Pump Noise

Noise is sound that people find undesirable. For example, prolonged exposure to loud noise can result in loss of hearing. In addition, noise can mask sounds that people want to hear, such as voice communication between people and warning signals coming from safety equipment.

The sounds that people hear come as pressure waves through the surrounding air medium.The pressure waves, which possess an amplitude and frequency, are generated by a vibrating object such as a pump, hydraulic motor, or pipeline. The human ear receives the sound waves and converts them into electrical signals that are transmitted to the brain. The brain translates these electrical signals into the sensation of sound

Sound Intensity Levels (dB)

The strength of a sound wave is described by its intensity. Intensity is defined as the rate at which sound energy is transmitted through a unit area. Note that this is the definition of power per unit area. As such, intensity is typically represented in units of W/m^2. However, it is general practice to express this energy-transfer rate in units of decibels (dB). Decibels give the relative magnitudes of two intensities by comparing the one under consideration to the intensity of a sound at the threshold of hearing (the weakest intensity that the human ear can hear). One bel (10 B 1 dB) represents a very large change in sound intensity. Thus, it has become standard practice to express sound intensity in units of decibels.

Note that intensity and loudness are not the same, because loudness depends on each person’s sense of hearing. The loudness of a sound may differ for two people sitting next to each other and listening to the same sound. However, the intensity of a sound, which represents the amount of energy possessed by the sound, can be measured and thus does not depend on the person hearing it.

One decibel equals approximately the smallest change in intensity that can be detected by most people. The weakest sound intensity that the human ear can hear is designated as 0 dB. In contrast, sound intensities of 120 dB or greater produce pain and may cause permanent loss of hearing.

Table: Common sound levels (dB).

	140	JET TAKEOFF AT CLOSE RANGE
	130	HYDRAULIC PRESS
THRESHOLD OF PAIN	120	NEARBY RIVETER
DEAFENING	110	AMPLIFIED ROCK BAND
	100	NOISY CITY TRAFFIC
VERY LOUD	90	NOISY FACTORY, GEAR PUMP
	80	VACUUM CLEANER, VANE PUMP
LOUD	70	NOISY OFFICE, PISTON PUMP
	60	AVERAGE FACTORY, SCREW PUMP
MODERATE	50	AVERAGE OFFICE
	40	PRIVATE OFFICE
FAINT	30	QUIET CONVERSATION
	20	RUSTLE OF LEAVES
VERY FAINT	10	WHISPER
	0	THRESHOLD OF HEARING

Control of Noise Levels

Controlling noise levels is critically important in terms of preventing human accidents due to noise masking as well as protecting against permanent loss of hearing.

Masking describes the ability of one sound to make the human ear incapable of hearing a second one, such as a safety threatening signal. In general, noise reduction can be accomplished as follows:

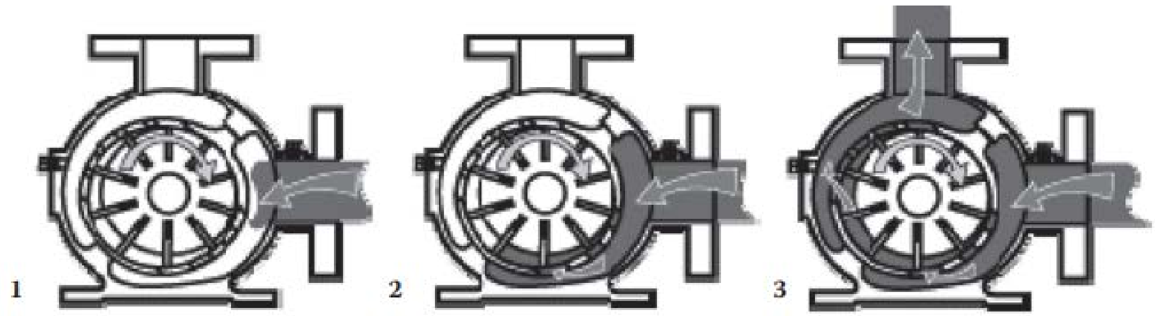
1. Make changes to the source of the noise, such as a noisy pump. Problems here include misaligned pump/motor couplings, improperly installed pump/motor mounting plates, pump cavitation and excess pump speed or pressure.
2. Modify components connected to the primary source of the noise. An example is the clamping of hydraulic piping at specifically located supports.
3. Use sound-absorption materials in nearby screens or partitions.This practice will reduce the reflection of sound waves to other areas of the building where noise can be a problem.

Fluid Power Components “noise wise”

Fluid power systems range in size from vehicle steering systems, which are very compact and relatively low power with a pressure typically up to 80 bar, to systems for industrial and off-road machinery with much larger size, power up to hundreds of kW, and pressures up to 300 bar. The primary components in the system are a pump, control valves, fluid reservoir, pipes, and the motor or actuator driving the load. Some of the main noise and vibration excitation components are described below.

Pumps

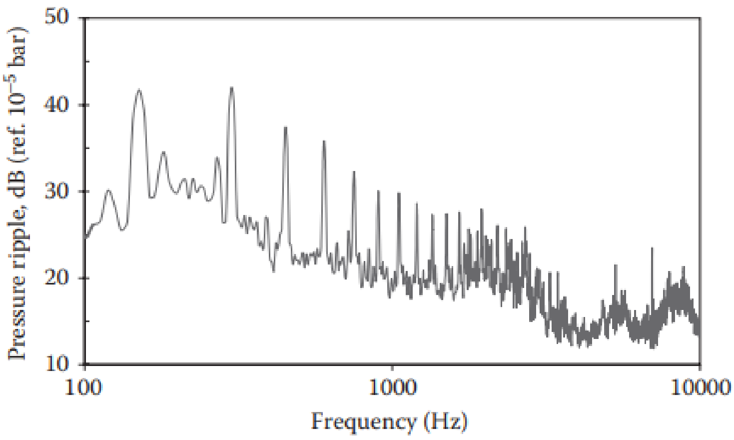
Pumps are, in most cases, the main source of noise and vibration, due to the non-steady, cyclic nature of producing high-pressure fluid at the outlet. Pumps generally produce periodic and repeatable noise. Hydraulic motors may also produce noise in a similar way. Different types of pump are used in hydraulic systems, such as piston pump, vane pump, external gear pump, internal gear pump and lobe pump. Next Figure shows a typical vane pump, such as might be used in a vehicle steering system.



Typical pumps for vehicle steering system. (1) suction, (2) compression, and (3) discharge.

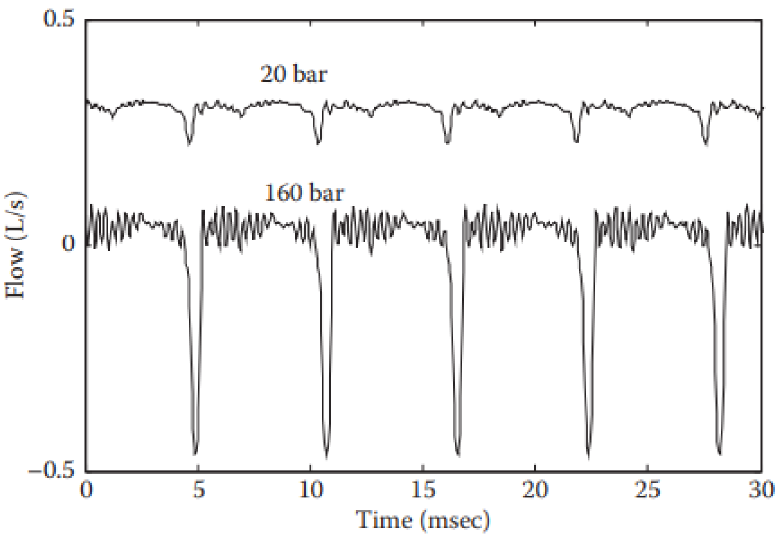
The noise generation can be fluid-borne noise (which is known as “pressure ripple”) or structure-borne noise. Positive displacement pumps tend not to produce an absolutely steady flow rate. Instead, the flow consists of a mean value on which is superimposed a flow ripple. The magnitude of the flow ripple is dependent upon the pump type and operating conditions, but usually has peak-to-peak amplitude of between 1% and 10% of the mean flow rate. Different classes of pump have different characteristic flow ripple waveforms. This flow ripple interacts with the characteristics of the connected circuit to produce a pressure ripple.

Next Figure shows measured pressure ripple from a vane pump with 10 vanes at 900 RPM. The main component occurs at a frequency $f = RPM \times \text{No. of blades}/(60) = 150$ Hz, and harmonics are produced at multiples of this. The noise generated at this low rotational speed is often called "moan" noise, and at a higher rotational speed of about 3000 RPM the noise is referred to as "whine" noise. There are methods available for measuring pump and motor flow ripple and fluid-borne noise characteristics. In these methods the flow ripple is determined indirectly from pressure ripple measurements.



Typical pressure ripple spectrum at low rotational speed of 900 RPM (MOAN noise).

Some examples of measured flow ripple for an axial piston pump are shown Figure. The pump's flow ripple produces a pressure ripple which is then transmitted throughout the circuit in a complex manner at the speed of sound in the fluid. The pump and its driving motor are also mechanical sources of noise and vibration due to force and moment generation. The excitation energies in hydraulic systems are mainly due to pressure ripple which is generated by the pump.



Flow ripple from an axial piston pump

Pump Noise as a Performance Parameter

Noise is a significant parameter used to determine the performance of a pump. Any increase in the noise level normally indicates increased wear and imminent pump failure. Pumps are good generators but poor radiators of noise. As such, pumps are one of the main contributors to noise in a fluid power system. However, the noise we hear is not just the sound coming directly from the pump. It includes the vibration and fluid pulsations produced by the pump as well. Pumps are compact and because of their relatively small size, they are poor radiators of noise, especially at lower frequencies. Reservoirs, electric motors and piping, being large, are better radiators.

Therefore, pump-induced vibrations or pulsations can cause them to radiate audible noise greater than that coming from the pump. In general, fixed displacement pumps are less noisy than variable displacement units because they have a more rigid construction.

As illustrated in the next Figure, pump speed has a strong effect on noise, whereas pressure and pump size have about equal but smaller effects. Since these three factors determine horsepower, they provide a trade-off for noise. To achieve the lowest noise levels, use the lowest practical speed (1000 or 2000 rpm where electric motors are used, a reducer gear for engine prime movers) and select the most advantageous combination of size and pressure to provide the needed horsepower.

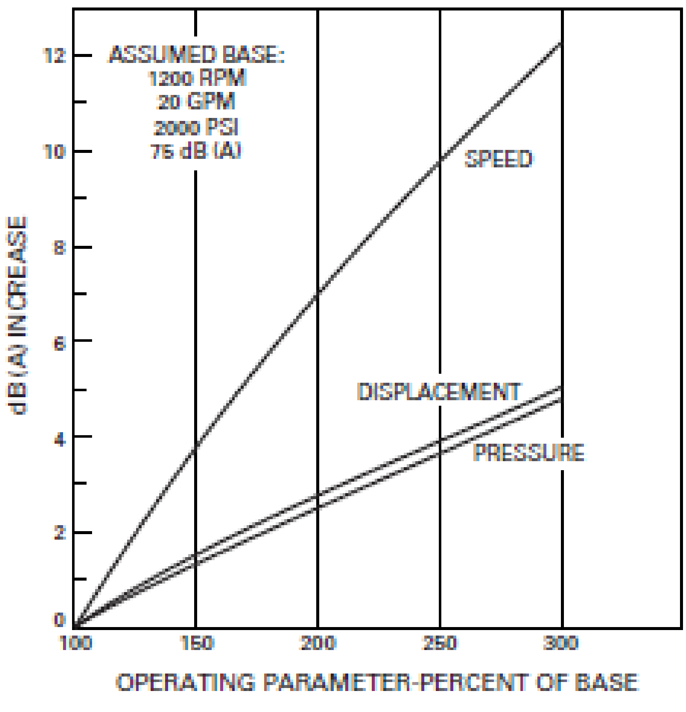


Figure . Data showing effect of changing size, pressure, and speed on noise. *(Courtesy of Sperry Vickers, Sperry Rand Corp., Troy, Michigan.)*

Pump Cavitation

Still another noise problem, called pump cavitation, can occur due to entrained air bubbles in the hydraulic fluid or vaporization of the hydraulic fluid. This occurs when pump suction lift is excessive and the pump inlet pressure falls below the vapor pressure of the fluid (usually about 5 psi suction). As a result, air or vapor bubbles, which form in the low-pressure inlet region of the pump, are collapsed when they reach the high-pressure discharge region. This produces high fluid velocity and impact forces, which can erode the metallic components and shorten pump life.

The following rules will control or eliminate cavitation of a pump by keeping the suction pressure above the saturation pressure of the fluid:

1. Keep suction line velocities below 4 ft/s (1.2 m/s).
2. Keep pump inlet lines as short as possible.
3. Minimize the number of fittings in the inlet line.
4. Mount the pump as close as possible to the reservoir.
5. Use low-pressure drop inlet filters or strainers. Use indicating-type filters and strainers so that they can be replaced at proper intervals as they become dirty.
6. Use the proper oil as recommended by the pump manufacturer. The importance of temperature control lies in the fact that increased temperatures tend to accelerate the liberation of air or vapor bubbles. Therefore, operating oil temperatures should be kept in the range of 120°F to 150°F (50°C to 65°C) to provide an optimum viscosity range and maximum resistance to liberation of air or vapor bubbles to reduce the possibility of cavitation.

Pump noise is created as the internal rotating components abruptly increase the fluid pressure from inlet to outlet. The abruptness of the pressure increases plays a big role in the intensity of the pump noise. Thus, the noise level at which a pump operates depends greatly on the design of the pump. Gear and vane pumps generate a much higher noise level than do screw pumps. Next Figure provides the approximate noise levels associated with various pump designs.

PUMP DESIGN	NOISE LEVEL (dB-A)
GEAR	80–100
VANE	65–85
PISTON	60–80
SCREW	50–70

Figure . Noise levels for various pump designs.

Hydraulic power units such as pumps and motors can operate at noise levels exceeding the limits established by OSHA (Occupational Safety and Health Administration). New standards for indoor systems require that pumps and motors operate at reduced noise levels without reducing power or efficiency. Fluid power manufacturers are offering power units that produce lower noise levels. In addition, noise-reduction methods such as modifying hydraulic hose designs, adding sound filters, baffles or coatings and providing equipment vibration-absorbing mounts are being developed.

Meeting stricter environmental requirements represents a challenge to which the fluid power industry is responding. These environmental issues make careers in the fluid power industry both challenging and exciting.

Noise and Vibration of Fluid Power Systems

A fluid power system can transmit high levels of power with high-power density and can deliver high force and torque with a good dynamic response, while providing more flexibility than a mechanical drive. However, the operation of the fluid power system components generates noise and vibration which may exceed the legislation requirements. Health, safety, and human comfort requirements with respect to noise and vibration levels have become increasingly demanding.

Fundamental of Noise and Vibration Control

Noise is a pressure wave caused by the vibration of fluid particles, and propagates in the medium at the speed of sound. Humans can generally perceive noise in the range of 20 Hz to 20 kHz, with acoustic pressure from the threshold of hearing, which is about 20μPa, to the pain threshold, which is around 20 Pa. The human ear's sensitivity to noise is not linear in frequency, but is often considered to follow the weighting scale and measurements are commonly expressed either in an unweighted dB scale or a weighted dBA scale.

What is difference between dB and dBA?

The dB scale is used to measure sound level. However, because the human ear does not respond equally to all frequencies, we often use dBA as a scale of measurement.

The three main sound parameters are:

1. Sound Pressure Level (SPL)
2. Sound Intensity Level (SIL)
3. Sound Power Level (SWL)

SPL and SIL depend on the distance between the sound source and the measurement point, and on the environment; whereas SWL is independent of any parameter except the source characteristics. Therefore SWL is a good parameter for source noise specification. Noise and vibration control can be carried out at the source (which is the most effective means achieving a solution), at the transmission path or at the receiver.

Different mechanisms can be used for noise and vibration control such as:

- Acoustic energy absorption or vibration damping
- Noise isolation and attenuation
- Vibration transmission isolation by flexible mounting
- Noise and vibration resonance reduction

Instrumentation and Sensors for Noise and Vibration

Systems for measurement of noise and vibration consist of a sensor, signal conditioning and signal analyzer. The most robust and reliable sensor for the measurement of vibration is the piezoelectric accelerometer. Accelerometers have a frequency response function from a fraction of 1Hz (depending on the signal conditioning) to about 15 kHz, and weigh from a fraction of a gram up to a few hundred grams. Next Figure shows a wide range of accelerometers. The most common noise sensor is an instrumentation microphone which can vary in diameter (1", 1/2", 1/4" or 1/8") and have a frequency range up to 100 kHz.

These microphones are designed to be omni-directional (sensitivity independent of direction) especially if the microphone diameter is much less than the wavelength.

Range of accelerometers.

Sound level meters are classified by their precision as Type I (high precision), and Type II and Type III (less precision). Usually Type I is used for good quality measurements. Sound Pressure Level (SPL) can be measured by a sound level meter (left Figure) whereas Sound Intensity Level (SIL) can be measured by a sound intensity probe (right Figure) which consists of two closely spaced, matched microphones with a two-channel analyzer.

A typical sound level meter

intensity probe

Sound Power Level (SWL) can be measured using a sound level meter in a special acoustic room such as reverberation room or anechoic room or by using a sound intensity meter without the need for a special acoustic room. For the measurement of pressure ripple or fluid-borne noise, a dynamic pressure sensor needs to be immersed in the fluid in order to measure the dynamic variation of the pressure inside the fluid. Generally speaking, miniature piezoelectric transducers are most effective because they have a small sensor area and a very high-frequency response (typically 10 kHz or more). Typical piezoelectric pressure transducers are shown in the next Figure.

Dynamic pressure transducers.(Courtesy of PCB Piezotronics Inc.)

Piezoelectric pressure transducers only detect pressure changes; they cannot normally be used for steady-state pressure measurement and the transducer and charge amplifier normally have a lower-frequency limit of about 1 Hz. The signal from an accelerometer, microphone or pressure transducer passes through signal conditioning, which is often integrated into the sensor. It is then fed to the frequency analyzer to capture and analyze the measured signal. A calibrator is needed to calibrate the measurement system.

Typical frequency analyzers.