VELOCITY AND PRESSURE DROP IN PIPES

Velocity

The velocity of hydraulic fluid through a conductor (pipe, tube or hose) is dependent on flow rate and cross sectional area. Recommended fluid velocities through pipes and hoses in hydraulic systems are as follows:

<table>
<thead>
<tr>
<th>Service</th>
<th>Velocity (ft/sec)</th>
<th>Velocity (m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>suction/intake</td>
<td>2 - 4</td>
<td>0.6 – 1.2</td>
</tr>
<tr>
<td>return</td>
<td>4 – 13</td>
<td>1.5 - 4</td>
</tr>
<tr>
<td>pressure/discharge</td>
<td>7 - 18</td>
<td>2 – 5.5</td>
</tr>
</tbody>
</table>

Use values at the lower end of the range for lower pressures or where operation is continuous. Refer to the flow/velocity nomograms on pages four and five for more information. Alternatively, fluid velocity can be calculated using the following formula:

\[
v = \frac{Q \times 0.408}{D^2}
\]

Where
- \(v\) = velocity in feet per second (ft/sec)
- \(Q\) = flow rate in US gallons per minute (US gpm)
- \(D\) = inside diameter of pipe or hose in inches (in.)

In metric units

\[
v = \frac{Q \times 21.22}{D^2}
\]

Where
- \(v\) = velocity in metres per second (m/sec)
- \(Q\) = flow rate in litres per minute (L/min)
- \(D\) = inside diameter of pipe or hose in millimetres (mm)

Pressure drop

Friction between the fluid flowing through a conductor and its inside wall causes losses, which are quantified as pressure drop. Pressure drop in conductors is an important consideration for the designer, especially in systems where long pipe or hose runs are necessary. The pressure drop over a length of pipe or hose can be calculated using the following formula, which for ease of calculation uses metric units. Before proceeding to the pressure drop calculations, the following variables need to be determined:

- Flow rate in litres per minute (L/min) \(Q\)
- Inside diameter of pipe or hose in millimetres (mm) \(D\)
- Kinematic viscosity of fluid (at operating temperature) in centistokes (cSt) \(\nu\)
- Density of the fluid in kilograms per cubic metre (kg/m³) \(\rho\)
- Length of the pipe, tube or hose in metres (m) \(L\)
1. Calculate fluid velocity:

\[ v = \frac{Q \times 21.22}{D^2} \]

Where

- \( v \) = velocity in metres per second (m/sec)
- \( Q \) = flow rate in litres per minute (L/min)
- \( D \) = inside diameter of pipe or hose in millimetres (mm)

2. Calculate the Reynolds Number (Re):

\[ Re = \frac{1000 \times v \times D}{\nu} \]

Where

- \( Re \) = Reynolds Number
- \( v \) = velocity in metres per second (m/sec)
- \( D \) = inside diameter of pipe or hose in millimetres (mm)
- \( \nu \) = kinematic viscosity of fluid (at operating temperature) in centistokes (cSt)

3. Calculate the friction factor (f):

The formula used to calculate the friction factor is dependent on the magnitude of the Reynolds Number.

If the Reynolds Number is less than 2300, flow is laminar and the following formula is used to calculate the friction factor:

\[ f = \frac{64}{Re} \]

Where

- \( f \) = friction factor
- \( Re \) = Reynolds Number < 2300

If the Reynolds Number is between 2300 and 4000, flow is transition and greater than 4000 flow is turbulent. For Reynolds Numbers greater than 2300 and less than 100,000 the following formula can be used to calculate the friction factor:

\[ f = 0.3164 \times Re^{-0.25} \]

Where

- \( f \) = friction factor
- \( Re \) = Reynolds Number > 2300 and < 100,000
In instances where the Reynolds Number is greater than 100,000, friction is highly dependant on the roughness of the conductor’s inner surface. In these cases Colebrook’s equation, which considers pipe roughness, is used to calculate the friction factor. However, due to the relatively low fluid velocities and high fluid viscosities present in hydraulic systems, Reynolds Numbers of this magnitude should not be encountered.

4. Calculate the pressure drop:

Finally, pressure drop can be calculated using the following formula:

\[
\Delta p = \frac{v^2 \times f \times L \times \rho}{2D}
\]

Where

\[\Delta p\] = pressure drop in Pascals (Pa)
\[v\] = velocity in metres per second (m/sec)
\[f\] = friction factor
\[L\] = length of pipe or hose in metres (m)
\[\rho\] = density of the fluid in kilograms per cubic metre (870-890 kg/m³ for hydraulic oil)
\[D\] = inside diameter of pipe or hose in metres (m)

<table>
<thead>
<tr>
<th>Conversions</th>
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</thead>
<tbody>
<tr>
<td>SUS (32 – 99)</td>
</tr>
<tr>
<td>SUS (100 – 240)</td>
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<tr>
<td>SUS (&gt; 240)</td>
</tr>
<tr>
<td>US gallon</td>
</tr>
<tr>
<td>inch</td>
</tr>
<tr>
<td>inch</td>
</tr>
<tr>
<td>feet</td>
</tr>
<tr>
<td>lb/ft³</td>
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<tr>
<td>Pascal (Pa)</td>
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<td>Pascal (Pa)</td>
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Flow / velocity nomogram (U.S.)

This chart is used to determine the size of hose needed to fill flow rate and velocity requirements. Place a straightedge along a line from the flow rate column to the velocity column. The recommended hose size is shown at the point where the line crosses the Hose I.D. column. If the line crosses the Hose I.D. column between sizes, use the next larger I.D.

In the illustration, a 5/8" hose is recommended for a 10 gpm flow rate at a 10 fps velocity.

NOTE: Unless flow of hydraulic fluid is intermittent or occasional, recommended velocities should not be exceeded.

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Flow / velocity nomogram (metric)

Recommended velocity range for intake lines

Recommended velocity range for pressure lines

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