

# Fluid Flow

The charts and formulas here will enable you to answer basic flow problems involving industrial hose. It contains the necessary information for dealing with various kinds of liquid and air. In general terms, this publication will enable you to determine:

- **pressure loss** through a given hose at a certain flow rate.
- **size of hose** required to deliver a certain volume of fluid a given distance (inlet pressure known)
- **flow rate** through a given hose either open end or with a given allowable pressure loss (inlet pressure known).
- **fluid flow velocity** resulting from a given flow rate (or rate from velocity).

To obtain these answers, the charts and formulas here relate the basic variables involved with flow: Type of fluid, flow rate, available pressure (or pressure loss), hose size (I.D.) and length.

## General Notes

- 1) The charts are based on average conditions and are to be used as a guide only. Changes in the basic characteristics of viscosity or specific gravity will affect pressure loss and flow rates.
- 2) Flow of Water through hose charts are based on a temperature of 68° F. and viscosity of one centipoise (or one centistoke).
- 3) The remaining charts show various common fluids with the specific gravity and viscosity as indicated. These curves can be used to get approximate values for other fluids that have the same general viscosity and specific gravity.
- 4) Pressure loss resulting from restrictive couplings is approximately equal to 5% of the loss through 100 ft. of hose. Any insert type couplings attached with bands or clamps are restrictive.
- 5) Built-in nipple, BIRF, Beaded Ends and Internal Expansion Couplings are considered nonrestrictive.

## Suggestions for Chart Usage and Related Data

- 1) The flow charts for liquids show pressure loss for a hose length of 100 ft. at various flow rates (gallons per minute). Usually, several hose sizes (inner diameters) are shown on each chart.
- 2) Pressure loss is proportional to length. The loss shown for 200 ft. will be twice that of the 100 ft. shown on the chart. The loss for a 50 ft. length will be one-half that for 100 ft. (assuming a constant flow rate).
- 3) Water pressure expressed as feet of head (height of a

column, or difference in elevation) can be converted to psi by multiplying by .43. For example, for a 100 ft. head;  $100 \text{ ft.} \times .43 = 43 \text{ psi}$ , or, as a rule of thumb, divide the head in feet by 2 to obtain approximate pressure, psi.

- 4) Normal manufacturing I.D. tolerance for general purpose hose up through 3/4" I.D. is +/- .03". This can cause a wide variation in pressure loss values for small I.D. hoses (3/16", 1/4", 5/16", 3/8", 1/2"). For example, pressure loss through a length of 1/4" I.D. hose will increase by a factor of about 3 between high side and low side tolerance (liquid or gas).
- 5) Most small air tools are designed to operate at 90 psi. Pressure loss through hose should be kept to a minimum to ensure efficient operation of these tools. As a rule of thumb, hose losses should be kept below 10%. Also note that tolerance (see 4, above) and size have a large effect on pressure loss. For example, increasing hose size from 1/4" to 5/16" would reduce pressure loss by at least 50% for a given application.
- 6) Open end discharge service does not necessarily mean low pressure operation. If the hose is full of liquid, the inlet end will be exposed to system pressure. This will decrease to zero at the open outlet end.
- 7) Temperature affects viscosity of many liquids, and changes in viscosity affect pressure loss. Oil which flows freely at 100° F. may be very stiff and viscous at 10° F., and consequently difficult to pump.
- 8) Fluid velocities:
  - Water, oils, fuels, gasoline - these systems are usually designed for fluid velocities up to 30 ft./sec.
  - Slurry lines are usually designed for velocities in the range of 8 - 16 ft. / sec. (depending on type of slurry). Depending on the system, line pressure may vary from 50 to 500 psi.
- 9) Air velocities - most pneumatic systems are designed for high velocities, in the range of 3000 to 7000 ft. / min. Pressures are either positive (up to about 25 psi) or negative (20" Hg vacuum).
- 10) Liquid viscosities\* are measured or referenced in several different units. Most common is Saybolt Seconds Universal (SSU). This unit is a time measurement of fluid flow under prescribed conditions.

The unit used in most calculations is a centistoke. SSU units can be converted to centistokes by use of a formula or chart.

Another viscosity unit is centipoise, and is used as a basic reference for many fluids. This unit can also be converted to centistokes by dividing it by the fluid specific gravity.

\*Kinematic Viscosity; Stoke, Centistoke, SSU

\*Absolute Viscosity; Poise, Centipoise

# Examples Using Charts

## Example:

What pressure loss will result if 500 gallons per minute of water is pumped through a 3" inside diameter x 150' length of hose consisting of three 50' coupled lengths.

## Solution:

- From **Chart #2, "Flow of Water Through Hose, 1-1/2" through 4" Inside Diameter"**, at 500 gpm, pressure loss per 100' of 3" I.D. hose is 20 psi.
- Pressure loss is directly proportional to hose length. Since the flow charts are based on 100' lengths, loss for 100' must be converted to 150' of hose. Pressure loss for 100' of hose is 20 psi, therefore, the loss in 150' of hose is:  $150'/100' \times 20 \text{ psi} = 30 \text{ psi}$ .
- As a rule of thumb, loss for each set of couplings equals 5% of the loss per 100' of hose. Therefore, pressure loss =  $.05 \times 20 \text{ psi} = 1 \text{ psi}$  per set of couplings.
- Pressure loss from three sets of couplings =  $3 \times 1 \text{ psi} = 3 \text{ psi}$ .
- Total pressure loss:  $30 \text{ psi (hose loss)} + 3 \text{ psi (coupling loss)} = 33 \text{ psi pressure loss per 150' of hose}$ .

## Example:

A pump transmits water through 3" inside diameter x 200' hose at a flow rate of 1000 gallons per minute to a traction machine requiring 120 psi to operate. What inlet pressure is necessary to assure the operation of the machine?

## Solution:

- From Chart #2, the pressure loss at a flow rate of 1000 gpm is 70 psi per 100' of hose.
- Flow charts are based on 100' hose lengths, so loss for 100' must be converted to 200' of hose. If pressure loss for 100' of hose is 70 psi, the loss for 200' of hose would be  $200'/100' \times 70 \text{ psi} = 140 \text{ psi}$ .
- Couplings are internal expansion type which are considered nonrestrictive.
- Since the machine requires 120 psi to operate, inlet pressure must be at least 260 psi. ( $140 \text{ psi loss from hose} + 120 \text{ psi required by machine}$ ).

## Example:

Pressure loss in a 6" inside diameter x 100' hose is 40 psi while unloading gasoline with viscosity of .476 centipoise at a flow rate of 6000 gallons per minute. What difference in pressure loss would result when using an 8" inside diameter x 70' hose with two 35' coupled lengths?

## Solution:

- From **Chart #14, "Flow of Gasoline through Hose, 4" through 16" Inside Diameter"**, the pressure at a flow rate of 6000 gpm is 10 psi per 100' of 8" I.D. hose.
- Flow charts are based on 100' lengths and pressure loss is directly proportional to length, therefore, pressure loss in only 70' of hose is  $70'/100' \times 10 \text{ psi} = 7 \text{ psi loss}$ .
- As a rule of thumb, loss for each set of couplings equals 5% of the loss per 100' of hose. For each set of couplings =  $.05 \times 10 \text{ psi loss per 100' hose} = .5 \text{ psi loss per set of couplings}$ .
- For two sets of couplings, loss =  $2 \times .5 \text{ psi} = 1 \text{ psi}$ .
- Total pressure loss:  $7 \text{ psi (hose loss)} + 1 \text{ psi (coupling loss)} = 8 \text{ psi loss per 70' hose}$ .
- The difference in pressure loss is:  
 $40 \text{ psi (100' of 6" I.D.)} - 8 \text{ psi (70' of 8" I.D.)} = 32 \text{ psi}$ . Therefore, pressure loss is decreased by:  $(40 \text{ psi} - 8 \text{ psi})/40 \text{ psi} \times 100 = 80\%$  in this case.

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## Example:

Estimate the pressure loss in a 1-1/2" inside diameter x 100' hose handling Kerosene with viscosity of 2.9 centipoises and .80 specific gravity at a flow rate of 150 gallons per minute. Note: Following flow charts do not include Kerosene.

## Solution:

- Since Fuel Oil, **Chart #5, "Flow of Fuel Oil through Hose, 3/4" through 3" Inside Diameter"**, (viscosity = 2.6 centipoise, specific gravity = .87) has similar viscosity and specific gravity to Kerosene, it can be used to estimate the pressure loss for this example.
- From Chart #5, at 10 gallons per minute, pressure loss from 1-1/2" I.D. hose is 70 psi per 100' of hose.
- If the viscosity is less, pressure loss is also less and vice versa. This is not a direct relationship, however. The difference in kinematic viscosity should be approximately 15% or greater to affect pressure loss significantly. In this example, the viscosities do not differ enough to affect pressure loss substantially.
- Specific gravity, like hose length, is proportional to pressure loss. The specific gravity is less for Kerosene than Fuel Oil in this example so pressure loss will be proportionally less also. The pressure loss for Kerosene is therefore:  $.80/.87 \times 70 \text{ psi} = 64 \text{ psi per 100' of hose}$ .