

# Reducing Hydraulic System Noise

by Brendan Casey

Many industrialized countries have regulations restricting noise levels in the workplace. The high-power density and corresponding high noise emission of hydraulic components cause industrial hydraulic systems to be the target of efforts to reduce mean noise levels.

The pump is the dominant source of noise in hydraulic systems. It transmits structure-borne and fluid-borne noise into the system and radiates air-borne noise.

All positive-displacement hydraulic pumps have a specific number of pumping chambers, which operate in a continuous cycle of opening to be filled (inlet), closing to prevent back flow, opening to expel contents (outlet) and closing to prevent back flow. These separate but superimposed flows result in a pulsating delivery, resulting in a corresponding sequence of pressure pulsations. These pulsations create fluid-borne noise, which cause downstream components to vibrate. The pump also creates structure-borne noise by producing vibration in any component it is mechanically linked to, for example, the tank lid. The transfer of fluid- and structure-induced vibration to the adjacent air mass results in air-borne noise.

## Reducing Fluid-borne Noise

While fluid-borne noise caused by pressure pulsation can be minimized through hydraulic pump design, it cannot be completely eliminated. In large hydraulic systems or noise-sensitive applications, the propagation of fluid-borne noise can be reduced by the installation of a silencer. The simplest type of silencer is the reflection silencer, which eliminates sound waves by superimposing a second sound wave of the same amplitude and frequency at a 180-degree phase angle to the first.

## Reducing Structure-borne Noise

Structure-borne noise created by the vibrating mass of the power unit (the hydraulic pump and its prime mover) can be minimized through the elimination of sound bridges between the power unit and tank, and the power unit and valves. This is normally achieved with the use of flexible connections, such as rubber mounting blocks and hoses. However, it is necessary to introduce additional mass in certain situations, where the inertia reduces the transmission of vibration at bridging points.

## Reducing Air-borne Noise

The magnitude of noise radiating from an object is proportional to its area and inversely proportional to its mass. Reducing an object's surface area or increasing its mass can therefore reduce its noise radiation. For example, constructing the hydraulic reservoir from thicker plates, which increases its mass, will reduce its noise radiation.

Air-borne noise can be reduced by mounting the hydraulic pump inside the tank. For full effectiveness, a clearance of half a meter between the pump and the sides of tank is required. The mounting arrangement must also incorporate decoupling between the power unit and tank to insulate against structure-borne noise. The obvious disadvantage to this is the access for maintenance and adjustment is restricted.

### **Energy Storage in Hydraulic Fluid**

Another source of noise in hydraulic systems derives from the storage and subsequent release of energy in the hydraulic fluid. Hydraulic fluid is not perfectly rigid, and the compression of the fluid results in energy storage, similar to the potential energy stored in a compressed spring. Like a compressed spring, compressed fluid has the ability to perform beneficial work. If decompression is not controlled, the stored energy dissipates instantaneously. This sudden release of energy accelerates the fluid, which affects anything in its path. Uncontrolled decompression creates noise and stresses conductors, and can cause pressure transients that damage system components.

### **Bulk Modulus and Decompression**

The ratio of a fluid's decrease in volume as a result of a pressure increase is given by its bulk modulus of elasticity. The bulk modulus for hydrocarbon-based hydraulic fluids is approximately 250,000 PSI, (17,240 bar) which results in a volume change of around 0.4 percent per 1,000 PSI (70 bar).

As a general rule, when the change in volume exceeds 10 cubic inches (160 cubic centimeters), decompression must be controlled. Decompression control is essential in presses or other applications that have large volume cylinders operating at high pressures. Although hydrocarbon-based hydraulic fluids compress 0.4 to 0.5 percent by volume per 1,000 PSI, in an actual applications compression should be calculated at 1 percent per 1,000 PSI. This compensates for the elasticity of the cylinder and conductors and variations in the volume of air entrained in the fluid.

If, for example, the combined captive volume of the cylinder and conductors on a press were 10 gallons and operating pressure was 5,000 PSI, the volume of compressed fluid would be half a gallon ( $10 \times 0.01 \times 5 = 0.5$ ). This equates to a potential energy of around 33,000 watt-seconds. If the release of this amount of energy is not controlled, a big bang will be heard throughout the plant! Decompression is controlled by converting the potential energy of the compressed fluid into heat. This is achieved by metering the compressed volume of fluid across an orifice.

### **Water Hammer**

Storage and release of energy in the fluid also occurs during a phenomenon know as "water hammer." Water hammer is the term used to describe the effect that occurs when the velocity of the fluid moving through a pipe suddenly changes. This change causes a pressure wave to propagate within the pipe. Under certain conditions, it can create a banging noise, similar to the noise made when beating a pipe with a hammer, hence the term water hammer. Not

surprisingly, common symptoms of this problem are high noise levels, vibration and broken pipes.

When a moving column of fluid hits a solid boundary, for example when a directional control valve closes suddenly, its velocity drops to zero and the fluid column deforms within the confines of the rigid cross-sectional area of the pipe to absorb the (kinetic) energy associated with its motion. This is similar to a car hitting a concrete wall. However, unlike a car, the fluid is almost incompressible; therefore the deformation is small and energy accumulates in the fluid - similar to compression of a spring. The magnitude of the pressure rise that results from the subsequent release of this stored energy can be mathematically expressed as follows:

$$P_f = P + \rho u c$$

where P is initial pressure, u and  $\rho$  are initial fluid velocity and density respectively, and c is the speed of sound through the fluid.

When attempting to control this situation, accumulators are sometimes installed. Unfortunately, accumulators address only the symptoms. The significance of the pressure rise equation shown above indicates that fluid velocity is the only variable that can be altered when addressing the root cause of this problem. In other words, reducing the velocity of the fluid column that hits the solid boundary reduces the magnitude of stored energy and the subsequent noise and pressure rise caused by its release. Returning to the traffic crash analogy - the slower the car is traveling upon hitting the wall, the less damage that occurs. In hydraulics, the most efficient way to do this, on paper at least, is to increase the diameter of the pipe, which reduces fluid velocity for a given flow rate. The alternative is to control deceleration of the fluid column by choking the valve switching time to the point where the pump's pressure compensator and/or system relief valve reacts fast enough to reduce flow rate through the pipe and therefore the velocity of the fluid column.

To get the knowledge you need to understand and effectively troubleshoot hydraulic equipment, visit Brendan Casey's Web site: [www.IndustrialHydraulicControl.com](http://www.IndustrialHydraulicControl.com)

**About the Author:**

Brendan Casey has more than 17 years experience in the maintenance, repair and overhaul of mobile and industrial hydraulic equipment. For more information on reducing the operating cost and increasing the uptime of your hydraulic equipment, visit his Web site: [www.InsiderSecretsToHydraulics.com](http://www.InsiderSecretsToHydraulics.com)