Specifying accumulators

LUBE OIL TRIPS CAN BE AVOIDED BY SIZING THESE PRESSURE CONTROL DEVICES

JOE CHEEMA
FLUID ENERGY CONTROLS, INC.

Loss of lubricant flow is a significant cause of lube oil system failures, leading to excessive wear and premature replacement of bearings. Accumulators can often prevent such failures by providing a temporary supply of lube oil in the event of flow disruptions. This article discusses accumulator types and standards, and their selection.

Function of accumulators

Hydraulic accumulators are energy storage devices that smooth the pulsation of oil pumps and provide short-term oil pressure during switchover between oil pumps. Accumulators help maintain a constant oil pressure during temporary changes of demand.

Lube oil systems for turbomachinery consist of three elements: a high flow-rate pump, a reservoir and an accumulator. Lube Oil System Accumulators (LOSA) prevent bearing damage and increase bearing life by supplying oil to the bearings when a power failure shuts down the pump, or when changing between the primary and backup oil pump.

An accumulator is essentially a pressure vessel that stores oil, and contains a mechanical means of maintaining pressure when the pump shuts down, thus cushioning fluctuations in oils pressure. Accumulators differ on the type of mechanical means used, such as spring, gravity and gas load.

Spring accumulators use a spring-loaded position in a cylinder. As the oil line pressure increases, more oil flows into the cylinder and compresses the spring, with the spring pressure matching the hydraulic pressure. Then, when the pressure drops, the spring forces the oil back out of the cylinder into the system.

Spring-loaded accumulators have three primary shortcomings. As the spring expands, the pressure gradually drops, rather than providing a constant pressure. These types of accumulators have moving parts that wear and need replacement. In addition, repeated compression and expansion of the spring fatigues the metal and reduces the amount of pressure the spring can provide. This limits their usefulness in high-cycle applications, as the metal will quickly fatigue and lose its elasticity.

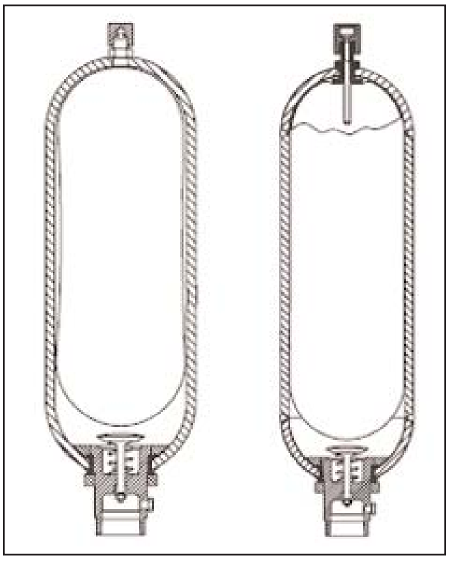

Figure: Bladder-type accumulators separate the working fluid from the lube oil

Gravity-loaded accumulators are similar to spring accumulators but, instead of using a spring, they use weights to drive the piston and provide the desired pressure. The advantage of this design is that it supplies a near constant pressure. It is, however, larger, heavier and more costly than other types of accumulators. In addition, it has moving parts that require maintenance. If the packing on the piston wears and develops a leak, the oil will gradually migrate to the top of the piston, adding to its weight and reducing the effective amount of oil in the accumulator.

Gas-loaded accumulators use compressed gas to provide pressure. These divide into two main categories: separator and non-separator accumulators. Non-separator accumulators do not have any barrier between the gas and the liquid. This is the simplest design and can store the greatest amount of oil.

However, its drawbacks make it unsuitable for use as a LOSA. Since there is no barrier separating the gas from the oil, the gas may become absorbed by the fluid, particularly at high pressures. Then, as the pressure drops, the absorbed gas forms bubbles in the oils, causing sponginess in the system and may damage the pump through cavitation.

The better approach, therefore, is to use a barrier between the gas and the fluid. For LOSA applications, the use of rubber bladders have proven to be useful.

A bladder-type LOSA (Figure) consists of a metal cylinder containing a pressurized bladder. These are designed in accordance with American Petroleum Institute (API) Standard 614/ISO 10438, which covers lubrication systems, and ASME Pressure Vessel and Boiler Code, Section VIII, DIV. 1.

In accordance with the standards, these accumulator vessels are made of 300 series stainless steel and can withstand maximum pressures of 1,020 psi, depending on the model selected. Inside is a bladder made of nitrile compound (BUNA-N). Because of its high flexibility and low weight, the bladder has a rapid response time, allowing the LOSA to quickly compensate for pressure drops in the system. Thus, the LOSA can maintain the desired pressure and flow of the lubricating oil and prevent damage to the bearings and other components.

If the working pressure is below 500 psi, a screen can be welded inside the flange to keep the bladder from extruding through the fluid port. At higher pressures, the bladder may extrude through the screen, so a plug and poppet assembly is used. As the pressure drops, the bladder pushes against the poppet and closes the fuel port, keeping the bladder inside the vessel.

Bladder-type LOSAs are installed vertically with a gas valve molded onto the top of the bladder, and a fluid port at bottom of the vessel. The bladder is precharged to 70% - 80% of the minimum working pressure of the system, and this pressure must be periodically verified. Typically nitrogen is used because the gas is stable and non-reactive even under pressure. Air is not a good choice because of its corrosive properties and risk of explosion under high pressure.

Following physics laws

By properly sizing and maintaining the LOSA, turbomachinery operators can avoid expensive and catastrophic damage, or even just excessive wear. Given the number of things that can potentially go wrong, whether through component or human failure, LOSAs are an easy means of gaining a little margin of safety.

Selecting the right size of LOSA and the correct pre-charge pressure requires an understanding of the underlying principles. Bladder accumulators operate based on Boyle's law, which states that the product of the pressure (P) and volume (V) of a fixed quantity of gas is a constant (C), assuming the temperature remains constant (PV=C). In simple terms, if you double the pressure, you halve the volume. Since the expansion and contraction of the bladder take place in under a minute, there is no transfer of heat into or out of the gas as the pressure changes. As a result, the formula for a nitrogen-charged bladder becomes $P_1V_1^{1.4}=P_2V_2^{1.4}$.

Applying this data to the sizing and operation of a LOSA, one gets the following:

V_1 = Size of the LOSA required in cubic inches. This is the maximum volume of gas in the accumulator bladder at the pre-charge pressure P_1.

V_X = The volume of lube oil to be discharged from the accumulator in cubic inches. This is the volume of lube oil demanded by the system. V_X is a function of the lube oil system for a particular type of turbomachinery and can be obtained from the manufacturer's specifications.

P_1 = Pre-charge gas pressure of the accumulator in psia. This pressure is always less than the minimum system pressure P_3.

P_2 = Maximum system design operating pressure in psia.

V_2 = The compressed volume of gas at maximum system pressure P_2 psia.

P_3 = The minimum system pressure at which the additional volume V_3 of lube oil is required.

V_3 = The expanded volume of gas at minimum pressure P_3 in cubic inches.

Calculating volumes

Let us assume that the gas turbine lube oil system requires a flow rate of 15 gpm at 100 psig system pressure and a maximum operating pressure of 115 psig. If the main oil pump shuts down, system pressure must be maintained within 10% of the system pressure for 15 seconds while the stand-by pump accelerates from an idle condition to operating speed.

In this case, the volume of fluid needed by the accumulator is:

V_x = (15 gpm / 60 seconds) x 15 seconds x 231 (cubic inches per gallons) = 866.25 cu. in.

Minimum system pressure (within 10% of the system pressure) P_3 = (100 x 0.90) + 14.7 = 104.7 psia.

Maximum operating pressure P_2 = 115 + 14.7 = 129.7 psia.

Polytropic constant n for nitrogen = 1.4.

Assuming a rule of thumb that the pre-charge pressure of the accumulator is 70% of minimum system pressure, P_1 = 73.29 psia.

By inserting the above values into the formula below, the size of the accumulator required V_1 can be calculated.

$V_1 = (V_x \text{ X } (P_3/P_1)^{1/n})/(1 - (P_3/P_2)^{1/n})$

This formula yields a volume of 7,878.28 cubic inches or 34.11 gallons.

Of course there will not be any accumulators made in that exact size. Usually the next larger size is selected, not the next smaller one. There is no harm in being able to provide lubricating oil for a little bit longer than needed, but there is a risk of damage if the undersized accumulator runs out of oil too soon.

Authors:

Joe Cheema is a senior project engineer for accumulator manufacturer Fluid Energy Controls Inc. in Los, Angeles, CA. For more information call 323-721-0588 ext 3267 (email: jc@fecintl.com) or visit www.fecintl.com.