FLUID POWER Design Data Sheet

Revised Sheet 56 - Womack Design Data File

TIPS ON SELECTION OF PLUMBING SIZE FOR HYDRAULIC SYSTEMS

There is an optimum size for the piping in each line of a hydraulic system. It must be large enough to carry the oil flow with an acceptable pressure loss, but should be no larger than necessary. Undersize piping creates too high a pressure and power loss and will contribute to overheating of the oil. Oversize piping will reduce losses but will be more expensive to purchase and install. A well-designed system may use several piping sizes in various parts of the circuit.

It is our opinion, based on our experience, that a very effective way to decide on optimum size is by using flow velocity and pressure as a guide rather than trying to calculate pressure loss in each section of piping and each fitting.

The circuit of **Figure 1** illustrates the major flow paths of the average hydraulic system. The cylinder in this diagram has a maximum diameter piston rod (approximately a 2:1 ratio between piston area and net area around the rod). This type cylinder has the greatest variation in oil flow in the lines which connect it to the 4-way valve and makes the best illustration.

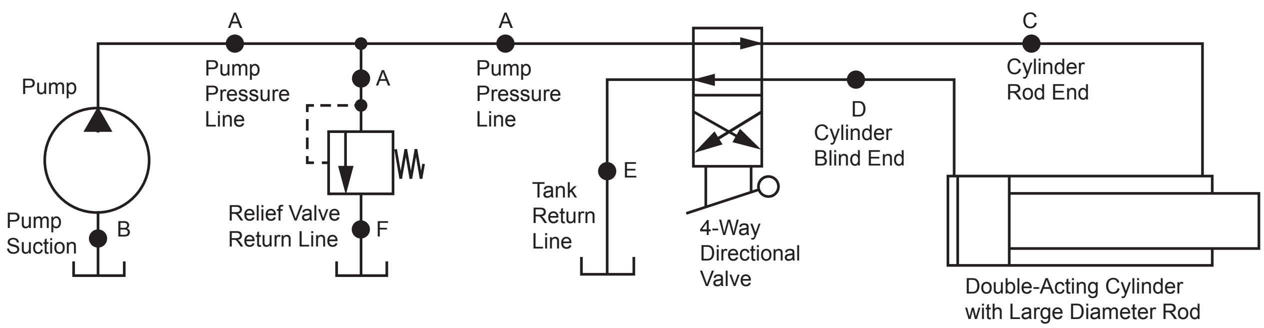

Figure 1. *In different parts of the hydraulic circuit, flows and pressures are different. The optimum piping size for each line can be determined from permissible flow velocity and available pressure in each line*

Point A - Figure 1

This is the pump pressure line. Usually there is enough pressure available so a relatively high flow velocity is acceptable and the pressure loss due to flow is a relatively small percentage of the pressure available from the pump. However, the inside diameter of the pipe, hose, or tubing should be at least equal to the inside diameter of Schedule 40 standard pipe of the same size as the pump pressure port.

Point B - Figure 1

This is the inlet (suction) line to the pump. The piping in this line should be much larger than in the pump outlet line. Velocity of the oil must be kept quite low by using large pipe. The only pressure forcing oil into the pump inlet is atmospheric pressure. Undersize piping will cause a pressure loss high enough to cavitate and damage the pump. An overhead reservoir will help to avoid cavitation, but only if the piping size is large enough to keep flow velocity low.

Of course the inlet line should be as short and direct as possible with a minimum number of bends. Elevation of the pump should be no higher than a foot or so above the top of the oil level in the reservoir.

Point C - Figure 1

Piping from the 4-way valve to the rod end of the cylinder can be the same size as the pump pressure line, Point A Flow in this line is equal to pump flow while the cylinder piston is retracting, and will be less than pump flow volume (actually only half of pump flow on a 2:1 ratio cylinder) while the cylinder piston is advancing.

Because of possible pressure intensification in this line, the pressure rating of the piping should be twice the relief valve setting on the pump (on a 2:1 ratio cylinder).

Point D - Figure 1

Flow volume in this line will be up to twice pump flow while the cylinder piston is retracting (on a 2:1 ratio cylinder). The back pressure in this line should be low, so the flow velocity should be kept low. Pressure rating of this line should be at least as high as the relief valve setting.

Point E - Figure 1

Flow varies in this line just as it does at Point D while the cylinder is moving, and it can be sized for the same velocity. Its pressure rating may be low because back pressure in the return line should never be allowed to exceed 100 PSI.

Point F - Figure 1

This line always carries the same flow volume as the pump flow, and can be sized for the same velocity as Point A. However, its pressure rating can be quite low.

RECOMMENDED FLOW VELOCITIES AND PIPE INSIDE AREAS FOR HYDRAULIC FLOW

*This chart is for use with **Figure 1** circuit*

Plumbing Location Refer to Figure 1.	Recommended Velocity Range, Feet per Second	Square Inch Inside Area* for Each 5 GPM of Flow
Points A, C, & F at pressures up to 1,000 PSI	10 to15	0.1604 to 0.1069
Points A, C, & F at pressures from 1,000 to 2,000 PSI	15 to 20	0.1069 to 0.0802
Points A, C, & F at pressures from 2,000 to 3,000 PSI	20 to 25	0.0802 to 0.0642
Points A, C, & F at pressures over 3,000 PSI	25 to 30	0.0642 to 0.0535
Point B (pump station)	2 to 4	0.8020 to 0.4010
Points D & E, oil return lines	10 to 15	0.1604 to 0.1609
All oil lines in an air-over-oil system	5 to 10	0.3208 to 0.1604

**Inside areas were calculated with the formula: A = 5 GPM × 0.3208 ÷ V (velocity, feet/second)*

Flow Velocity

The optimum diameter (and internal area) of the piping at each one of the points, A through F on **Figure 1**, is calculated from the optimum· flow velocity and pressure level shown in the chart above.

The first column of the chart identifies the piping location and pressure range. Larger pipes are used in systems or lines which operate at lower pressure to keep pressure losses to a relatively small percentage of total available pressure. At higher pressures, smaller pipes with a higher pressure loss are acceptable because the pressure loss is still a relatively small percentage of total pressure in the line.

The second column of the chart shows a recommended range of velocity for each piping location. Pipe size should be sufficiently large to keep from exceeding the maximum specified limit on velocity.

The third column of the chart shows the range of inside pipe areas to keep within the same range of velocity shown in the second column. Note that these areas are given for each 5 GPM of oil flowing in that line. **Example:** If the flow is 50 GPM, multiply these values by 10, etc.

At Points A, B, C, E, and F, the maximum flow will not exceed pump flow, but the maximum flow at Point D must be calculated. When the cylinder piston is retracting, the flow will be higher than pump flow by the same ratio that the full piston area is higher than the annulus area around the piston rod. When a hydraulic motor is used instead of a single-end-rod cylinder, the oil flow at all points will be the same as the pump flow.

How to Use the Chart

Take each section of plumbing on your fluid diagram and identify it with one of the lines in the first column of the chart. Then, use the third column to find the range of pipe inside areas recommended. For a very conservative design the high end of this range may be used. Where it is necessary to economize on plumbing costs, the low end of the range may be used. For average designs, a value approximately in the middle may be used. Remember these area values are for each 5 GPM flowing in the line.

From the inside area, calculate the inside diameter.

$$\mathbf{D = \sqrt{4 \times A \div \pi}}$$

A is area, square inches
D is diameter, inches
π is 3.14

Calculation Example

The pump flow is 35 GPM; pressure at full load is 3,000 PSI. The cylinder bore is 4 inches, rod diameter 1¾. Find the optimum inside pipe diameter for flow at Point D.

Solution: First find the piston, rod, and annulus areas: From table of circle areas, piston area = 12.57 square inches; rod area = 2.41 square inches. Therefore, annulus area = 12.57 - 2.41 = 10.16 square inches.

Next, find the maximum volume which will be carried past Point D while the cylinder piston is retracting. Ratio of piston to annulus area is: 12.5 7 ÷ 10.16 = 1.28. Oil flow = 1.28 × 35 GPM = 44.8, or say, 45 GPM.

Recommended area for the pipe at Point D, from column three of the chart, is in the range of 0.1604 to 0.1069 square inches for each 5 GPM of flow. For this example we will select a mid value of 0.133 square inches per 5 GPM. Inside area for 45 GPM is: A = 0.133 × 9 = 1.197 square inches total area.

Find the inside diameter of a pipe which has an area of 1.197 square inches, using formula in opposite column:

$$\mathbf{D = \sqrt{4 \times 1.197 \div 3.14} = 1.524 \text{ inches}}$$

Drain Lines

Component External Drain Lines. Some valves such as sequence, counterbalance, pressure reducing, flow control, and 4-way pilot-operated solenoid valves may sometimes require an external drain line to tank. Usually, steel tubing, 3/8 to 1/2″ O.D. is large enough to handle the drain flow with very little back pressure. Drain lines should not be teed into tank return lines from 4-way valves, but should be run separately all the way back to tank and discharged above the oil level. However, the drains from several valves may be combined into one 1/2″ O.D. common drain line.

Motor and Pump Case Drains. All piston-type hydraulic motors, and sometimes pumps, have a case drain port which must be run separately to tank. The piping from these drain ports should be at least the same size as the drain port in order to keep back pressure low in the motor case. Excessive pressure build-up inside the case will blow out the shaft seal.

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