Pressure Sensors

Protecting Pressure Sensor Diaphragm From Rupture Due To Water Hammer – Note #8

Introduction

Many hydraulic systems exhibit short duration pressure pulses or shocks, called ''water hammer.'' These shocks are generated by the rapid change of system flow rates by components such as compressors, pumps, pistons and valves. Water hammer can reach pressure levels far exceeding the over pressure rating of our pressure sensors causing destruction of the pressure sensing diaphragm.

There are four factors that determine water hammer:

1. System length (the longer the line, the greater the shock).
2. System pipe diameter.
3. System fluid velocity.
4. Closing time of valves or other flow modifiers.

The pressure increase in a fluid system due to water hammer can be described by:

$\Delta P = ec\Delta V$

Where:

e = density of fluid

c = velocity of sound in the system fluid (ft./sec.)

ΔV = change in velocity (ft./sec.)

ΔP = change in pressure (lb./ft.^{2})

(Divide by 144 for pressure in psi)

The magnitude of water hammer shock can be reduced thru reducing the system fluid velocity. Often the GPM (gallons per minute) flow rate can be reduced or the system pipe diameter increased.

Water Hammer Protection Systems

Fluid systems can be developed in three ways to eliminate or control water hammer.

1. Surge tank

An air chamber or surge tank can be placed between the components that generate the flow rate change, and the pressure sensor. The higher the volume of the tank, the higher the pressure shock it will absorb. Inlet and outlet ports should never be opposite each other to prevent direct transmittal of shock pulses. Some fluid collection can be expected in most pneumatic systems. The area required for the surge tank is the major problem with this approach.

2. Slowing operation

Water hammer is developed only by a rapid change in flow rate. If the operation of valves or other flow rate modifiers is slowed beyond the critical time of change (t_c), shock pulses can be prevented. Critical time of change is defined as:

$t_c = 2\ D/c$

Where:

$\mathbf{t_c}$ = Time of change (seconds).

D = Distance from flow restriction point to pressure sensor to be protected (feet).

c = Velocity of sound in system fluid (feet/second).

For most fluids, the velocity of sound lies between 1000 and 7000 feet per second. If system distances are great (a few hundred feet), the time of change can be 0.5 second or more. One problem with this approach is that some components may not accommodate such slow operation.

3. Pressure snubber

A pressure snubber is a device for slowing the rate of change of system flow. Installation of a properly sized snubber at or near the input of a pressure sensor will protect it from water hammer damage.

Typically, pressure snubbers are cylindrical cross-section devices ranging from 0.75 to 1.5 inches in diameter and 0.75 to 5.0 inches long. Two types commonly used employ either a porous metal plug or filter in the pressure path, or a movable plunger restricting the flow rate. Sensor response to significant pressure changes will be slowed from about 1.0 millisecond to as much as a few seconds when a snubber is used.

If the pressure sensor is mounted only by the input port at the end of a long pressure snubber, resistance to shock and vibration will be reduced. Rated shock and vibration divided by the increased mounting length in inches approximates the expected shock and vibration resistance. Adding a 3 inch long snubber will reduce shock and vibration resistance to about one third of the rated value.

Following is a list of vendors for pressure snubbers:

Allied Witan Company
Arcco Instrument Company, Inc.
Autoclave Engineers Inc.
Cajon Company
Chemiquip
Cutler Controls Incorporated
Duro Instrument Corporation
Enerpack Division Applied Power Inc.
Fluid Kinetics Corporation
Greer Hydraulics
ITT Grinnell Corporation
Metserco
Mid-West Instrument Division Astra Associates Inc.
Mott Metallurgical Corporation
Oligear-Ball Products
Pulsafeeder/Interpace
Sigma-Netics Incorporated
Trerice, H O Company
Weiss, Albert A & Sons Inc.