.)

FIGURE 2 SUMP DIMENSIONS VERSUS FLOW

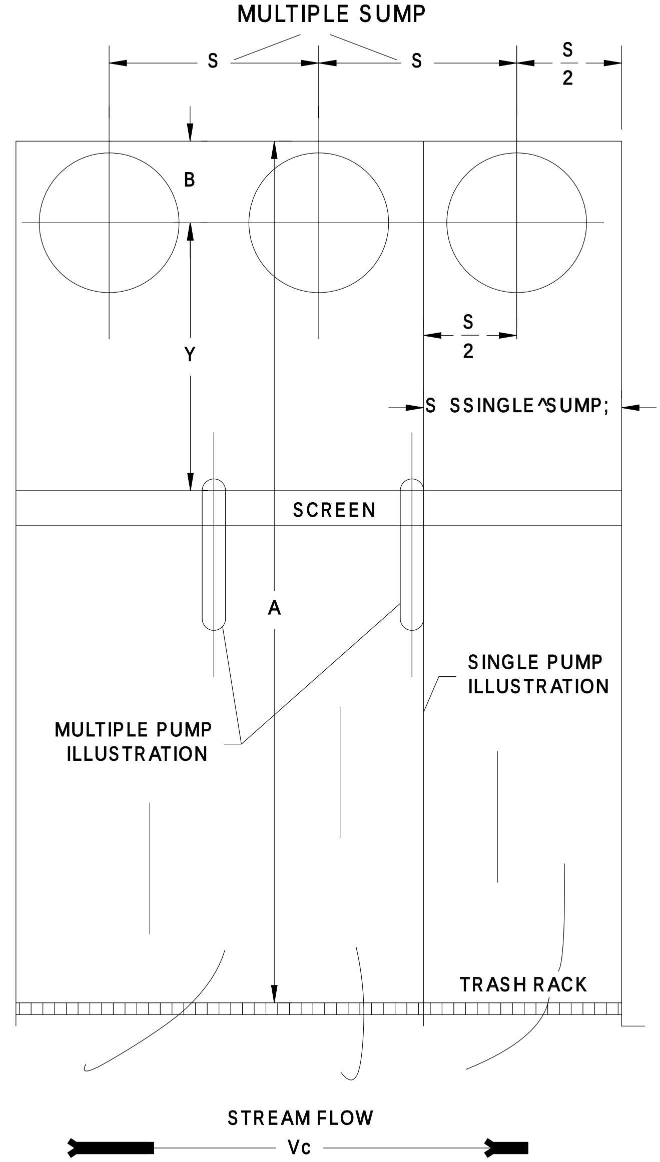
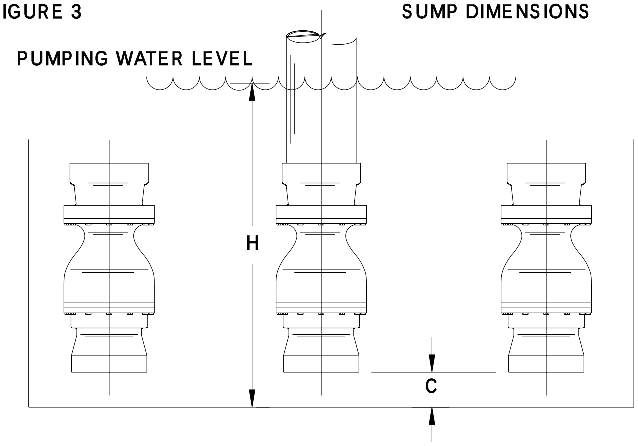
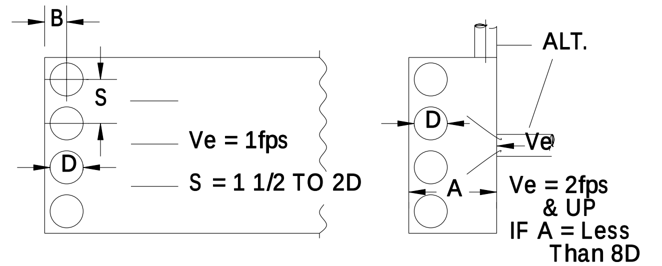



FIGURE 3 SUMP DIMENSIONS



# INTAKE DESIGN

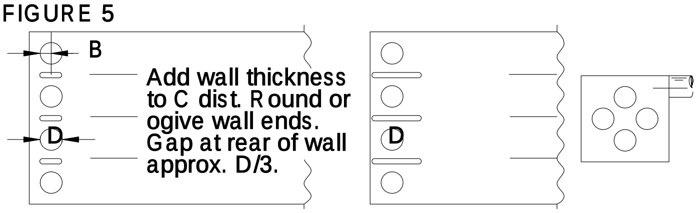
FIGURE 4




RECOMMENDED NOT RECOMMENDED

Figure 5 (multiple pumps in same sump) indicates best operation without separating walls. If all pumps are in operation at the same time, the use of separating walls will improve operation. If walls are to be used for structural purposes, and pumps will operate intermittently, flow space should be left behind each wall from the pit floor up to at least the minimum water level. The wall should not extend upstream beyond the rim of the suction bell. Pumps should NOT be placed around the edge of a sump either with or without dividing walls.

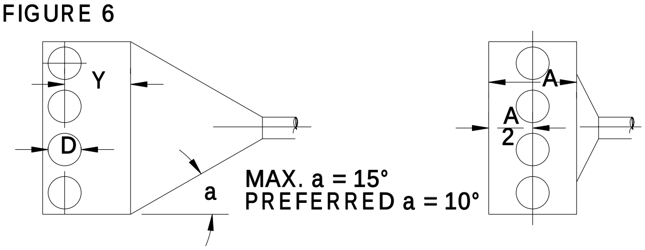
FIGURE 5




RECOMMENDED NOT RECOMMENDED

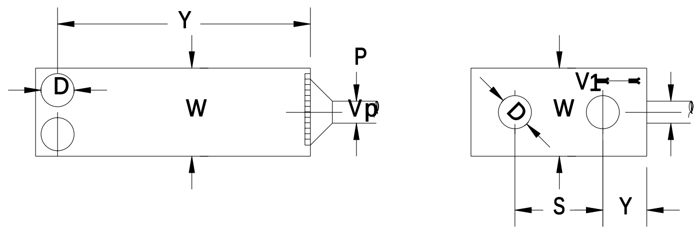
Figure 6 correctly shows a small pipe emptying into a large pump pit with a gradually increasing taper section. Abrupt changes in size are not desirable. The angle should be as large as possible, preferably not less than 45 degrees. Pit velocities should be kept at less than one foot per second.

FIGURE 6




RECOMMENDED NOT RECOMMENDED

Figure 7 demonstrates how an abrupt change from inlet pipe to pit con be accommodated. Pit velocities must be kept below one foot per second and the length must equal or exceed the values shown. As ratio W/P increases, the inlet velocity at P may be increased up to an allowed maximum of eight feet per second at W/P = 10. In line pumps are not recommended unless the ratio of pit to pump size is quite large, and pumps are separated by a generous margin longitudinally.




Baffles, grating or strainer should be introduced across inlet channel at beginning of maximum width section.

| W/P | 1.0 | 1.5 | 2.5 | 4.0 | 10.0 |
|---|---|---|---|---|---|
| Y | 3D | 5D | 8D | 10D | 15D |
| Vp | 1 | 2 | 4 | 6 | 8 |

RECOMMENDED

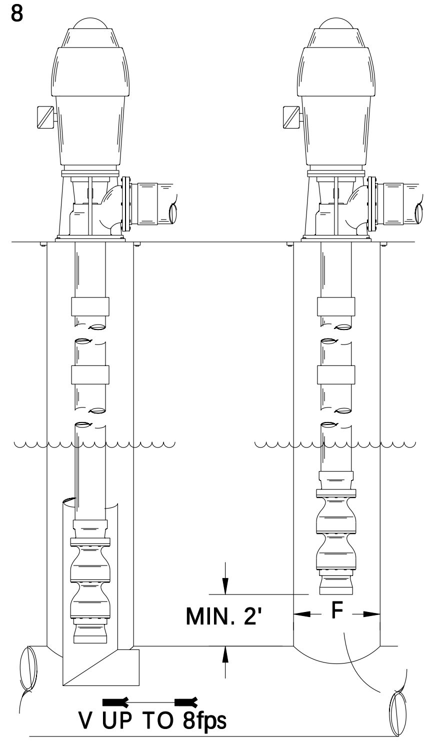
NOT Recommended Unless:

W = 5D or more, or
V1= 0.2fps or less AND
Y = Same as chart to left
S = is greater than 4D

NOT RECOMMENDED

Figure 8 illustrates installation in a tunnel or pipe line. The intake design must incorporate an inlet "ell" (suitable for flows up to 8 feet per second) or suction bell with the pump located at least two pipe diameters above the top of the tunnel. The tunnel must be free of air or it may be necessary to lower the scoop.

FIGURE 8




RECOMMENDED

NOTES:
1. The dimension D is generally the diameter of the suction bell measured at the inlet. This dimension may vary depending upon pump design. Contact factory for specific dimensions.
2. Figures apply to sumps for clear liquid. Contact factory for fluid/solids mixtures.

# INTAKE DESIGN

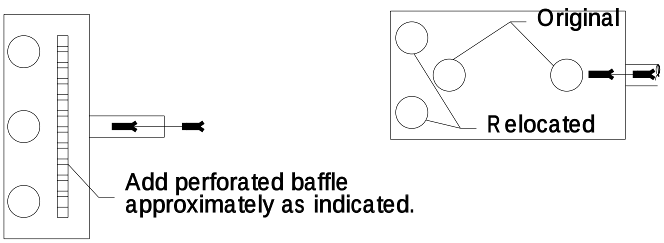
CORRECTION OF EXISTING SUMPS

Vortexing in pump suction pits is harmful to pit structures and the pumps themselves. While it is possible to eliminate sump problems in the design phases, it is much more difficult and often expensive to solve problems in existing sumps or modified sumps Sump model tests are recommended to test the effectiveness of proposed changes before construction begins. Figures 9 through 19 illustrate typical sump problems with possible solutions.

In Figure 9 the inlet velocity should be reduced by spreading the inflow over a larger area or by adding baffling to change its direction and speed. The baffles may be floor mounted extending above the minimum water level or ceiling mounted extending close to the floor.

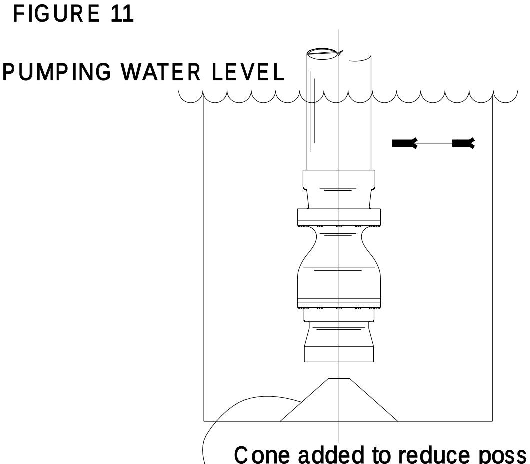
In Figure 10 the location of the pumps should be changed in relation to the direction of inflow.

FIGURE 9




In Figure 11 a cone is added to reduce the possibility of submerged vortex formation.

FIGURE 11




In Figures 12 and 13 the "noflow" bays are modified by either breaking them open at the back and rounding the edges (Figure 12) or by removing them altogether (figure 13).

FIGURE 12

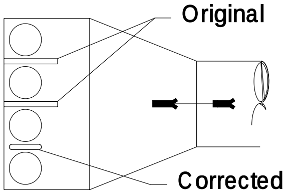
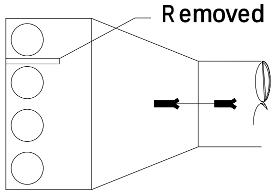



FIGURE 13




In Figure 14 sharp corners at gates, screens, etc., are eliminated to allow a smooth flow.

In Figure 15 velocity and vortexing is reduced by adding a bell extension suction plate and splitter to the suction bell. The splitter is attached in line with the flow.

FIGURE 14

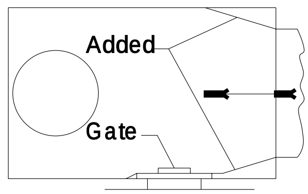
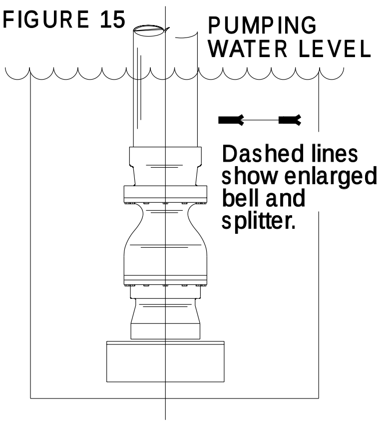



FIGURE 15

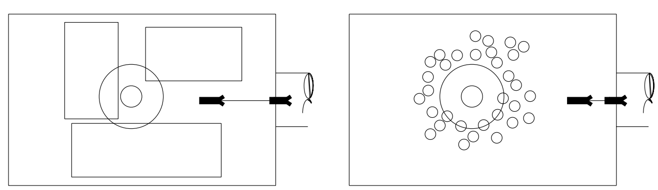



Splitter must be in-line with flow to prevent submerged vortexing.

Figure 16 shows the use of floating rafts around the pump column to prevent surface vortices.

Figure 17 shows the use of floating large spheres to prevent surface vortices.

FIGURE 16



Floating rafts are used around the pump column to prevent vortexing.

Large spheres are used to prevent surface vortexes.

In Figure 18 the clearance between the back wall and the pump was reduced to improve the velocity pattern to the pump and to reduce the possibility of vortex formation.

In Figure 19 the direction of inlet flow was changed gradually by means of parallel turning vanes.

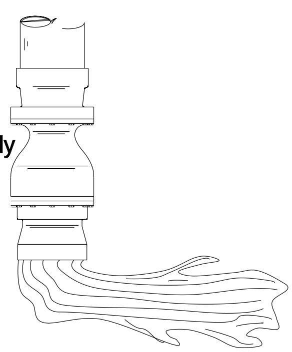
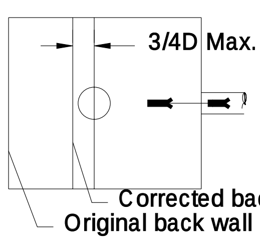
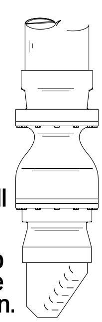


FIGURE 18




The velocity pattern to the pump can often be improved to reduce the possibility of vortex formation.

FIGURE 19



# MAXIMUM BEARING SPACING ON OPEN LINESHAFT PUMPS

| SPEED (rpm) | | SHAFT DIAMETER (INCHES) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 3/4 | 1 | 1 3/16 | 1 1/2 | 1 11/16 | 1 15/16 | 2 3/16 |
| 880 | R | | | 120 | 120 | 120 | 120 | 120 |
| | SB | | | 60 | 84 | 90 | 96 | 100 |
| 1200 | R | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| | SB | 60 | 60 | 60 | 72 | 78 | 84 | 88 |
| 1460 | R | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| | SB | 42 | 48 | 54 | 66 | 66 | 72 | 76 |
| 1760 | R | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| | SB | 42 | 48 | 48 | 60 | 60 | 66 | 70 |
| 2900 | R | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| | SB | 30 | 36 | 36 | 42 | 48 | 48 | 52 |
| 3600 | R | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| | SB | 30 | 30 | 36 | 36 | 42 | 48 | 48 |

Note: R - Standard Rubber Bearing
SB - Solid Bearing (brass, carbon, graphite, teflon, etc.)

The above chart is to aid in the selection of lineshaft bearing spacing for pump column on vertical turbine pumps.

These recommendations are based on manufacture standards and first critical frequency shaft calculation.

Solid type bearings tend to have a slight running noise.

# SUCTION BARREL SELECTION

Recommended capacity for a suction barrel can be determined by calculation of the fluid velocity. Recommended flow past the largest portion of the pump should not exceed 5 ft/sec. (V.)

TO CALCULATE:

$$V = \frac{GPM \times Q}{(D_1)^2 - (d_2)^2}$$

where: GPM - amount of flow required
Q - constant 0.4085 (cubic feet per sec)
$D_1$ - I.D. of barrel in inches
$d_2$ - O.D. of bowl in inches

EXAMPLE:

12 3/4" steel suction barrel with a wall thickness of 0.375 would have an I.D. of 12"

10MC bowl with an O.D. of 9 1/2"

Flow design of 500 GPM

TO CALCULATE:

$$V = \frac{GPM \times Q}{(D_1)^2 - (d_2)^2}$$

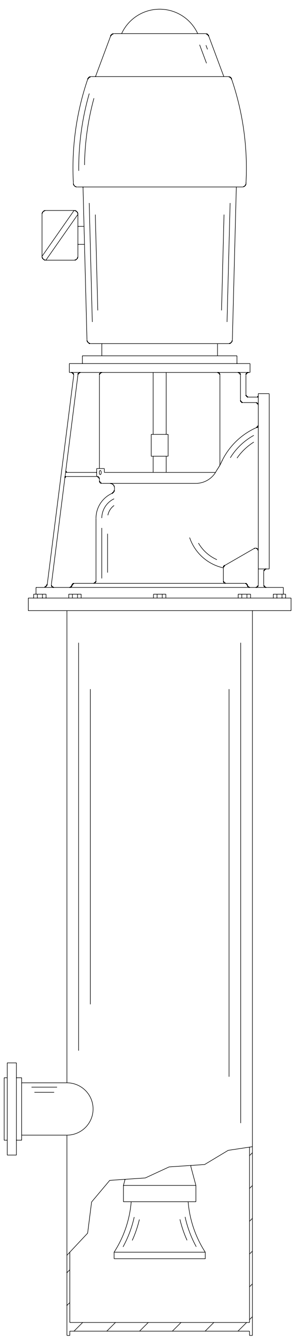
$$V = \frac{500 \times 0.4085}{(12)^2 - (9\ 1/2)^2} =$$

$$\frac{500 \times 0.4085}{144 - 90.25} =$$

$$\frac{204.25}{53.75} = 3.8 \text{ ft/sec.}$$

This indicates that this bowl will work in this size barrel.

1. NPSH should always be considered when placing any pump into a suction can.
2. The pump suction should be located (2) barrel diameters below barrel inlet or (2) suction diameters above the barrel inlet, never allow the suction inlet of the pump to be set in the area of the suction barrel inlet.
3. Suction inlet size should have an inlet velocity of equal to or less than 5 ft/sec.
4. If the suction of the barrel is below the suction inlet of the pump, the fluid velocity can be disregarded in barrel selections.
5. If there is sufficient NPSH and efficiency is not important, it is permissible to exceed 5 ft/sec. - the maximum recommended ever would be 9 ft/sec.



# A SIMPLE METHOD OF SURVEYING A DEEP WELL

FIGURE NO. 1 FIGURE NO. 2

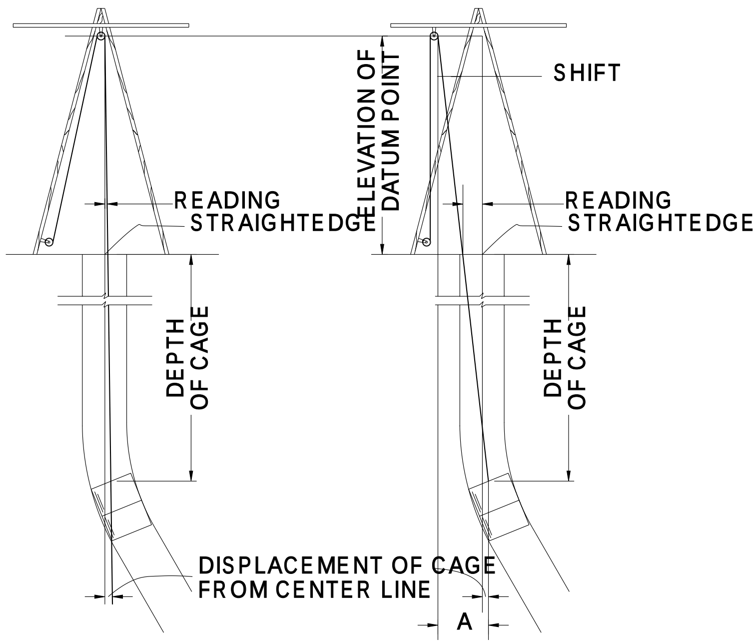



FIGURE NO. 3

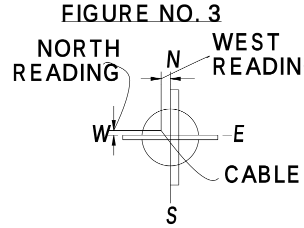
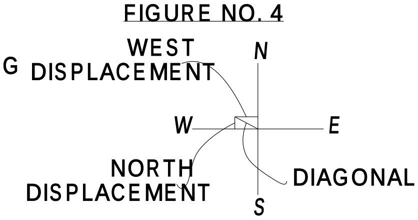



FIGURE NO. 4




(1) PURPOSE OF SURVEYING A WELL - It is advantageous to know whether or not a pump will fit in a well and operate normally. Since the pump column can be curved, within limits, without being detrimental to pump operation, a well is surveyed to find out in what directions and how sharply it curves throughout its length.

(2) EQUIPMENT NECESSARY - The equipment to be used is listed below.

(a) A reel of small steel cable long enough to reach to the desired depth.

(b) A cage about two feet long with a diameter about 1/4" smaller than the I.D. of the well casing.

(c) A small pulley for the steel cable, having a frame which can be bolted to a board.

(3) EQUIPMENT SET-UP - Attach the pulley to a board thick enough to carry the weight of the cage and line without bending. Support the board horizontally at least ten feet above the top of the well casing. The board and supports should be arranged so that the location of the pulley can be shifted at least two feet in any horizontal direction by sliding the board. A derrick is the most convenient support, but if there is no derrick a tripod or other structure must be constructed.

Run the cable through the pulley and attach the end to the center of the cage. Hang the cage slightly above the well casing and move the pulley until the axis of the cage is in line with the center of the well.

Next, establish with a straightedge four marks on the well casing or floor which can be used to determine two horizontal lines at right angles to each other, passing as near to the center of the well as the cable will permit without the cable being deflected from its center position. To simplify the procedure, one of these lines should be parallel to the board carrying the pulley. Usually the lines are laid off as North-South and East-West lines.

(4) CAGE POSITION READINGS - Lower the cage ten feet at a time and measure deflections in the North, South, East or West directions from the center, as shown in Figure No. 3, at each ten-foot interval. The vertical distance of the center of the pulley above the level of the place where deflection measurements are made must also be measured. The center of the pulley is called the datum point.

Figure No. 1 shows an elevation of a well with a cage in the well, and Figure No. 3 shows a plan view of the top of the well with a straightedge in its two positions. In making the measurements indicated, it must be remembered that the straightedge was located by the side of the cable instead of the center. Since the cable was in the center of the well, the straightedge does not lie exactly on a diameter and deflections must always be measured on the same sides of the cable that determined the North-South and East-West lines.

(5) SHIFTING THE DATUM POINT - The cable must not be touching the side of the well casing when readings are taken. By refering to Figure No. 1 it is evident that if the well is crooked the cable can touch the well casing when the cage is lowered past a bend or spiral. When the cable touches the casing, any readings beyond this point are valueless. It is necessary to shift the datum point so that the cable will not touch the casing. If the crook is above the water level, this condition can be observed. If it is below the water level, it may be suspected if the location of the cable remains constant as the cage is lowered. It occasionally happens, however, that the well is actually slanting or curving so that it will give a constant reading for a while and, since shifting the pulley is apt to introduce errors unless great care is used, it is best to be sure that the cable is touching before any shifts are made. If the well is so crooked that the cable touches at a second point after being shifted, it is impossible to survey it beyond this point by using this method.

If the data is worked up and plotted, it is possible to see whether or not any of the above difficulties are present. Usually, a shift in one direction will be sufficient, but sometimes it is necessary to shift in the other direction also. The pulley should be shifted as far as the surveyor deems necessary and for every shift it is important that the position (vertically and in both directions horizontally) of the datum point be accurately determined. Figure No. 2 shows a well being surveyed with the datum point shifted.

(6) PLOTTING THE CAGE POSITIONS - After the data has been calculated it should be plotted on graph paper. The deflections for the true view are determined graphically by drawing the diagonals of parallelograms produced by plotting the displacement readings as shown in Figure No. 4. Cross-section paper with one-inch squares, divided into ten smaller squares to the inch, is convenient for laying out the well. If the depth is laid out with ten feet to the inch and the cage displacement with ten inches to the inch, it usually results in a satisfactory representation of the well. The horizontal scale should be large enough to show the defects in the well clearly, but at the same time it must be

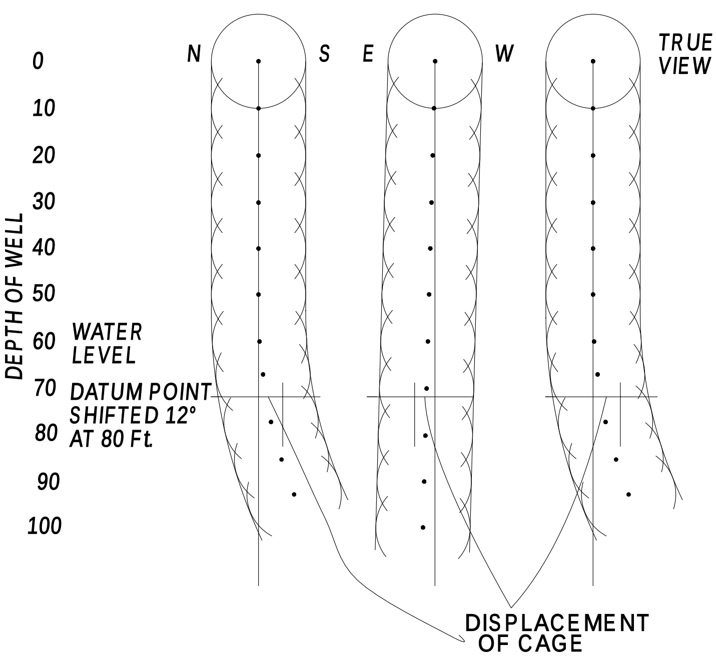
# SAMPLE DATA, CALCULATIONS AND PLOT 18" WELL

recognized that unless the well diameter is plotted to exactly the same scale as the side deflection, the well plot will be misleading and of practically no value.

On the plot a straightedge can be used to represent the cable and to indicate whether or not the cable was touching the casing at any point.

If it is determined from the plot that the cable probably did not touch the well casing at any of the readings, during the survey, it is an indication that the readings were accurate. In order to determine what size of column pipe and bowl diameter can be safely operated in the well, construct from cardboard a cross-section of the column and bowl unit to the same scale as used in plotting the survey. If the model of column and bowl unit can be placed in the well without binding on the well casing, when inserted on the plot of the true view of the survey, it is a good indication that the actual pump will do likewise.

CENTER LINES INDICATE CENTER OF THE WELL AT ITS SURFACE




Elevation of datum point 20 ft. Water level 60 ft.
Datum point shifted 12" North at 80 ft.

| *Depth Cage Feet* | *Readings of Deflections of Cable Inches* N | S | E | W | *Displacement of Cage Inches* N | S | E | W |
|---|---|---|---|---|---|---|---|---|
| 10 | 0.10 | | | | 0.15 | | | |
| 20 | 0.15 | | 0.10 | | 0.30 | | 0.20 | |
| 30 | 0.20 | | 0.20 | | 0.50 | | 0.50 | |
| 40 | 0.10 | | 0.30 | | 0.30 | | 0.90 | |
| 50 | | | 0.35 | | | | 1.25 | |
| 60 | | 0.50 | 0.37 | | | 0.20 | 1.48 | |
| 70 | | 1.10 | 0.40 | | | 6.75 | 1.80 | |
| 80 | 8.00 | | 0.40 | | | 8.00 | 2.00 | |
| 90 | 7.80 | | 0.42 | | | 11.10 | 2.30 | |
| 100 | 7.50 | | 0.44 | | | 15.00 | 2.64 | |

FORMULA

No. 1 *Displacement of cage from center line =*

$$\frac{\text{Reading x (depth of cage + El. of Datum)}}{\text{El. of Datum}}$$

*Sample Calculation at 10 ft. depth:*

$$\text{Cage displacement} = \frac{0.10 \text{ x } (10 + 20)}{20} = .15"$$

No. 2 *Displacement of cage from center line when datum point is shifted =*

$$\text{*(shift = reading) x } \frac{\text{(Cage Depth + El. of Datum)}}{\text{El. of Datum}} \text{ - shift}$$

**Add the reading to the shift when shift and reading are on opposite sides of center line: Subtract when shift and reading are on same side of center line.*

*Sample Calculation at 80 ft. depth:*

*Cage diplacement =*

$$(12 - 8) \text{ x } \frac{(80 + 20)}{20} - 12 = 8"$$

Since distance A (see Figure No. 2 ) is greater than the shift, it is evident that the cage displacement is south from the center line.

Formula No. 1 is used in all EAST calculations in this case, but if there is a shift in the East-West direction, Formula No. 2 would have to be used in the same manner as for the North-South direction.

# PRELUBRICATION RECOMMENDATION FOR WATER LUBRICATED OPEN SHAFT TURBINE PUMPS

Open line shaft pumps utilize neoprene line shaft bearings which must be kept wet when the unit is operating. After the pump liquid fills the column pipe, the bearings are kept lubricated by this liquid. At start-up and shut-down, however, certain precautions must be taken to provide lubrication to these bearings.

START-UP: Under normal conditions if the static water level is 30 feet of less, prelubrication is not required since the bearings will hold enough moisture to provide initial lubrication. On deeper settings, however, it is necessary that the bearings receive prelubrication as outlined below.

SHUT-DOWN: Non-Reverse Ratchet mechanisms mounted in the driver are recommended on units with settings of 50 feet or more. The Non-Reverse Ratchet prevents reverse rotation due to backflow, thus eliminating post lubrication requirements. If Non-reverse ratchets are not employed, post lubrication must be provided using methods similar to those outlined below.

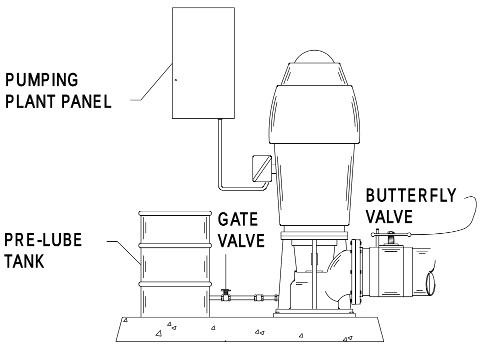



FIGURE 1

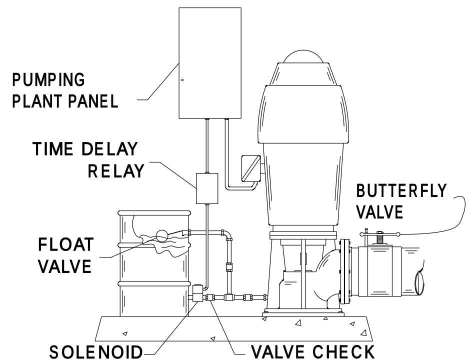



FIGURE 2

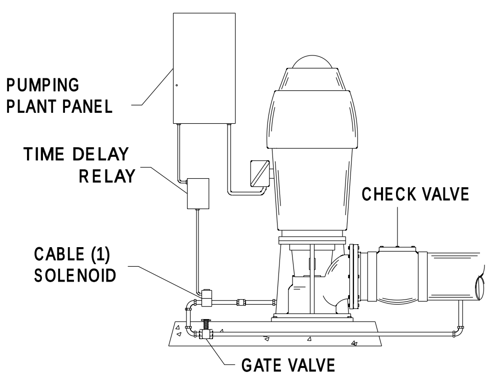



FIGURE 3

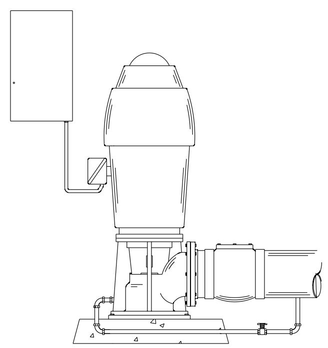


FIGURE 4

SOLENOID VALVE AND FITTINGS

| PRESSURE ON SOLENOID VALVE | OUTER COLUMN SIZE (INCHES) | | |
|---|---|---|---|
| | 5" SMALLER | 6" AND 8" | 10" AND LARGER |
| | SOLENOID VALVE AND FITTING SIZE INCHES | | |
| 1-10 PSI | 1-1/4" | 1-1/2" | 2-1/2" |
| 11-75 PSI | 1" | 1-1/4" | 2" |
| 76-150 PSI | 3/4" | 1" | 1-1/2" |

TIME DELAY RELAY

| STATIC WATER LEVEL (FEET) | TIME DELAY (MINUTES) |
|---|---|
| 0'-30' | 1/2 min. |
| 31'-70' | 1 min. |
| 71'-150' | 1-1/2 min. |
| 151'-250' | 2-1/2 min. |
| 251'-350' | 3-1/2 min. |
| 351'-450' | |

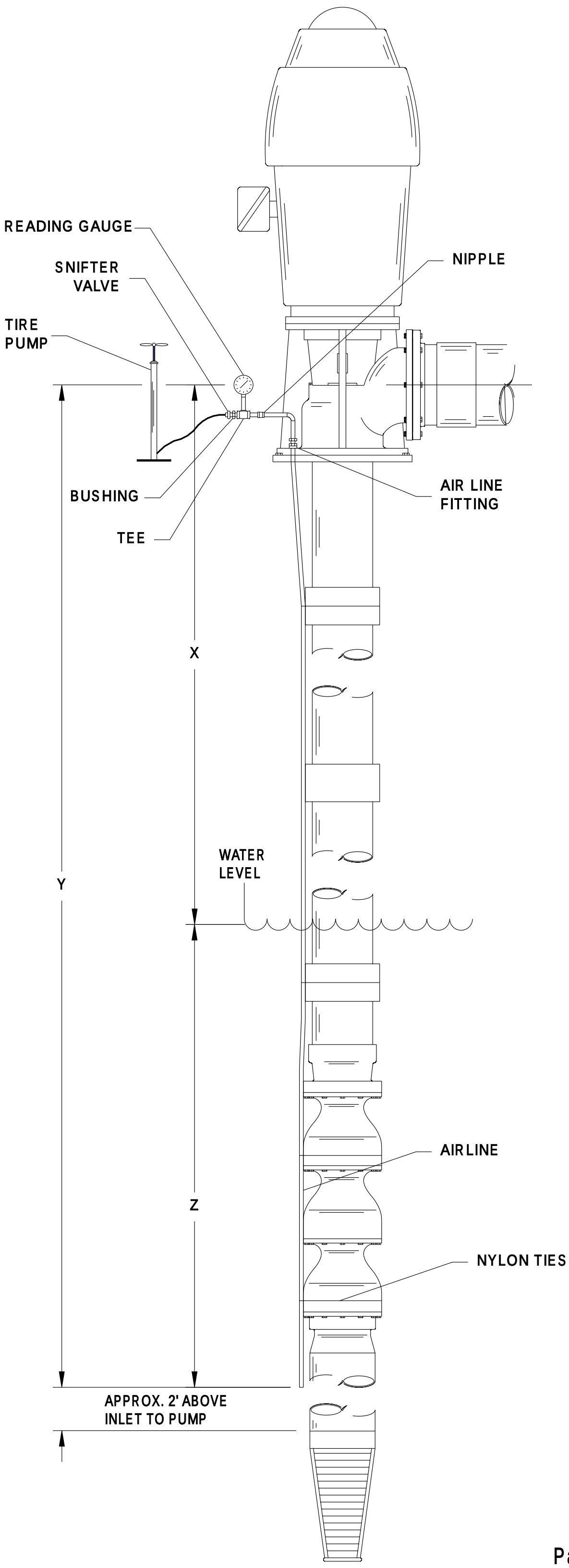
TANK & FITTING SIZES

| OUTER COLUMN SIZE | SIZE | | | | | |
|---|---|---|---|---|---|---|
| | FITTINGS 1" | TANK 50 GAL. | FITTINGS 1-1/2" | TANK 100 GAL. | FITTINGS 2" | TANK 200 GAL. |
| | STATIC WATER LEVEL (FEET) | | | | | |
| 2-1/2" TO 4" | 30'-300' | | 300'-400' | | | |
| 4-1/2" TO 6" | 30'-200' | | 200'-400' | | | |
| 8" TO 10" | 30'-125' | | 125'-300' | | 300'-400' | |
| 12" | 30'-70' | | 70'-200' | | 200'-400' | |
| 14" | 30'-50' | | 50'-150' | | 150'-300' | |

NOTES:
TIME DELAY SETTING BASED ON PROPER SOLENOID SELECTION

0-30 FT. SETTING NO PRE-LUBRICATION REQUIRED.

# WATER LEVEL TESTING




There are two commonly used methods to determine the water level in wells - airline and gauge, or an electric sounder.

AIRLINE METHOD:

The airline method can use a standard pressure gauge, indirect reading depth gauge, or direct reading depth gauge.

INSTALLATION: The airline is installed so that the lower end is approx. 2' from the inlet of the pump - for reliable readings the airline should extend 20' below low water level if possible. All airline joints must be air tight for proper operation. The upper end of the airline is connected to a gauge and snifter valve. Exact vertical length of the airline must be recorded at installation, by noting on the face of the gauge. Use as many nylon ties as necessary to firmly attach the airline to the column and bowl assembly without collapsing the airline.

METHOD OF OPERATION: A tire pump is used to expel all water from the airline, when this point is reached the gauge reading will remain constant. The maximum maintained pressure is equal to the height of water above the end of the airline (DIM Z).

INDIRECT READING DEPTH GAUGE (FIXED DIAL): Pump up airline until maximum pressure (all water is expelled from airline) is reached, reading on gauge will be distance "Z". Water level (below surface) is obtained by subtracting "Z" from "Y" (W.L. = Y - Z).

DIRECT READING DEPTH GAUGE (MOVABLE DIAL): Set the movable gauge dial so that the length of airline (Y) is at the pin stop (gauge pointer position at 0 pressure). Pump airline to maximum pressure, gauge will read water level (Y - Z) direct.

PRESSURE GAUGE: A pressure gauge can be used by converting PSI to feet of water as follows:

Feet of Water = PSI x 2.31

Operation would be identical to indirect reading gauge.

---

ELECTRIC SOUNDER METHOD

The electric sounder consists essentially of a battery, a spool of well insulated waterproof wire and a millivolt meter. One terminal of the battery is connected to the pump head and the other through the potentiometer to one end of the spool of wire. The other end of the wire from the spool must be protected so that it will not close the circuit, if it should bump against the pump in being lowered into the well, but at the same time so arranged that the circuit will be closed when the end of the wire contacts the water in the well. The wire from spool, then, is lowered into the well until; the needle of the potentiometer deflects, indicating that the water level has been reached and the contact closed. The wire is then properly marked, pulled from the well and measured with a steel tape to determine the water level. (It is possible to calibrate the spool of wire so that it is direct reading.)

---

X = Depth to water in feet (this is unknown).
Y = Length of air line in feet (this was measured at installation).
Z = Water pressure on airline, in feet head of water. Standard gauge reads in lb./sq. in. Multiply reading by 2.31 to convert to feet of water. Altitude type gauge reads directly in feet of water.

EXAMPLE:

X = Y - Z
Y = 100 ft.
Z = 15 lb./sq. in.
= 15 x 2.31 = 34.65 ft.

X = ?
X = 100 - 34.65
= 65.35 ft.

*If the effective length of the airline is not known, it may be determined by measuring the actual water level. When the pump is idle by some other method, and comparing it to the maximum reading obtained on the direct reading gauge or adding to the maximum reading of the indirect gauge.

# FORMULA FOR CHANGING PUMP SPEED CHANGES IN PERFORMANCE

Pump curves are generally based on standard motor speeds. For performance of pumps at speeds other than those published, it is necessary to calculate new Capacity, Head, and BHP.

The following "Affinity Laws" are used in speed variation calculations:

1. The capacity of a turbine pump varies in direct proportion to the speed.
2. The head of a turbine pump varies in proportion to the square of the speed.
3. The horsepower varies in proportion to the cube of the speed.

In general, it is good engineering practice not to increase the speed of a turbine pump designed for 1760 RPM to more than 2200 RPM. At higher RPM harmonic or shaft vibration may occur causing excessive wear in the pump.

FORMULAS:

$$Q_2 = Q_1 \frac{N_2}{N_1}$$

$$H_2 = H_1 \left(\frac{N_2}{N_1}\right)^2$$

$$BHP_2 = BHP_1 \left(\frac{N_2}{N_1}\right)^3$$

Q = Quantity in GPM
H = Head in Feet
BHP = Brake Horsepower
$N_1$ = Speed in RPM (published)
$N_2$ = Speed in RPM (required)

NOTE: DO NOT EXCEED MINIMUM TRIM DIAMETER INDICATED ON STANDARD CATALOG CURVE.

## EXAMPLE

An impeller operating at 1760 RPM is rated to deliver 900 GPM at 76 Feet of Head, and requires 20.3 BHP to drive it. What will the effect of changing the speed to 1460 RPM?

| | |
|---|---|
| The direct ratio of speeds will be: | $\frac{1460}{1760}$ = 0.82955 |
| 1460 RPM CAPACITY will be: | 0.82955 x 900 = 746.59 GPM |
| The square of the ratio will be: | 0.82955 x 0.82955 = 0.68815 |
| 1460 RPM HEAD will be; | 0.68815 x 76 = 52.30 Feet of Head |
| The cube of the ratio will be: | 0.82955 x 0.82955 x 0.82955 = 0.57085 |
| 1460 RPM BRAKE HORSEPOWER will be: | 0.57085 x 20.3 = 11.59 BHP |

The efficiency is still another factor to be considered, but is not seriously altered for small changes in speed. If the above pump had an efficiency of 85% at 900 GPM when operating at 1760 RPM, the efficiency would still be approximately 85% at 746.59 GPM when operating at 1460 RPM.

MULTIPLIERS FOR PUMP PERFORMANCE AT VARIOUS SPEEDS USING 1760 RPM AS REFERENCE SPEED

| RPM | GPM | HEAD | HP |
|---|---|---|---|
| 1400 | 0.7955 | 0.6327 | 0.5033 |
| 1450 | 0.8239 | 0.6788 | 0.5592 |
| 1500 | 0.8523 | 0.7264 | 0.6191 |
| 1550 | 0.8807 | 0.7756 | 0.6831 |
| 1600 | 0.9091 | 0.8264 | 0.7513 |
| 1650 | 0.9375 | 0.8789 | 0.8240 |
| 1700 | 0.9659 | 0.9330 | 0.9012 |
| 1760 | REFER TO PERFORMANCE CURVE | | |
| 1800 | 1.0227 | 1.0460 | 1.0697 |
| 1850 | 1.0511 | 1.1049 | 1.1614 |
| 1900 | 1.0795 | 1.1654 | 1.2581 |
| 1950 | 1.1080 | 1.2276 | 1.3601 |
| 2000 | 1.1364 | 1.2913 | 1.4674 |
| 2050 | 1.1648 | 1.3567 | 1.5802 |
| 2100 | 1.1932 | 1.4237 | 1.6987 |
| 2150 | 1.2216 | 1.4923 | 1.8230 |
| 2200 | 1.2500 | 1.5625 | 1.9531 |
| 2250 | 1.2784 | 1.6343 | 2.0893 |
| 2300 | 1.3068 | 1.7078 | 2.2317 |
| 2350 | 1.3352 | 1.7828 | 2.3805 |
| 2400 | 1.3636 | 1.8595 | 2.5357 |
| 2450 | 1.3920 | 1.9378 | 2.6975 |

| RPM | GPM | HEAD | HP |
|---|---|---|---|
| 2500 | 1.4205 | 2.0177 | 2.8660 |
| 2550 | 1.4489 | 2.0992 | 3.0415 |
| 2600 | 1.4773 | 2.1823 | 3.2239 |
| 2650 | 1.5057 | 2.2671 | 3.4135 |
| 2700 | 1.5341 | 2.3534 | 3.6104 |
| 2750 | 1.5625 | 2.4414 | 3.8147 |
| 2800 | 1.5909 | 2.5310 | 4.0266 |
| 2850 | 1.6193 | 2.6222 | 4.2462 |
| 2900 | 1.6477 | 2.7150 | 4.4736 |
| 2950 | 1.6761 | 2.8094 | 4.7090 |
| 3000 | 1.7045 | 2.9055 | 4.9525 |
| 3050 | 1.7330 | 3.0031 | 5.2043 |
| 3100 | 1.7614 | 3.1024 | 5.4645 |
| 3150 | 1.7898 | 3.2033 | 5.7332 |
| 3200 | 1.8182 | 3.3058 | 6.0105 |
| 3250 | 1.8466 | 3.4099 | 6.2967 |
| 3300 | 1.8750 | 3.5156 | 6.5918 |
| 3350 | 1.9034 | 3.6230 | 6.8960 |
| 3400 | 1.9318 | 3.7319 | 7.2094 |
| 3450 | 1.9602 | 3.8425 | 7.5322 |
| 3500 | 1.9886 | 3.9547 | 7.8644 |
| 3520 | 2.000 | 4.000 | 8.000 |

# IMPELLER DIAMETER TRIM PROCEDURE
# CHANGES IN PERFORMANCE

The effect of changing the outer diameter is to decrease the peripheral speed of the impeller which has exactly the same effect as reducing the rotative speed without altering the diameter. The effect is to change the Head generated in proportion to the square of the speed, or the square of the diameter, according to the fundamental formula:

$V^2 = 2GH$
G = Gravity (32.17 feet per second)
H = Head (in feet)

When the peripheral speed is changed, however, the velocity of the water flowing through the impeller is changed in direct proportion. Since this changes the quantity of water delivered, both changes must be considered when trimming an impeller.

There is still a third factor to be considered. Assuming there is no major change in the speed (with the quantity in direct proportion to the diameter, and the head in proportion to the square) the work done (or power required) will be as the product of the two which is proportional to the cube of the diameter.

EXAMPLE:
An impeller of 9.313 inch outside diameter (of vanes) is rated to deliver 900 GPM at 76 Feet of Head, and requires a driver of 20.3 BHP. (Data taken form a published curve.) What will be the effect of changing the diameter to 8.750 inches?

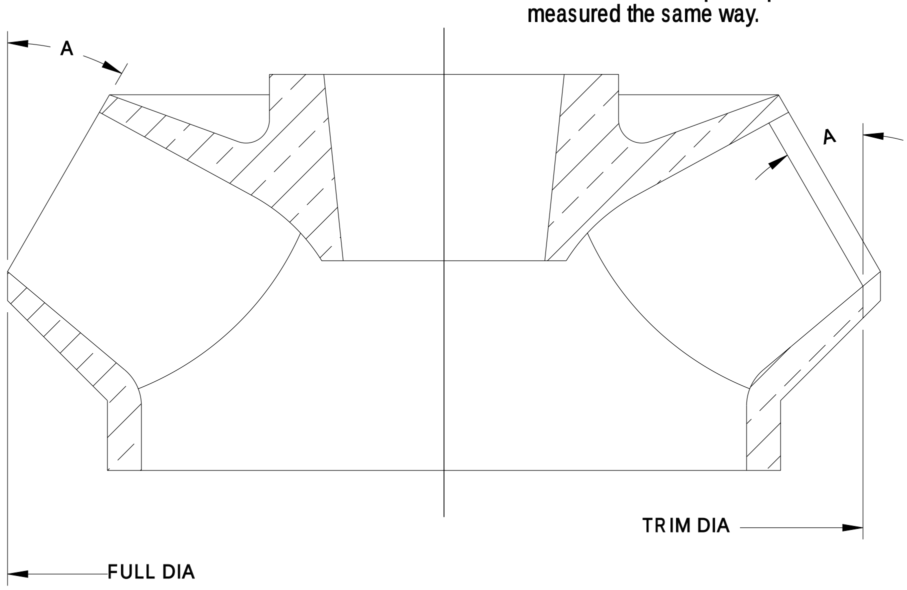
SOLUTION:
The direct ratio of diameters will be: 8.750 - 9.313 = 0.93955
So the new Quantity will be: 0.93955 x 900 = 845.59 GPM
The square of the ratio will be: 0.93955 x 0.93955 = 0.88275
So the new Head will be: 0.88275 x 76 = 67.09 Feet of Head
The cube of the ration will be: 0.93955 x 0.93955 x 0.93955 = 0.82938
So the new power will be: 0.82938 x 20.3 = 16.84 BHP

The efficiency is still another factor to be considered. It is not seriously altered for small changes in diameter. Refer to bowl performance curves for actual change in efficiency.

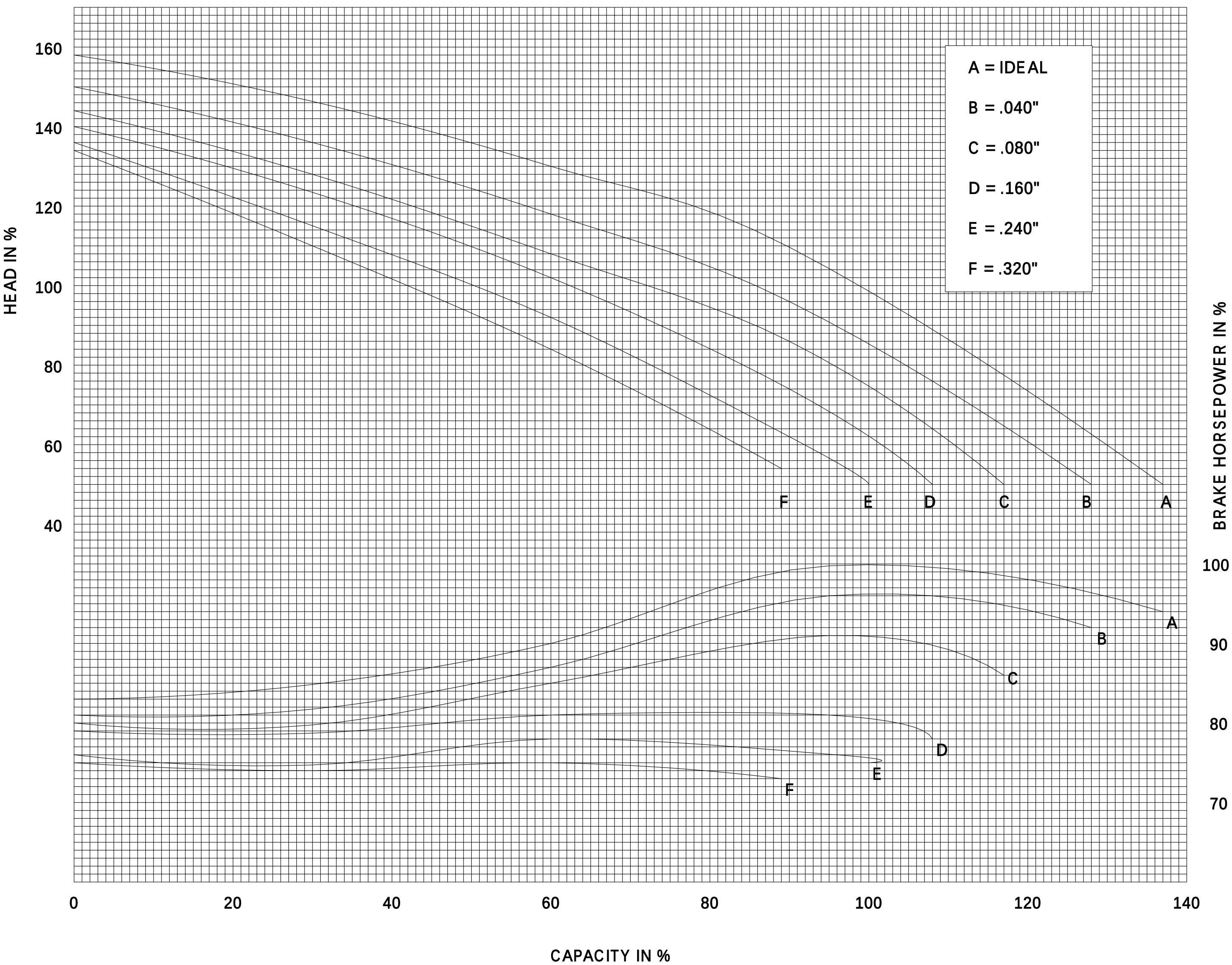
Since a pump is made of several bowls with impellers, it is only necessary to figure one impeller. The new head is multiplied by the number of stages for the whole pump. The quantity and efficiency, however, will be as calculated for the single impeller, as all will perform the same in series.

This procedure applies in the same way to open and enclosed impellers.

*All impellers require lower shroud removal for all trim diameters. Semi-open impeller trim diameters are measured the same way.



# EFFECTS OF RAISING SEMI-OPEN IMPELLERS




The above chart indicates the approximate effect of raising semi-open impellers from their ideal (A) operating position. Raising the impellers increases the clearance between impeller and bowl seat and reduces the performance accordingly. The chart is general and will not be exactly correct for any particular pump model since each model will react differently. 100% head and capacity are to be taken as the head and capacity of the pump at peak efficiency. - EXAMPLE: If a particular pump delivers 250 GPM at 50' head at peak efficiency when the impellers are properly adjusted, raising the impellers 0.080" would reduce the capacity to approximately 181 GPM (72 1/2% of 250 GPM) while maintaining the 50' head - or conversely, the pump would deliver 250 GPM at 37 1/2' head (75% of 50'.) The horsepower would be about 91 1/2% of the previous horsepower.

# VELOCITY HEAD

The Velocity Head (Head due to Velocity) of moving water at a given velocity is the equivalent Head through which it would have to fall to acquire the same velocity, or the Head necessary to accelerate water. The Velocity head must always be considered when accurate testing is required, but normally is such a negligible amount that its factor is a small value when figuring total Head conditions. It is important to consider Velocity Head when your Total Head values are low, which occurs in Axial Flow pumps or when Suction Lift valves are high, such as in centrifical pump applications.

The formula for Velocity Head is:

$hv = \frac{v^2}{2g}$ where "g" is the acceleration due to gravity (32.174 feet per second)

By knowing the head we can transpose the formula to read:

$v = \sqrt{2gh}$ this obtains the velocity.

Velocity can also be obtained by applying the values to these formulas.

$hv = 0.0155v^2$ where $v = \frac{0.4085 \times GPM}{D^2}$ or $v = \frac{0.321 \times GPM}{Area}$

$hv = \frac{0.00259\ (GPM)^2}{D^4}$

where hv = velocity head

v = velocity in feet/second

GPM = Gallons per minute

D = I.D. of column pipe

d = O.D. of shaft or oil tube

A (area) = 0.7854 x (D+d)(D-d)

Example

Calculations Based on: GPM = 1219.35
D = 10" (Pipe O.D. = 10.750, Wall thickness 0.330)
d = 1.6875

$hv = \frac{0.00259 \times GPM^2}{D^4}$

$hv = \frac{0.00259 \times 1219.35^2}{10^4}$

$hv = \frac{0.00259 \times 1486814.422}{10,000}$

$hv = \frac{3850.849354}{10,000} = 0.38508$

or

$hv = 0.0155v^2$ where $v = \left(\frac{0.321 \times GPM}{AREA}\right)^2$

$hv = 0.0155v^2$ where $v = \left(\frac{0.321 \times 1219.35}{77.72353}\right)^2$

$hv = 0.0155v^2$ where $v = \left(\frac{391.41135}{77.72353}\right)^2$

$hv = 0.0155\ (5.035944)^2 = 0.39309$

Notes:
to calculate velocity in column pipe with lineshaft or oil tubing the following formula is used to determine the area.

# SPECIFIC SPEED

Specific speed is the speed in RPM at which a given impeller would operate if reduced proportionally in size so as to deliver a capacity of one GPM at one foot of head.

TO CALCULATE:

$$Ns = \frac{R/MIN \times (GAL/MIN)^{.5}}{FT^{.75}} \quad \text{or} \quad Ns = \frac{R/MIN \times \sqrt{GAL/MIN}}{FT^{.75}}$$

*WHERE:* *R/MIN = Pump rotational speed in revolutions per minute.*

*GAL/MIN = Pump discharge in U.S. gallons per minute*

*FT = Total bowl head per stage in feet of liquid pumped*

FOR METRIC:

$$Ns = \frac{R/MIN \times (M^3/H)^{.5}}{M^{.75}}$$

*WHERE:* *$M^3/H$ = Pump discharge in cubic meters per hour*

*M = Total bowl head per stage in meters of liquid pumped*

1. The capacity and head should be selected at the best efficiency point of the largest diameter impeller used in the pump.
2. Specific Speed (Ns) is always calculated for a single stage.
3. Specific Speed (Ns) of any given pump is the same at all rotative speeds.
4. Low specific speed (Ns) indicates the pump design is for low capacity and high head.
5. High specific speed (Ns) indicates the pump design is for high capacity and low head.

EXAMPLE

*WHERE:* *R/MIM = 1780*

*GAL/MIN = 200*

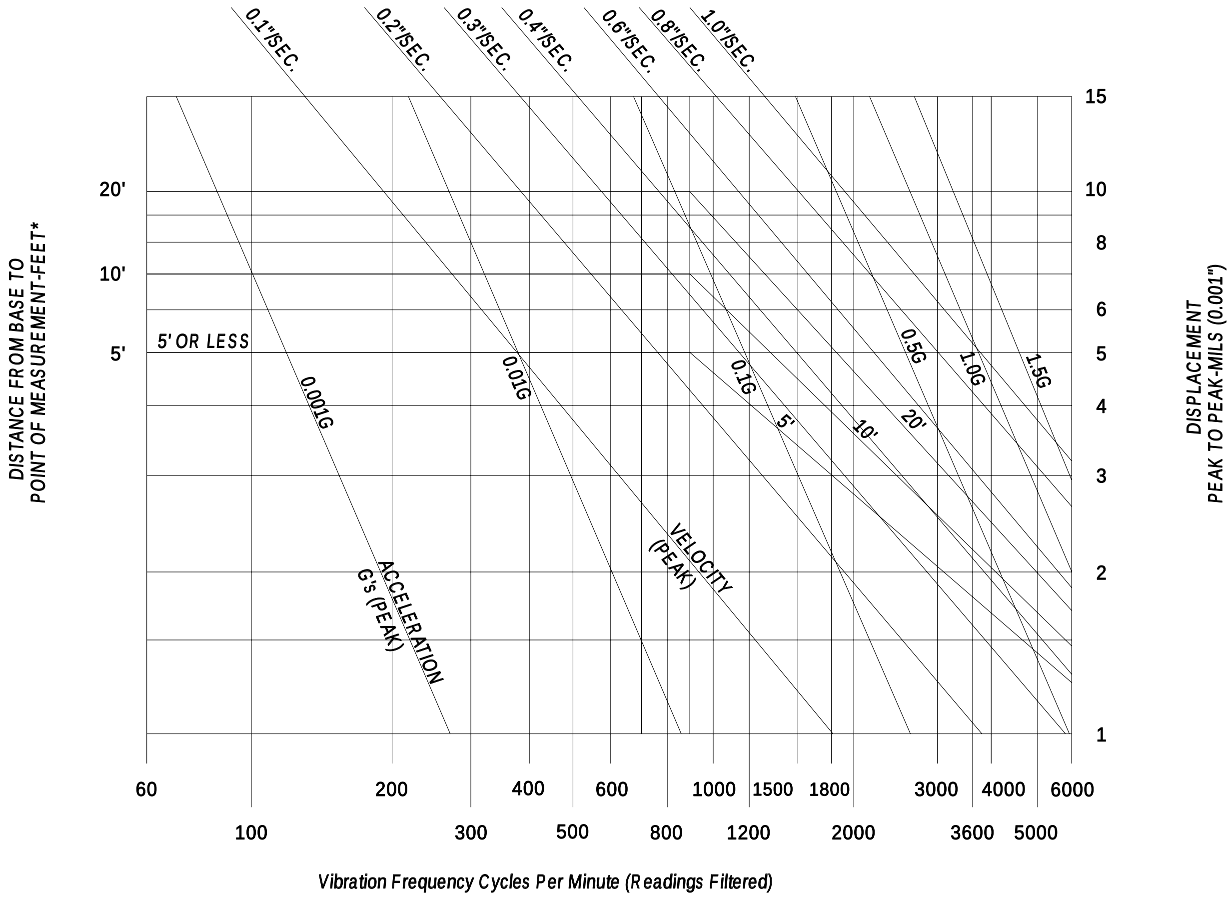
*FT = 14.375*

$$Ns = \frac{R/MIN \times (GAL/MIN)^{.5}}{FT^{.75}} \qquad Ns = \frac{R/MIN \times \sqrt{GAL/MIN}}{FT^{.75}}$$

$$Ns = \frac{1780 \times (200)^{.5}}{14.375^{.75}} \quad \text{or} \quad Ns = \frac{1780 \times \sqrt{200}}{14.375^{.75}}$$

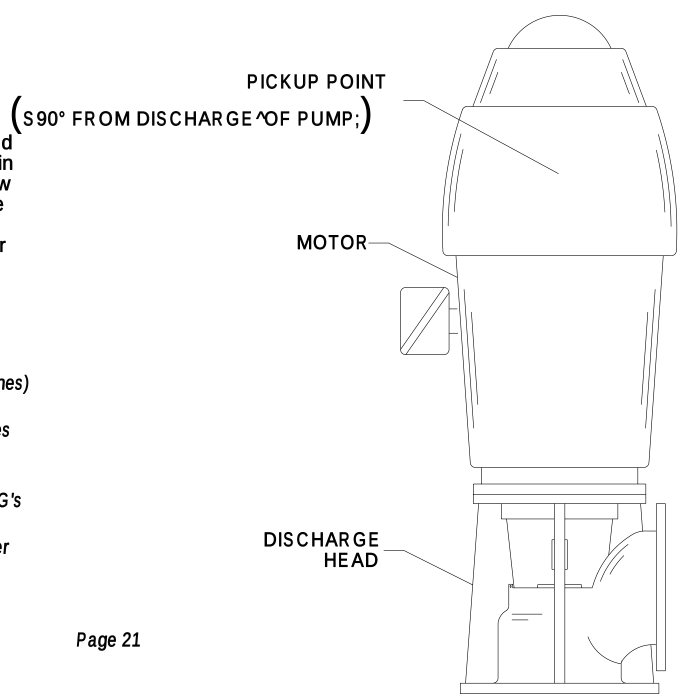
$$Ns = \frac{25173.00141}{7.38254} = 3409.80 \qquad Ns = \frac{25173.00141}{7.38254} = 3409.80$$

# MOTOR VIBRATION LIMITS




**Measure Vibration at top motor bearing*

*ACCEPTABLE FIELD VIBRATION LIMITS FOR VERTICAL PUMPS (NON-RIGID STRUCTURES) - Based on Hydraulic Institute Standards, 14th Edition, 1983*




The chart and illustration represented is the recommended acceptable vibration limits for vertical pumps. Vibrations in excess of the chart values may be acceptable if they show no continued increase over long periods of time and there is no other indication of damage, such as an increase in bearing clearance or noise level. Conversion formulas for vibration readings are as follows:

$D = 1.910 \times 10^{4} \frac{v}{f}$

$v = 3.696 \times 10^{3} \frac{a}{f}$

$a = 2.704 \times 10^{-4} vf$

*where,*

*D = Displacement, peak to peak, in mils (0.001 inches)*

*v = Velocity, peak, in inches per second*

*a = Acceleration, peak, in G's*

*f = Frequency in cycles per minute*

# TORQUE REGUIRED TO ACCELERATE A REVOLVING BODY

$$\text{Torque (lb. ft.)} = \frac{WR^2 N}{307 \times t}$$

W = weight in lbs. (weight of impeller + weight of taper lock)

R = radius of gyration in feet

N = change in RPM

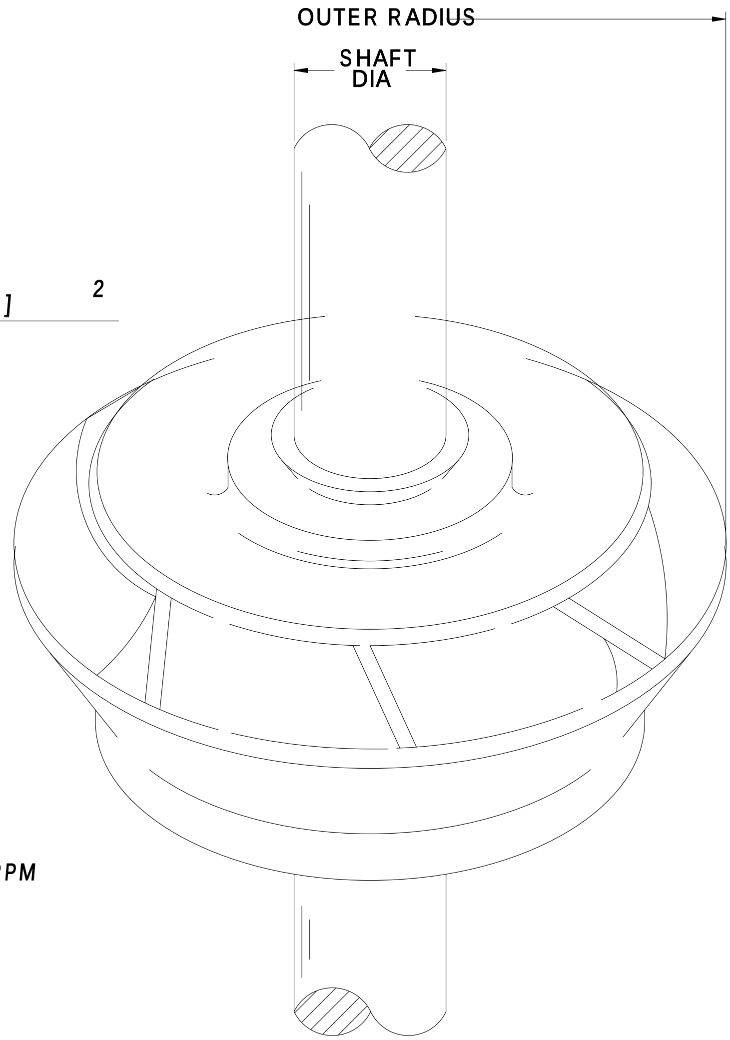
t = time of acceleration in seconds

Inertia of a cylinder about its axis

$$WR^2 = \frac{\text{Weight (lbs.)} \times [\text{radius (ft.)}]^2}{2}$$

Inertia of an impeller about its axis

$$WR^2 = \frac{\text{Weight (lbs.)} \times [(\text{outer radius in ft.})^2 - (\text{shaft diameter})^2]}{2}$$




CONVERTING LINEAR TO ROTATIONAL INERTIA

$$\text{Equivalent } WR^2 = \frac{W}{39.48}\left(\frac{V}{N}\right)^2$$

W = Weight in pounds (lbs.)

V = Linear Velocity in feet per min. (fpm) = 0.262 x Dia. (in.) x RPM

N = Motor speed in RPM when load is moving at velocity V

EQUIVALENT $WR^2$ FOR BELTED OR GEARED LOADS

$$\text{Equivalent (at Motor Shaft) } WR^2 = WR^2_{(load)} \left(\frac{N \text{ load}}{N \text{ motor}}\right)^2$$

$$WR^2 = \frac{\text{Actual Calculated}}{WR^2 \text{ of load}}$$

N load = Full Speed of Load (RPM)

N motor = Full Speed of Motor (RPM)

# THRUST

There are two types of thrust in a vertical turbine. It's very important to understand these types and their effects on performance and failures of pumps and drivers.

In a vertical turbine the water or liquid is picked up by a vaned impeller and discharged thru a number of equally spaced diffusion vanes. Sometimes, if this vane spacing is not equal or the inlet angles are not equal, you will have a small amount of unbalance radial thrust due to the hydraulic forces.

Axial thrust is created from the pressure difference of the impeller and is normally in the downward position. However, the most important is the upward force coming form the velocity of liquid entering the impeller eye. The liquid flow enters axially and is turned by the vanes, leaving the impeller in a semi-radial direction. The angle of exit depends on the specific speed. The upward dynamic force in the low-specific speed impeller is significant enough to overcome the effect of pressure difference, therefore causing a net upthrust, which will start at 120% of BEP. This is not unusual for enclosed impellers.

In a normal operating pump, the upthrust is usually momentary and much smaller than the downthrust. Because the predominant force is downward, driver manufactures design their units (whether electric motors or right angle gear drives) for continuos downthrust operation. Most drivers are designed to handle 30% momentary upthrust loads. Sometimes, when a pump is run at a very high capacity, the upthrust can be greater than the downthrust, especially on close coupled turbines.

In a typical deep well turbine, the static weight of the driveshaft serves as sufficient static head to offset most upthrust situations. Close-coupled barrel pumps should be started against a closed valve or system head which eliminates the momentary upthrust problem.

When a pump must fill a long pipeline, the initial startup head is low and it may run in upthrust until the system head develops. And in some applications the NPSHR may exceed the NPSHA allowing it to run in upthrust. A throttling valve or temporary orifice plate is a good solution. This is especially important in a submersible pump.

Some of the problems caused by continuous operation in upthrust are:

1. Mechanical seal failure caused when the shaft moves upward in an excess amount. This changes the adjustment between the stationary face and the rotating face.

2. Bent lineshaft caused by compression loads which cause rapid bearing wear and vibration.

3. Impellers can rub or bump the top of the bowls hub causing wear on the bowl and impellers. Sometimes enough pressure is applied to loosen the taperlock and allow the impeller to spin freely on the shaft.

4. Damage to thrust bearings in the drivers.

# THRUST LOADS

(The total downthrust produced is the sum of the hydraulic thrust plus the static thrust (dead weight) of the shaft and impellers.

| SHAFT WEIGHTS AND AREAS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DIA. (IN's) | 3/4 | 1 | 1 3/16 | 1 1/4 | 1 1/2 | 1 11/16 | 1 15/16 | 2 3/16 | 2 1/4 | 2 7/16 |
| LBS./FT. | 1.50 | 2.67 | 3.77 | 4.17 | 6.01 | 7.60 | 10.02 | 12.78 | 13.52 | 15.87 |
| AREA | 0.44 | 0.78 | 1.11 | 1.23 | 1.77 | 2.24 | 2.95 | 3.76 | 3.97 | 4.67 |

TOTAL THRUST FORMULA

*TOTAL THRUST = (K x H x SG) + (W x S) + (Imp. Weight x No. of Stages)*

*K = Thrust Factor for Pump*

*H = Bowl Head (Total Head + Column Friction Loss) in Feet*

*W = Weight of Shaft in Pounds*

*S = Setting (Total Column Length) in Feet*

*SG = Specific Gravity of Liquid*

EXAMPLE: *The total thrust for a 12KCA-4 stage pump with a 1 1/2" line shaft with a total head of 304 feet and a setting of 250 feet, would be calculated as follows:*

*TOTAL THRUST = (K x H x SG) + (W x S) + (Imp. Weight x No. of Stages)*

*K = 6.50 H = 306 W = 6.01 S = 250 SG = 1.00*

*TOTAL THRUST = (6.50 x 306 x 1) + (6.01 x 250) + (16 x 4)*

*= 1989 + 1502.5 + 64 = 3555.5*

NOTES:
The driver selected must have thrust capacity greater than the total thrust value.
Thrust factors (K) and impeller weights can be found on the performance curve page for the specific model.

*FRICTION H.P. LOSS PER 100 FEET*

| SHAFT SIZE | REVOLUTIONS PER MINUTE | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3600 | 2900 | 1800 | 1500 | 1200 | 1000 | 900 |
| 3/4 | 0.60 | 0.52 | 0.32 | 0.26 | 0.20 | 0.17 | 0.15 |
| 1 | 1.10 | 0.88 | 0.55 | 0.44 | 0.35 | 0.29 | 0.26 |
| 1 3/16 | 1.45 | 1.30 | 0.75 | 0.61 | 0.48 | 0.40 | 0.36 |
| 1 1/4 | | 1.33 | 0.79 | 0.67 | 0.52 | 0.44 | 0.39 |
| 1 1/2 | | 1.90 | 1.20 | 0.96 | 0.75 | 0.60 | 0.55 |
| 1 11/16 | | 2.36 | 1.40 | 1.20 | 0.94 | 0.78 | 0.70 |
| 1 15/16 | | | 1.90 | 1.60 | 1.20 | 1.00 | 0.90 |
| 2 3/16 | | | 2.30 | 2.00 | 1.50 | 1.30 | 1.15 |
| 2 1/4 | | | 2.50 | 2.07 | 1.60 | 1.41 | 1.26 |
| 2 7/16 | | | 2.90 | 2.40 | 1.90 | 1.60 | 1.40 |

# NPSHR CALCULATIONS

## NPSH

(NET POSITIVE SUCTION HEAD) Is the total suction head in feet of the liquid being pumped (absolute at the pump centerline or impeller eye) less the absolute vapor pressure (in feet) of the liquid being pumped. It must always have a positive value and can be calculated by the following equations: To help explain the conditions two expressions
will be used: the first expression is basis for when the suction lift-liquid supply level is below the pump centerline
or impeller eye; the second expression is basis for positive suction, (flooded), where the liquid supply level is above
the pump centerline or impeller eye.

*For Suction Lift:*

$$NPSH = h_a - h_{vpa} - h_{st} - h_{fs}$$

*For Positive (flooded) Suction:*

$$NPSH = h_a - h_{vpa} + h_{st} - h_{fs}$$

## NPSHR

(NET POSITIVE SUCTION HEAD REQUIRED) Is the amount of suction head, over vapor pressure, required to prevent more than 3% loss in total head to the first stage of the pump at a specific capacity. NPSHR is obtained by laboratory testing, (closed loop system). In a closed-loop test facility you can obtain deareated water, which can not be accomplished in a open pit installation. Deareation occurs in a closed-loop system when the static pressure is below atmospheric pressure and it increases at higher water temperature. Therefore, it is necessary to run comparable NPSHR test at the same water temperature. Also a closed-loop system can be used in special requirement situations when pumping liquids other than water.

*Calculations with regard to NPSHR as follows:

$$NPSHR = h_a - h_{vpa} + (Z_i - Z_e)$$

$$Z_s = NPSHR - \frac{2.31}{S.G.} Pa + \frac{2.31}{S.G.} Pvpa - Z_{st} - \frac{V_s^2}{2g} + h_3 + h_4$$

## NPSHA

(NET POSITIVE SUCTION HEAD AVAILABLE) Is the total suction head in feet (meters) of liquid absolute, determined at the first stage impeller datum, less the absolute vapor pressure of the liquid in feet (meters).

*Calculations with regard to NPSHA as follows:

$$NPSHA = h_a - h_{vpa} + Z_s \qquad OR \qquad NPSHA = \frac{2.31}{S.G.}(Pa - Pvpa) + Z_s$$

SYMBOLS AND DEFINITIONS

$Z_i$ (Required submergence ) $= NPSHR - h_a + h_{vpa} + Z_s$

$h_a$ = absolute pressure (in feet of the liquid being pumped) on the surface of the liquid supply level (this will be barometric pressure if suction is from an open tank or sump; or the absolute pressure existing in a closed tank such as a condenser hotwell or deareator).

$h_{vpa}$ = Vapor pressure of pumped liquid, ft (m) absolute, at pumping temperature.

$h_{st}$ = Static height in feet that the liquid supply level is above or below the pump centerline or impeller eye.

$h_{fs}$ = All suction line losses (in feet) including entrance losses and friction losses through pipe, valves and fittings, ect.

$Z_s$ = Water depth over impeller eye or the vertical distance from the suction pipe centerline to the eye of the bottom impeller, ft (m).

$Z_e$ = the vertical distance from the suction inlet to the impeller centerline.

$Z_{st}$ = the vertical distance from the pumping water level to the discharge centerline.

$P_s$ = Suction pressure, lb/in$^2$ (KPa), above atmospheric pressure. This may be positive or negative.

$h_3$ = Friction loss between pressure tap connection and suction flange.

$h_4$ = Summation of friction and shock losses in suction elbow and barrel.

$P_a$ = Atmospheric pressure in lb/in$^2$ (KPa) absolute.

$Pvpa$ = Vapor pressure of water in lb/in$^2$ (KPa) absolute at pumping temperature.

S.G. = Specific gravity of liquid at pumping temperature.

$V_s^2/2g$ = the velocity head in suction pipe at point of pressure tap or piezometer connection.

$g$ = 32.16 feet per second (acceleration of gravity).

## NOTES:

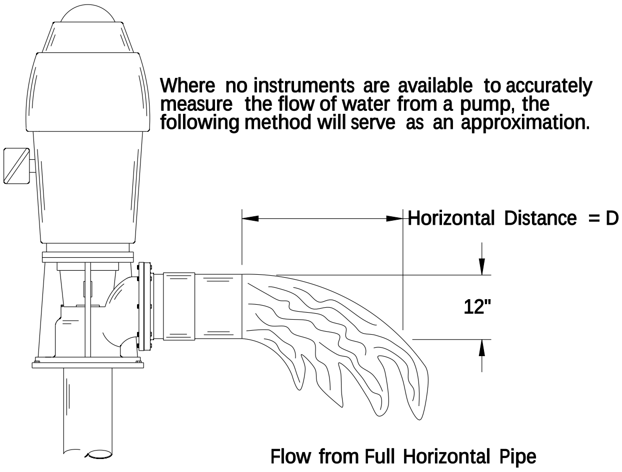
The typical pump curve depicts NPSHR or NPSH with the NPSHR rising as the capacity rises.

# ATMOSPHERIC PRESSURE

| ALTITUDE vs. ATMOSPHERIC PRESSURE | | | ALTITUDE OF SOME MAJOR CITIES | |
|---|---|---|---|---|
| ALTITUDE | PSIA | FT. OF WATER | CITY | APPROX. ALTITUDE |
| *0* | *14.7* | *34.0* | *ALBUQUERQUE* | *5,200* |
| *500* | *14.4* | *33.3* | *ATLANTA* | *1,100* |
| *1,000* | *14.2* | *32.8* | *AMARILLO* | *370* |
| *1,500* | *13.9* | *32.1* | *CALGARY* | *3,440* |
| *2,000* | *13.7* | *31.5* | *CHEYENNE* | *6,100* |
| *2,500* | *13.4* | *31.0* | *CHICAGO* | *600* |
| *3,000* | *13.2* | *30.4* | *CINCINNATI* | *550* |
| *3,500* | *12.9* | *29.8* | *CLEVELAND* | *700* |
| *4,000* | *12.7* | *29.2* | *DENVER* | *5,270* |
| *4,500* | *12.4* | *28.8* | *DETROIT* | *580* |
| *5,000* | *12.2* | *28.2* | *EDMONTON* | *2,200* |
| *5,500* | *12.0* | *27.6* | *FORT WORTH* | *700* |
| *6,000* | *11.8* | *27.2* | *IDAHO FALLS* | *4,700* |
| *6,500* | *11.5* | *26.7* | *KANSAS CITY* | *800* |
| *7,000* | *11.3* | *26.2* | *MINNEAPOLIS* | *900* |
| *7,500* | *11.1* | *25.7* | *MONTREAL* | *100* |
| *8,000* | *10.9* | *25.2* | *NASHVILLE* | *500* |
| *8,500* | *10.7* | *24.7* | *OMAHA* | *1,000* |
| *9,000* | *10.5* | *24.3* | *OTTAWA* | *290* |
| *9,500* | *10.3* | *23.8* | *PHOENIX* | *1,100* |
| *10,000* | *10.1* | *23.4* | *PITTSBURGH* | *800* |
| *10,500* | *9.9* | *22.9* | *REGINA* | *1,900* |
| *11,000* | *9.7* | *22.4* | *ROSWELL* | *3,570* |
| *11,500* | *9.5* | *22.0* | *SALT LAKE CITY* | *4,250* |
| *12,000* | *9.3* | *21.6* | *SPOKANE* | *1,900* |
| *12,500* | *9.1* | *21.1* | *TORONTO* | *350* |
| *15,000* | *8.3* | *19.2* | *TULSA* | *800* |
| | | | *WINNIPEG* | *760* |

# ESTIMATING FLOW FROM HORIZONTAL OR INCLINED PIPES

Where no instruments are available to accurately measure the flow of water from a pump, the following method will serve as an approximation.

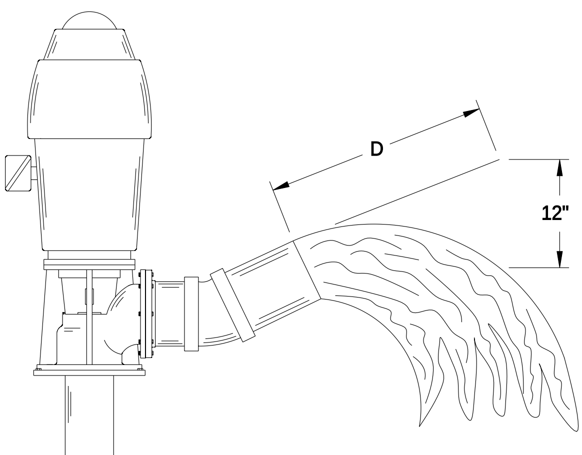



Flow from Full Horizontal Pipe

Using an ordinary rule of carpenters square, measure the horizontal distance from the end of the discharge pipe to a point exactly 12 inches above the falling stream of water. The discharge pipe must be level and running full of water when the reading is taken. Multiply this distance (in inches) by the cross sectional area of the pipe in square inches and the answer will be the approximate capacity in gallons per minute.

By checking this method of estimation using accurate flow meters it has been found a correction factor of 1.015 should be applied.

Flow (GPM) = A x D x 1.105
Where: A = Area of pipe in square inches
D = Horizontal distance in inches
1.015 = Correction Factor

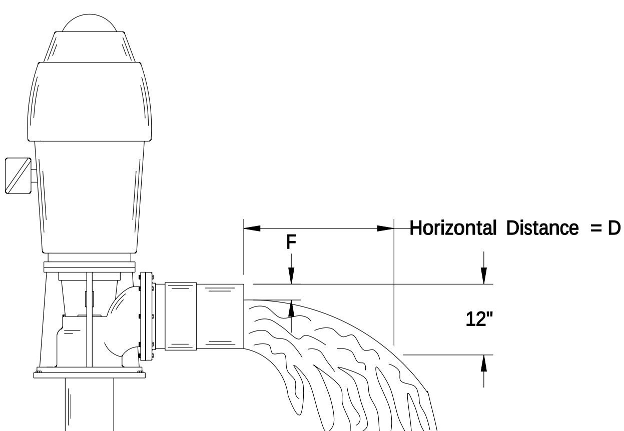



Flow from Inclined Pipe

Where: A = 78.54 (10" pipe)
D = 20"

EXAMPLE: A x D x 1.105
78.54 x 20 x 1.105
GPM = 1736

## PARTIALLY FILLED PIPES



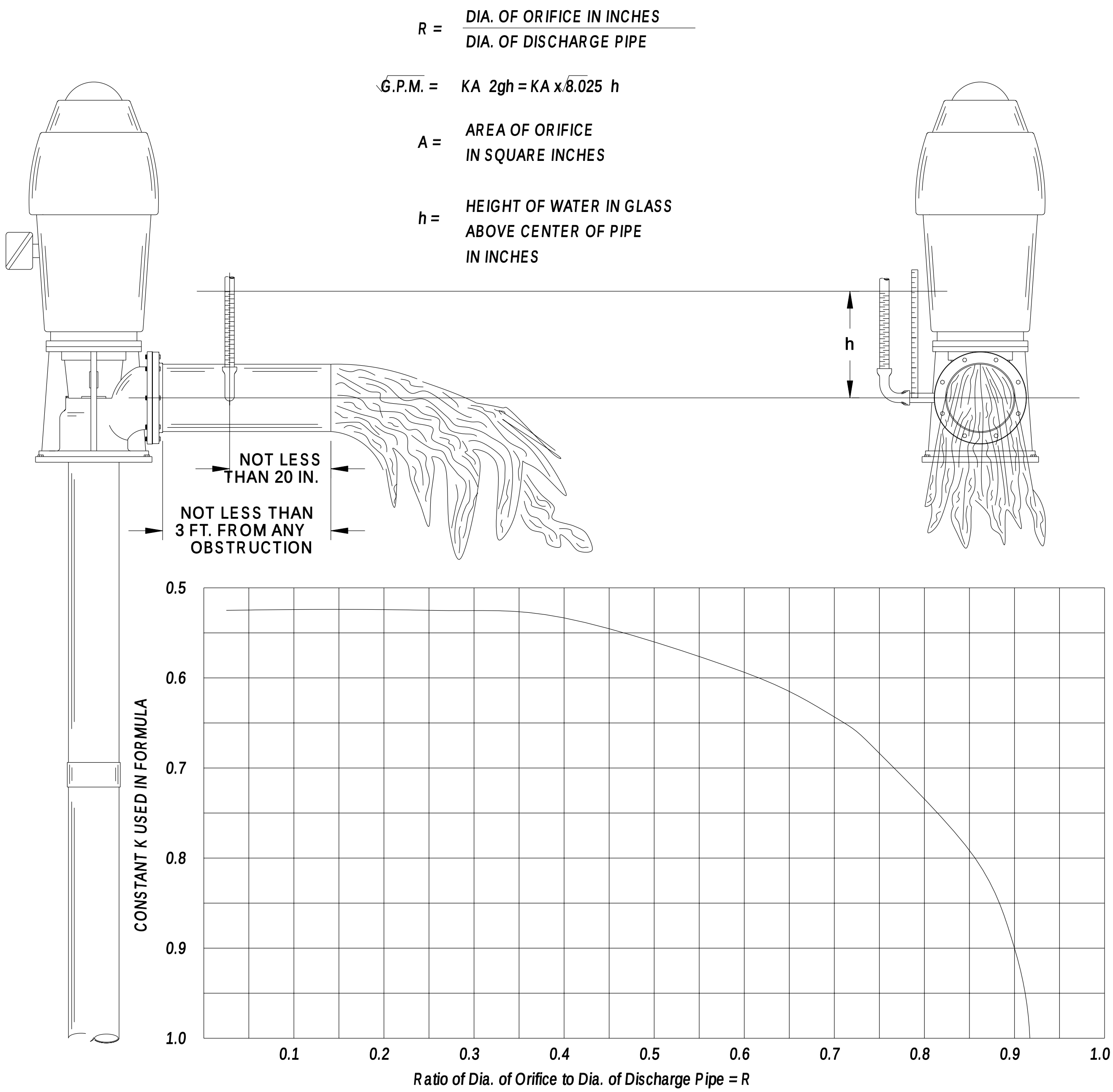

Flow From Horizontal Pipe (Partially Filled)

Flow (GPM) = A x D x 1.039 x F
Where: A = Area of pipe in square inches
D = Horizontal distance in inches
F = Effective area factor shown below
Area of pipe equals inside Dia. x 0.7854 $^2$

| RATIO F/D = R % | EFF. AREA FACTOR F | RATIO F/D = R % | EFF. AREA FACTOR F |
|---|---|---|---|
| 5 | 0.981 | 55 | 0.436 |
| 10 | 0.948 | 60 | 0.373 |
| 15 | 0.905 | 65 | 0.312 |
| 20 | 0.858 | 70 | 0.253 |
| 25 | 0.805 | 75 | 0.195 |
| 30 | 0.747 | 80 | 0.142 |
| 35 | 0.688 | 85 | 0.095 |
| 40 | 0.627 | 90 | 0.052 |
| 45 | 0.564 | 95 | 0.019 |
| 50 | 0.500 | 100 | 0.000 |

EXAMPLE: D = 20 Inches - Pipe inside diameter = 10 inches -
F = 2 1/2 inches
A = 10 x 10 x 0.7854 = 78.54 square inches
R = 2 1/2 - 10 = 25%
F = 0.805
Flow = 78.54 x 20 x 1.039 x 0.805 = 1314 GPM

# ORIFICE METHOD OF MEASURING WATER




The orifice method is a simple way to measure the flow of water from a pipe discharging horizontally into open air without bends or obstruction in the last three feet. The sketch shows the arrangement.

A plate is clamped over the end of the pipe with the circular orifice located at the exact center of the pipe. The size of the orifice should preferably be from one-half to three-quarter the size of the pipe, but must be selected of such size that it will be running full of water.

At a point on the side of the discharge pipe not less than 20 inches back from the orifice a hole should be drilled and tapped for an 1/8" or 1/4" pipe. A short piece of pipe is screwed into this hole until the inner end is just flush with the inner wall of the discharge pipe. A piece of rubber hose is slipped over this pipe and also over one end of a piece of glass tubing supported in a vertical position.

The diameter of the orifice divided by the inside pipe diameter gives the ratio "R" and from the curve the proper value of "K" is found. In the formula "A" is figured as the area of the orifice in square inches, "G" equals 32.2, and "H" is read as the height of the water column in the glass tube above the center of the pipe in inches. Gallons per minute "G.P.M." can then be figured. This method is simpler than a weir and fully as accurate.

# ORIFICE METHOD OF MEASURING WATER

| H. INCHES | $\sqrt{H}$ | GALLONS PER MINUTE 3" PIPE 1 3/4" ORIFICE | 4" PIPE 2 1/2" ORIFICE | 6" PIPE 3" ORIFICE | 6" PIPE 4 3/4" ORIFICE | 8" PIPE 6" ORIFICE | 10" PIPE 8" ORIFICE | H. INCHES | $\sqrt{H}$ | GALLONS PER MINUTE 3" PIPE 1 3/4" ORIFICE | 4" PIPE 2 1/2" ORIFICE | 6" PIPE 3" ORIFICE | 6" PIPE 4 3/4" ORIFICE | 8" PIPE 6" ORIFICE | 10" PIPE 8" ORIFICE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.000 | 11.3 | 24.0 | 31.7 | 101.6 | 154.5 | 296.5 | 61 | 7.810 | 88.3 | 187.5 | 248.1 | 793.0 | 1207.0 | 2314.0 |
| 2 | 1.414 | 16.1 | 33.9 | 44.9 | 143.8 | 218.5 | 419.0 | 62 | 7.874 | 89.2 | 189.0 | 250.1 | 799.0 | 1217.0 | 2332.0 |
| 3 | 1.732 | 19.6 | 41.6 | 55.2 | 176.0 | 267.6 | 513.0 | 63 | 7.937 | 89.8 | 190.5 | 252.1 | 806.0 | 1227.0 | 2352.0 |
| 4 | 2.000 | 22.7 | 48.0 | 63.5 | 203.3 | 309.0 | 593.0 | 64 | 8.000 | 90.6 | 192.0 | 254.1 | 813.0 | 1237.0 | 2371.0 |
| 5 | 2.236 | 25.3 | 53.6 | 71.1 | 227.4 | 345.5 | 692.0 | 65 | 8.062 | 91.3 | 193.5 | 256.1 | 819.0 | 1247.0 | 2389.0 |
| 6 | 2.449 | 27.8 | 58.8 | 77.8 | 249.0 | 378.5 | 727.0 | 66 | 8.124 | 92.2 | 195.2 | 258.1 | 826.0 | 1256.0 | 2408.0 |
| 7 | 2.646 | 30.0 | 63.5 | 84.0 | 268.7 | 409.0 | 785.0 | 67 | 8.185 | 92.7 | 196.4 | 260.1 | 832.0 | 1265.0 | 2426.0 |
| 8 | 2.828 | 32.0 | 67.9 | 89.9 | 287.2 | 437.0 | 838.0 | 68 | 8.246 | 93.4 | 198.0 | 262.0 | 837.0 | 1274.0 | 2442.0 |
| 9 | 3.000 | 34.0 | 72.0 | 95.4 | 305.0 | 463.0 | 889.0 | 69 | 8.307 | 94.1 | 199.5 | 264.0 | 844.0 | 1284.0 | 2461.0 |
| 10 | 3.162 | 35.9 | 76.0 | 100.6 | 321.2 | 488.0 | 938.0 | 70 | 8.367 | 94.8 | 201.0 | 265.9 | 850.0 | 1293.0 | 2479.0 |
| 11 | 3.317 | 37.6 | 79.6 | 105.4 | 337.0 | 512.0 | 982.0 | 71 | 8.426 | 95.5 | 202.3 | 267.9 | 856.0 | 1303.0 | 2496.0 |
| 12 | 3.464 | 39.3 | 83.2 | 110.2 | 352.0 | 530.0 | 1027.0 | 72 | 8.485 | 96.1 | 203.9 | 269.9 | 862.0 | 1312.0 | 2518.0 |
| 13 | 3.606 | 40.8 | 86.6 | 114.6 | 367.0 | 557.0 | 1069.0 | 73 | 8.544 | 96.8 | 205.0 | 271.9 | 868.0 | 1321.0 | 2538.0 |
| 14 | 3.742 | 42.3 | 89.8 | 119.0 | 381.0 | 577.5 | 1108.0 | 74 | 8.602 | 97.5 | 206.6 | 273.8 | 874.0 | 1330.0 | 2550.0 |
| 15 | 3.873 | 43.9 | 93.0 | 123.1 | 394.0 | 598.0 | 1148.0 | 75 | 8.660 | 98.2 | 208.0 | 275.6 | 880.0 | 1339.0 | 2565.0 |
| 16 | 4.000 | 45.3 | 96.0 | 127.2 | 407.0 | 618.0 | 1186.0 | 76 | 8.718 | 98.8 | 209.3 | 277.2 | 886.0 | 1348.0 | 2583.0 |
| 17 | 4.123 | 46.7 | 98.9 | 131.0 | 419.0 | 637.0 | 1222.0 | 77 | 8.775 | 99.4 | 210.6 | 279.0 | 892.0 | 1356.0 | 2605.0 |
| 18 | 4.243 | 48.1 | 101.8 | 135.0 | 432.0 | 655.0 | 1258.0 | 78 | 8.832 | 100.1 | 211.9 | 280.8 | 898.0 | 1365.0 | 2619.0 |
| 19 | 4.359 | 49.3 | 104.7 | 138.5 | 442.0 | 673.0 | 1291.0 | 79 | 8.888 | 100.7 | 213.2 | 282.7 | 903.0 | 1374.0 | 2632.0 |
| 20 | 4.472 | 50.7 | 107.4 | 142.3 | 454.0 | 692.0 | 1327.0 | 80 | 8.944 | 101.3 | 214.6 | 284.0 | 908.0 | 1383.0 | 2653.0 |
| 21 | 4.583 | 52.0 | 110.0 | 145.8 | 466.0 | 708.0 | 1359.0 | 81 | 9.000 | 102.0 | 216.0 | 286.0 | 914.0 | 1392.0 | 2664.0 |
| 22 | 4.690 | 53.2 | 112.6 | 149.3 | 477.0 | 725.0 | 1391.0 | 82 | 9.055 | 102.6 | 217.3 | 287.8 | 920.0 | 1400.0 | 2682.0 |
| 23 | 4.796 | 54.3 | 115.0 | 152.5 | 487.0 | 740.0 | 1421.0 | 83 | 9.110 | 103.2 | 218.6 | 289.4 | 926.0 | 1408.0 | 2700.0 |
| 24 | 4.899 | 55.5 | 117.6 | 155.7 | 497.0 | 757.0 | 1452.0 | 84 | 9.165 | 103.8 | 219.9 | 291.0 | 932.0 | 1416.0 | 2713.0 |
| 25 | 5.000 | 56.7 | 120.0 | 159.0 | 508.0 | 772.0 | 1482.0 | 85 | 9.220 | 104.4 | 221.2 | 292.6 | 937.0 | 1424.0 | 2731.0 |
| 26 | 5.099 | 57.7 | 122.3 | 162.0 | 518.0 | 788.0 | 1512.0 | 86 | 9.274 | 105.2 | 222.6 | 294.6 | 942.0 | 1433.0 | 2748.0 |
| 27 | 5.196 | 58.8 | 124.8 | 165.2 | 528.0 | 802.0 | 1539.0 | 87 | 9.327 | 105.7 | 223.9 | 296.6 | 947.0 | 1441.0 | 2764.0 |
| 28 | 5.292 | 60.0 | 127.0 | 168.4 | 538.0 | 817.0 | 1568.0 | 88 | 9.381 | 106.3 | 225.2 | 298.2 | 953.0 | 1449.0 | 2780.0 |
| 29 | 5.385 | 61.1 | 129.2 | 171.3 | 547.0 | 833.0 | 1598.0 | 89 | 9.434 | 106.9 | 226.4 | 300.0 | 958.0 | 1457.0 | 2798.0 |
| 30 | 5.477 | 62.1 | 131.5 | 174.2 | 557.0 | 846.0 | 1623.0 | 90 | 9.487 | 107.5 | 227.6 | 301.6 | 964.0 | 1465.0 | 2812.0 |
| 31 | 5.568 | 63.0 | 133.8 | 177.0 | 566.0 | 860.0 | 1651.0 | 91 | 9.539 | 108.0 | 228.9 | 303.2 | 970.0 | 1473.0 | 2827.0 |
| 32 | 5.657 | 64.0 | 135.9 | 180.0 | 575.0 | 874.0 | 1675.0 | 92 | 9.592 | 108.7 | 230.2 | 304.8 | 975.0 | 1481.0 | 2845.0 |
| 33 | 5.745 | 65.1 | 137.9 | 182.7 | 584.0 | 887.0 | 1702.0 | 93 | 9.644 | 109.3 | 231.5 | 306.4 | 980.0 | 1489.0 | 2859.0 |
| 34 | 5.831 | 66.1 | 140.0 | 185.5 | 593.0 | 900.0 | 1729.0 | 94 | 9.695 | 109.8 | 232.7 | 308.0 | 985.0 | 1497.0 | 2875.0 |
| 35 | 5.916 | 67.0 | 141.8 | 188.0 | 602.0 | 913.0 | 1751.0 | 95 | 9.747 | 110.4 | 233.9 | 309.6 | 990.0 | 1505.0 | 2890.0 |
| 36 | 6.000 | 68.0 | 144.0 | 190.8 | 610.0 | 927.0 | 1779.0 | 96 | 9.798 | 111.0 | 235.2 | 311.2 | 995.0 | 1513.0 | 2905.0 |
| 37 | 6.083 | 68.9 | 146.0 | 193.5 | 617.0 | 940.0 | 1802.0 | 97 | 9.849 | 111.6 | 236.5 | 312.8 | 1000.0 | 1521.0 | 2920.0 |
| 38 | 6.164 | 69.8 | 148.0 | 196.0 | 626.0 | 952.0 | 1828.0 | 98 | 9.900 | 112.2 | 237.6 | 314.7 | 1006.0 | 1529.0 | 2936.0 |
| 39 | 6.245 | 70.7 | 149.9 | 198.5 | 634.0 | 964.0 | 1850.0 | 99 | 9.950 | 112.7 | 238.8 | 316.2 | 1011.0 | 1537.0 | 2950.0 |
| 40 | 6.325 | 71.7 | 151.9 | 201.0 | 643.0 | 977.0 | 1875.0 | 100 | 10.000 | 113.3 | 240.0 | 317.7 | 1017.0 | 1545.0 | 2965.0 |
| 41 | 6.403 | 72.5 | 153.8 | 203.5 | 651.0 | 989.0 | 1899.0 | 101 | 10.050 | 113.9 | 241.2 | 319.3 | 1022.0 | 1553.0 | 2980.0 |
| 42 | 6.481 | 73.4 | 155.7 | 206.0 | 659.0 | 1001.0 | 1921.0 | 102 | 10.100 | 114.4 | 242.4 | 321.0 | 1027.0 | 1560.0 | 2995.0 |
| 43 | 6.557 | 74.2 | 157.5 | 208.5 | 666.0 | 1013.0 | 1942.0 | 103 | 10.149 | 115.0 | 243.8 | 322.6 | 1032.0 | 1568.0 | 3010.0 |
| 44 | 6.633 | 75.0 | 159.2 | 211.0 | 674.0 | 1025.0 | 1965.0 | 104 | 10.198 | 115.5 | 244.8 | 324.0 | 1037.0 | 1573.0 | 3025.0 |
| 45 | 6.708 | 75.9 | 161.0 | 213.5 | 681.0 | 1037.0 | 1987.0 | 105 | 10.247 | 116.2 | 246.0 | 325.9 | 1042.0 | 1583.0 | 3039.0 |
| 46 | 6.782 | 76.8 | 162.8 | 215.7 | 689.0 | 1049.0 | 2010.0 | 106 | 10.296 | 116.6 | 247.2 | 327.0 | 1047.0 | 1591.0 | 3052.0 |
| 47 | 6.856 | 77.7 | 164.9 | 218.0 | 696.0 | 1060.0 | 2032.0 | 107 | 10.344 | 117.2 | 248.4 | 328.8 | 1052.0 | 1598.0 | 3068.0 |
| 48 | 6.928 | 78.5 | 166.4 | 220.0 | 704.0 | 1071.0 | 2050.0 | 108 | 10.392 | 117.7 | 249.4 | 330.0 | 1057.0 | 1606.0 | 3079.0 |
| 49 | 7.000 | 79.2 | 168.0 | 222.5 | 712.0 | 1082.0 | 2073.0 | 109 | 10.440 | 118.3 | 250.6 | 332.0 | 1062.0 | 1613.0 | 3095.0 |
| 50 | 7.071 | 80.0 | 169.9 | 224.7 | 718.0 | 1093.0 | 2095.0 | 110 | 10.488 | 118.8 | 251.7 | 333.6 | 1067.0 | 1620.0 | 3110.0 |
| 51 | 7.141 | 80.8 | 171.5 | 227.0 | 725.0 | 1104.0 | 2118.0 | 111 | 10.536 | 119.4 | 252.8 | 335.0 | 1071.0 | 1628.0 | 3128.0 |
| 52 | 7.211 | 81.6 | 173.1 | 229.0 | 732.0 | 1114.0 | 2135.0 | 112 | 10.583 | 119.9 | 254.0 | 336.5 | 1076.0 | 1635.0 | 3140.0 |
| 53 | 7.280 | 82.5 | 174.9 | 231.5 | 740.0 | 1125.0 | 2157.0 | 113 | 10.630 | 120.4 | 255.2 | 338.0 | 1081.0 | 1642.0 | 3152.0 |
| 54 | 7.349 | 83.2 | 176.3 | 233.5 | 747.0 | 1135.0 | 2178.0 | 114 | 10.677 | 121.0 | 256.2 | 339.5 | 1086.0 | 1650.0 | 3163.0 |
| 55 | 7.416 | 83.8 | 178.0 | 235.5 | 753.0 | 1145.0 | 2195.0 | 115 | 10.724 | 121.3 | 257.5 | 341.0 | 1090.0 | 1657.0 | 3179.0 |
| 56 | 7.483 | 84.8 | 179.5 | 238.0 | 761.0 | 1156.0 | 2219.0 | 116 | 10.770 | 122.0 | 258.5 | 342.5 | 1095.0 | 1664.0 | 3193.0 |
| 57 | 7.550 | 85.5 | 181.4 | 240.0 | 767.0 | 1167.0 | 2239.0 | 117 | 10.817 | 122.5 | 259.6 | 344.0 | 1100.0 | 1671.0 | 3210.0 |
| 58 | 7.616 | 86.2 | 182.8 | 242.0 | 773.0 | 1177.0 | 2253.0 | 118 | 10.863 | 123.1 | 260.7 | 345.5 | 1105.0 | 1678.0 | 3219.0 |
| 59 | 7.681 | 86.8 | 184.2 | 244.2 | 781.0 | 1187.0 | 2278.0 | 119 | 10.909 | 123.6 | 261.8 | 347.0 | 1109.0 | 1685.4 | 3235.0 |
| 60 | 7.746 | 87.7 | 186.0 | 246.2 | 787.0 | 1197.0 | 2297.0 | 120 | 10.955 | 124.1 | 262.9 | 348.3 | 1114.0 | 1693.0 | 3243.0 |

To arrive at capacities in Gallons per Minute when the reading of H is more than 120" use the following formulas:

*G.P.M. 3" pipe 1 3/4" orifice = 11.329 x the square root of H.*

*G.P.M. 4" pipe 2 1/2" orifice = 24.00 x the square root of H.*

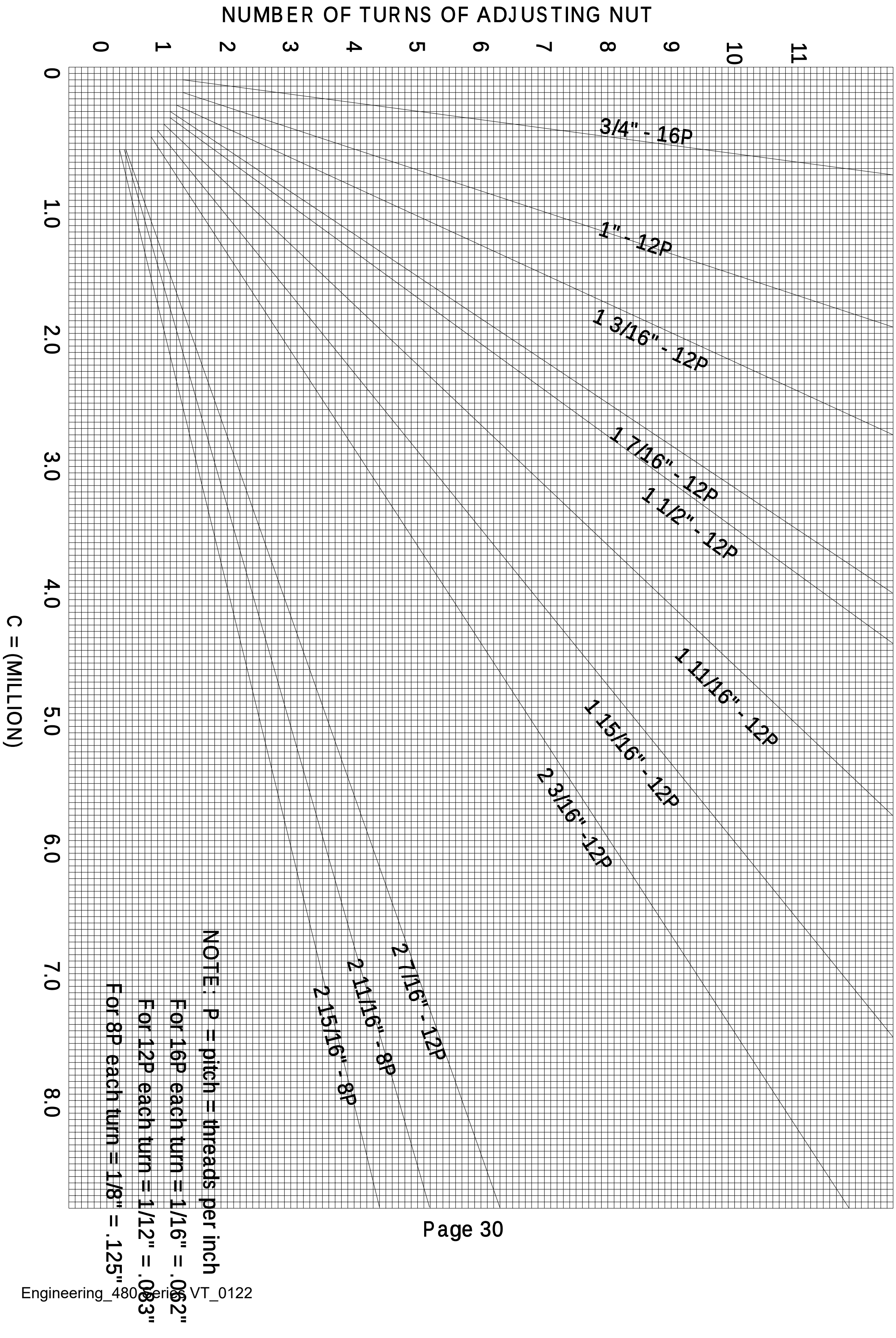
*G.P.M. 6" pipe 3" orifice = 31.77 x the square root of H.*

*G.P.M. 6" pipe 4 3/4" orifice = 101.69 x the square root of H.*

*G.P.M. 8" pipe 6" orifice = 154.50 x the square root of H.*

*G.P.M. 10" pipe 8" orifice = 296.50 x the square root of H.*

# SHAFT ADJUSTMENT



# SHAFT STRETCH THRUST LOAD

The turbine pump lineshaft stretches when the pump is in operation due to a downward pull or hydraulic thrust. The stretch due to this thrust may be determined and the impellers raised by that amount so that they will operate in the desired location with respect to the bowls when the pump is running.

Careful adjustment must be made, particularly with semi-open impellers where optimum performance is obtained with only a few thousands of an inch clearance between the bottom of the impeller and the bowl face. For side seal or combination seal impellers, the location is not critical, and they are usually set so there is adequate clearance to prevent rubbing.

The End Play (Lateral) - Thrust Constant table shows the thrust constant (K) for each bowl size representing the pounds thrust for each foot of pumping head.

Following is a curve sheet indicating the turns of the adjusting nut to equal the shaft stretch as a function of "C" for various shaft sizes.

"C" is the product of bowl thrust constant (K), the total pumping head and the shaft length or setting.

*The following is an example of how the shaft stretch is determined:*

| | | |
|---|---|---|
| | *Bowls* | *12MC* |
| | *Shaft Size* | *1 3/16"* |
| | *Setting* | *400'* |
| | *Total Head* | *180'* |

*"C" = Bowl thrust constant (K) x total pumping head x setting = 10.6 x 180 ft. x 400 ft. = 763,200.*

*From chart for "C" on back = 763,200 and 1 3/16" shaft, number of turns = 3.25.*

The shaft should be raised 0.85 turns after the impellers just clear the bowl face to allow for the shaft stretch due to hydraulic thrust.

THRUST BEARING LOAD

The thrust-bearing load that the driver thrust bearing must carry can be determined by adding the weight of the lineshafting to the product of the thrust constant (K) and the total pumping head plus the weight of impellers.

The table below show the weight of the lineshafting for common sizes.

| | | |
|---|---|---|
| *Example:* | *Bowls* | *12MCB3* |
| | *Total Head* | *180'* |
| | *Setting* | *400'* |
| | *Shaft Size* | *1 3/16"* |
| | *Motor 75 Hp* | *1750 RPM* |

Hydraulic Thrust = thrust constant (K) times total head (ft.).
Thrust constant from the table for 12MC = 10.6 Lbs. per foot.
Hydraulic Thrust = 10.6 Lbs./ft. x 180 ft. = 1,908 Lbs.
Shaft weight per foot for 1 1 3/16" shafting from Data Sheet E 210A = 3.8 Lbs. per foot.
Total shaft weight = 3.8 Lbs./ft. x 400' = 1520 Lbs.
Total Impeller weight = 3 x 15 = 45 Lbs.
Total load on thrust bearing equals hydraulic thrust plus shaft weight plus impeller wt. 1908 Lbs. + 1520 Lbs. + 45 Lbs. = 3,473 Lbs.

From the motor manufacture's specification, allowable thrust load for 75 Hp, 1,750 RPM motor is 4,800 Lbs.

Therefore the thrust is well within the permissible load for the standard heavy thrust motor. If the thrust load exceeded the motor rating, and extra heavy thrust bearing would be required.

See Reverse for Shaft Adjustment Chart.

| *Shaft Diameter* | *Weight Per Foot (Lbs.)* |
|---|---|
| *3/4"* | *1.50* |
| *1"* | *2.70* |
| *1 3/16"* | *3.80* |
| *1 7/16"* | *6* |
| *1 1/2"* | *6* |
| *1 11/16"* | *7.60* |
| *1 15/16"* | *10.00* |
| *2 3/16"* | *13* |
| *2 7/16"* | *15.90* |
| *2 11/16"* | *19.30* |
| *2 15/16"* | *23* |

# SHAFT SELECTION CHART

| SHAFT DIAMETER (in.) | SPEED (rpm) | PUMP THRUST (LBS) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1,000 | | 2,000 | | 3,000 | | 5,000 | | 7,500 | | 10,000 | | 15,000 | | 20,000 | | 30,000 | |
| | | POWER RATING (H.P.) | | | | | | | | | | | | | | | | | |
| | | 1045 | SS | 1045 | SS | 1045 | SS | 1045 | SS | 1045 | SS | 1045 | SS | 1045 | SS | 1045 | SS | 1045 | SS |
| 1 | 3450 | 114 | 140 | 114 | 140 | 113 | 139 | 111 | 139 | 107 | 134 | | | | | | | | |
| | 2900 | 95 | 117 | 94 | 117 | 94 | 116 | 92 | 115 | 88 | 112 | | | | | | | | |
| | 2200 | 72 | 89 | 72 | 89 | 71 | 88 | 70 | 87 | 67 | 85 | | | | | | | | |
| | 1760 | 57 | 70 | 57 | 70 | 57 | 70 | 56 | 69 | 53 | 67 | | | | | | | | |
| | 1460 | 47 | 58 | 47 | 58 | 47 | 58 | 46 | 57 | 44 | 55 | | | | | | | | |
| | 1160 | 38 | 46 | 37 | 46 | 37 | 46 | 36 | 55 | 35 | 44 | | | | | | | | |
| | 880 | N/A | 34 | N/A | 34 | N/A | 34 | N/A | 33 | N/A | 32 | | | | | | | | |
| 1 3/16 | 3450 | 203 | 248 | 202 | 248 | 202 | 247 | 200 | 245 | 196 | 243 | 191 | 238 | | | | | | |
| | 2900 | 168 | 208 | 168 | 208 | 167 | 207 | 166 | 205 | 162 | 204 | 158 | 200 | | | | | | |
| | 2200 | 127 | 158 | 127 | 158 | 127 | 157 | 125 | 156 | 123 | 154 | 120 | 151 | | | | | | |
| | 1760 | 102 | 124 | 101 | 124 | 101 | 124 | 100 | 123 | 98 | 122 | 96 | 120 | | | | | | |
| | 1460 | 84 | 102 | 84 | 102 | 84 | 102 | 83 | 102 | 82 | 101 | 80 | 99 | | | | | | |
| | 1160 | 67 | 82 | 67 | 82 | 67 | 82 | 66 | 81 | 65 | 80 | 63 | 79 | | | | | | |
| | 880 | | 61 | | 60 | | 60 | | 60 | | 59 | | 58 | | | | | | |
| | 770 | | 48 | | 47 | | 47 | | 47 | | 46 | | 46 | | | | | | |
| 1 1/2 | 3450 | | | | | 433 | 530 | 432 | 528 | 429 | 526 | 425 | 523 | 413 | 514 | | | | |
| | 2900 | | | | | 359 | 445 | 357 | 443 | 355 | 442 | 352 | 439 | 342 | 432 | | | | |
| | 2200 | | | | | 272 | 337 | 271 | 336 | 269 | 335 | 267 | 333 | 260 | 327 | | | | |
| | 1760 | | | | | 217 | 266 | 217 | 265 | 215 | 264 | 213 | 263 | 208 | 258 | | | | |
| | 1460 | | | | | 180 | 220 | 180 | 219 | 179 | 218 | 177 | 218 | 172 | 214 | | | | |
| | 1160 | | | | | 143 | 175 | 143 | 175 | 143 | 174 | 140 | 173 | 137 | 170 | | | | |
| | 880 | | | | | 106 | 130 | 106 | 129 | 105 | 129 | 104 | 128 | 101 | 126 | | | | |
| | 700 | | | | | | 103 | | 102 | | 101 | | 101 | | 100 | | | | |
| 1 11/16 | 2200 | | | | | | 485 | | 485 | | 483 | | 482 | | 476 | | | | |
| | 1760 | | | | | 318 | 388 | 317 | 388 | 316 | 387 | 314 | 386 | 309 | 381 | 302 | | | |
| | 1460 | | | | | 263 | 321 | 263 | 321 | 262 | 321 | 260 | 320 | 256 | 316 | 250 | | | |
| | 1160 | | | | | 209 | 256 | 209 | 256 | 208 | 255 | 207 | 254 | 204 | 251 | 199 | | | |
| | 880 | | | | | 155 | 190 | 155 | 189 | 154 | 189 | 153 | 188 | 151 | 186 | 147 | | | |
| | 700 | | | | | | 151 | | 150 | | 150 | | 149 | | 147 | | | | |
| 1 15/16 | 1760 | | | | | | | 493 | 603 | 492 | 602 | 490 | 601 | 486 | 597 | 480 | 592 | | 578 |
| | 1460 | | | | | | | 409 | 500 | 408 | 499 | 407 | 498 | 403 | 495 | 398 | 491 | 384 | 479 |
| | 1160 | | | | | | | 325 | 397 | 324 | 397 | 323 | 396 | 320 | 394 | 316 | 390 | 305 | 381 |
| | 880 | | | | | | | 241 | 294 | 240 | 294 | 239 | 293 | 237 | 292 | 234 | 289 | 226 | 282 |
| | 700 | | | | | | | | 233 | | 233 | | 233 | | 232 | | 229 | | 224 |
| 2 3/16 | 1760 | | | | | | | 724 | 885 | 723 | 884 | 721 | 883 | 718 | 880 | 712 | 876 | 697 | 863 |
| | 1460 | | | | | | | 600 | 734 | 599 | 733 | 598 | 732 | 595 | 729 | 591 | 726 | 578 | 715 |
| | 1160 | | | | | | | 477 | 583 | 476 | 582 | 475 | 582 | 473 | 580 | 469 | 577 | 459 | 569 |
| | 880 | | | | | | | 353 | 432 | 353 | 432 | 352 | 431 | 350 | 430 | 348 | 428 | 340 | 422 |
| | 700 | | | | | | | 280 | 343 | 280 | 343 | 279 | 342 | 278 | 342 | 276 | 340 | 270 | 335 |
| 2 7/16 | 1760 | | | | | | | | | 951 | 1163 | 949 | 1162 | 946 | 1159 | 941 | 1155 | 927 | 1144 |
| | 1460 | | | | | | | | | 788 | 964 | 787 | 963 | 785 | 961 | 782 | 958 | 769 | 948 |
| | 1160 | | | | | | | | | 626 | 766 | 626 | 765 | 623 | 764 | 620 | 761 | 611 | 754 |
| | 880 | | | | | | | | | 464 | 568 | 464 | 567 | 462 | 566 | 460 | 560 | 453 | 558 |
| | 700 | | | | | | | | | 369 | 568 | 369 | 450 | 367 | 450 | 365 | 445 | 360 | 443 |
| 2 15/16 | 1760 | | | | | | | | | | | | 2106 | | 2103 | | 2100 | | 2091 |
| | 1460 | | | | | | | | | | | | 1746 | | 1744 | | 1741 | | 1734 |
| | 1160 | | | | | | | | | | | | 1387 | | 1385 | | 1383 | | 1377 |
| | 880 | | | | | | | | | | | | 1053 | | 1051 | | 1050 | | 1045 |
| | 700 | | | | | | | | | | | | 837 | | 836 | | 835 | | 831 |

*Determine pump thrust from the thrust constant and shaft stretch thrust load pages of this section.

# SHAFT ELONGATION

*Inches per 100 Ft. of Shaft*
*USE OF THIS TABLE IS LIMITED TO 500 FT. SETTING. FOR DEEPER SETTING, CONSULT THE FACTORY*

| | SHAFT DIAMETER | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HYDRAULIC THRUST | 3/4 | 1 | 1 3/16 | 1 1/2 | 1 11/16 | 1 15/16 | 2 3/16 | 2 7/16 | 2 11/16 | 2 15/16 | 3 3/16 | 3 7/16 | 3 11/16 | 3 15/16 |
| 500 | 0.047 | 0.026 | 0.018 | 0.012 | 0.009 | 0.007 | | | | | | | | |
| 600 | 0.056 | 0.032 | 0.022 | 0.014 | 0.011 | 0.008 | 0.006 | | | | | | | |
| 800 | 0.075 | 0.042 | 0.030 | 0.019 | 0.015 | 0.011 | 0.009 | | | | | | | |
| 1000 | 0.094 | 0.053 | 0.037 | 0.024 | 0.019 | 0.014 | 0.011 | 0.009 | | | | | | |
| 1200 | 0.112 | 0.063 | 0.045 | 0.028 | 0.022 | 0.017 | 0.013 | 0.011 | | | | | | |
| 1400 | 0.131 | 0.074 | 0.052 | 0.033 | 0.026 | 0.020 | 0.015 | 0.012 | 0.010 | | | | | |
| 1600 | 0.150 | 0.084 | 0.060 | 0.038 | 0.030 | 0.022 | 0.018 | 0.014 | 0.012 | | | | | |
| 1800 | 0.169 | 0.095 | 0.067 | 0.042 | 0.033 | 0.025 | 0.020 | 0.016 | 0.013 | 0.011 | | | | |
| 2000 | 0.187 | 0.105 | 0.075 | 0.047 | 0.037 | 0.028 | 0.022 | 0.018 | 0.015 | 0.012 | | | | |
| 2400 | 0.225 | 0.127 | 0.090 | 0.056 | 0.044 | 0.034 | 0.026 | 0.021 | 0.018 | 0.015 | 0.012 | | | |
| 2800 | 0.262 | 0.148 | 0.105 | 0.066 | 0.052 | 0.039 | 0.030 | 0.025 | 0.020 | 0.017 | 0.015 | | | |
| 3200 | | 0.169 | 0.119 | 0.075 | 0.059 | 0.045 | 0.035 | 0.028 | 0.023 | 0.020 | 0.017 | 0.014 | | |
| 3600 | | 0.190 | 0.135 | 0.085 | 0.067 | 0.051 | 0.040 | 0.032 | 0.026 | 0.022 | 0.019 | 0.016 | | |
| 4000 | | 0.211 | 0.150 | 0.094 | 0.074 | 0.056 | 0.044 | 0.036 | 0.029 | 0.025 | 0.021 | 0.018 | 0.016 | |
| 4400 | | 0.240 | 0.164 | 0.103 | 0.081 | 0.062 | 0.048 | 0.039 | 0.032 | 0.027 | 0.024 | 0.020 | 0.017 | |
| 4800 | | 0.253 | 0.179 | 0.113 | 0.089 | 0.067 | 0.053 | 0.043 | 0.035 | 0.029 | 0.025 | 0.021 | 0.019 | 0.016 |
| 5200 | | 0.274 | 0.194 | 0.122 | 0.096 | 0.073 | 0.057 | 0.046 | 0.038 | 0.032 | 0.027 | 0.023 | 0.020 | 0.018 |
| 5600 | | | 0.209 | 0.131 | 0.107 | 0.079 | 0.062 | 0.050 | 0.041 | 0.034 | 0.029 | 0.025 | 0.022 | 0.019 |
| 6000 | | | 0.224 | 0.141 | 0.111 | 0.084 | 0.066 | 0.053 | 0.044 | 0.037 | 0.031 | 0.027 | 0.023 | 0.020 |
| 6500 | | | 0.243 | 0.153 | 0.120 | 0.091 | 0.071 | 0.058 | 0.047 | 0.040 | 0.034 | 0.029 | 0.025 | 0.022 |
| 7000 | | | 0.260 | 0.164 | 0.129 | 0.098 | 0.077 | 0.062 | 0.051 | 0.043 | 0.036 | 0.031 | 0.027 | 0.024 |
| 7500 | | | | 0.176 | 0.139 | 0.105 | 0.082 | 0.067 | 0.055 | 0.046 | 0.039 | 0.033 | 0.029 | 0.026 |
| 8000 | | | | 0.188 | 0.148 | 0.112 | 0.088 | 0.071 | 0.058 | 0.049 | 0.042 | 0.036 | 0.031 | 0.027 |
| 9000 | | | | 0.211 | 0.167 | 0.126 | 0.098 | 0.080 | 0.066 | 0.055 | 0.047 | 0.040 | 0.035 | 0.031 |
| 10,000 | | | | 0.234 | 0.185 | 0.140 | 0.110 | 0.089 | 0.073 | 0.061 | 0.052 | 0.045 | 0.039 | 0.034 |
| 12,000 | | | | 0.281 | 0.222 | 0.168 | 0.132 | 0.106 | 0.088 | 0.073 | 0.062 | 0.054 | 0.047 | 0.041 |
| 14,000 | | | | | 0.259 | 0.196 | 0.154 | 0.124 | 0.102 | 0.086 | 0.073 | 0.062 | 0.055 | 0.048 |
| 16,000 | | | | | 0.296 | 0.224 | 0.176 | 0.142 | 0.117 | 0.098 | 0.083 | 0.071 | 0.062 | 0.054 |
| 18,000 | | | | | | 0.252 | 0.198 | 0.160 | 0.131 | 0.110 | 0.093 | 0.080 | 0.070 | 0.061 |
| 20,000 | | | | | | 0.280 | 0.220 | 0.176 | 0.146 | 0.122 | 0.104 | 0.089 | 0.078 | 0.068 |
| 22,000 | | | | | | | 0.242 | 0.195 | 0.160 | 0.134 | 0.114 | 0.098 | 0.086 | 0.074 |
| 24,000 | | | | | | | 0.264 | 0.213 | 0.175 | 0.147 | 0.124 | 0.107 | 0.094 | 0.082 |
| 26,000 | | | | | | | 0.286 | 0.230 | 0.190 | 0.159 | 0.135 | 0.116 | 0.102 | 0.088 |
| 28,000 | | | | | | | | 0.248 | 0.204 | 0.171 | 0.145 | 0.125 | 0.109 | 0.095 |
| 30,000 | | | | | | | | 0.266 | 0.219 | 0.183 | 0.156 | 0.134 | 0.117 | 0.104 |
| 32,000 | | | | | | | | 0.283 | 0.233 | 0.196 | 0.166 | 0.143 | 0.125 | 0.109 |
| 34,000 | | | | | | | | | 0.248 | 0.208 | 0.176 | 0.152 | 0.133 | 0.116 |
| 36,000 | | | | | | | | | 0.262 | 0.220 | 0.187 | 0.160 | 0.140 | 0.122 |
| 38,000 | | | | | | | | | 0.277 | 0.232 | 0.197 | 0.170 | 0.148 | 0.129 |
| 40,000 | | | | | | | | | 0.292 | 0.245 | 0.207 | 0.178 | 0.156 | 0.136 |

Downthrust due to the hydraulic thrust of the pump causes the shaft and column to stretch after the pump is in operation. Unless the impellers can be and are raised off the impeller fit in the bowls enough to allow for this stretch plus some running clearance, the impellers will rub, causing the pump to wear and increase the horsepower required. With the total hydraulic downthrust known and the Column Elongation determined from this Chart the total stretch of the column tube for the setting in question can be determined. To find the net elongation subtract the shaft elongation from column elongation.

$$e = \frac{L \times 12 \times H.T.}{E \times G.S.A.}$$

Where:
e = Elongation (in inches)
L = Shaft Length (feet)
E = Modulus of Elasticity (29,000,000)
H.T. = Hydraulic Thrust (pounds)
G.S.A. = Gross Shaft Area (sq. inches)

# COLUMN AND TUBE ELONGATION

*Inches per 100 Ft. of Column (For open Line Shaft Column multiply values by 1.3)*
*USE OF THIS TABLE IS LIMITED TO 500 FT. SETTING. FOR DEEPER SETTING, CONSUL T THE FOACT OR Y*

| | COLUMN DIAMETER Standard pipe, nominal I.D. except as indicated by* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| HYDRAULIC THRUST | 3" | 4" | 5" | 6" | 8" | 10" | 12" | 14" | 16" |
| 500 | 0.007 | 0.005 | 0.004 | 0.003 | | | | | |
| 600 | 0.008 | 0.006 | 0.005 | 0.004 | | | | | |
| 800 | 0.011 | 0.008 | 0.006 | 0.005 | | | | | |
| 1000 | 0.013 | 0.010 | 0.008 | 0.006 | 0.004 | | | | |
| 1200 | 0.016 | 0.012 | 0.009 | 0.007 | 0.005 | | | | |
| 1400 | 0.019 | 0.014 | 0.011 | 0.008 | 0.006 | | | | |
| 1600 | 0.021 | 0.016 | 0.012 | 0.009 | 0.007 | 0.005 | | | |
| 1800 | 0.024 | 0.018 | 0.014 | 0.011 | 0.008 | 0.006 | | | |
| 2000 | 0.027 | 0.020 | 0.015 | 0.012 | 0.009 | 0.007 | | | |
| 2400 | 0.032 | 0.023 | 0.019 | 0.014 | 0.010 | 0.008 | 0.006 | | |
| 2800 | 0.037 | 0.027 | 0.022 | 0.016 | 0.012 | 0.010 | 0.007 | | |
| 3200 | 0.043 | 0.031 | 0.025 | 0.019 | 0.014 | 0.011 | 0.008 | | |
| 3600 | 0.048 | 0.035 | 0.028 | 0.021 | 0.016 | 0.012 | 0.009 | 0.008 | |
| 4000 | | 0.039 | 0.031 | 0.023 | 0.017 | 0.014 | 0.010 | 0.008 | |
| 4400 | | 0.043 | 0.034 | 0.026 | 0.019 | 0.015 | 0.011 | 0.009 | |
| 4800 | | 0.047 | 0.037 | 0.028 | 0.021 | 0.016 | 0.013 | 0.010 | 0.009 |
| 5200 | | 0.051 | 0.040 | 0.030 | 0.023 | 0.018 | 0.014 | 0.011 | 0.010 |
| 5600 | | 0.055 | 0.043 | 0.033 | 0.024 | 0.019 | 0.015 | 0.012 | 0.011 |
| 6000 | | | 0.046 | 0.035 | 0.026 | 0.020 | 0.016 | 0.013 | 0.011 |
| 6500 | | | 0.050 | 0.038 | 0.028 | 0.022 | 0.017 | 0.014 | 0.012 |
| 7000 | | | 0.054 | 0.041 | 0.030 | 0.024 | 0.018 | 0.015 | 0.013 |
| 7500 | | | 0.058 | 0.044 | 0.033 | 0.025 | 0.020 | 0.016 | 0.014 |
| 8000 | | | 0.062 | 0.047 | 0.035 | 0.027 | 0.021 | 0.017 | 0.015 |
| 9000 | | | | 0.053 | 0.039 | 0.030 | 0.023 | 0.019 | 0.017 |
| 10,000 | | | | 0.059 | 0.043 | 0.034 | 0.026 | 0.021 | 0.019 |
| 12,000 | | | | 0.070 | 0.052 | 0.041 | 0.031 | 0.025 | 0.023 |
| 14,000 | | | | 0.082 | 0.061 | 0.048 | 0.036 | 0.029 | 0.026 |
| 16,000 | | | | 0.094 | 0.070 | 0.054 | 0.042 | 0.034 | 0.030 |
| 18,000 | | | | | 0.078 | 0.061 | 0.047 | 0.038 | 0.034 |
| 20,000 | | | | | 0.087 | 0.068 | 0.052 | 0.042 | 0.037 |
| 22,000 | | | | | 0.096 | 0.075 | 0.057 | 0.046 | 0.041 |
| 24,000 | | | | | 0.104 | 0.082 | 0.063 | 0.050 | 0.045 |
| 26,000 | | | | | 0.113 | 0.088 | 0.068 | 0.055 | 0.049 |
| 28,000 | | | | | | 0.095 | 0.073 | 0.059 | 0.052 |
| 30,000 | | | | | | 0.102 | 0.078 | 0.063 | 0.056 |
| 32,000 | | | | | | 0.109 | 0.083 | 0.067 | 0.060 |
| 34,000 | | | | | | 0.115 | 0.089 | 0.071 | 0.064 |
| 36,000 | | | | | | 0.122 | 0.094 | 0.076 | 0.068 |
| 38,000 | | | | | | 0.129 | 0.099 | 0.080 | 0.071 |
| 40,000 | | | | | | 0.136 | 0.104 | 0.084 | 0.075 |

Downthrust due to the hydraulic thrust of the pump causes the shaft and column to stretch after the pump is in operation. Unless the impellers can be and are raised off the impeller fit in the bowls enough to allow for this stretch plus some running clearance, the impellers will rub, causing the pump to wear and increase the horsepower required. With the total hydraulic downthrust known and the Column Elongation determined from this Chart the total stretch of the column tube for the setting in question can be determined. To find the net elongation subtract the shaft elongation from column elongation.

$$e = \frac{L \times 12 \times H.T.}{E \times G.S.A.}$$

e = Elongation (in inches)
L = Shaft Length (feet)
E = Modulus of Elasticity (29,000,000)
H.T. = Hydraulic Thrust (pounds)
G.S.A. = Gross Shaft Area (sq. inches)

# HORSEPOWER THRUST BEARING

The published efficiencies of drivers do not include any external thrust on rotor. The thrust load as a unit operating loss must be added to the brake horsepower along with mechanical friction in BHP to arrive at the actual pump brake horsepower requirements of a pump (field BHP).

FORMULA:

*Convert total thrust to loss in H.P. by the following formula:*

$$\text{Thrust Bearing H.P.} = 0.0075 \times \frac{RPM}{100} \times \frac{THRUST}{1000}$$

Example: *Total Thrust of 4457.3*

$$\text{Thrust Bearing H.P.} = 0.0075 \times \frac{1770}{100} \times \frac{4457.3}{1000}$$

*= 0.6 Thrust Bearing H.P. Loss.*

*THRUST BEARING LOSSES*

| TOTAL THRUST IN POUNDS | THRUST BEARING LOSS | | | |
|---|---|---|---|---|
| | RPM | | | |
| | 3500 | 1770 | 1170 | 880 |
| 1000 | 0.262 | 0.133 | 0.088 | 0.066 |
| 2000 | 0.525 | 0.268 | 0.175 | 0.132 |
| 3000 | 0.790 | 0.400 | 0.263 | 0.198 |
| 4000 | 1.05 | 0.532 | 0.350 | 0.264 |
| 5000 | 1.32 | 0.665 | 0.438 | 0.330 |
| 6000 | 1.58 | 0.796 | 0.525 | 0.396 |
| 7000 | 1.84 | 0.930 | 0.615 | 0.460 |
| 8000 | 2.10 | 1.06 | 0.700 | 0.528 |
| 9000 | 2.36 | 1.20 | 0.79 | 0.593 |
| 10,000 | 2.62 | 1.33 | 0.88 | 0.66 |
| 15,000 | 3.95 | 1.98 | 1.40 | 0.99 |
| 20,000 | 5.25 | 2.68 | 1.75 | 1.32 |
| 25,000 | | 3.32 | 2.20 | 1.65 |
| 30,000 | | 4.00 | 2.63 | 1.98 |
| 35,000 | | 4.65 | 3.07 | 2.30 |
| 40,000 | | 5.32 | 3.50 | 2.64 |
| 45,000 | | 5.98 | 3.95 | 2.97 |
| 50,000 | | | 4.38 | 3.30 |

NOTE:
THE ABOVE EXPRESSION IS BASED ON ANGULAR CONTACT ANTI-FRICTION BEARINGS ONLY.

# POWER CONSUMPTION AND COST

POWER CONSUMPTION OF ELECTRIC MOTORS
There are two methods commonly used to check the power consumption of an electric motor.

The first of these requires the use of an ammeter and voltmeter. The following formula is then used utilizing the instrument readings:

$$\text{Kilowatts} = \frac{I \times E \times P.F. \times C}{1000}$$

where I = amperes (meter reading)

E = volts (meter reading)

P.F. = Power Factor (See manufacturer's published operating characteristics for vertical motors.)

C = 1 for single phase current
= 2 for two phase, four wire control
= 1.73 for three phase current

The second method commonly used to determine power consumption utilizes the watt-hour meter in the power line. The exact time for a given number of revolutions of the meter disc is measured with a stopwatch and the following formula used:

Kilowatts = 3.6 x K x M x R/t

where K = Disc constant, representing watt-hours per revolution. This factor is found on the meter nameplate or painted on the disc.

M = Product of current transformer ratio and potential transformer ratio. (When either transformer is not used the equivalent ratio is 1.)

R = Total revolutions of watt-hour meter disc.

t = Time for total revolutions of disc in seconds.

COST OF PUMPING USING AN ELECTRIC MOTOR
The cost of operating a vertical turbine pump may be determined by several different methods.

1. If the cost of operation per hour is desired, the power consumption as determined by use of the methods previously described may be used:

Cost/hour of operation = KW's consumed x cost per KWh.

2. The cost of operation may be estimated by determining the input horsepower and converting it to kilowatts:

Cost/hour of operation = 1 HP x 0.746 x cost per KWh.

3. A somewhat less accurate estimate may be made by using the following formula:

$$\text{Cost/hr. of operation} = \frac{\text{GPM} \times \text{Tot. Hd.} \times 0.746 \times \text{Cost/KWh}}{3960 \times \text{Pump Eff.} \times \text{Motor Eff.}}$$

4. It is often desirable to express the cost of operating a pump in terms of "cost per 1000 gallons". To do this the above figures of cost per hour of operation may be used with the rated capacity of the pump as follows:

$$\text{Cost per 1000 Gallons} = \frac{\text{Cost per Hour}}{1000}$$

5. For convenience the following table may be used to estimate power consumption and cost of operation when the overall efficiencies are known. The table gives power consumed pumping 1000 GPM at one foot total head at various overall pump efficiencies.

| OVERALL EFFICIENCY PUMP UNIT | KILOWATTS PER 1000 GALLONS AT ONE FOOT TDH |
|---|---|
| 32 | 0.00980 |
| 33 | 0.00951 |
| 34 | 0.00922 |
| 35 | 0.00896 |
| 36 | 0.00871 |
| 37 | 0.00848 |
| 38 | 0.00826 |
| 39 | 0.00804 |
| 40 | 0.00784 |
| 41 | 0.00765 |
| 42 | 0.00747 |
| 43 | 0.00730 |
| 44 | 0.00713 |
| 45 | 0.00697 |
| 46 | 0.00682 |
| 47 | 0.00667 |
| 48 | 0.00653 |
| 49 | 0.00640 |
| 50 | 0.00627 |
| 51 | 0.00615 |
| 52 | 0.00603 |
| 53 | 0.00592 |
| 54 | 0.00581 |
| 55 | 0.00570 |
| 56 | 0.00560 |
| 57 | 0.00550 |
| 58 | 0.00541 |
| 59 | 0.00532 |
| 60 | 0.00523 |
| 61 | 0.00514 |

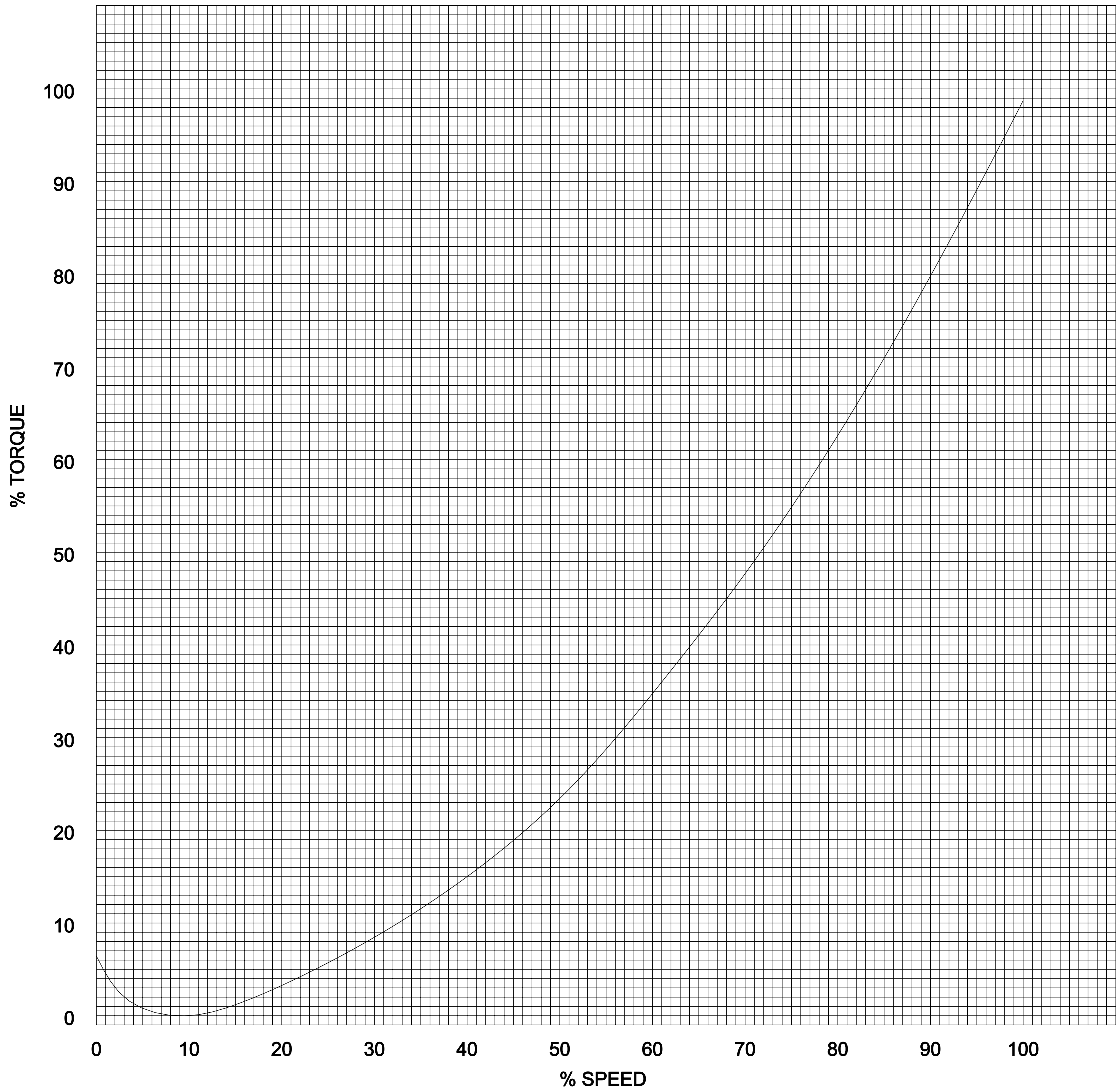
| OVERALL EFFICIENCY PUMP UNIT | KILOWATTS PER 1000 GALLONS AT ONE FOOT TDH |
|---|---|
| 62 | 0.00506 |
| 63 | 0.00498 |
| 64 | 0.00490 |
| 65 | 0.00482 |
| 66 | 0.00475 |
| 67 | 0.00468 |
| 68 | 0.00461 |
| 69 | 0.00454 |
| 70 | 0.00448 |
| 71 | 0.00442 |
| 72 | 0.00435 |
| 73 | 0.00430 |
| 74 | 0.00424 |
| 75 | 0.00418 |
| 76 | 0.00413 |
| 77 | 0.00407 |
| 78 | 0.00402 |
| 79 | 0.00397 |
| 80 | 0.00392 |
| 81 | 0.00387 |
| 82 | 0.00382 |
| 83 | 0.00378 |
| 84 | 0.00373 |
| 85 | 0.00369 |
| 86 | 0.00365 |
| 87 | 0.00360 |
| 88 | 0.00356 |
| 89 | 0.00352 |
| 90 | 0.00348 |

Overall efficiency as indicated is the input-output efficiency including all losses in the pump unit, pumping 1000 gallons of clear water one foot of total head. Therefore, in determining the kilowatts per 1000 gallon pumped, it is only necessary to multiply the factor corresponding to the overall efficiency by the number of feet head at which the total dynamic head has been calculated.

EXAMPLE: Assume an overall efficiency of 65% and a total head of 200 feet.

Kilowatts per 1000 gallons = 0.00482 x 200 = 0.964

# PUMP SPEED TORQUE CURVE AND FORMULA




The driver must be capable of supplying more torque at each successive speed from zero to full load RPM than what is required by the pump in order to reach rated speed. This means that the Speed - Torque curve of the driver must not intersect the pump torque curve anywhere on the curve before 100% speed is reached.

$$\text{Torque (ft.-lbs.)} = \frac{(5250)\,(\text{BHP})}{\text{RPM}}$$

Torque varies as the square of the speed; therefore, to obtain torque at:
3/4 speed - multiply full speed torque by 0.563
1/2 speed - multiply full speed torque by 0.250
1/4 speed - multiply full load speed torque by 0.063
1/8 speed - multiply full load speed torque by 0.016

NOTE: If the pump starts against a closed valve, use the shut off BHP for torque calculation.

*Based on Hydraulic Institute Standards.

# CORROSION

Webster defines it as the "action or process or effect of corroding" and corroding is defined as "eating away by degrees by chemical action". Pertaining to pumps, we should think of corrosion as any action which is detrimental to
its performance. Thus, a pump's performance can be destroyed by corrosion, abrasion or plugging action of solids, or a combination of the above.

The usual is to think in terms of only one of these conditions being present and affecting the pump's performance. In the case of metallic corrosion where this is true, the solution is one of selection of materials in contact with the fluid which will corrode very slowly. Vertical pumps present additional considerations in that because of costs, further refinement between rotating and non-rotating, wetted parts may require examination. Many coatings have been developed and we will not attempt to advise on the proper selection or application in this writing.

The area where we notice the greatest difficulties are those where corrosion and abrasion are present. All metals gain their projection against corrosive agents by a thin skin of corrosion. If this skin is wiped clean, the metal will recorrode, forming a new skin. Thus, if minor amounts of abrasion are found in the corrosive fluid, it is possible for these to cause this wiping action. This will occur whenever the pumped fluid abrasive content is harder than the skin corrosion or coating when it is used. Thus, soft abrasives can be present in large quantities without causing excessive wear. This condition is further activated by the velocity within the pump. By slowing the pump speed or oversizing the pump for the design conditions, the internal velocity is lowered. This will reduce the abrasive wear and can be considered on some corrosion-abrasion problems.

This brings us to the second combination which can cause difficulties. A vertical pump utilizes sleeve bearings inside a bearing retainer for proper shaft support. The straightness of this shafting is the secret of long vertical pump life. Each shaft runs with a thin film of fluid around it. By centrifugal force, this film is kept even in all bearings, thus assuring lubrication and balance in the pump. Anything which upsets this balance can cause difficulties. Thus, abrasion can wipe away bearing surfaces causing the bearing to become elliptical. The shaft then tends to destroy all bearings by its own out-of balance action and the pump fails. This same difficulty can develop in chemical fluids which tend to precipitate out. Then this solid material falling into the pump's path in large quantities causes an imbalance within the pump. This will destroy it over a period of time even when the material has a lower brinell number than the pump components.

The lack of lubricating qualities within the fluid can cause the same difficulties in the bearings. This is overcome by injection of a fluid with good lubricating qualities at each bearing journal. This injected fluid must be compatible with the fluid being pumped even though only small quantities are used. When abrasives are present in corrosive fluids, this system can be utilized by taking the pumped fluid through a small centrifugal separator, building the pressure with a small pump and lubricating the packing nut and the enclosed line shaft. This pressure should be approximately 12/15 PSI above the maximum design pressure. The shaft should be in an enclosed tube or with fluid injected through the spider to the line shaft bearing. By bringing a flushing line down to the tail bearing and rifle drilling the shaft, bearing holes can be bored at each of the bowl bearings. This will insure that clean fluid is being used for lubrication at each bearing. This flow will be away from the bearing, thus keeping all abrasives out in the main fluid flow passage.

One of the most difficult corrosive fluids to handle and understand is sea water. This is because of several variables which can alter the effects of this fluid upon different metals being employed. The first consideration is temperature. All corrosive fluids are more active as the temperature is elevated. Therefore, where cast iron might be used successfully at 30°F, the story changes at 90°F. The other chemicals in sea water can cause difficulty if their presence is not known. Around oil docks, drilling, etc., sulfides might be present. Even though found in small quantities, this can cause the fluid to be much more corrosive than just the primary fluid. The other consideration is the quantity of sand present. Offshore installations are subject to tides and wave action. This can cause the sand content to continually change and therefore, present a difficult system to analyze. The electolitic action of dissimilar metals in the presence of the sea water must also be taken into account.

The best corrosive defense is your own experience on any given unit. Thus, good records are a necessity. Each pump should be checked for vibration and amperage periodically. This information, along with the shut-off head, should be noted in the permanent record. Any changes should be cause for investigation. Any repairs should be noted with complete description of parts used, materials and conditions of the parts being replaced. With this type of record, it is possible to ascertain improvements in performance and be aware of what materials or action brought them about. Without this information it is not possible to be certain that the solution is correct for a particular application and expensive parts can be lost. Corrosion is a never-ceasing battle to extend the life of equipment to acceptable economic limits, and good records are essential for proper determination. A qualified J-Line sales engineer stands ready to assist you in this endeavor at all times - give us a call.

# CONVERSION TABLES

## UNITS OF PRESSURE AND HEAD

| UNITS | LBS. PER SQUARE INCH | FEET OF WATER | METERS OF WATER | INCHES OF MERCURY | ATMOS-PHERES | KILOGRAMS PER SQ. C.M. |
|---|---|---|---|---|---|---|
| 1 LB. PER SQ. INCH | 1. | 2.31 | 0.704 | 2.04 | 0.0681 | 0.0703 |
| 1 FT. OF WATER | 0.433 | 1. | 0.305 | 0.882 | 0.02947 | 0.0305 |
| 1 METER OF WATER | 1.421 | 3.28 | 1. | 2.89 | 0.0967 | 0.1 |
| 1 INCH OF MERCURY | 0.491 | 1.134 | 0.3456 | 1. | 0.0334 | 0.0345 |
| 1 ATMOSPHERE (AT SEA LEVEL) | 14.70 | 33.93 | 10.34 | 29.92 | 1. | 1.033 |
| 1 KILOGRAM PER SQ. C.M. | 14.22 | 32.8 | 10. | 28.96 | 0.968 | 1. |

Equivalent units are based on density of fresh water from 32° to 62°F.
Equivalent units are based on density of mercury from 32° to 62° F. - sufficient accuracy.
Each 1000 ft. of ascent decreases pressure about 1/2 lb./sq. in.

## UNITS OF VOLUME AND WEIGHT

| UNITS | U.S. GALLONS | IMPERIAL GALLONS | CUBIC INCHES | CUBIC FEET | ACRE FEET | * POUNDS | CUBIC METERS | LITERS |
|---|---|---|---|---|---|---|---|---|
| 1 U.S. GALLON | 1. | 0.833 | 231. | 0.1337 | 0.00000307 | 8.35 | 0.003785 | 3.785 |
| 1 IMPERIAL GALLON | 1.201 | 1. | 277.4 | 0.1605 | 0.00000369 | 10.02 | 0.004546 | 4.546 |
| 1 CUBIC INCH | 0.00433 | 0.00360 | 1. | 0.000579 | | 0.0361 | | 0.0164 |
| 1 CUBIC FOOT | 7.48 | 6.23 | 1728. | 1. | 0.0000230 | 62.4 | 0.02832 | 28.32 |
| 1 ACRE - FOOT | 325.850 | 271.335 | | 43.560 | 1. | | 1233.5 | |
| 1 POUND | 0.120 | 0.0998 | 27.7 | 0.0160 | | 1. | | 0.454 |
| 1 CUBIC METER | 264.2 | 220. | 61.023 | 35.314 | 0.000811 | 2205. | 1. | 1000. |
| 1 LITER | 0.2642 | 0.220 | 0.061023 | 0.0353 | | 2.205 | | 1. |

*WTS. Shown based on maximum density of fresh water at 39° Fahrenheit.

## UNITS OF AREA

| UNITS | SQUARE INCH | SQUARE FEET | SQUARE YARD | ACRES | SQUARE MILES | SQUARE CENTI-METER | SQUARE METERS | HECTARES |
|---|---|---|---|---|---|---|---|---|
| 1 SQUARE INCH | 1. | 0.00694 | 0.00077 | | | 6.452 | | |
| 1 SQUARE FOOT | 144. | 1. | 0.111 | | | 929. | 0.0929 | |
| 1 SQUARE YARD | 1296. | 9 | 1. | 0.000207 | | 8361. | 0.836 | |
| 1 ACRE | | 43,560. | 4840. | 1. | 0.00156 | | 4049. | 0.405 |
| 1 SQUARE MILE | | 27,878,400. | 3,097,600. | 640. | 1. | | 2,593,388.16 | 258. |
| 1 SQUARE CENTIMETER | 0.155 | 0.001076 | | | | 1. | 0.0001 | |
| 1 SQUARE METER | 1549. | 10.76 | 1.196 | 0.000247 | | 10.000 | 1. | 0.0001 |
| 1 HECTARE | | 107,639. | 11,960. | 2.471 | 0.00386 | 99,996,631. | 10,000. | 1. |

# CONVERSION TABLES

UNITS OF FLOW

| UNITS | U.S. GALLONS PER MINUTE | MILLION U.S. GALLONS PER DAY | CUBIC FEET PER SECOND | CUBIC METERS PER HOUR | LITERS PER SECOND | MINER'S INCH* | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | I | II | III |
| 1 U.S. GALLON PER MINUTE | 1. | 0.001440 | 0.00223 | 0.2270 | 0.0631 | 0.0891 | 0.1114 | 0.0856 |
| 1 MILLION U.S. GALLONS PER DAY | 694.5 | 1. | 1.547 | 157.73 | 43.8 | 61.9 | 77.4 | 59.4 |
| 1 CU. FOOT PER SEC. | 448.8 | 0.646 | 1. | 101.9 | 28.32 | 40. | 50. | 38.4 |
| 1 CU. METER PER HOUR | 4.403 | 0.00634 | 0.00981 | 1. | 0.2778 | | | |
| 1 LITER PER SEC. | 15.85 | 0.0228 | 0.0353 | 3.60 | 1. | | | |
| 1 MINER'S INCH* I | 11.22 | 0.01618 | 0.0250 | | | | | |
| 1 MINER'S INCH* II | 8.98 | 0.01294 | 0.0200 | | | | | |
| 1 MINER'S INCH* III | 11.69 | 0.01682 | 0.0260 | | | | | |
| 1 MINER'S INCH* IV | 12.58 | 0.01811 | 0.0280 | | | | | |

**The Miner's Inch varies in definition in different areas. State laws have set the value as follow:*
*I. 40 M.I. = 1 CFS. in Arizona, California, Montana and Oregon*
*II. 50 M.I. = 1 CFS. in Idaho, Nebraska, Nevada, New Mexico, Utah, Kansas, S. Dakota, N. Dakota*
*III. 38.4 M.I. = 1 CFS. in Colorado*
*IV. 35.7 M.I. = 1 CFS. in British Columbia*
*Usual practice in Southern California, 50 M.I. = 1 CFS = 448.8 GPM*

UNITS OF POWER

| UNITS | HORSE-POWER | FT.-LBS. PER MINUTE | WATTS | KILOWATTS | METRIC HORSE-POWER | B.T.U. PER MINUTE |
|---|---|---|---|---|---|---|
| 1 HORSEPOWER | 1. | 33,000. | 746. | 0.746 | 1.014 | 42.4 |
| 1 FT.-LB. PER MINUTE | 0.0000303 | 1. | 0.0226 | 0.0000226 | 0.0000307 | 0.001285 |
| 1 WATT | 0.001340 | 44.2 | 1. | 0.001 | 0.001360 | 0.0568 |
| 1 KILOWATT | 1.341 | 44,250. | 1000. | 1. | 1.360 | 56.8 |
| 1 METRIC HORSEPOWER | 0.986 | 32,550. | 736. | 0.736 | 1. | 41.8 |
| 1 BTU PER MINUTE | 0.0236 | 778.4 | 17.6 | 0.0176 | 0.0239 | 1. |

UNITS OF LENGTH

1 Inch = 0.0833 ft. = 0.0278 yd. = 25.4 millimeters = 2.54 centimeters
1 Foot = 12 inches = 0.333 yd. = 30.48 centimeters = 0.3048 meters
1 Yard = 36 inches = 3 feet = 91.44 centimeters = 0.9144 meters
1 Mile = 5280 ft. = 1760 yds. = 1.61 kilometer = 1609 meters
1 Meter = 3.281 ft. = 39.37 in. = 0.000622 miles = 0.001 kilometers
1 Kilometer = 1000 meters = 1093.61 yds. = 0.62137 miles = 3281 feet

# TURBINE COLUMN FRICTION LOSS TABLE

| COL. SIZE | 3" | 4" | | | 5" | | | 6" | | | 8" | | | 10" | | | 12" | | | | COL. SIZE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHAFT SIZE | 3/4" | 3/4" | 1" | 1 3/16" | 3/4" | 1" | 1 3/16" | 1" | 1 3/16" | 1 1/2" | 1 3/16" | 1 1/2" | 1 15/16" | 1 3/16" | 1 1/2" | 1 15/16" | 1 3/16" | 1 1/2" | 1 15/16" | 2 3/16" | SHAFT SIZE |
| TUBE SIZE | 1 1/4" | 1 1/4" | 1 1/2" | 2" | 1 1/4" | 1 1/2" | 2" | 1 1/2" | 2" | 2 1/2" | 2" | 2 1/2" | 3" | 2" | 2 1/2" | 3' | 2" | 2 1/2" | 3" | 3 1/2" | TUBE SIZE |
| G.P.M. | COLUMN FRICTION LOSS (IN FEET) PER 100 FEET OF COLUMN | | | | | | | | | | | | | | | | | | | | G.P.M. |
| 25 | 1.8 | | | | | | | | | | | | | | | | | | | | 25 |
| 50 | 4.6 | 0.65 | 0.86 | 1.6 | | | | | | | | | | | | | | | | | 50 |
| 75 | 9.0 | 1.3 | 1.7 | 3.3 | | | | | | | | | | | | | | | | | 75 |
| 100 | 14.0 | 2.2 | 2.8 | 5.3 | 0.54 | 0.65 | 0.94 | | | | | | | | | | | | | | 100 |
| 125 | | 3.2 | 4.2 | 7.8 | 0.81 | 0.96 | 1.4 | | | | | | | | | | | | | | 125 |
| 150 | | 4.4 | 5.8 | 10.6 | 1.1 | 1.3 | 1.9 | | | | | | | | | | | | | | 150 |
| 175 | | 5.8 | 7.5 | 13.8 | 1.5 | 1.7 | 2.5 | | | | | | | | | | | | | | 175 |
| 200 | | 7.3 | 9.4 | 17.1 | 1.8 | 2.2 | 3.1 | 0.73 | 0.96 | 1.4 | | | | | | | | | | | 200 |
| 225 | | 9.0 | 12.0 | 21.1 | 2.3 | 2.7 | 3.9 | 0.90 | 1.2 | 1.7 | | | | | | | | | | | 225 |
| 250 | | 10.9 | 14.0 | | 2.7 | 3.3 | 4.7 | 1.1 | 1.4 | 2.0 | | | | | | | | | | | 250 |
| 275 | | 13.0 | 16.8 | | 3.3 | 3.9 | 5.6 | 1.3 | 1.7 | 2.4 | | | | | | | | | | | 275 |
| 300 | | 15.2 | 19.2 | | 3.8 | 4.5 | 6.4 | 1.5 | 2.0 | 2.8 | | | | | | | | | | | 300 |
| 325 | | 19.8 | | | 4.4 | 5.2 | 7.4 | 1.7 | 2.3 | 3.2 | | | | | | | | | | | 325 |
| 350 | | | | | 5.0 | 6.0 | 8.4 | 2.0 | 2.6 | 3.6 | | | | | | | | | | | 350 |
| 375 | | | | | 5.6 | 6.7 | 9.5 | 2.2 | 2.9 | 4.1 | | | | | | | | | | | 375 |
| 400 | | | | | 6.3 | 7.5 | 10.6 | 2.5 | 3.3 | 4.6 | 0.61 | 0.74 | 1.0 | | | | | | | | 400 |
| 450 | | | | | 7.8 | 9.3 | 13.1 | 3.1 | 4.1 | 5.7 | 0.77 | 0.91 | 1.3 | | | | | | | | 450 |
| 500 | | | | | 9.2 | 11.2 | 15.7 | 3.7 | 5.0 | 6.9 | 0.93 | 1.1 | 1.5 | | | | | | | | 500 |
| 550 | | | | | 11.0 | 13.2 | 18.6 | 4.4 | 5.8 | 8.1 | 1.1 | 1.3 | 1.8 | | | | | | | | 550 |
| 600 | | | | | 12.9 | 15.5 | | 5.2 | 6.8 | 9.5 | 1.3 | 1.5 | 2.1 | | | | | | | | 600 |
| 650 | | | | | 14.8 | 20.3 | | 6.0 | 7.9 | 11.0 | 1.5 | 1.8 | 2.5 | | | | | | | | 650 |
| 700 | | | | | 16.8 | | | 6.9 | 9.1 | 12.5 | 1.7 | 2.0 | 2.8 | | | | | | | | 700 |
| 750 | | | | | 19.0 | | | 7.9 | 10.3 | 14.1 | 1.9 | 2.3 | 3.2 | | | | | | | | 750 |
| 800 | | | | | | | | 8.8 | 11.5 | 15.7 | 2.2 | 2.6 | 3.6 | 0.57 | 0.65 | 0.77 | | | | | 800 |
| 850 | | | | | | | | 9.9 | 12.8 | 17.7 | 2.4 | 2.9 | 4.0 | 0.63 | 0.72 | 0.86 | | | | | 850 |
| 900 | | | | | | | | 11.0 | 14.3 | 19.5 | 2.7 | 3.2 | 4.5 | 0.70 | 0.80 | 0.96 | | | | | 900 |
| 950 | | | | | | | | 12.1 | 15.8 | 21.5 | 2.9 | 3.5 | 4.9 | 0.77 | 0.88 | 1.1 | | | | | 950 |
| 1000 | | | | | | | | | | | 3.2 | 3.9 | 5.4 | 0.85 | 0.97 | 1.2 | 0.34 | 0.38 | 0.44 | 0.50 | 1000 |
| 1200 | | | | | | | | | | | 4.5 | 5.4 | 7.6 | 1.2 | 1.4 | 1.6 | 0.47 | 0.54 | 0.62 | 0.71 | 1200 |
| 1400 | | | | | | | | | | | 6.0 | 7.2 | 10.0 | 1.6 | 1.8 | 2.2 | 0.62 | 0.71 | 0.82 | 0.94 | 1400 |
| 1600 | | | | | | | | | | | 7.6 | 9.1 | 13.0 | 2.0 | 2.3 | 2.8 | 0.80 | 0.90 | 1.1 | 1.2 | 1600 |
| 1800 | | | | | | | | | | | 9.4 | 11.0 | 15.7 | 2.5 | 2.8 | 3.4 | 0.99 | 1.1 | 1.3 | 1.5 | 1800 |
| 2000 | | | | | | | | | | | 11.0 | 13.0 | 19.2 | 3.0 | 3.5 | 4.2 | 1.2 | 1.4 | 1.6 | 1.8 | 2000 |
| 2200 | | | | | | | | | | | 13.2 | 16.5 | 22.9 | 3.6 | 4.1 | 5.0 | 1.4 | 1.6 | 1.9 | 2.1 | 2200 |
| 2400 | | | | | | | | | | | 15.5 | 19.3 | | 4.2 | 4.9 | 5.8 | 1.7 | 1.9 | 2.2 | 2.5 | 2400 |
| 2600 | | | | | | | | | | | 17.9 | 22.4 | | 4.9 | 5.6 | 6.8 | 1.9 | 2.2 | 2.5 | 2.9 | 2600 |
| 2800 | | | | | | | | | | | 20.5 | | | 5.6 | 6.4 | 7.8 | 2.2 | 2.5 | 2.8 | 3.3 | 2800 |
| 3000 | | | | | | | | | | | | | | 6.4 | 7.4 | 8.8 | 2.5 | 2.9 | 3.3 | 3.8 | 3000 |
| 3200 | | | | | | | | | | | | | | 7.1 | 8.1 | 9.9 | 2.8 | 3.2 | 3.7 | 4.3 | 3200 |
| 3400 | | | | | | | | | | | | | | 7.9 | 9.0 | 11.1 | 3.2 | 3.6 | 4.2 | 4.8 | 3400 |
| 3600 | | | | | | | | | | | | | | 8.8 | 10.0 | 12.4 | 3.5 | 4.0 | 4.7 | 5.3 | 3600 |
| 3800 | | | | | | | | | | | | | | 9.8 | 11.1 | 13.7 | 3.9 | 4.4 | 5.1 | 5.9 | 3800 |
| 4000 | | | | | | | | | | | | | | 10.7 | 12.2 | 15.0 | 4.3 | 4.9 | 5.6 | 6.4 | 4000 |
| 4200 | | | | | | | | | | | | | | 11.8 | 13.4 | 16.4 | 4.7 | 5.3 | 6.2 | 7.1 | 4200 |
| 4400 | | | | | | | | | | | | | | 12.9 | 14.6 | 17.9 | 5.1 | 5.8 | 6.7 | 7.7 | 4400 |
| 4600 | | | | | | | | | | | | | | 13.9 | 15.8 | 19.3 | 5.6 | 6.3 | 7.4 | 8.4 | 4600 |
| 4800 | | | | | | | | | | | | | | 15.0 | 17.2 | 21.0 | 6.0 | 6.8 | 7.9 | 9.0 | 4800 |

The following table will serve as a guide in figuring column friction losses to allow for condition of pipe:

| Condition of Pipe Inside | Approx. Age of Pipe in Ordinary Use for Cold Clear Water | Use Friction Loss Figures from table multiplied by the following factor |
|---|---|---|
| Very Smooth | New | 1.00 |
| Fairly Smooth | 1 - 5 years | 1.51 |
| Rough | 6 or more years | 2.35 |

# FRICTION LOSSES IN STEEL PIPES-3 THROUGH 36 INCH

## 3 INCH

3" 3.00 I.D.

| U.S. GALLONS PER MIN. | VELOCITY FT. PER SECOND | HEAD LOSS FT. HEAD/ 100 FT. |
|---|---|---|
| 40 | 1.82 | 0.91 |
| 60 | 2.72 | 1.94 |
| 80 | 3.63 | 3.30 |
| 100 | 4.54 | 4.98 |
| 120 | 5.45 | 6.98 |
| 140 | 6.35 | 9.28 |
| 160 | 7.26 | 11.9 |
| 180 | 8.16 | 14.8 |
| 200 | 9.08 | 18.0 |
| 250 | 11.3 | 27.1 |
| 300 | 13.6 | 38.0 |
| 350 | 15.9 | 50.5 |
| 400 | 18.2 | 64.7 |
| 450 | 20.5 | 80.5 |
| 500 | 22.7 | 97.8 |

## 4 INCH

4" 4.026 I.D.

| U.S. GALLONS PER MIN. | VELOCITY FT. PER SECOND | FRICTION LOSS FT. HEAD/100 FT. PIPE | |
|---|---|---|---|
| | | STEEL C=100 | PVC C=150 |
| 50 | 1.26 | 0.33 | 0.16 |
| 75 | 1.89 | 0.70 | 0.34 |
| 100 | 2.52 | 1.19 | 0.58 |
| 125 | 3.15 | 1.80 | 0.87 |
| 150 | 3.78 | 2.53 | 1.22 |
| 200 | 5.05 | 4.29 | 2.08 |
| 250 | 6.30 | 6.45 | 3.12 |
| 300 | 7.57 | 9.09 | 4.41 |
| 350 | 8.82 | 12.0 | 5.82 |
| 400 | 10.1 | 15.5 | 7.52 |
| 500 | 12.6 | 23.4 | 11.3 |
| 600 | 15.1 | 32.8 | 15.9 |
| 700 | 17.6 | 43.6 | 21.1 |
| 800 | 20.2 | 55.8 | 27.0 |
| 900 | 22.7 | 69.3 | 33.6 |

## 5 INCH

5" 5.00 I.D.

| U.S. GALLONS PER MIN. | VELOCITY FT. PER SECOND | HEAD LOSS FT. HEAD/ 100 FT. |
|---|---|---|
| 75 | 1.22 | 0.24 |
| 100 | 1.63 | 0.42 |
| 125 | 2.04 | 0.63 |
| 150 | 2.45 | 0.88 |
| 175 | 2.86 | 1.17 |
| 200 | 3.27 | 1.50 |
| 250 | 4.09 | 2.27 |
| 300 | 4.90 | 3.17 |
| 400 | 6.54 | 5.39 |
| 500 | 8.17 | 8.15 |
| 600 | 9.80 | 11.7 |
| 700 | 11.4 | 15.2 |
| 800 | 13.1 | 19.4 |
| 1000 | 16.3 | 29.4 |
| 1200 | 19.6 | 41.1 |

## 6 INCH

6" 6.065 I.D.

| U.S. GALLONS PER MIN. | VELOCITY FT. PER SECOND | FRICTION LOSS FT. HEAD/100 FT. PIPE | |
|---|---|---|---|
| | | STEEL C=100 | PVC C=150 |
| 100 | 1.11 | 0.16 | 0.07 |
| 150 | 1.67 | 0.34 | 0.16 |
| 200 | 2.22 | 0.58 | 0.28 |
| 250 | 2.77 | 0.89 | 0.42 |
| 300 | 3.33 | 1.24 | 0.58 |
| 400 | 4.44 | 2.11 | 0.99 |
| 500 | 5.55 | 3.19 | 1.50 |
| 600 | 6.66 | 4.46 | 2.10 |
| 700 | 7.78 | 5.93 | 2.79 |
| 800 | 8.90 | 7.60 | 3.60 |
| 900 | 10.0 | 9.44 | 4.46 |
| 1000 | 11.1 | 11.5 | 5.44 |
| 1200 | 13.3 | 16.1 | 7.62 |
| 1400 | 15.6 | 21.4 | 10.1 |
| 1600 | 17.8 | 27.4 | 13.0 |

## 8 INCH

8" STD. WT. STEEL 7.981" I.D.

| FLOW GALLONS PER MIN. | VELOCITY FT. PER SECOND | VELOCITY HEAD FT. | HEAD FT. PER 100 FT. |
|---|---|---|---|
| 130 | 0.83 | 0.01 | 0.069 |
| 140 | 0.90 | 0.01 | 0.079 |
| 150 | 0.96 | 0.01 | 0.091 |
| 160 | 1.03 | 0.02 | 0.102 |
| 170 | 1.09 | 0.02 | 0.114 |
| 180 | 1.15 | 0.02 | 0.126 |
| 190 | 1.22 | 0.02 | 0.140 |
| 200 | 1.28 | 0.03 | 0.154 |
| 220 | 1.41 | 0.03 | 0.183 |
| 240 | 1.54 | 0.04 | 0.215 |
| 260 | 1.67 | 0.04 | 0.250 |
| 280 | 1.80 | 0.05 | 0.286 |
| 300 | 1.92 | 0.06 | 0.325 |
| 350 | 2.24 | 0.08 | 0.433 |
| 400 | 2.57 | 0.10 | 0.554 |
| 450 | 2.88 | 0.13 | 0.689 |
| 500 | 3.20 | 0.16 | 0.838 |
| 550 | 3.52 | 0.19 | 0.999 |
| 600 | 3.85 | 0.23 | 1.170 |
| 650 | 4.17 | 0.27 | 1.360 |
| 700 | 4.49 | 0.31 | 1.560 |
| 750 | 4.81 | 0.36 | 1.770 |
| 800 | 5.13 | 0.41 | 1.990 |
| 850 | 5.45 | 0.46 | 2.230 |
| 900 | 5.77 | 0.52 | 2.480 |
| 950 | 6.09 | 0.58 | 2.740 |
| 1000 | 6.41 | 0.64 | 3.020 |
| 1100 | 7.05 | 0.77 | 3.600 |
| 1200 | 7.69 | 0.92 | 4.230 |
| 1300 | 8.33 | 1.08 | 4.900 |
| 1400 | 8.97 | 1.25 | 5.620 |
| 1500 | 9.61 | 1.44 | 6.390 |
| 1600 | 10.30 | 1.70 | 7.200 |
| 1800 | 11.50 | 2.10 | 8.950 |
| 2000 | 12.80 | 2.50 | 10.900 |
| 2200 | 14.10 | 3.10 | 13.000 |
| 2400 | 15.40 | 3.70 | 15.200 |
| 2600 | 16.70 | 4.30 | 17.700 |
| 2800 | 18.00 | 5.00 | 20.300 |
| 3000 | 19.20 | 5.70 | 23.000 |
| 3500 | 22.40 | 7.80 | 30.600 |
| 4000 | 25.60 | 10.20 | 39.200 |
| 4500 | 28.80 | 12.90 | 48.800 |
| 5000 | 32.00 | 15.90 | 59.300 |
| 5500 | 35.30 | 19.40 | 70.700 |

## 10 INCH

10" STD. WT. STEEL 10.02" I.D.

| FLOW GALLONS PER MIN. | VELOCITY FT. PER SECOND | VELOCITY HEAD FT. | HEAD FT. PER 100 FT. |
|---|---|---|---|
| 180 | 0.73 | 0.01 | 0.042 |
| 200 | 0.81 | 0.01 | 0.051 |
| 220 | 0.89 | 0.01 | 0.061 |
| 240 | 0.98 | 0.01 | 0.071 |
| 260 | 1.06 | 0.02 | 0.083 |
| 280 | 1.14 | 0.02 | 0.095 |
| 300 | 1.22 | 0.02 | 0.108 |
| 350 | 1.42 | 0.03 | 0.143 |
| 400 | 1.63 | 0.04 | 0.183 |
| 450 | 1.83 | 0.05 | 0.228 |
| 500 | 2.04 | 0.06 | 0.277 |
| 550 | 2.24 | 0.08 | 0.330 |
| 600 | 2.44 | 0.09 | 0.388 |
| 650 | 2.64 | 0.11 | 0.450 |
| 700 | 2.85 | 0.13 | 0.516 |
| 800 | 3.25 | 0.16 | 0.660 |
| 900 | 3.66 | 0.21 | 0.821 |
| 1000 | 4.07 | 0.26 | 0.998 |
| 1100 | 4.48 | 0.31 | 1.190 |
| 1200 | 4.89 | 0.37 | 1.400 |
| 1300 | 5.30 | 0.44 | 1.620 |
| 1400 | 5.70 | 0.50 | 1.860 |
| 1500 | 6.10 | 0.58 | 2.110 |
| 1600 | 6.51 | 0.66 | 2.380 |
| 1700 | 6.92 | 0.74 | 2.660 |
| 1800 | 7.32 | 0.83 | 2.960 |
| 1900 | 7.73 | 0.93 | 3.270 |
| 2000 | 8.14 | 1.03 | 3.600 |
| 2200 | 8.95 | 1.24 | 4.290 |
| 2400 | 9.76 | 1.48 | 5.040 |
| 2600 | 10.60 | 1.70 | 5.840 |
| 2800 | 11.40 | 2.00 | 6.700 |
| 3000 | 12.20 | 2.30 | 7.610 |
| 3200 | 13.00 | 2.70 | 8.580 |
| 3400 | 13.80 | 3.00 | 9.600 |
| 3600 | 14.60 | 3.30 | 10.700 |
| 3800 | 15.50 | 3.70 | 11.800 |
| 4000 | 16.30 | 4.10 | 13.000 |
| 4500 | 18.30 | 5.20 | 16.100 |
| 5000 | 20.30 | 6.40 | 19.600 |
| 5500 | 22.40 | 7.80 | 23.400 |
| 6000 | 24.40 | 9.30 | 27.500 |
| 6500 | 26.40 | 10.8 | 31.800 |
| 7000 | 28.50 | 12.6 | 36.500 |
| 7500 | 30.50 | 14.5 | 41.500 |

## 12 INCH

12" STD. WT. STEEL 12.000" I.D.

| FLOW GALLONS PER MIN. | VELOCITY FT. PER SECOND | VELOCITY HEAD FT. | HEAD FT. PER 100 FT. |
|---|---|---|---|
| 200 | 0.57 | 0.01 | 0.021 |
| 250 | 0.71 | 0.01 | 0.032 |
| 300 | 0.85 | 0.01 | 0.045 |
| 350 | 0.99 | 0.02 | 0.059 |
| 400 | 1.14 | 0.02 | 0.076 |
| 450 | 1.28 | 0.03 | 0.095 |
| 500 | 1.42 | 0.03 | 0.115 |
| 550 | 1.56 | 0.04 | 0.137 |
| 600 | 1.70 | 0.05 | 0.161 |
| 700 | 1.99 | 0.06 | 0.214 |
| 800 | 2.27 | 0.08 | 0.275 |
| 900 | 2.56 | 0.10 | 0.341 |
| 1000 | 2.84 | 0.13 | 0.415 |
| 1100 | 3.12 | 0.15 | 0.495 |
| 1200 | 3.41 | 0.18 | 0.581 |
| 1300 | 3.69 | 0.21 | 0.674 |
| 1400 | 3.98 | 0.25 | 0.773 |
| 1500 | 4.26 | 0.28 | 0.878 |
| 1600 | 4.55 | 0.32 | 0.990 |
| 1800 | 5.11 | 0.41 | 1.230 |
| 2000 | 5.68 | 0.50 | 1.500 |
| 2200 | 6.25 | 0.61 | 1.780 |
| 2400 | 6.81 | 0.72 | 2.100 |
| 2600 | 7.38 | 0.85 | 2.430 |
| 2800 | 7.95 | 0.98 | 2.780 |
| 3000 | 8.52 | 1.13 | 3.170 |
| 3500 | 9.95 | 1.54 | 4.210 |
| 4000 | 11.4 | 2.00 | 5.390 |
| 4500 | 12.8 | 2.50 | 6.700 |
| 5000 | 14.2 | 3.10 | 8.150 |
| 5500 | 15.6 | 3.80 | 9.720 |
| 6000 | 17.0 | 4.50 | 11.400 |
| 6500 | 18.4 | 5.30 | 13.200 |
| 7000 | 19.9 | 6.20 | 15.200 |
| 7500 | 21.3 | 7.10 | 17.300 |
| 8000 | 22.7 | 8.00 | 19.400 |
| 8500 | 24.2 | 9.10 | 21.700 |
| 9000 | 25.6 | 10.2 | 24.200 |
| 9500 | 27.0 | 11.3 | 26.700 |
| 10000 | 28.4 | 12.5 | 29.400 |
| 11000 | 31.2 | 15.1 | 35.000 |
| 12000 | 34.1 | 18.1 | 41.200 |
| 13000 | 36.9 | 21.2 | 47.700 |
| 14000 | 39.8 | 24.6 | 54.700 |
| 15000 | 42.6 | 28.2 | 62.200 |

## 14 INCH

14" STD. WT. STEEL 13.25" I.D.

| FLOW GALLONS PER MIN. | VELOCITY FT. PER SECOND | VELOCITY HEAD FT. | HEAD FT. PER 100 FT. |
|---|---|---|---|
| 300 | 0.70 | 0.01 | 0.028 |
| 400 | 0.93 | 0.01 | 0.047 |
| 500 | 1.16 | 0.02 | 0.071 |
| 600 | 1.40 | 0.03 | 0.100 |
| 700 | 1.63 | 0.04 | 0.132 |
| 800 | 1.86 | 0.05 | 0.170 |
| 900 | 2.09 | 0.07 | 0.211 |
| 1000 | 2.33 | 0.08 | 0.256 |
| 1100 | 2.56 | 0.10 | 0.306 |
| 1200 | 2.79 | 0.12 | 0.359 |
| 1300 | 3.02 | 0.14 | 0.416 |
| 1400 | 3.26 | 0.17 | 0.477 |
| 1500 | 3.49 | 0.19 | 0.542 |
| 1600 | 3.72 | 0.22 | 0.611 |
| 1700 | 3.95 | 0.24 | 0.684 |
| 1800 | 4.19 | 0.27 | 0.760 |
| 1900 | 4.42 | 0.30 | 0.840 |
| 2000 | 4.65 | 0.34 | 0.924 |
| 2500 | 5.81 | 0.52 | 1.400 |
| 3000 | 6.98 | 0.76 | 1.960 |
| 3500 | 8.15 | 1.03 | 2.600 |
| 4000 | 9.31 | 1.35 | 3.320 |
| 4500 | 10.5 | 1.70 | 4.130 |
| 5000 | 11.6 | 2.10 | 5.030 |
| 6000 | 14.0 | 3.00 | 7.050 |
| 7000 | 16.3 | 4.10 | 9.380 |
| 8000 | 18.6 | 5.40 | 12.000 |
| 9000 | 20.9 | 6.80 | 14.900 |
| 10000 | 23.3 | 8.40 | 18.100 |
| 11000 | 25.6 | 10.2 | 21.600 |
| 12000 | 27.9 | 12.1 | 25.400 |
| 13000 | 30.2 | 14.2 | 29.500 |
| 14000 | 32.6 | 16.5 | 33.800 |
| 15000 | 34.9 | 18.9 | 38.400 |
| 16000 | 37.2 | 21.5 | 43.300 |
| 17000 | 39.5 | 24.2 | 48.400 |
| 18000 | 41.9 | 27.3 | 53.800 |
| 20000 | 46.5 | 33.6 | 65.400 |
| 22000 | 51.2 | 40.7 | 78.000 |
| 24000 | 55.8 | 48.4 | 91.600 |

# FRICTION LOSSES IN STEEL PIPES-3 THROUGH 36 INCH (CONT.)

## 16 INCH

16" STD. WT. STEEL 16.000" I.D.

| FLOW GALLONS PER MIN. | VELOCITY FT. PER SECOND | VELOCITY HEAD FT. | HEAD FT. PER 100 FT. |
|---|---|---|---|
| 500 | 0.88 | 0.01 | 0.036 |
| 600 | 1.05 | 0.02 | 0.050 |
| 700 | 1.23 | 0.02 | 0.067 |
| 800 | 1.41 | 0.03 | 0.086 |
| 900 | 1.58 | 0.04 | 0.106 |
| 1000 | 1.76 | 0.05 | 0.129 |
| 1200 | 2.11 | 0.07 | 0.181 |
| 1400 | 2.46 | 0.09 | 0.241 |
| 1600 | 2.81 | 0.12 | 0.308 |
| 1800 | 3.16 | 0.16 | 0.383 |
| 2000 | 3.51 | 0.19 | 0.466 |
| 2500 | 4.39 | 0.30 | 0.704 |
| 3000 | 5.27 | 0.43 | 0.987 |
| 3500 | 6.15 | 0.59 | 1.310 |
| 4000 | 7.03 | 0.77 | 1.680 |
| 4500 | 7.91 | 0.97 | 2.090 |
| 5000 | 8.79 | 1.20 | 2.540 |
| 6000 | 10.5 | 1.70 | 3.560 |
| 7000 | 12.3 | 2.40 | 4.730 |
| 8000 | 14.1 | 3.10 | 6.060 |
| 9000 | 15.8 | 3.90 | 7.530 |
| 10000 | 17.6 | 4.80 | 9.150 |
| 11000 | 19.3 | 5.80 | 10.900 |
| 12000 | 21.1 | 6.90 | 12.800 |
| 13000 | 22.8 | 8.10 | 14.900 |
| 14000 | 24.6 | 9.40 | 17.100 |
| 15000 | 26.3 | 10.7 | 19.200 |
| 16000 | 28.1 | 12.3 | 21.800 |
| 18000 | 31.6 | 15.5 | 27.100 |
| 20000 | 35.1 | 19.1 | 33.000 |
| 22000 | 38.7 | 23.3 | 39.300 |
| 24000 | 42.2 | 27.7 | 46.200 |
| 25000 | 43.9 | 30.0 | 49.900 |
| 26000 | 45.7 | 32.6 | 53.600 |
| 28000 | 49.2 | 37.6 | 61.500 |
| 30000 | 52.7 | 43.2 | 69.800 |
| 32000 | 56.2 | 49.1 | 78.700 |
| 34000 | 59.8 | 55.6 | 88.300 |
| 36000 | 63.3 | 62.3 | 97.600 |
| 38000 | 66.8 | 69.3 | 108.000 |

## 18 INCH

18" STD. WT. STEEL 17.18" I.D.

| FLOW GALLONS PER MIN. | VELOCITY FT. PER SECOND | VELOCITY HEAD FT. | HEAD FT. PER 100 FT. |
|---|---|---|---|
| 500 | 0.69 | 0.01 | 0.020 |
| 600 | 0.83 | 0.01 | 0.028 |
| 700 | 0.97 | 0.01 | 0.037 |
| 800 | 1.11 | 0.02 | 0.048 |
| 900 | 1.25 | 0.02 | 0.060 |
| 1000 | 1.38 | 0.03 | 0.072 |
| 1200 | 1.66 | 0.04 | 0.101 |
| 1400 | 1.94 | 0.06 | 0.135 |
| 1600 | 2.21 | 0.08 | 0.173 |
| 1800 | 2.49 | 0.10 | 0.215 |
| 2000 | 2.77 | 0.12 | 0.261 |
| 2500 | 3.46 | 0.19 | 0.394 |
| 3000 | 4.15 | 0.27 | 0.553 |
| 3500 | 4.85 | 0.37 | 0.735 |
| 4000 | 5.54 | 0.48 | 0.941 |
| 4500 | 6.23 | 0.60 | 1.170 |
| 5000 | 6.92 | 0.74 | 1.420 |
| 6000 | 8.31 | 1.10 | 1.990 |
| 7000 | 9.70 | 1.50 | 2.650 |
| 8000 | 11.1 | 1.90 | 3.390 |
| 9000 | 12.5 | 2.40 | 4.220 |
| 10000 | 13.8 | 3.00 | 5.120 |
| 12000 | 16.6 | 4.30 | 7.180 |
| 14000 | 19.4 | 5.80 | 9.550 |
| 16000 | 22.1 | 7.60 | 12.200 |
| 18000 | 24.9 | 9.60 | 15.200 |
| 20000 | 27.7 | 11.9 | 18.500 |
| 22000 | 30.3 | 14.3 | 22.000 |
| 24000 | 33.2 | 17.1 | 25.900 |
| 26000 | 36.0 | 20.1 | 30.000 |
| 28000 | 38.8 | 23.4 | 34.400 |
| 30000 | 41.5 | 26.8 | 39.100 |
| 32000 | 44.3 | 30.5 | 44.100 |
| 34000 | 47.1 | 34.5 | 49.400 |
| 36000 | 49.9 | 38.7 | 54.800 |
| 38000 | 52.6 | 43.0 | 60.600 |
| 40000 | 55.4 | 47.1 | 66.600 |
| 42000 | 58.2 | 52.6 | 72.900 |
| 44000 | 61.0 | 57.8 | 79.400 |
| 46000 | 63.7 | 63.0 | 86.300 |

## 20 INCH

20" STD. WT. STEEL 19.18" I.D.

| FLOW GALLONS PER MIN. | VELOCITY FT. PER SECOND | VELOCITY HEAD FT. | HEAD FT. PER 100 FT. |
|---|---|---|---|
| 800 | 0.89 | 0.01 | 0.028 |
| 1000 | 1.11 | 0.02 | 0.042 |
| 1200 | 1.33 | 0.03 | 0.059 |
| 1400 | 1.55 | 0.04 | 0.079 |
| 1500 | 1.78 | 0.05 | 0.101 |
| 1800 | 2.00 | 0.06 | 0.126 |
| 2000 | 2.22 | 0.08 | 0.153 |
| 2500 | 2.78 | 0.12 | 0.231 |
| 3000 | 3.33 | 0.17 | 0.323 |
| 3500 | 3.89 | 0.24 | 0.430 |
| 4000 | 4.45 | 0.31 | 0.551 |
| 5000 | 5.55 | 0.48 | 0.832 |
| 6000 | 6.67 | 0.69 | 1.170 |
| 7000 | 7.78 | 0.94 | 1.550 |
| 8000 | 8.89 | 1.20 | 1.980 |
| 10000 | 11.1 | 1.90 | 3.000 |
| 12000 | 13.3 | 2.70 | 4.200 |
| 14000 | 15.5 | 3.70 | 5.590 |
| 15000 | 16.7 | 4.30 | 6.350 |
| 16000 | 17.8 | 4.90 | 7.150 |
| 18000 | 20.0 | 6.20 | 8.900 |
| 20000 | 22.2 | 7.70 | 10.800 |
| 22000 | 24.4 | 9.30 | 12.900 |
| 24000 | 26.7 | 11.1 | 15.100 |
| 25000 | 27.8 | 12.0 | 16.300 |
| 26000 | 28.9 | 13.0 | 17.600 |
| 28000 | 31.1 | 15.0 | 20.100 |
| 30000 | 33.3 | 17.2 | 22.900 |
| 32000 | 35.6 | 19.7 | 25.800 |
| 34000 | 37.8 | 22.2 | 28.900 |
| 35000 | 38.9 | 23.5 | 30.400 |
| 36000 | 40.0 | 24.9 | 32.100 |
| 38000 | 42.2 | 27.7 | 35.400 |
| 40000 | 44.5 | 30.8 | 39.000 |
| 45000 | 50.0 | 38.9 | 48.500 |
| 50000 | 55.5 | 47.9 | 58.900 |
| 55000 | 61.1 | 58.0 | 70.300 |
| 60000 | 66.7 | 69.0 | 82.300 |
| 65000 | 72.2 | 81.0 | 95.700 |
| 70000 | 77.8 | 94.0 | 110.000 |

## 24 INCH

24" STD. WT. STEEL 24" I.D.

| FLOW GALLONS PER MIN. | VELOCITY FT. PER SECOND | VELOCITY HEAD FT. | HEAD FT. PER 100 FT. |
|---|---|---|---|
| 350 | 0.252 | 0.00 | 0.002 |
| 700 | 0.495 | 0.00 | 0.007 |
| 1000 | 0.712 | 0.01 | 0.014 |
| 1400 | 0.999 | 0.01 | 0.026 |
| 1700 | 1.210 | 0.02 | 0.038 |
| 2000 | 1.420 | 0.03 | 0.051 |
| 2400 | 1.700 | 0.045 | 0.071 |
| 2700 | 1.920 | 0.060 | 0.089 |
| 3100 | 2.210 | 0.080 | 0.114 |
| 3400 | 2.410 | 0.090 | 0.136 |
| 3800 | 2.700 | 0.113 | 0.167 |
| 4200 | 2.990 | 0.130 | 0.200 |
| 4500 | 3.200 | 0.160 | 0.226 |
| 4800 | 3.410 | 0.180 | 0.255 |
| 5200 | 3.690 | 0.210 | 0.298 |
| 5500 | 3.910 | 0.240 | 0.329 |
| 5900 | 4.190 | 0.270 | 0.377 |
| 6200 | 4.410 | 0.320 | 0.413 |
| 6500 | 4.620 | 0.330 | 0.450 |
| 6900 | 4.900 | 0.370 | 0.502 |
| 7600 | 5.400 | 0.500 | 0.603 |
| 8300 | 5.900 | 0.540 | 0.713 |
| 9000 | 6.400 | 0.640 | 0.820 |
| 9700 | 6.900 | 0.740 | 0.950 |
| 10000 | 7.110 | 0.790 | 1.000 |
| 11000 | 7.820 | 0.950 | 1.190 |
| 12000 | 8.550 | 1.140 | 1.400 |
| 12500 | 8.860 | 1.220 | 1.520 |
| 13000 | 9.250 | 1.340 | 1.630 |
| 14000 | 9.950 | 1.540 | 1.860 |
| 15000 | 10.630 | 1.770 | 2.110 |
| 16000 | 11.380 | 2.020 | 2.420 |
| 18000 | 12.800 | 2.570 | 2.980 |
| 19000 | 13.500 | 2.850 | 3.280 |
| 20000 | 14.200 | 3.160 | 3.610 |

## 30 INCH

30" STD. WT. STEEL 30" I.D.

| FLOW GALLONS PER MIN. | VELOCITY FT. PER SECOND | VELOCITY HEAD FT. | HEAD FT. PER 100 FT. |
|---|---|---|---|
| 700 | 0.322 | 0.00 | 0.002 |
| 1000 | 0.450 | 0.00 | 0.004 |
| 1300 | 0.590 | 0.01 | 0.008 |
| 1700 | 0.780 | 0.01 | 0.013 |
| 2000 | 0.910 | 0.01 | 0.017 |
| 2400 | 1.095 | 0.02 | 0.023 |
| 2700 | 1.230 | 0.02 | 0.030 |
| 3100 | 1.430 | 0.03 | 0.039 |
| 3400 | 1.550 | 0.04 | 0.046 |
| 3800 | 1.740 | 0.05 | 0.057 |
| 4100 | 1.870 | 0.06 | 0.065 |
| 4500 | 2.050 | 0.07 | 0.077 |
| 4800 | 2.190 | 0.08 | 0.087 |
| 5200 | 2.370 | 0.09 | 0.101 |
| 5500 | 2.510 | 0.10 | 0.112 |
| 5900 | 2.690 | 0.11 | 0.127 |
| 6200 | 2.830 | 0.12 | 0.139 |
| 6900 | 3.120 | 0.15 | 0.170 |
| 7600 | 3.470 | 0.18 | 0.203 |
| 8300 | 3.790 | 0.22 | 0.240 |
| 9000 | 4.100 | 0.26 | 0.278 |
| 9700 | 4.420 | 0.306 | 0.319 |
| 10000 | 4.560 | 0.325 | 0.337 |
| 11000 | 5.010 | 0.392 | 0.401 |
| 12000 | 5.470 | 0.47 | 0.473 |
| 12500 | 5.700 | 0.51 | 0.510 |
| 13000 | 5.940 | 0.55 | 0.550 |
| 14000 | 6.400 | 0.64 | 0.630 |
| 15000 | 6.850 | 0.73 | 0.710 |
| 16000 | 7.300 | 0.83 | 0.810 |
| 18000 | 8.200 | 1.05 | 1.000 |
| 19000 | 8.670 | 1.17 | 1.110 |
| 20000 | 9.120 | 1.30 | 1.220 |
| 24000 | 10.090 | 1.89 | 1.730 |
| 28000 | 12.750 | 2.46 | 2.270 |

## 36 INCH

36" STD. WT. STEEL 36" I.D.

| FLOW GALLONS PER MIN. | VELOCITY FT. PER SECOND | VELOCITY HEAD FT. | HEAD FT. PER 100 FT. |
|---|---|---|---|
| 1400 | 0.44 | 0.00 | 0.004 |
| 1700 | 0.53 | 0.00 | 0.005 |
| 2000 | 0.63 | 0.01 | 0.007 |
| 2400 | 0.75 | 0.01 | 0.010 |
| 2800 | 0.88 | 0.01 | 0.015 |
| 3400 | 1.07 | 0.02 | 0.019 |
| 4000 | 1.26 | 0.02 | 0.026 |
| 4800 | 1.51 | 0.04 | 0.036 |
| 5600 | 1.76 | 0.05 | 0.048 |
| 6200 | 1.95 | 0.06 | 0.057 |
| 7000 | 2.20 | 0.07 | 0.072 |
| 7600 | 2.39 | 0.09 | 0.084 |
| 8300 | 2.61 | 0.10 | 0.098 |
| 9000 | 2.83 | 0.12 | 0.114 |
| 9700 | 3.05 | 0.14 | 0.131 |
| 10000 | 3.14 | 0.16 | 0.139 |
| 11000 | 3.46 | 0.19 | 0.164 |
| 12000 | 3.78 | 0.22 | 0.193 |
| 13000 | 4.09 | 0.26 | 0.226 |
| 14000 | 4.40 | 0.30 | 0.260 |
| 15000 | 4.71 | 0.34 | 0.294 |
| 16000 | 5.03 | 0.39 | 0.330 |
| 18000 | 5.66 | 0.50 | 0.412 |
| 19000 | 5.98 | 0.56 | 0.454 |
| 20000 | 6.30 | 0.61 | 0.504 |
| 21000 | 6.60 | 0.67 | 0.544 |
| 22000 | 6.92 | 0.74 | 0.590 |
| 23000 | 7.24 | 0.81 | 0.640 |
| 24000 | 7.55 | 0.88 | 0.695 |
| 26000 | 8.18 | 1.04 | 0.806 |
| 28000 | 8.80 | 1.20 | 0.935 |
| 30000 | 9.44 | 1.38 | 1.065 |
| 34000 | 10.70 | 1.77 | 1.340 |
| 38000 | 11.95 | 2.20 | 1.650 |
| 42000 | 13.20 | 2.70 | 1.990 |

# FRICTION LOSSES IN STEEL PIPES-3 THROUGH 30 INCH

*FRICTION LOSSES AS EQUIVALENT LENGTHS OF PIPE - FEET*

| Type of fitting and application | Nominal Size of Pipe and Fitting | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3" | 4" | 5" | 6" | 8" | 10" | 12" | 14" | 16" | 20" | 24" | 30" |
| ELBOWS - | | | | | | | | | | | | |
| 90° Standard Elbow - or Run of Tee reduced by 1/2 | 7.7 | 10 | 13 | 15 | 20 | 25 | 30 | 35 | 40 | 50 | 61 | 76 |
| 90° Long Radius - or Run of Standard Tee | 5.2 | 6.8 | 8.5 | 10 | 14 | 17 | 20 | 24 | 27 | 34 | 40 | 50 |
| 45° Standard | 3.6 | 4.7 | 5.9 | 7.1 | 9.4 | 12 | 14 | 17 | 19 | 24 | 28 | 35 |
| Standard Tee through Side Outlet | 16 | 20 | 26 | 31 | 40 | 51 | 61 | 71 | 81 | 101 | 121 | 151 |
| Gate Valve (fully open) | 1.6 | 2.1 | 2.7 | 3.2 | 4.3 | 5.3 | 6.4 | 7.5 | 8.5 | 11 | 13 | 16 |
| Swing Check Valve (fully open) | 20 | 26 | 33 | 39 | 52 | 65 | 77 | 90 | 104 | 129 | 155 | 193 |
| Ordinary Entrance | 4.5 | 6.0 | 7.3 | 9.0 | 12 | 15 | 17 | 20 | 22 | 28 | 35 | 43 |

*FITTINGS - Friction losses expressed as equivalent lengths of pipe (feet)*

| Type of Fitting | Material | 1" | 1 1/4" | 1 1/2" | 2" | 2 1/2" | 3" | 3 1/2" | 4" | 5" | 6" | 8" | 10" | 12" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90° Standard Elbow, or run of tee reduced to half size | Steel | 3 | 4 | 4 | 5 | 6 | 8 | - | 10 | 13 | 15 | 20 | 25 | 30 |
| | Plastic | 6 | 7 | 8 | 9 | 10 | 14 | - | 17 | - | 25 | - | - | - |
| | Copper | 3 | 4 | 4 | 5 | 6 | 8 | 9 | 10 | 13 | 15 | 20 | - | - |
| 45° Elbow | Steel | 1.3 | 1.7 | 2.1 | 2.6 | 3 | 3.6 | - | 4.7 | 5.9 | 7.1 | 9.4 | 12 | 14 |
| | Plastic | 2.5 | 3 | 4 | 5 | 6 | 7 | - | 9 | - | 13 | 13 | - | - |
| | Copper | 1.3 | 1.7 | 2.1 | 2.6 | 3 | 3.6 | 4.1 | 4.7 | 5.9 | 7.1 | 9.4 | - | - |
| Standard Tee with flow through branch | Steel | 6 | 8 | 9 | 11 | 14 | 16 | - | 20 | 26 | 31 | 40 | 51 | 61 |
| | Plastic | 9 | 12 | 13 | 17 | 20 | 23 | - | 29 | - | 45 | - | - | - |
| | Copper | 6 | 8 | 9 | 11 | 14 | 16 | 18 | 20 | 26 | 31 | 40 | - | - |
| 90° long radius elbow, or run of standard tee | Steel | 1.7 | 2.3 | 2.8 | 3.6 | 4.2 | 5.2 | - | 6.8 | 8.5 | 10 | 14 | 17 | 20 |
| | Plastic | 3 | 4 | 5 | 7 | 8 | 10 | - | 12 | - | 17 | - | - | - |
| | Copper | 1.7 | 2.3 | 2.8 | 3.6 | 4.2 | 5.2 | 6.1 | 6.8 | 8.5 | 10 | 14 | - | - |
| Adapter-slip/solder fitting to thread Insert coupling | Steel | 3 | 3 | 3 | 3 | 3 | 3 | - | 3 | - | 3 | - | - | - |
| | Plastic | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - |
| | Copper | 3 | 3 | 3 | 3 | 3 | 3 | - | 3 | - | 3 | - | - | - |
| Gate Valve (fully open) | | 0.60 | 0.80 | 0.95 | 1.15 | 1.4 | 1.6 | 1.85 | 2.1 | 2.7 | 3.2 | 4.3 | 5.3 | 6.4 |
| Swing Check Valve | | 7 | 9 | 11 | 13 | 16 | 20 | 23 | 26 | 33 | 39 | 52 | 67 | 77 |
| Ordinary entrance | | 1.5 | 2.0 | 2.4 | 3.0 | 3.7 | 4.5 | 5.2 | 6.0 | 7.3 | 9.0 | 12 | 15 | 17 |

# CAST DISCHARGE HEAD FRICTION LOSS CHART

## CAST DISCHARGE HEAD FRICTION LOSS CHART

| Discharge Size | Capacity in Gallons Per Minute | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 1000 | 1200 | 1400 |
| 6" | 0.016 | 0.062 | 0.140 | 0.248 | 0.388 | 0.558 | 0.760 | 0.922 | 1.550 | | |
| 8" | | | | 0.078 | 0.125 | 0.176 | 0.226 | 0.312 | 0.488 | 0.703 | 0.958 |
| | Capacity in Gallons Per Minute | | | | | | | | | | |
| | 500 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 | 5000 | |
| 10" | 0.048 | 0.192 | 0.433 | 0.769 | 1.202 | 1.731 | | | | | |
| 12" | | 0.091 | 0.204 | 0.363 | 0.565 | 0.861 | 1.110 | 1.145 | | | |
| 14" | | | | 0.201 | 0.314 | 0.452 | 0.615 | 0.803 | 1.017 | 1.255 | |

## VERTICAL TURBINE FAB DISCHARGE HEAD FRICTION LOSS CHART

| Discharge Size | Capacity in Gallons Per Minute | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 40 | 80 | 100 | 140 | 180 | 200 | 300 | 400 | 500 | 600 | 700 |
| 2" | 0.517 | 2.069 | 3.233 | | | | | | | | |
| 3" | | 0.419 | 0.655 | 1.283 | 2.122 | 2.620 | | | | | |
| 4" | | | | 0.534 | 0.675 | 0.834 | 1.875 | 3.333 | | | |
| 6" | | | | | | 0.220 | 0.355 | 0.630 | 0.990 | 1.419 | 1.932 |
| | Capacity in Gallons Per Minute | | | | | | | | | | |
| | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2500 | 3000 | 4000 | 5000 |
| 8" | 0.812 | 1.216 | 1.827 | 2.487 | 3.248 | | | | | | |
| 10" | | 0.545 | 0.786 | 1.069 | 1.396 | 1.767 | 2.182 | 3.409 | | | |
| 12" | | | | 0.488 | 0.638 | 0.807 | 0.996 | 1.557 | 2.242 | | |
| 14" | | | | | | 0.523 | 0.646 | 1.009 | 1.453 | 2.584 | |
| 16" | | | | | | | | 0.554 | 0.798 | 1.419 | 2.217 |

# MECHANICAL FRICTION IN TURBINE PUMP LINE SHAFTS

| MECHANICAL FRICTION IN TURBINE PUMP LINE SHAFTS (HORSEPOWER/100 FEET SHAFT LENGTH) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SHAFT DIA. (inches) | B.H.P. AT R.P.M. | | | | | | | |
| | 3450 | 2900 | 2200 | 1760 | 1460 | 1160 | 880 | 700 |
| 3/4 | | | 0.38 | 0.30 | 0.25 | 0.22 | | |
| 1 | 1.04 | 0.87 | 0.65 | 0.52 | 0.45 | 0.35 | | |
| 1 3/16 | 1.44 | 1.20 | 0.90 | 0.72 | 0.60 | 0.44 | | |
| 1 1/2 | 2.30 | 1.92 | 1.44 | 1.15 | 0.95 | 0.74 | 0.56 | |
| 1 11/16 | | | | 1.40 | 1.20 | 0.92 | 0.70 | |
| 1 15/16 | | | | 1.80 | 1.50 | 1.20 | 0.90 | 0.72 |
| 2 3/16 | | | | 2.30 | 1.90 | 1.50 | 1.15 | 0.92 |
| 2 7/16 | | | | 2.85 | 2.40 | 1.85 | 1.40 | 1.13 |

| SHAFT WEIGHTS (WT./FT. - LBS.) | | |
|---|---|---|
| SHAFT DIAMETER | ENCLOSED *(1) | OPEN |
| 3/4 | 1.50 | 1.30 |
| 1 | 2.60 | 2.30 |
| 1 3/16 | 3.80 | 3.30 |
| 1 11/16 | 6.00 | 5.30 |
| 1 15/16 | 7.60 | 6.30 |
| 2 3/16 | 10.00 | 8.80 |
| 2 7/16 | 12.80 | 11.20 |

*NOTE: (1) Oil lubricated shaft does not displace liquid above the pumping water level and therefore has a greater net weight.

# HARDNESS OF MATERIAL

Hardness is one of the physical properties generally considered to be an important factor in the selection of the best material for given service. Numerous methods have been developed to describe the degree of hardness of a material. Brinell, Rockwell, Vickers and Shore are the most widely used scales and can be compared by use of the conversion tables on the following pages. As you will note, various scales must be used with the Brinell and Rockwell methods in order to cover the full range of hardness. Only the more commonly used scales are listed in the table. A hard material (high hardness number) is likely to have a high tensile strength and be somewhat brittle. The tensile strength of steel can be roughly approximated by multiplying the Brinell hardness by 500.

The approximate range of Brinell hardness for a number of the metals commonly used are:

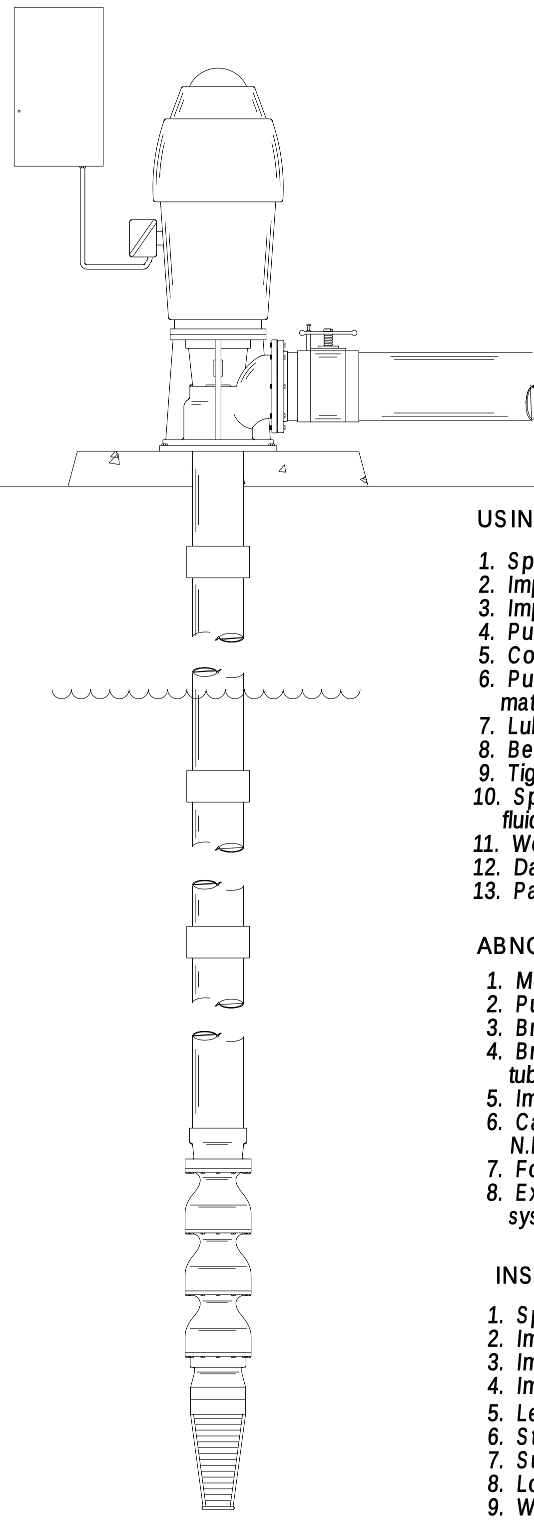
(Typical)

| METAL | TENSILE STRENGTH (PSI) | BRINELL HARDNESS RANGE |
|---|---|---|
| *CAST IRON* | *30,000* | *190 - 210* |
| | *40,000* | *210 - 250* |
| | *50,000* | *230 - 280* |
| *410 - 416 STAINLESS STEEL* | *75,000 - 135,000* | *155 - 290* |
| *DUCTILE IRON* | *60,000* | *132* |
| | | |
| *1045 STEEL* | *80,000 - 120,000* | *160 - 240* |
| *316 STAINLESS STEEL* | *80,000 - 90,000* | *150 - 190* |
| *304 STAINLESS STEEL* | *85,000 - 125,000* | *212 - 277* |
| *MONEL 400* | *84,000 - 120,000* | *160 - 225* |
| *K MONEL* | *135,000 - 185,000* | *255 - 370* |
| | | |
| *17-4 PH STAINLESS STEEL* | *145,000 - 200,000* | *311 - 420* |
| *ALUMINUM BRONZE* | *80,000 - 110,000* | *150 - 250* |
| *SAE 40 BRONZE* | *26,000 - 42,000* | *60 - 80* |
| | | |
| *NICKEL ALUMINUM BRONZE* | *85,000* | *159* |

The hardness and tensile strength of many materials can be changed considerably by heat-treating or cold-working. An example of the latter is cold-drawn shafting which has harder and stronger metal near the surface of the shaft than in the center.

It is difficult to obtain accurate hardness measurements of thin sections of materials such as coatings and overlays applied over a softer material. The actual hardness is not of great importance in this instance as the wear characteristics of a material are more likely to be related to its "toughness" or the mating surface than to the hardness. This is not to say that materials with low hardness ratings have excellent wear resistance.

# TROUBLE SHOOTING OPERATING SYMPTOMS



## INSUFFICIENT PRESSURE

1. Speed too slow (check voltage.)
2. Impeller trimmed incorrectly.
3. Impeller loose.
4. Impeller plugged.
5. Wear rings worn.
6. Entrained air in pump.
7. Leaking joints or bowl casings.
8. Wrong rotation.
9. Incorrect impeller adjustment.

## NO LIQUID DELIVERED

1. Pump suction broken (water level) below inlet.)
2. Suction valve closed.
3. Impeller plugged.
4. Strainer clogged.
5. Wrong rotation.
6. Shaft broken or unscrewed.
7. Impeller loose.
8. Barrel or discharge not vented.
9. Driver inoperative.

## VIBRATION

1. Motor imbalance-electrical.
2. Motor bearing not properly seated or worn.
3. Motor drive coupling out of balance or alignment.
4. Misalignment of pump, casings, discharge head column, or bowls.
5. Discharge head misaligned by improper mounting or pipe strain.
6. Bent shafting.
7. Worn pump bearings.
8. Clogged impeller or foreign material in pump.
9. Improper impeller adjustment.
10. Vortex problems in sump.
11. Reasonance-system frequency at or near pump speed.
12. Cavitation.
13. Impeller out of balance.

## USING TOO MUCH POWER

1. Speed too high.
2. Improper impeller adjustment.
3. Improper impeller trim.
4. Pump out of alignment.
5. Coupling out of alignment.
6. Pumping sand, silt, or foreign material.
7. Lubricating oil too heavy.
8. Bent shaft.
9. Tight bearing or packing.
10. Specific gravity or viscosity of fluid higher than design.
11. Worn pump.
12. Damaged pump.
13. Partial freezing of pump liquid.

## ABNORMAL NOISE

1. Motor noise.
2. Pump bearing running dry.
3. Broken column bearing retainers.
4. Broken shaft or shaft enclosing tube.
5. Impellers dragging on bowl case.
6. Cavitation due to insufficient N.P.S.H.A. and/or submergence.
7. Foreign material in pump.
8. Excessive fluid velocity in pipe system.

## INSUFFICIENT CAPACITY

1. Speed too slow.
2. Impeller trimmed incorrectly.
3. Impeller loose.
4. Impeller or bowl partially plugged.
5. Leaking joints.
6. Strainer or suction pipe clogged.
7. Suction valve throttled.
8. Low water level.
9. Wrong rotation.
10. Insufficient submergence.
11. Insufficient N.P.S.H.A.
12. Incorrect impeller adjustment.
13. Worn pump.
14. System pressure higher than design.

# COMPONENT PROBLEM SOLVING

## BEARINGS

| TROUBLE SOURCE | PROBABLE CAUSE | REMEDY |
|---|---|---|
| *Premature bearing wear* | *Abrasive action* | *Consider converting to fresh water flushing on all bearings or pressure grease or oil lubrication.* |
| *Bearing seized or galling on shaft* | *Running dry without lubrication.* | *Check lubrication, look for plugged suction or evidence of flashing.* |
| *Bearing failure or bearing seized* | *High temperature failure.* | *Check pump manufacturer for bearing temperature limits.* |
| *Excessive shaft wear under rubber bearings* | *Rubber bearings will swell in hydro-carbon, $H_2S$ & High temperature.* | *Change bearing material.* |
| *Uneven wear on bearings, uniform wear on shaft.* | *Pump non-rotating parts misaligned.* | *Check mounting & discharge pipe connection, dirt between column joints. Correct misalignment, replace bearings & repair or replace shaft.* |
| *Uniform wear on bearing and shaft* | *Abrasive action.* | *Replace parts, consider changing material or means of lubrication.* |
| *Uniform wear on bearings, uneven wear on shaft* | *1. Shaft runnout caused by bent shafts, shafts not butted in couplings, dirt or grease between shafts.*<br>*2. Shaft ends not properly faced.* | *1. Straighten shaft or replace, clean & assemble correctly.*<br>*2. Face parallel & concentric.* |

## SHAFT AND COUPLINGS

| | | |
|---|---|---|
| *Bent shaft* | *Mishandling in transit or assembly.* | *Check straightness. Correct to 0.0005/ft. total runout or replace.* |
| *Shaft coupling unscrewed.* | *Pump started in reverse rotation.* | *Shafts may be bent; check shafts & couplings. Correct rotation.* |
| *Shaft coupling elongated. (neck down)* | *1. Motor started while the pump was running in reverse.*<br>*2. Corrosion.*<br>*3. Pipe wrench fatigue on reused couplings.*<br>*4. Power being applied to shafts that are not butted in coupling.* | *1. Look for faulty check valve. Could also be momentary power failure or improper starting timers.*<br>*2. Replace couplings.*<br>*3. Replace couplings.*<br>*4. Check for galling on shaft ends.* |
| *Broken shaft or coupling.* | *1. Can be caused by same reasons listed for coupling elongation.*<br>*2. Can also be caused by bearings seized due to lack of lubrication.*<br>*3. Foreign material locking impellers or galling wear rings.*<br>*4. Metal fatigue due to vibrations.*<br>*5. Improper impeller adjustment or continuous upthrust conditions, causing impeller to drag.* | *1. Same as above.*<br>*2. Same as above for bearing seizure.*<br>*3. Add strainers or screens.*<br>*4. Check alignment of pump components to eliminate vibration.*<br>*5. See Sections on Impeller Adjustment and Upthrusting.* |

## INNER COLUMN

| | | |
|---|---|---|
| *Water in inner column* | *1. Bypass ports plugged.*<br>*2. Badly worn bypass seal or bearings.*<br>*3. Tubing joint leaking.*<br>*4. Crack or hole in tubing.* | *1. Remove cause.*<br>*2. Replace worn parts.*<br>*3. Ensure tubing joint face is clean and butted squarely.*<br>*4. Replace section affected.* |

# COMPONENT PROBLEM SOLVING

IMPELLERS

| TROUBLE SOURCE | PROBABLE CAUSE | REMEDY |
|---|---|---|
| *Wear on exit vanes and shrouds* | *Abrasive action* | *Replace impeller if excessive. Consider coating or upgrading material.* |
| *Pitting on entrance vanes of impeller* | *Cavitation:* | *Correct condition or upgrade material to extend life.* |
| *Pitting on impellers and bowl casting.* | *Corrosion/Erosion.* | *Investigate cost of different materials vs. frequency of replacements.* |
| *Wear on impeller skirts and/or bowl seal ring area.* | *1. Abrasive action or excess wear allowing impeller skirts to function as bearing journal.*<br>*2. Impellers set to high.* | *1. Install new bearings and wear rings. Upgrade material if abrasive action.*<br>*2. Re-ring & adjust impellers correctly.* |
| *Impeller loose on shaft (extremely rare occurrence)* | *1. Repeated shock load by surge in suction or discharge line. (Can loosen first or last stage impellers.)*<br>*2. Foreign material jamming impeller. (May break shaft or trip overloads before impeller becomes loose.)*<br>*3. Differential expansion due to temperature.*<br>*4. Parts improperly machined and/or assembled.*<br>*5. Torsion loading on submersible pumps.* | *1. Re-fit impellers. If collet mounted, consider changing to key mounting.*<br>*2. Remove cause of jamming.*<br>*3. If collet mounted, consider changing to key mounted. Avoid sudden thermal shock.*<br>*4. Correct parts if necessary and re-fit.*<br>*5. Add keyway to collet mounting.* |

PACKING HOUSING

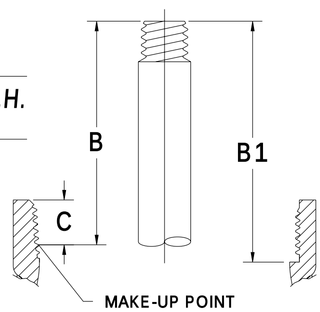
| | | |
|---|---|---|
| *Packing Housing overheating* | *1. Improper packing procedure.*<br>*2. Packing too tight.*<br>*3. Insufficient lubrication.*<br>*4. Incorrect type of packing.* | *1. Repack correctly.*<br>*2. Release gland pressure.*<br>*3. Repack correctly.*<br>*4. Repack with correct grade for service.* |
| *Packing wears prematurely* | *1. Improper packing procedure.*<br>*2. Insufficient lubrication.*<br>*3. Shaft or sleeve scored.*<br>*4. Incorrect type of packing.*<br>*5. Abrasives in liquid.* | *1. Repack correctly.*<br>*2. Repack correctly.*<br>*3. Remachine or replace scored parts.*<br>*4. Repack with correct grade for service.*<br>*5. Remove source of abrasives.* |
| *Excessive leakage* | *1. Improper packing procedure.*<br>*2. Incorrect type of defective packing.*<br>*3. Worn shaft or sleeve.* | *1. Repack correctly.*<br>*2. Repack with correct grade for service.*<br>*3. Remachine or replace scored parts.* |

BOWLS

| | | |
|---|---|---|
| *Wear on bowl vanes* | *Abrasive action* | *Coat bowls, upgrade materials, or rubber line.* |

# WATER LUBE BOWL REPLACEMENT

SHAFT:
DIA. ______
THREADS/IN. ______ L.H.
THREAD LENGTH. ______




TAPER COLUMN
SHAFT PROJECTION (B) ______ IN.
COLUMN MAKE-UP (C) ______ IN.

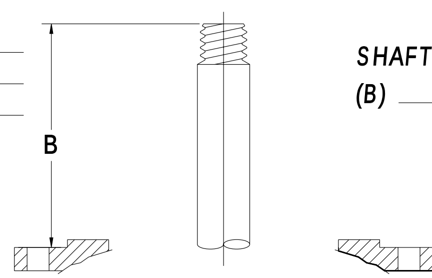
BUTT COLUMN
SHAFT PROJECTION (B1) ______ IN.

TAPER OUTER COLUMN
COLUMN SIZE ______ I.D. ☐ O.D. ☐
THREADS/IN. ______
TAPER: 3/16 ☐ 3/8 ☐ 3/4 ☐

BUTT JOINT THREADS
COLUMN SIZE ______ I.D. ☐ O.D. ☐
THREADS/IN. ______

## FLANGED COLUMN

SHAFT:
DIA. ______
THREADS/IN. ______
THREAD LENGTH. ______




SHAFT PROJECTION
(B) ______ IN.

PURCHASER ______

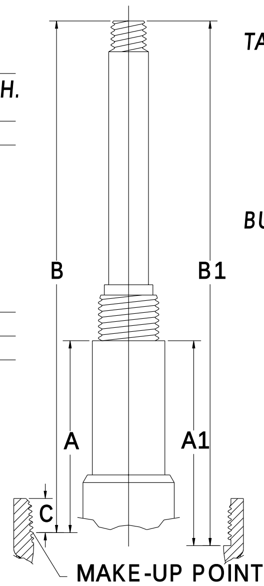
MODEL ______

P.O. NUMBER ______

# OIL LUBE BOWL REPLACEMENT

SHAFT:
DIA. ____________
THREADS/IN. ________ L.H.
THREAD LENGTH. ________
COUPLING O.D. ________

LINESHAFT BEARING:
O.D. ____________
THREADS/IN. ________
THREAD LENGTH. ________
RH ☐
LH ☐




TAPER COLUMN
TUBE PROJECTION (A) ____________ IN.
SHAFT PROJECTION (B) ____________ IN.
COLUMN MAKE-UP (C) ____________ IN.

BUTT COLUMN
TUBE PROJECTION (A1) ____________ IN.
SHAFT PROJECTION (B1) ____________ IN.

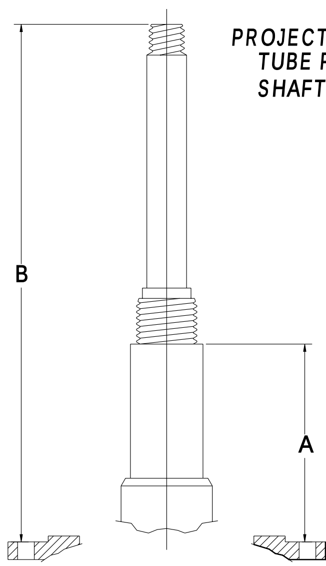
TAPER OUTER COLUMN
COLUMN SIZE ________ I.D. ☐ O.D. ☐
THREADS/IN. ____________
TAPER: 3/16 ☐ 3/8 ☐ 3/4 ☐

BUTT JOINT THREADS
COLUMN SIZE ________ I.D. ☐ O.D. ☐
THREADS/IN. ____________

FLANGED COLUMN

SHAFT:
DIA. ____________
THREADS/IN. ________
THREAD LENGTH. ________
COUPLING O.D. ________

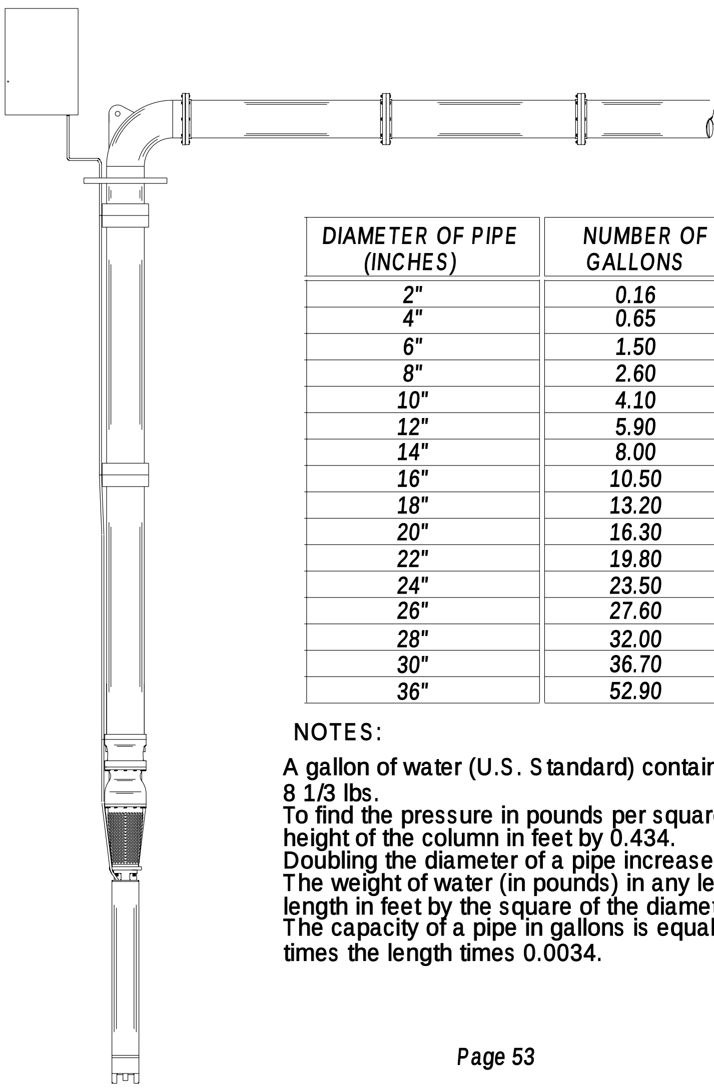
LINESHAFT BEARING:
O.D. ____________
THREADS/IN. ________
THREAD LENGTH. ________
RH ☐
LH ☐




PROJECTION
TUBE PROJECTION (A) ____________ IN.
SHAFT PROJECTION (B) ____________ IN.

PURCHASER ____________
MODEL ____________
P.O. NUMBER ____________

# CAPACITY OF PIPE FOR WATER PER FOOT



| DIAMETER OF PIPE (INCHES) | NUMBER OF GALLONS | WEIGHT (POUNDS) |
|---|---|---|
| 2" | 0.16 | 1.335 |
| 4" | 0.65 | 5.421 |
| 6" | 1.50 | 12.510 |
| 8" | 2.60 | 21.684 |
| 10" | 4.10 | 34.194 |
| 12" | 5.90 | 49.206 |
| 14" | 8.00 | 66.72 |
| 16" | 10.50 | 87.57 |
| 18" | 13.20 | 110.08 |
| 20" | 16.30 | 135.94 |
| 22" | 19.80 | 165.13 |
| 24" | 23.50 | 195.99 |
| 26" | 27.60 | 230.18 |
| 28" | 32.00 | 266.88 |
| 30" | 36.70 | 306.07 |
| 36" | 52.90 | 441.18 |

NOTES:

A gallon of water (U.S. Standard) contains 231 cubic inches and weights approximately 8 1/3 lbs.
To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by 0.434.
Doubling the diameter of a pipe increases its capacity four times.
The weight of water (in pounds) in any length of pipe is obtained by multiplying the length in feet by the square of the diameter and by 0.34.
The capacity of a pipe in gallons is equal to the square of the diameter in inches times the length times 0.0034.

# CABLE SELECTION FOR SINGLE AND THREE PHASE MOTORS

| *Single Phase Cable, 60 HZ (Service Entrance to Motor - Maximum Length in Feet)* | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Motor Rating* | | *Maximum Feet of AWG Copper Wire Size* | | | | | | | | | | | | |
| *Volts* | *HP* | *14* | *12* | *10* | *8* | *6* | *4* | *3* | *2* | *1* | *0* | *00* | *000* | *0000* |
| *Two or Three Wire Cable, 60 HZ* | | | | | | | | | | | | | | |
| *230V Single Phase* | *1/2* | *130* | *210* | *340* | *540* | *840* | *1300* | *1610* | *1960* | *2390* | *2910* | *3540* | *4210* | *5060* |
| | *3/4* | *100* | *160* | *250* | *390* | *620* | *960* | *1190* | *1460* | *1780* | *2160* | *2630* | *3140* | *3770* |
| | *1* | *250* | *400* | *630* | *990* | *1540* | *2380* | *2960* | *3610* | *4410* | *5360* | *6520* | | |
| | *1 1/2* | *190* | *310* | *480* | *770* | *1200* | *1870* | *2320* | *2850* | *3500* | *4280* | *5240* | | |
| | *2* | *150* | *250* | *390* | *620* | *970* | *1530* | *1910* | *2360* | *2930* | *3620* | *4480* | | |
| | *3* | *120** | *190* | *300* | *470* | *750* | *1190* | *1490* | *1850* | *2320* | *2890* | *3610* | | |
| | *5* | *0* | *0* | *180** | *280* | *450* | *710* | *890* | *1110* | *1390* | *1740* | *2170* | *2680* | |
| | *7 1/2* | *0* | *0* | *0* | *200** | *310* | *490* | *610* | *750* | *930* | *1140* | *1410* | *1720* | |
| | *10* | *0* | *0* | *0* | *0* | *250** | *390* | *490* | *600* | *750* | *930* | *1160* | *1430* | *1760* |
| | *15* | *0* | *0* | *0* | *0* | *170** | *270** | *340* | *430* | *530* | *660* | *820* | *1020* | *1260* |

Lengths without the asterisk* meet the U. S. National Electrical Code ampacity for either individual conductors or jacketed 60° C cable.

Lengths marked* meet the NEC ampacity only for individual conductor 60° C cable in free air or water, not in conduit. If cable rated other than 60° cable is used, lengths remain unchanged, but the minimum size acceptable for each rating must be based on the NEC table column for that temperature cable.

Flat molded cable is considered jacketed cable.

Maximum lengths shown maintain motor voltage at 95% of service entrance voltage, running at maximum nameplate amperes. If service entrance voltage will be at least motor nameplate voltage under normal load conditions, 50% additional length is permissible for all sizes.

This table is based on copper wire. If aluminum wire is to be used; it must be two sizes larger. Example: If the table calls for #12 copper wire, #10 aluminum wire would be required.

The portion of the total cable length which is between the supply and single phase control box with line contractor should not exceed 25% of the maximum allowable, to ensure reliable contactor operation. Single-phase control boxes without line contactors may be connected at any point in the total cable length.

Lengths represent a 5% voltage drop. If 3% is required, multiply by 0.6 for maximum feet.

| *Three Phase Cable, 60 HZ (Service Entrance to Motor - Maximum Length in Feet)* | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Motor Rating* | | *AWG Copper Wire Size* | | | | | | | | | | | | |
| *Volts* | *HP* | *14* | *12* | *10* | *8* | *6* | *4* | *3* | *2* | *1* | *0* | *00* | *000* | *0000* |
| *230V 60 HZ Three Phase Three Wire* | *1 1/2* | *420* | *670* | *1060* | *1670* | *2610* | *4050* | *5030* | *6160* | *7530* | *9170* | *0* | *0* | *0* |
| | *2* | *320* | *510* | *810* | *1280* | *2010* | *3130* | *3890* | *4770* | *5860* | *7170* | *8780* | *0* | *0* |
| | *3* | *240* | *390* | *620* | *990* | *1540* | *2400* | *2980* | *3660* | *4480* | *5470* | *6690* | *8020* | *9680* |
| | *5* | *140* | *230* | *370* | *590* | *920* | *1430* | *1790* | *2190* | *2690* | *3290* | *4030* | *4850* | *5870* |
| | *7 1/2* | *0* | *160** | *260* | *420* | *650* | *1020* | *1270* | *1560* | *1920* | *2340* | *2870* | *3440* | *4160* |
| | *10* | *0* | *0* | *190** | *310* | *490* | *760* | *950* | *1170* | *1440* | *1760* | *2160* | *2610* | *3160* |
| | *15* | *0* | *0* | *0* | *210** | *330* | *520* | *650* | *800* | *980* | *1200* | *1470* | *1780* | *2150* |
| | *20* | *0* | *0* | *0* | *0* | *250** | *400* | *500* | *610* | *760* | *930* | *1140* | *1380* | *1680* |
| | *25* | *0* | *0* | *0* | *0* | *0* | *320** | *400* | *500* | *610* | *750* | *920* | *1120* | *1360* |
| | *30* | *0* | *0* | *0* | *0* | *0* | *260** | *330** | *410** | *510* | *620* | *760* | *930* | *1130* |
| *460 V 60 HZ Three Phase Three Wire* | *1 1/2* | *1700* | *2710* | *4270* | *6730* | | | | | | | | | |
| | *2* | *1300* | *2070* | *3270* | *5150* | *8050* | | | | | | | | |
| | *3* | *1000* | *1600* | *2520* | *3970* | *6200* | | | | | | | | |
| | *5* | *590* | *950* | *1500* | *2360* | *3700* | *5750* | | | | | | | |
| | *7 1/2* | *420* | *680* | *1070* | *1690* | *2640* | *4100* | *5100* | *6260* | *7680* | | | | |
| | *10* | *310* | *500* | *790* | *1250* | *1960* | *3050* | *3800* | *4680* | *5750* | *7050* | | | |
| | *15* | *0* | *340** | *540* | *850* | *1340* | *2090* | *2600* | *3200* | *3930* | *4810* | *5900* | *7110* | |
| | *20* | *0* | *0* | *410** | *650* | *1030* | *1610* | *2000* | *2470* | *3040* | *3730* | *4580* | *5530* | |
| | *25* | *0* | *0* | *0* | *530** | *830* | *1300* | *1620* | *1990* | *2450* | *3010* | *3700* | *4470* | *5430* |
| | *30* | *0* | *0* | *0* | *430** | *680* | *1070* | *1330* | *1640* | *2030* | *2490* | *3060* | *3700* | *4500* |
| | *40* | *0* | *0* | *0* | *0* | *500** | *790* | *980* | *1210* | *1490* | *1830* | *2250* | *2710* | *3290* |
| | *50* | *0* | *0* | *0* | *0* | *0* | *640** | *800* | *980* | *1210* | *1480* | *1810* | *2190* | *2650* |
| | *60* | *0* | *0* | *0* | *0* | *0* | *540** | *670** | *830** | *1020* | *1250* | *150* | *1850* | *2240* |
| | *75* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *680** | *840** | *1030* | *1260* | *1520* | *1850* |
| | *100* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *620** | *760** | *940** | *1130* | *1380* |
| | *125* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *740** | *890** | *1000** |
| | *150* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *760* | *920** |
| | *175* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *810** |
| | *200* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |

# SUBMERSIBLE MOTOR FLOW RATE

To calculate the flow required to keep a submersible motor cool, use the following formula:

$$V_F = \frac{GPM \times 0.408}{(W_{ID})^2 - (M_{OD})^2}$$

*WHERE:* $V_F$ = *VELOCITY FLOW*

*GPM = GALLONS PER MINUTE*

$W_{ID}$ = *WELL CASING INSIDE DIAMETER*

$M_{OD}$ = *MOTOR OUTSIDE DIAMETER*

At a maximum temperature of 86°F (30°C) the minimum Velocity Flow past motor would be:

*0.25 ft/sec (7.62 CM/sec) - 4" diameter motor*

*0.50 ft/sec (15.24 CM/sec) - 6" diameter and larger motor)*

If the flow past the motor is less than the minimum velocity, the motor needs to be installed in a flow sleeve.

When the water temperature is greater than 86°F (30°C) the flow rate past the motor should not be less than 3.0 ft/sec.

To calculate Horsepower required at temperature greater than 86°F (30°C):

$$H_{PR} = P_{HP} \times HF$$

*WHERE:* $H_{PR}$ = *HORSEPOWER REQUIRED*

$P_{HP}$ = *PUMP HORSEPOWER AT DESIGN*

*HF = HEAT FACTOR MULTIPLIER AT 3 ft/sec FLOW*

Heat Factor Multiplier at 3 ft/sec flow

| MAXIMUM WATER TEMPERATURE | up to 5 H.P. | up to 30 H.P. | over 30 H.P. |
|---|---|---|---|
| 140°F (60°C) | 1.25 | 1.62 | 2.00 |
| 131°F (55°C) | 1.11 | 1.32 | 1.62 |
| 122°F (50°C) | 1.00 | 1.14 | 1.32 |
| 113°F (45°C) | 1.00 | 1.00 | 1.14 |
| 104°F (40°C) | 1.00 | 1.00 | 1.00 |
| 95°F (35°C) | 1.00 | 1.00 | 1.00 |

NOTE: (The above chart is for can type submersible motor, for water proof wire type consult factory.)

# CABLE SPLICING

Select first correct cable copper cross-section based on motor rating and length required.

600V TAPE SPLICING

A) Strip individual conductor of insulation only as for as necessary to provide room for a stake type connector. Tubular connectors of the staked type are preferred. If the connector O.D. is not as large as the cable insulation, build-up with rubber electrical tape.

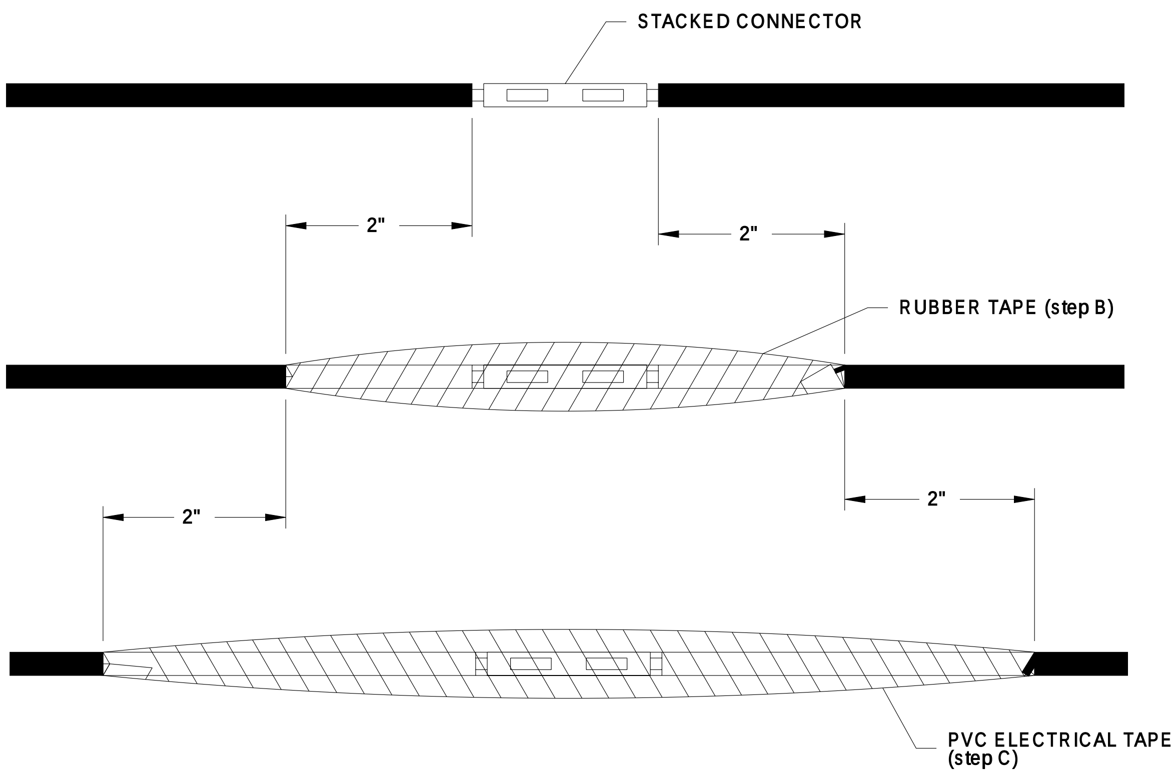
B) Tape the individual joints with rubber electrical tape, using two layers: the first extending two inches beyond each end of the conductor insulation end, the second layer two inches beyond the ends of the first layer. Wrap tightly, eliminating air spaces as much as possible.

C) Tape over the rubber electrical tape with #33 Scotch electrical tape, (Minnesota Mining Co.) or equivalent, using two layers as in step "B" and making each layer overlap the end of the preceding layer by at least two inches.

NOTES:

In the case of a cable with three conductors encased in a single outer sheath, tape the individual conductors as described, staggering joints.

Total thickness of tape should be no less than the thickness of the conductor insulation.



# CABLE SPLICING

ATTENTION

*The key factor of success is to follow exactly the manufacturer's application instructions for the splicing kits. The basis for a good splice is the connection of the copper wires for which we recommend the use of crimping connectors available for almost any common wire size.*

*Special attention should be given that the crimp connectors match the wire sizes used in order to get an electrically low resistance joint.*

ATTENTION

In case of splicing cables of a six-lead motor for Y start, be sure that the extension cables continue with the same lead colors and phase designation as the original motor cables. This will ease up above ground connections to the Y panel or an external connection for DOL start.

ATTENTION

Loose wire connections can cause the burn out of the splice and short circuit, leading to possible motor failure.

## INSULATION RESISTANCE READINGS

NORMAL OHM AND MEGOHM VALUES BETWEEN ALL LEADS AND GROUND

Insulation resistance varies little with rating. Motors of all H.P., voltage, and phase rating have similar values of insulation.

| *CONDITION OF MOTOR AND LEADS* | *OHM VALUE* | *MEGOHM VALUE* |
|---|---|---|
| *A new motor (without drop cable)* | *20,000,000 (or more)* | *>20.0* |
| *A used motor which can be reinstalled in the well* | *10,000,000 (or more)* | *>10.0* |

| *MOTOR IN WELL. Ohm readings are for drop cable plus motor.* | *OHM VALUE* | *MEGOHM VALUE* |
|---|---|---|
| *A new motor in the well.* | *2,000,000 (or more)* | *>2.0* |
| *A motor in the well in reasonably good condition* | *500,000-2,000,000* | *0.5-2.0* |
| *A motor which may have been damaged by lightning or which may have damaged leads. Do not pull the pump for this reason.* | *20,000-500,000* | *0.02-0.5* |
| *A motor which definitely has been damaged or with damaged cable. The pump should be pulled and repairs made to the cable or the motor replaced. The motor will not fail for this reason alone, but it will probably not operate for long.* | *10,000-20,000* | *0.01-0.02* |
| *A motor which has failed or with completely destroyed cable insulation. The pump must be pulled and the cable repaired or the motor replaced.* | *less than 10,000* | *0-0.01* |

# DEALING WITH THREE PHASE UNBALANCE

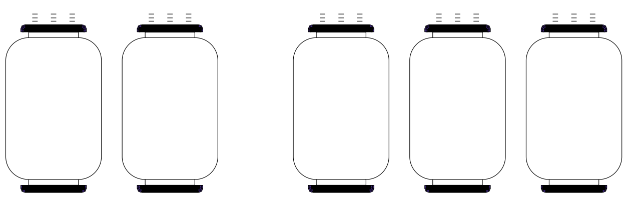
Current unbalance, particularly in rural areas with heavy single-phase loads, can cause premature motor failure - a result of reduced starting and breakdown torque, excessive and uneven heating, and excessive vibration.

It is important that the electrical load to the submersible motor be reasonable balanced. It is also important that the installation be made properly. Here's how to make a proper electrical installation and what to do if you can't.

## STEP 1 PRE-INSTALLATION

Prior to installation, the power company should be notified of the motor data, plus other loads that are on the transformer bank.

You should know if the service provided is a true three-phase, three transformer system or a two transformer system. This can be determined by counting the transformers if the service is in, or by questioning the power company if service is not yet in. Here is an open-delta or wye system (on the left), with a true three-phase, three transformer system (on the right).



*OPEN DELTA OR WYE* *TRUE THREE PHASE*

Make sure that the transformer rating, in KVA, is adequate for the motor load by referring to this chart which references the KVA requirement by horsepower. Note that the minimum KVA rating, at the right on the chart, refers to "each" transformer used. This chart, incidentally, covers only the motor KVA requirements and does not make allowances for other loads.

| SUBMERSIBLE 3" DIA MOTOR H.P. RATING | TOTAL EFFECTIVE KVA REQUIRED | SMALLEST KVA RATING "EACH TRANSFORMER" | |
|---|---|---|---|
| | | OPEN WYE OR DELTA 2 TRANSFORMERS | WYE OR DELTA 3 TRANSFORMERS |
| 1 1/2 | 3 | 2 | 1 |
| 2 | 4 | 2 | 1 1/2 |
| 3 | 5 | 3 | 2 |
| 5 | 7 1/2 | 5 | 3 |
| 7 1/2 | 12 | 7 1/2 | 5 |
| 10 | 15 | 10 | 5 |
| 15 | 20 | 15 | 7 1/2 |
| 20 | 27 | 15 | 10 |
| 25 | 32 | 20 | 10 |
| 30 | 40 | 25 | 15 |
| 40 | 53 | 30 | 20 |
| 50 | 65 | 37 1/2 | 25 |

## STEP 2 SYSTEM REQUIREMENTS

Select the proper size magnetic starter or pump panel for the H.P. rating of the motor.

Use ambient compensated extra quick trip heaters on all three legs. The recommended heater size for the make of panel is provided with the motor.

Manufacturer's recommended cable size must be followed from the transformer to the pump panel and from the panel to the motor, based on H.P. and voltage rating. Make sure that the length of cable in each case is no longer than the manufacturer's recommendation for that size of cable.

If the pump is to operate properly on a system with two transformers, it is good practice to use both the next higher H.P. motor rating and the nest larger cable size. Taking these steps gives a greater margin of safety and provides more tolerance to current unbalance.

## STEP 3 START UP

While the pump is still above ground check the insulation resistance of the motor to make sure that it is at least two million or more ohms (two megohms).

After the drop cable has been spliced to the motor leads and the pump is installed in the well, check the insulation resistance again to determine if your splice and cable are good.

If insulation resistance is still one million ohms or more, voltage can be applied to the motor.

Whatever you do, remember "SAFETY FIRST!" Before working inside the pump panel or magnetic starter, always disconnect the line to the panel or starter. Be sure it is off. Double-check this with a voltmeter.

Check for correct rotation of the motor by running it first in one direction and then the other. Use a discharge valve and pressure gage. The rotation that gives the highest pressure is always the correct one.

Rotation can be changed by switching any two of the three motor leads at the pump panel.

Now that correct rotation is established, the amount of current unbalance between legs should be calculated.

CURRENT UNBALANCE BETWEEN LEGS SHOULD NOT EXCEED 5% OF THE AVERAGE.

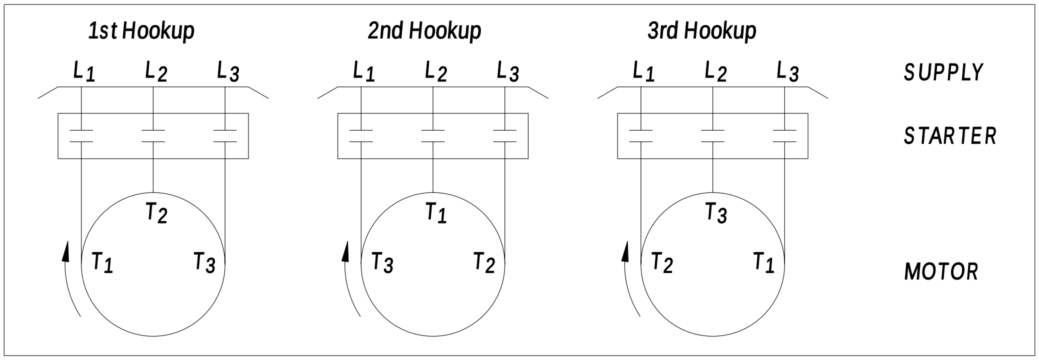
The percent of current unbalance is defined and calculated as follows:

$$\text{Percent current unbalance} = \frac{\text{maximum current difference from average current}}{\text{average current}} \times 100$$

Current readings in amps should be checked on each leg using the three possible hookups shown in the illustration. The best hookup is the one that has the lowest percentage of unbalance.

To prevent changing motor rotation when taking these readings, the motor leads should be rolled across the starter terminals by always moving them in the same direction as shown in the illustration. (On next page).

# DEALING WITH THREE PHASE UNBALANCE




Use simple arithmetic to calculate the percentage of current unbalance for all three hookups. Here is an example of current readings at maximum pump loads on each leg of a three-wire hookup. To start with, add up all three readings for hookup number 1.

| *Hookup 1* | *Hookup 2* | *Hookup 3* |
|---|---|---|
| *$T_1$= 51 Amps* | *$T_3$= 50 Amps* | *$T_2$= 50 Amps* |
| *$T_2$= 46 Amps* | *$T_1$= 48 Amps* | *$T_3$= 49 Amps* |
| *$T_3$= 53 Amps* | *$T_2$= 52 Amps* | *$T_1$= 51 Amps* |

*Total for each of the three hookups are as follows:*

*$T_1$= 51 Amps*

*$T_2$= 46 Amps*

*$T_3$= 53 Amps*

*TOTAL 150 Amps*

*Divide the total by three to obtain the average.*

*150 Amps - 3 = 50 Amps*

*Calculate the greatest amp difference from the average.*

*50 Amps*
*-46 Amps*
*4 Amps*

*Divide this difference by the average to obtain the percentage of unbalance.*

*4.00 Amps - 50 = 0.08 or 8%*

In this case, the current unbalance for hookup number 1 is 8%.

If you use the same method of calculation, the maximum current unbalance for hookup number 2 is 4% and for hookup number 3 is 2%.

Next, compare the percentage of unbalance for all three hookups. The first hookup exceeds 5% current unbalance and should not be used. The second and third hookups did not exceed 5%, so either would be satisfactory. However, the third hokup had the lowest percentage of current unmbalance and it should be used, since the motor will then be operating at maximum efficiency and reliability.

By observing where the highest current reading is for each leg on the various hookups, you can now determine if the unbalance is caused by the power source or the electric motor. For example, note in the example that the highest leg was always on the same leg, L ; this indicates that most of the unbalance was from the power source.

If the high current were on a different leg each time the motor leads were changed, you would know that the motor or a poor connection caused most of the unbalance.

Since loads on a transformer bank may vary during the day, readings should be taken at least twice - once during the day in what would be considered the normal load period and once in the evening during the usual peak load period. The installation should then be connected for the lowest percentage of current unbalance (again, not to exceed 5%.)

Should you continue to have problems with balance or if you encounter heater trip problems. contact your power company for help.

So you can fully explain the situation to the power use engineer, or to your pump supplier, keep a complete log of your pump installation.

You should keep a record of:

Well location and owner
Depth to water
Horsepower
Motor make
Size of control panel
Heaters used
Cable sizes and lengths
Current and voltage readings, by leg

With this type of log, you will be on solid ground when you discuss the current unbalance problem with your power company. You can show what you did and why. This will help pinpoint the problem.

# COMPONENT PROBLEM SOLVING
# SUBMERSIBLE PUMP AND MOTOR

## PROBLEM: MOTOR DOES NOT START

| CAUSE OF TROUBLE | CHECKING PROCEDURE | REMEDY |
|---|---|---|
| No power or incorrect voltage. | Using voltmeter check the line terminals. Voltage must be ± 10% of rated voltage. | Contact power company if voltage is incorrect. |
| Fuses blown or circuit breakers tripped. | Check fuses for recommended size and check for loose, dirty or corroded connections in fuse receptacle. Check for tripped circuit breaker. Look for damage from heat, lightning or surge. | Replace with proper fuse or reset circuit breaker. |
| Defective pressure switch. | Check voltage at contact points. Improper contact of switch points can cause voltage less than line voltage. | Replace pressure switch or clean points. |
| Control panel malfunction. | For detailed procedure, see panel manufacturers instructions. | |
| Defective wiring. | Check for loose or corroded connections. Check the motor lead terminals with a voltmeter for power. | Correct faulty wiring or connections. |
| Bound pump. | Locked rotor conditions can result from misalignment between pump and motor or sand bound pump. Amp readings 3 to 6 times higher than normal will be indicated. Well may be crooked. | Sand bound pumps can sometimes be corrected by temporarily reversing any two leads in the control panel. If pump does not rotate freely, it must be pulled. |
| Defective cable or motor. | Check insulation resistance. | Repair or replace. |

## PROBLEM: MOTOR STARTS TOO OFTEN

| CAUSE OF TROUBLE | CHECKING PROCEDURE | REMEDY |
|---|---|---|
| Pressure switch. | Check setting on pressure switch and examine for defects. | Reset limit or replace switch. |
| Check valve, stuck open. | Damaged or defective check valve will not hold pressure. | Replace if defective. |
| Waterlogged tank (air supply) | Check air volume control or snifter valve for proper operation. | Clean or replace. Drain and recharge tank. |
| Leak in system. | Check system for leaks. | Replace damaged pipes or repair leaks. |

## PROBLEM: MOTOR RUNS BUT OVERLOAD PROTECTOR TRIPS

| CAUSE OF TROUBLE | CHECKING PROCEDURE | REMEDY |
|---|---|---|
| Incorrect voltage. | Using voltmeter check the line terminals. Voltage must be ± 10% of rated voltage. | Contact power company if voltage is incorrect. |
| Overheated protectors. | Direct sunlight or other heat source can make control box hot causing protectors to trip. The box must not be too hot to touch. | Shade box, provide ventilation or move box away from heat source. |
| Control panel malfunction. | For detailed procedure, see panel manufacturers instructions. | |
| Defective cable or motor. | Check insulation resistance. | Repair or replace. |
| Worn pump or motor. | Check running current. | Repair or replace pump and/or motor. |
| Water system malfunction. | Check for waterlogged tank or defective pressure switch. | Repair or replace. |
| Pump load too great. | Incorrect pump for motor. Operating too far out on curve. Rotation backwards. | |

# COMPONENT PROBLEM SOLVING
# SUBMERSIBLE PUMP AND MOTOR

## PROBLEM: MOTOR RUNS CONTINUOUSLY

| CAUSE OF TROUBLE | CHECKING PROCEDURE | REMEDY |
|---|---|---|
| *Pressure switch.* | *Switch points may be "welded" in closed position. Pressure switch may be set too high.* | *Clean points or replace switch, or readjust setting.* |
| *Low level well.* | *Pump may exceed well capacity. Shut off pump, wait for well to recover. Check static and draw-down levels from well head.* | *Throttle back pump output or reset pump at a lower level. Do not lower if sand may clog pump.* |
| *Leak in system.* | *Check system for leaks.* | *Replace damaged pipes or repair leaks.* |
| *Worn Pump.* | *Symptoms of worn pump are similar to those of drop pipe leak or low water level in well. Reduce pressure switch setting, if pump shuts off, worn parts may be at fault. Sand is usually present in tank.* | *Pull pump and replace worn impellers, casing or other close fitting parts.* |
| *Loose or broken motor shaft.* | *No or little water will be delivered if coupling between motor and pump shaft is loose or if a jammed pump has caused the motor shaft to shear off.* | *Check for damaged shafts if coupling is loose and replace worn or defective units.* |
| *Pump screen blocked.* | *Restricted flow may indicate a clogged intake screen on pump. Pump may be installed in mud or sand.* | *Clean screen and reset at less depth. It may be necessary to clean well.* |
| *Check valve stuck closed.* | *No water will be delivered if check valve is in closed position.* | *Replace if defective.* |
| *Control panel malfunction.* | *See panel manufacturers instructions.* | |
| *Pump performance* | *Pump selection incorrect for system.* | *Recalculate Requirements.* |

## PROBLEM: NO WATER DELIVERED

| CAUSE OF TROUBLE | CHECKING PROCEDURE | REMEDY |
|---|---|---|
| *Pump not turning.* | *Check for broken pump/motor shaft or coupling. Motor is not running.* | *Repair or Replace.* |
| *Discharge line restricted.* | *Check valve could be installed backwards or could be stuck closed.* | *Replace if defective.* |
| *Inlet restricted.* | *Screen could be plugged, well may be collapsed or the water level may be too low.* | *Repair or change well locations.* |
| *Wrong rotation.* | *Rotation of three phase motor.* | *Repair or Replace.* |
| *Wrong pump selection.* | *Recalculate requirements.* | *Replace.* |

## PROBLEM: LOW WATER DELIVERY

| CAUSE OF TROUBLE | CHECKING PROCEDURE | REMEDY |
|---|---|---|
| *Pump speed or selection.* | *Rotation could be backwards. Check for low voltage or low phase. Wrong speed, pump vs. motor.* | *Recalculate requirements.* |
| *Restricted discharge.* | *Line clogged, corroded or ruptured. Check valve stuck partially closed.* | *Repair or Replace.* |
| *Restricted inlet.* | *Partially clogged inlet screen. Well partially collapsed. Water level too low in well. Plugged impeller.* | *Repair or change well locations.* |
| *Mechanical problem.* | *Pump worn or loose impeller.* | *Repair or Replace.* |

# COMPONENT PROBLEM SOLVING SUBMERSIBLE PUMP AND MOTOR

## PROBLEM: ELECTRIC SHOCK

| CAUSE OF TROUBLE | CHECKING PROCEDURE | REMEDY |
|---|---|---|
| Grounding | Improper (or absence of) ground on electrical system, controls or motor. | Repair or Replace. |
| Wiring | Check for improper wiring, grounded motor or cable. | Repair or Replace. |
| Controls | Defective or burned out component. | Repair or Replace. |
| Moisture | Wet controls or wiring. | Repair or Replace. |

CAUTION: *Electric shock from contact with any pumping system part is never safe to ignore! Find and correct the cause!*

## AMMETER ANALYSIS OF MOTOR PROBLEMS

| OPERATION AND AMMETER READINGS | CONDITION INDICATED | WHAT TO LOOK FOR: | |
|---|---|---|---|
| | | 1 PHASE MOTOR | 3 PHASE MOTOR |
| Motor won't start. Ammeter reads zero on all lines. | Power is not connected to motor. | Dead power line.<br>Blown fuses.<br>Tripped overload.<br>Defective pressure switch.<br>Defective control box.<br>Separated motor leads. | Same<br>Same<br>Same<br>Same<br>Same<br>Same |
| Motor won't start. Ammeter reads high on two lines, zero on other line. | Power is connected to only part of motor windings. | Defective control box.<br>Control box not mounted vertically.<br>Very low voltage.<br>Damaged cables or splice. | Same<br>One blown fuse<br>One lead in power supply<br>Same |
| Motor won't start. Ammeter reads several times normal on all leads. | Power is connected to motor but something prevents starting. | Tight motor bearings.<br>Tight pump bearings.<br>Damaged cables or splice.<br>Very low voltage. | Same<br>Same<br>Same<br>Same |
| Single phase motor runs but ammeter reads high, especially on red lead. Overload may trip. | Controls are not switching out start capacitor. | Control box not mounted vertically.<br>Defective relay.<br>Very low voltage.<br>Motor connected to wrong phase or voltage. | Not applicable |
| Motor runs but ammeter reads high on some or all leads. Overload may trip. | Motor is overloaded or voltage is incorrect. | Faulty motor.<br>Faulty pump.<br>Low or high voltage.<br>Incorrect pump for motor. | Same<br>Same<br>Same<br>Same |

# END PLAY (LATERAL) -THRUST CONSTANT

| CLOSED IMPELLER BOWLS IMPELLER SEAL - BOTTOM FACE AND SKIRT TO MATCHING BOWL SECTION | | | | SEMI-OPEN IMPELLER SEAL - BOTTOM OF VANES TO MATCHING BOWL SECTION | | |
|---|---|---|---|---|---|---|
| BOWL MODEL | END PLAY STANDARD (inches) | END PLAY *SPECIAL (inches) | THRUST CONSTANT K (Lbs./Ft. Head) | BOWL MODEL | END PLAY SPECIAL (inches) | THRUST CONSTANT K (Lbs./Ft. Head) |
| 6JC | 3/8 | N/A | 1.56 | M4 | 3/8 | 1.50 |
| 6LC | | | | H4 | 1/4 | |
| 6MC | 1/2 | | 2.24 | | | |
| 6HC | | | | | | |
| 6XC | 5/8 | | 2.83 | | | |
| 6WC | 3/8 | | 4.13 | | | |
| 6YC | 1/4 | | 4.10 | | | |
| 8JC | 7/16 | 23/32 | 2.98 | 8JS | 7/16 | 3.52 |
| 8LC | | | | 8LS | | 3.34 |
| 8KC | | 11/16 | 3.93 | 8KS | | 4.42 |
| 8MC | | | | 8MS | | 4.28 |
| 8EHC | 3/8 | 5/8 | 5.40 | 8EHS | 3/8 | 5.40 |
| 8WC | 1/2 | 5/8 | 6.20 | | | |
| 8YC | 3/8 | 5/8 | 8.00 | 8YS | 3/8 | 8.00 |
| 10JC | 1/2 | 3/4 | 3.98 | | | |
| 10KC | | | 4.20 | | | |
| 10LC | 5/8 | 7/8 | 6.60 | 10LS | 5/8 | 7.50 |
| 10MC | | | | 10MS | | |
| 10HC | | 1 | 8.10 | 10HS | | 9.20 |
| 10WC | 7/8 | 1 1/4 | 10.30 | 10WS | 7/8 | 11.20 |
| 10YC | 3/4 | 1 1/8 | | 10YS | 3/4 | 11.40 |
| 10ZC | 1/2 | 7/8 | 13.60 | 10ZS | 1/2 | 13.50 |
| 12JC | 5/8 | 7/8 | 6.60 | | | |
| 12IC | 5/8 | 7/8 | 6.75 | 12IS | 5/8 | 8.20 |
| 12KC | 5/8 | 7/8 | 6.50 | 12KS | 1/2 | 7.75 |
| 12LC | 3/4 | 1 3/8 | 10.60 | 12LS | 7/8 | 12.50 |
| 12MC | | 1 1/4 | | 12MS | 3/4 | |
| 12HC | | | 16.50 | 12HS | 3/4 | 19.00 |
| 12XC | 7/8 | 1 1/4 | 18.20 | 12XS | 7/8 | 20.80 |
| 12WC | 3/4 | 1 3/16 | 16.20 | 12WS | 3/4 | 17.40 |
| 12YC | 7/8 | 1 1/2 | 14.20 | 12YS | 7/8 | 16.50 |
| 13M | 15/16 | 1 3/16 | 8.00 | | | |
| 14LC | 7/8 | 1 3/8 | 17.20 | 14LS | 7/8 | 19.70 |
| 14MC | | | 21.80 | 14MS | | 23.40 |
| 14HC | | | | 14HS | | 25.20 |
| 14XC | | | | 14XS | | 23.40 |
| 14WC | | | 24.80 | 14WS | | 26.20 |
| 14YC | 1/2 | 5/8 | 24.00 | | | |
| 14ZC | 1/2 | 5/8 | 24.70 | | | |
| 15KC | 11/16 | 1 1/8 | 28.00 | 15KS | 11/16 | 30.00 |
| 18LC | 1/2 | 3/4 | 21.75 | | | |
| 18MC | 1/2 | 3/4 | 21.75 | | | |
| 18HC | 1/2 | 3/4 | 23.50 | | | |
| 20MC | 3/4 | 1 | 29.40 | | | |
| 20HC | 5/8 | 1 | 58.00 | | | |

*Special End Play may reduce performance.
NOTE: CONSULT FACTORY if additional end play is required.