Protecting Pressure Sensor Diaphragm From Rupture Due To Water Hammer - Note #5

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 rate 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 (refer to the chapter on Pressure Sensing).

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:

$t_c = 2D/c$

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.

RESISTANCE THERMOMETERS

RESISTANCE THERMOMETER THEORY

The resistance of a conductor varies according to its temperature and this principle is employed in resistance thermometry. By specifying a conductor material which displays a stable and approximately linear temperature coefficient of resistance over the required range, a reliable thermometer can be made.

Since Platinum is chosen for the world standard resistance thermometer material, the PRT assembly is the predominant choice for both laboratory and industry.

As sensing element, Platinum has many virtues. In a pure form it will resist contamination and is stable both mechanically and electrically. The relationship between temperature and resistance is nearly linear which allows production of accurately interchangeable detectors.

Materials other than Platinum are sometimes used but only to a limited extent; only PRT assemblies are therefore offered.

The use of the PRT is in practice much simpler than that of the thermocouple:- copper wires are used between sensor and instrument and since the calibration is absolute, no reference or CJC correction techniques are required.

Standard PRT detectors have a resistance of 100 Ohms at 0°C and have a resistance/temperature characteristic which conforms to BS1904:1984 or to DIN4376:1980 class A or B. The resistance change over the range °C to 100°C is 38.5 Ohms and is referred to as the fundamental interval.

PLATINUM RESISTANCE THERMOMETER PRACTICE

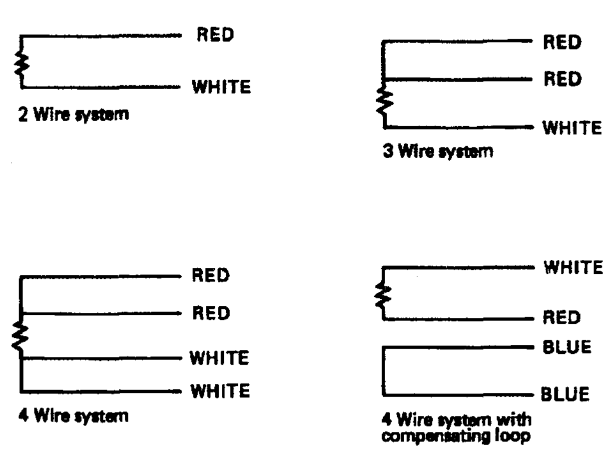
The PRT detector is available in many different types of construction but most commonly as a miniature ceramic assembly. The platinum wire is wound in a small spiral and located in axial holes in a high purity alumina rod. Glass adhesive is used to seal the lead exit points, fired to form a permanent bond. Many shapes and sizes of detector are employed but the majority are 25mm long by 3mm diameter. During construction, the element resistance at 0°C is trimmed to 100 ohms with a very close tolerance.

This detector arrangement, when located in a suitable protecting sheath results in a **stem sensing** assembly (sensing occurs along the entire detector body length) as opposed to the tip sensing thermocouple.

Alternative arrangements include a flat film construction which is very compact and has a low thermal mass.

Lead Configuration – The accuracy of PRT temperature measurement is largely determined by the number of leads used between the probe and the instrument. Two leads are often acceptable in the case of short cable runs, three leads compensating for lead resistance variations give improved accuracy and four leads provide the greatest precision. The choice of 2, 3 or 4 wires **must be made in context with the measuring instrument** input arrangement.

CONNECTIONS CONFIGURATIONS AND TERMINATION COLOUR CODES (BS1904:1984)



RESISTANCE v TEMPERATURE AND TOLERANCES FOR 100Ω THERMOMETERS

BS1904:1984/DIN43760

Temperature	Resistance	Tolerance Class A		Tolerance Class B	
(°C)	(Ω)	(±°C)	(±Ω)	(t °C)	(±Ω)
-200	18.49	0.55	0.24	1.3	0.56
-100	60.25	0.35	0.14	0.8	0.32
0	100.00	0.15	0.06	0.3	0.12
100	138.50	0.35	0.13	0.8	0.30
200	175.85	0.55	0.20	1.3	0.48
300	212.02	0.75	0.27	1.8	0.64
400	247.04	0.95	0.33	2.3	0.79
500	280.90	1.15	0.38	2.8	0.93
600	313.59	1.35	0.43	3.3	1.06
650	329.51	1.45	0.46	3.6	1.13
700	345.13	-	-	3.8	1.17
800	375.51	-	-	4.3	1.28
850	390.26	-	-	4.6	1.34

F.I. = 38.5 Ro = 100.00Ω α = 0.003850

Note that these figures are for detectors and not for assemblies. Any assembly will inevitably introduce some degradation in the overall tolerance figures.