Whitepaper

Understanding and Preventing Water Hammer Damage

How to protect a pressure transducer

OVERVIEW

Water hammer is one of the most misunderstood phenomenons in fluid handling. Water hammer, fluid hammer and hydraulic shock are all terms used to describe a sudden momentum change in a fluid. This sudden change causes a pressure wave that propagates through the fluid. When this pressure wave comes into contact with an object, such as a pressure transducer, it will impart a damaging load.

This whitepaper will cover the following:

- Water hammer basics
- Prevention methods
- Symptoms of water hammer damage

CONTENT

1. What is Water Hammer?

Water hammer was utilized before there was a name for the effect. John Whitehurst built a hydraulic ram in 1772 that leveraged the power of water hammer. Water hammer was first investigated as a theory in the late 1800's. Today, fluid system engineers and building contractors alike have to be mindful of potential damage that water hammer can cause. Even home owners can experience the power of water hammer.

A hammer occurs because a fluid is forced to stop or change direction very quickly. Simply turning off a shower or sink quickly can cause an audible water hammer inside the pipes. Any of the following fluid components are capable of producing water hammer:

- Valves (solenoid, relief, etc)
- Pumps
- Regulators

It is important to understand that any system with fluid is capable of generating very high pressures for a short duration of time. Let's look at how a very high pressure can be generated in a typical house with 1 inch diameter water pipes.

Below is the equation to calculate the change in pressure:

$$\Delta P = \frac{rc\Delta v}{g}$$

Where:

r = fluid density (62 lb/ft^3 for this example)
c = speed of sound in the fluid (4880 ft/sec for this example)
Δv = change in fluid velocity, defined by the change in flow rate / area
g = gravitational constant (32.2 ft/sec^2)

In this example, the water is flowing at 9 gallons per minute (0.02 cubic feet per second) and comes to a stop when the sink valve is closed. The change in pressure is then:

$$\Delta P = \frac{\left(62\,\frac{lb}{ft^3}\right)\left(\frac{4880 ft}{\text{sec}}\right)\left(\frac{\frac{0.02\,ft^3}{\text{sec}}}{0.06 ft^2}\right)}{32.2\,\frac{ft}{\text{sec}\,2}} = 31{,}321\,\frac{lb}{ft^2} = 218\,psi$$

This change in pressure is added to the existing system pressure. If the water pressure for the house is 60 PSI, the pressure force felt by all the components in the system is much higher:

$$P = 60 + 218 = 278\,psi$$

As we can see from our simple household example, any system where fluid is flowing and is suddenly stopped can generate very high fluid pressures for a brief period of time. Damage most certainly will occur if water hammer is not prevented or mitigated.

2. Prevention Methods

The best way to manage the effects of water hammer is to prevent it. Managing the speed of valves closing and opening is an excellent way to prevent a shock wave within the system. If there are multiple valves in a system, evaluating the timing and order of these valves may help prevent water hammer.

Where water hammer cannot be prevented, other methods may be used. Plumbers design in air chambers, or cushions, to prevent water hammer damage in a home plumbing system. Since fluid is incompressible but air is, the air absorbs the shock wave. Adding air cushions may not be possible in an industrial application. For these systems, a snubber or restrictor can be used. A snubber is often an adaptor screwed onto the pressure connection side of the pressure transducer. It evens out the rate of the fluid entering into the pressure transducer - inside is a porous disk or filter-like screen that disrupts a pressure wave but allows for normal fluid pressure measurements. A restrictor is a small orifice installed inside of the pressure side of the pressure transducer. This small hole does the same job as the snubber but eliminates the need for an adaptor.

Figure 1: A Standard Pressure Transducer (Left) and a Transducer with Installed Restrictor (right)

Neither method alters or prevents accurate pressure readings during normal operation – they are only employed to prevent short pressure spikes from damaging a pressure transducer. It is also important to realize that neither method prevents overpressure, a situation where a pressure transducer is subjected to sustained pressure above the transducer's rated proof pressure.

3. Symptoms of Water Hammer Damage

Water hammer can cause permanent damage to a pressure transducer. One symptom to look for is a "zero shift", a situation where there is a higher than normal output when the pressure transducer should be reading zero. This zero shift indicates that the diaphragm has been permanently damaged and cannot physically return to its starting position. Another symptom is no output, where the transducer no longer produces a readable output at any pressure input.

Often symptom damage can be traced back to a specific time or event, for example during a specific valve opening or closing. Evaluating both the transducer and where the transducer is located within the system is important to pinpointing and eliminating the root cause.

Water hammer is one of the most misunderstood phenomenons in fluid handling and can be very damaging to system components like a pressure transducer. Even though a pressure wave created by the sudden change in fluid momentum lasts for milliseconds, the pressure force generated can be very high. If not accounted for, water hammer can permanently damage a pressure transducer in a system.

About the Author:

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