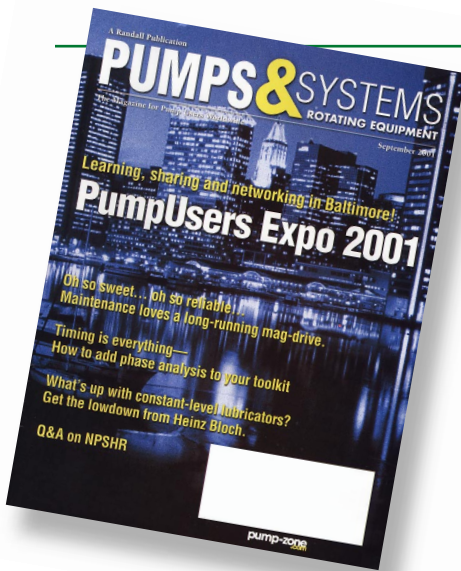


Bearing Protection Devices and Equipment Reliability: Part I – Constant-Level Lubricators

By Heinz P. Bloch, P.E, Consulting Engineer, Process Machinery Consulting



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To this day, important lubricant-application and bearing-protection issues are overlooked or misunderstood in the typical process-plant environment. Solid explanations are not widely disseminated and industry sacrifices potential equipment reliability

For decades, constant-level lubricators have been the standard lubricant-supply system for huge numbers of bearing housings. They have been used on millions of centrifugal pumps, gear units, and electric motors with oil-lubricated bearings. However, certain types of constant-level lubricating devices require an understanding of how they function, and can be misapplied. When lubricators are misapplied, bearings could be deprived of lubrication and may fail.

More recently developed rotating labyrinth seals (commonly called “bearing protectors” and “bearing isolators”) can now be found in many OEM and retrofit applications. They are an improvement over the old stationary labyrinth, but they come in different versions, and some may not perform as expected.

There are pressure-relief poppet valves being marketed for the bearing housings of centrifugal pumps and other machinery. It can be shown that they are rarely, if ever, of any merit.

Finally, a new generation of on-line moisture monitoring devices and desiccant-containing absorber cans are now offered by competent manufacturers. They are intended for mounting at the top of the vapor space of pump bearing housings but are not always cost-justified.

Part I of this article examines when and why some constant-level lubricators are

often involved in equipment failures. Part II will cover:

- Why some bearing-housing seals, or bearing protectors/isolators may not fulfill their intended function,
- When bearing housing pressure-relief poppets serve no useful purpose, and
- Where it makes economic sense to apply on-line moisture monitoring and/or moisture reduction devices.

Understanding Different Constant-Level Lubricators

As the name implies, constant-level lubricators are designed to supply lubricant, as needed, to maintain a constant level within the bearing housing (see sidebar, “The Basics”). The design relies on simple physics, and the regulated flow from filler bottle to bearing is quite reliable. Problems can arise, however, when reverse flow *to* the lubricator occurs.

To begin with, the user community needs to be aware of the two distinctly different types of constant-level oil lubricators in use on the majority of small machines. The most widely used “open-to-atmosphere” (OTA) type is shown in Figure 1. It does not incorporate a balance line connection to the bearing housing and, if used on bearing housings with restricted venting provisions, may not adequately protect against catastrophic bearing failure.

On the OTA-type shown here, the desired oil level is determined by the height setting of a wing nut, threaded into a centrally located rod. The oil level at “x” is open to the atmosphere so higher-than-atmospheric pressures in the bearing housing will cause level “x” to rise, often

Pressure to improve: the risk of failure outweighs any disadvantages.

to the point of overflowing (although the risk of an overflow condition can be minimized with extended-height surge chambers).

This phenomenon is easily explained by two phenomena. First, any increase in housing pressure (Δp) will be equilibrated in the lubricator (as per the static-fluid form of the Bernoulli equation). Some lubricant will be forced up into the filler bottle, to compress the space at the top. Oil also will be forced up into the OTA surge chamber, until the liquid head there is sufficient to balance Δp . Secondly, oil is essentially incompressible, and the entire *volume* of lubricant displaced from the bearing housing must go somewhere. Even a fractional psi pressure increase, pushing the large-area lubricant surface in the bearing housing down by only a small distance (Δx) would force the fluid a much larger distance (ΔX) up into the narrow surge chamber. Which of these processes predominate will vary with system geometry but without a properly sized surge volume, the rising fluid could overflow the rim (or reach an air-vent passage present in some models) and be lost from the system.

Figure 2 shows a different constant-level lubricator. An internal O-ring or similar sealing means, prevents the ambient

atmosphere from reaching the oil level at “x.” This closed-loop, pressure-equalized lubricator (PEL) incorporates a balance tube, or pressure-equalizing line to prevent pressure differentials between the bearing housing and the lubricator.

What Makes Housing Pressures Rise?

Note that the location of the wing nut in Figure 1 or slanted tube in Figure 2, determines the oil level in the bearing housing. Either the bottle height in Fig. 1, or the bottle-and-tube height in Fig. 2, is usually set with the machine not operating. At that time, temperature equilibrium exists, i.e. the machine components, lubricating oil and surrounding environment are probably all at or near the same temperature.

Most bearing-housing vents, and especially small vents, offer a restriction that might allow a small amount of pressure build-up in bearing housings. It is also reasonable to expect that some oil will get flung into the close-clearance region, typically fitted with lip seals or labyrinth seals, where the shaft penetrates the bearing housing. The oil has film strength, which makes it cling to surfaces. This oil now tends to bridge the gap between the rotating shaft and the surrounding stationary components.

In that event, the trapped air above the oil level will constitute a *closed* volume.

As this volume of air is warmed by sun exposure or by frictional heat generated in the bearings, its pressure will increase in accordance with the perfect gas law:

$$(P_2) = (P_1)(T_2/T_1)$$

Using Rankine (absolute) temperatures and absolute pressures, it is easy to see how relatively minor temperature increases may cause pressures to rise by amounts that cannot be ignored.

Granted, as pressures go up beyond the rupture strength of oil

films, the sealing oil film will be temporarily interrupted. The bearing housing seal will “burp,” or open up for a fraction of a second. Nonetheless, rising bearing-housing pressure may lead to one of two undesirable events:

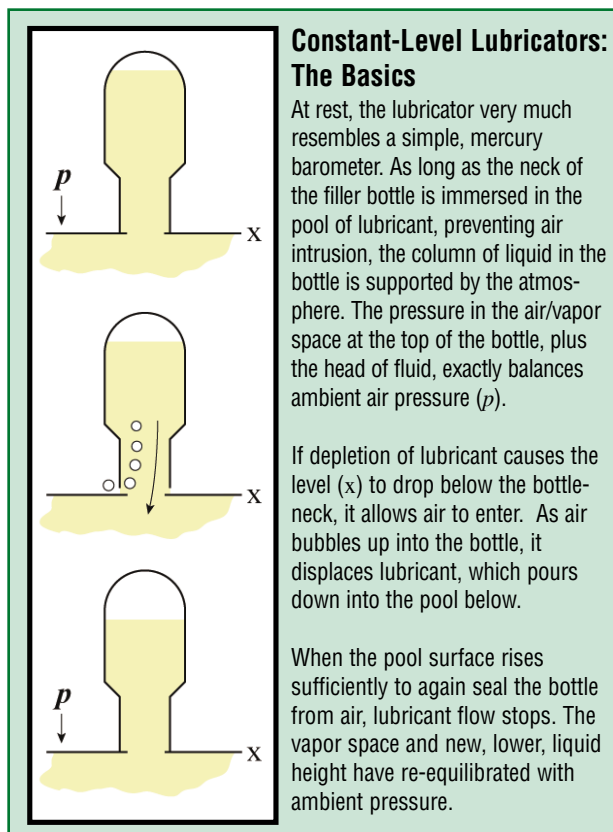
- During a pressure rise, the oil level will go down in the bearing housing and will rise in the lower surge chamber supporting the lubricator bottle (Bernoulli’s law). If the housing level drops sufficiently, the bottom of the bearing may be deprived of oil, or slinger ring immersion may no longer be sufficient for satisfactory lubrication.
- If oil overflows the surge chamber during a pressure rise, it is lost from the system, while the pressure in the lubricator adjusts to the new housing pressure. Oil from the bottle refills the housing when the system re-equilibrates with each “burp.” As the cycle repeats itself, more and more oil will be lost.

These problems are caused by system features that allow for pressure differentials between the housing interior and the environment. There is evidence that installing bearing isolators and other narrow-gap housing closures increases the likelihood of potential problems with lubricators that had served perfectly well as long as not-so-close fitting labyrinth seals were being used.

Fortunately, the pressure-balanced constant-level lubricator in Figure 2 does not introduce the same risk. As mentioned earlier, the oil levels “x” at locations inside the bearing housing and inside the lubricator are always exposed to identical pressures. The problem is solved, and another step towards increased equipment reliability has been implemented.

Only PELs and *not* OTA-type lubricators should be used in reliability-minded plants. By providing a piping connection between the lubricator and bearing housing, lubricator port “x” and the bearing housing operate at the same pressure and the risk of oil leakage or unintended lowering of oil levels due to pressure buildup in bearing housings is eliminated. This approach provides protection from airborne contaminants, as well.

Disadvantages? The pressure-balanced constant-level lubricator probably costs a few pennies more, but the resulting



reduction in the risk of failure far outweighs any disadvantages, both perceived and real. ■

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Editor's Note: This excerpt is adapted from "Constant Level Lubricators and

Other Bearing Protection Devices: Smart Retrofits will Improve Equipment Reliability," by Heinz P. Bloch, P.E.

Part II will explore the use of other bearing-protection devices, including bearing protectors, pressure-relief poppets, moisture monitoring devices and lubricant desiccants.

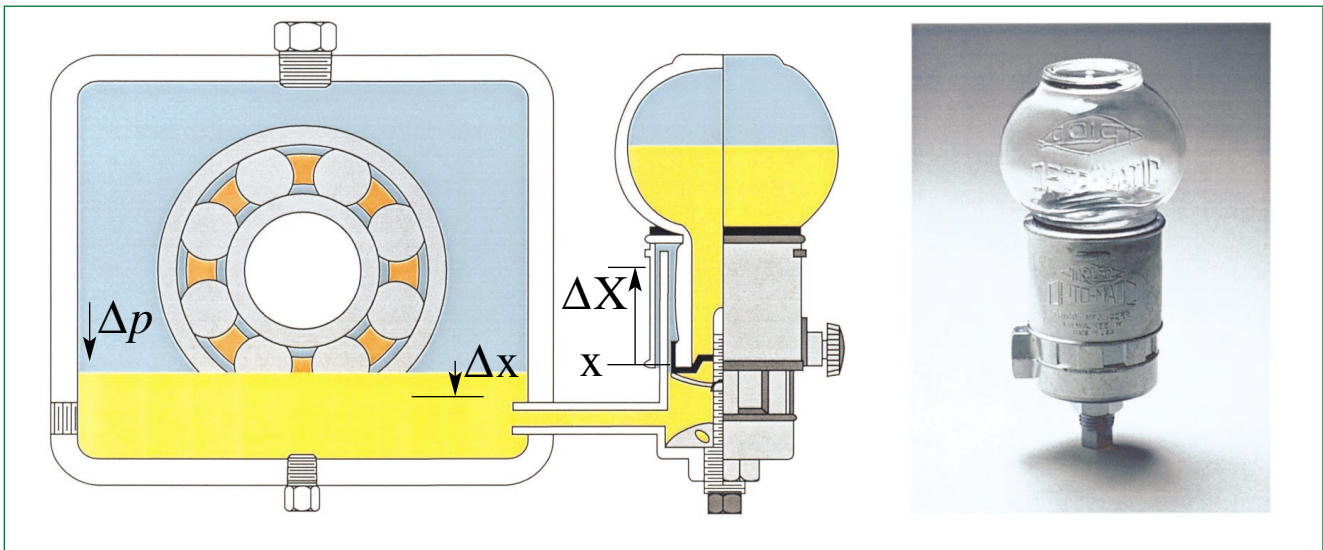


Figure 1. Unbalanced constant level lubricator (Adapted from: Trico Mfg. Corp., Pewaukee, WI; www.tricomfg.com)

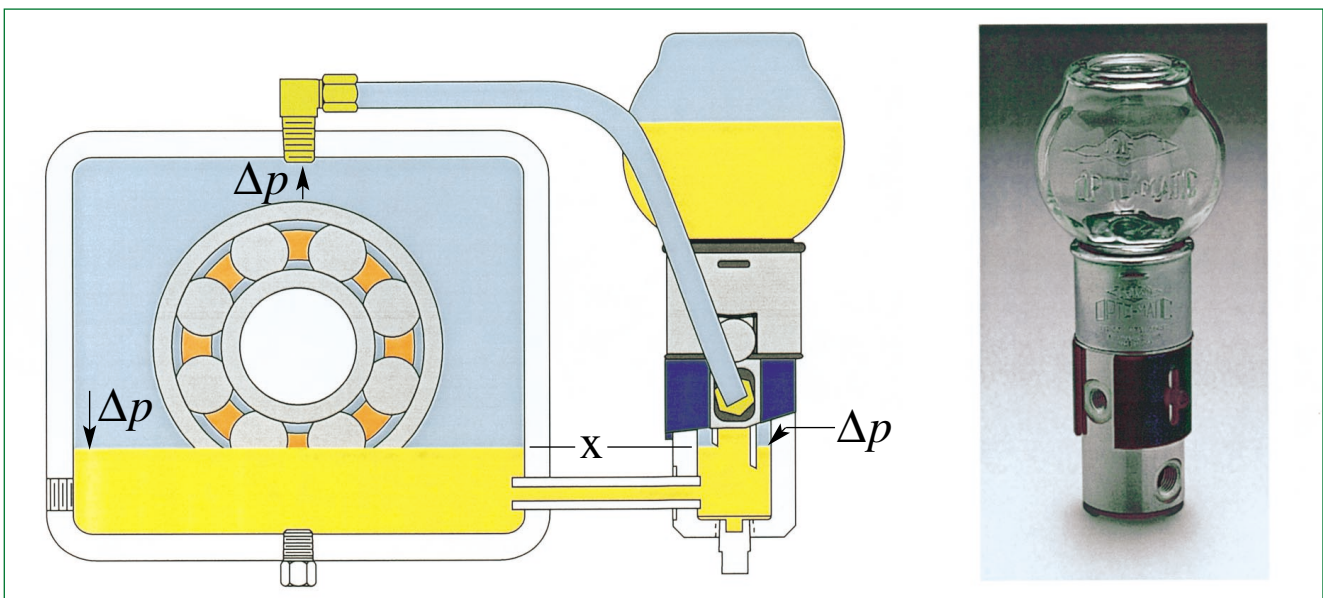


Figure 2. Balanced constant level lubricator (Adapted from: Trico Mfg. Corp., Pewaukee, WI; www.tricomfg.com)

Bearing Protection Devices and Equipment Reliability: Part II – What is Really Justified?

By Heinz P. Bloch, P.E, Consulting Engineer, Process Machinery Consulting



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Rotating labyrinth seals (commonly called “bearing protectors” and “bearing isolators”) can be found in many OEM and retrofit applications. Bearing isolators are an improvement over the older stationary labyrinths. They come in different versions, however, and some may not perform as expected.

Pressure-relief poppet valves are marketed for the bearing housings of centrifugal pumps and other machinery. It can be shown that they are rarely, if ever, of any merit.

Finally, a new generation of on-line moisture-monitoring devices and desiccant-containing absorber cans are offered by competent manufacturers. They are intended for mounting at the top of the vapor space of pump bearing housings but are not always cost-justified.

Rotating-Labyrinth Bearing-Housing Seals

It has long been recognized that as many as 91% of all the rolling element bearings installed in the world's machinery fall short of reaching the manufacturer's calculated L-10 life. L-10 is defined as the number of operating hours at which 10% of an identical bearing population will either have failed, or will exhibit visible or measurable damage. Simple subtraction reveals that 90% of bearings *should* be expected to *survive* to L-10 life. Research and follow-up analysis have established lubricant contamination as the predominant cause of failure.

Much airborne contamination finds its way into bearing housings through openings where shafts protrude through

bearing housings, or at vents and breathers on the lubricated assembly. Bearing housings undergo temperature shifts between day and night, and in operating/idle cycles. With increasing temperatures, the vapors above the liquid oil will expand and, with decreasing temperatures, they will contract. In a closed volume, increasing temperatures cause pressures to go up, while decreasing temperatures cause pressures to decrease.

In an effort to reduce the pressure-related, in-and-out flow of contaminated air, conventional labyrinths are often replaced by rotating-labyrinth seals (which we will describe as protector/isolators, for short). A typical version is shown in Fig. 3). These devices are designed with inherent clearances, so an air gap separates the rotating and stationary elements. Except when the clearance is bridged by an oil film, this gap is large enough to allow the exchange of air with its ever-present contaminants, water vapor and airborne dust.

It has been pointed out that bearing protector/isolators work best when the housing vent is plugged. To quote one prominent manufacturer (Ref.1):

“If the housing vent is left open, the slight vacuum created by the contaminant expulsion elements will induce the flow of airborne dust, dirt, vapors and everything available in the immediate environment through the bearing enclosure not unlike an oil-bath vacuum cleaner. This action is constant and the amount of induced debris build-up can be significant.”

An ounce of prevention is worth a pound of cure.

“To this day, some important lubricant-application and bearing-protection issues are overlooked or misunderstood in the typical process-plant environment.” In Part I of this series concerning those issues, the author compared the types of available constant-level lubricators, and found the pressure-equalized (PEL) designs superior to those that were “open-to-atmosphere” (OTA). In this conclusion, the noted lubrication expert reviews various contamination-prevention and pressure-relief alternatives, with focus on cost and reliability-based justifications.

Bearing isolators fitted with dynamic O-rings (Fig. 4) try to close the gap through which airborne contaminants can enter the bearing housing. The expectation is for the O-ring to effectively seal off the gap at standstill (Ref. 2). The designer/manufacturer hopes that centrifugal force, acting on the rotating O-ring during operation, will cause the ring to lift off sufficiently to avoid the scraping and galling wear modes noted on circumferentially contacting dynamic O-rings (such modes are why O-ring manufacturers do not recommend high-cycle, dynamic, circumferential sealing applications). Bearing protector/isolators equipped with dynamic “vapor blocking” O-rings are likely to outperform isolators that do not incorporate a dynamic O-ring, in that they do prevent air intrusion on shutdown. Current production of these components exceeds 175,000 per year (Ref.2).

Many practicing engineers, however, have voiced concerns with mistaken claims that these devices provide “hermetic” sealing. Reliability professionals correctly reason that if the O-ring does lift off, there still will be a gap through which contaminated air moves. Conversely, if there is no gap, there will be wear. Thus, contrary to written claims dating back about a decade, even bearing protector/isolators designed with dynamic O-rings will not achieve hermetic sealing during operation.

Hermetic Sealing is the Preferred Solution

Hermetically sealing the bearing housing implies that *nothing* enters and nothing escapes. Only face-to-face sealing devices meet this definition. In view of the generally limited axial space between bearing housings and fluid casings of centrifugal pumps and other machinery, narrow-width, magnetically closing face seals have been developed in recent decades.

Whenever there exists a thin film of clean oil between either spring-activated or magnet-activated seal faces, long seal life and hermetic containment of the lubricat-

ing fluids result. Tens of thousands of the magnetic face seals shown in Fig. 5 have been used in aircraft task pumps, as aircraft generator seals, and on vertical stabilizer units (Ref.3). They can tolerate rubbing velocities as high as 86 m/s (17,000 fpm) and temperatures to 200 °C (392°F), and have frequently served to everyone’s satisfaction for over 50,000 operating hours. These seals have performed equally well in such industrial applications as gun drills, gearboxes and pump housings. They use a single Al-Ni-Co magnet annulus to attract the opposing seal face.

A rather similar seal (Fig. 6) incorporates a series of strong rare-earth magnetic rods to attract the opposing face. Superior face-material combinations achieve coefficients of friction that, even without lubrication present, rival those of PTFE. The stationary seal face of the product in Fig. 6 (also shown in insert, Fig. 8) has a diamond-like hardness (RC90, Ref.4). Thousands of machines in

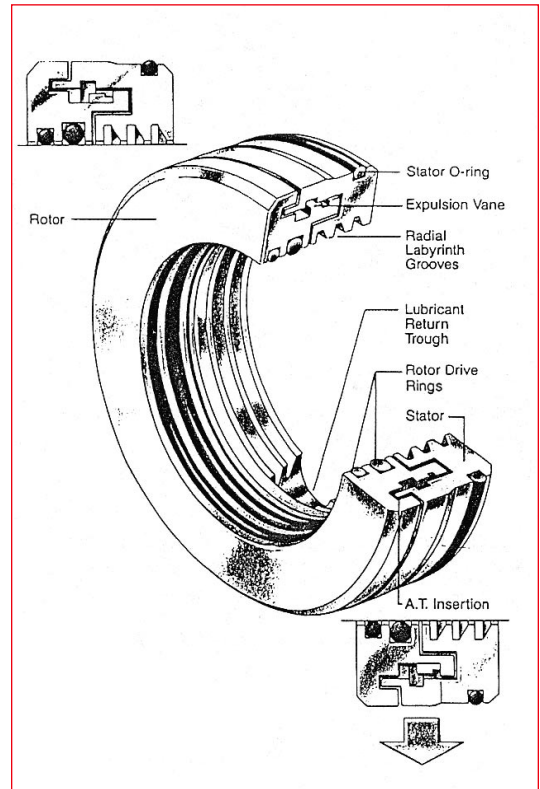


Figure 3: Rotating labyrinth seal (bearing protector/isolator) (Source: Inpro/Seal Company, Milan, Illinois; www.inpro-seal.com)

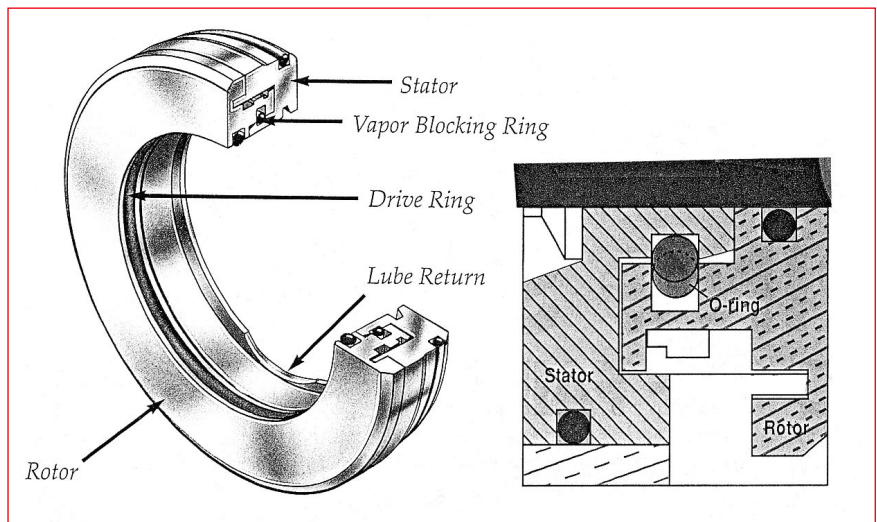


Figure 4: Bearing protector/isolator with dynamic O-ring (Source: Inpro/Seal Company, Milan, Illinois; www.inpro-seal.com)

different industries have been fitted with this particular type of seal, and yearly production exceeds 60,000 (with primary applications in centrifugal pumps in hydrocarbon processing and related industries).

Figure 7 shows a magnetic seal whose contacting faces are *pushed* together by the repelling action of rod magnets of like polarity. Although repulsion magnetic seals embody certain advantages over the pulling configurations they are more expensive to make and take up more axial space. Very few of these seals have been sold since their introduction in 1992, and only a few dozen were produced in 2000.

Magnetic seals obtain lubrication and cooling from the ever-present oil fog that surrounds oil-lubricated bearings. Properly designed, using appropriate face materials and applying suitable selection criteria, they represent the ideal choice of bearing-housing seal to prevent both egress of lube oil and ingress of atmospheric contaminants. Should the temperature-dependent pressure inside a non-vented bearing housing rise above the magnetic closing force, the seal would release pressure by opening and immediately re-closing.

Magnetic seals of the type shown in Figs. 5 and 6 will perform flawlessly, either with pressure-balanced constant-level lubricators or non-vented bearing housings, and they are ideal for closed, environmentally acceptable oil-mist lubrication systems. In a closed, oil-mist application, the oil mist is introduced in the space between magnetic seal and bearing (Ref.5). Excess liquid or vaporized oil is led off or collected at the bottom-center location of the bearing housing (Fig. 8, and Ref.6).

Pressure-Relief Poppet Valves are Rarely Needed

Pressure-relief poppets, similar to the one shown in Fig.9, have been offered as retrofit items for bearing housings of centrifugal pumps and other machinery. The weight of the ball exerts a downward force on the seat. Whenever the product of pressure inside the bearing housing multiplied by the exposed area (= upward force) exceeds the

downward force on the seat, the ball will unseat itself and will allow excess internal pressure to escape to atmosphere.

A steel ball of 3/8 inch (9.5 mm) diameter weighs 0.00646 lb (2.9 gm). Assuming an exposed area of 0.11 sq. in., it would take a pressure increase of 0.059 psi [or 1.6 in. (40 mm) of H₂O column] over atmospheric to unseat the steel ball (although PVC balls would relieve at lower pressures).

If equipment is fitted with labyrinth seals or bearing protector/isolators (either with or without O-rings), slightly *negative* pressures may actually exist inside the bearing housing due to pumping action brought on by the contaminant expulsion elements (Ref. 1). Bearing protector/isolators with designs that avoid such pumping action have a liberal separation between rotating and stationary elements, and will provide pressure equalization between housing interior and the surrounding, external atmosphere. Consistent pressure build-up can occur only in truly hermetically sealed bearing housings, (i.e., with magnetic seals). However, lightly loaded seals with face orientations per Fig. 8 would

“burp” before the poppet would release. Only heavily loaded magnetic face seals would benefit from poppet relief valves or expansion chambers (described below). Experience shows that the seal of Figs. 6 and 7 will not need either device.

Expansion Chambers: Use where Needed

Expansion chambers (Fig. 10) are designed to absorb the expansion of gases or fluids in closed (hermetically sealed) systems. A rolling diaphragm provides a variable volume that, when correctly dimensioned, will reduce pressure buildup. On some seal models, this will extend seal life or prevent “burping.”

Moisture Monitors and Desiccant Cans

There is ample evidence that free water in lubricating oils seriously curtails bearing life. Water vapor, from in-leaking moist air, will condense once saturation limits are exceeded. Since the 1990's, competent manufacturers have offered on-line monitoring devices, capable of annunciating maximum safe levels of relative humidity (Ref. 7). Also, add-on air dryers are now available.

Desiccant technology works. It has been around for hundreds of years and packets of a chemically suitable desiccating substance are found in the packing containers of cameras, sunglasses, kitchen appliances, etc. At issue is the technical and cost justification of an air dryer requiring replacement upon color change and, thus, future maintenance. Smart companies design away maintenance, not add to it. On the overwhelming majority of pumps and similar process plant machinery, it makes far more sense to invest in failure avoidance (i.e. preventing the moisture intrusion), rather than investing in either moisture removal or moisture annunciation. Hermetic sealing is usually the right strategy, and renders measures to remove moisture unnecessary.

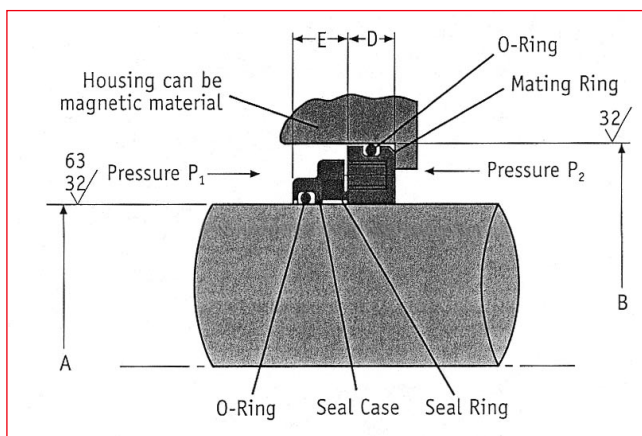


Figure 5: Magnetic seal used in aerospace applications (Source: Magnetic Seal Corp., Warren, RI; info@magseal.com)

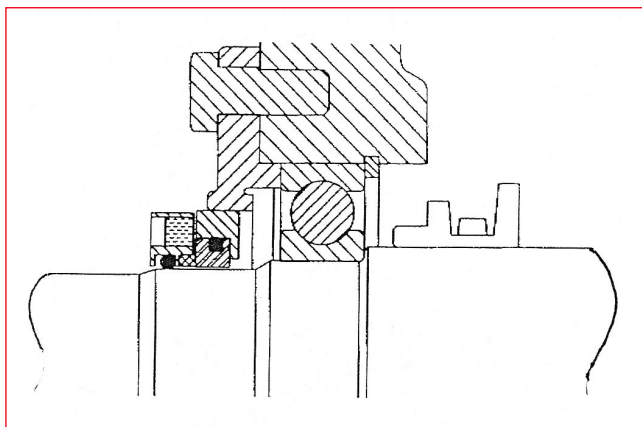


Figure 6: Magnetic seal applied in process equipment (Source: Isomag Corporation, Baton Rouge, LA; isomagcorp@aol.com)

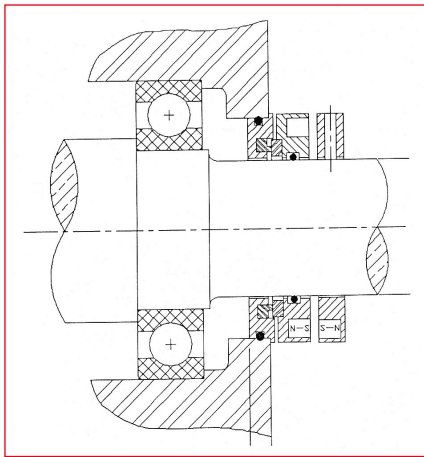


Figure 7: Inpro “RMS 700” (three-piece) repulsion magnetic seal (Source: Inpro/Seal Company, Milan, Illinois; www.inpro-seal.com)

There are, however, applications where moisture monitoring and/or desiccant-based moisture removal makes technical and economic sense. Machine components that both rotate and undergo axial movement, or gearbox installations where hermetic sealing is not practical, are where moisture monitoring and removal often are easily justified.

Conclusions are Supported by Basic Physics

- A reliability-minded process plant will give serious consideration to upgrading from the “traditional” non-balanced constant-level lubricator. Pressure-balanced configurations are clearly becoming the norm among Best-Of-Class performers.
- Bearing protector/isolators perform better than lip seals and/or labyrinth seals.
- Bearing protector/isolators with dynamic O-rings perform better than those without the O-ring.
- Bearing protector/isolators with expulsion vanes have been known to create small pressure differences that promote the outward leakage of oil.
- Magnetic bearing-housing seals are a cost-effective means of precluding the alternating, in-and-out movement of airborne contaminants.
- Magnetic seals are the only practical hermetic bearing-housing closure. Hermetic sealing optimally extends the life of lubricants and bearings. Precluding lubricant contamination also makes the use of more expensive, but superior, synthesized hydrocarbon lubricants

economically attractive.

- Magnetic seals render constant-level lubricators obsolete. Constant-level lubricators are no longer needed in hermetically sealed bearing housings.
- Poppet relief valves are very rarely needed. Their usefulness is a function of seal closing forces and must be determined on a case-by-case basis.
- Moisture monitoring and removal are

of economic value in equipment whose geometry and component features preclude the hermetic exclusion of water from the bearing housing.

- Expansion chambers are low-cost, readily justified add-ons where undue pressure rises may either jeopardize the life of hermetic sealing devices, or allow outward leakage of lubricant.

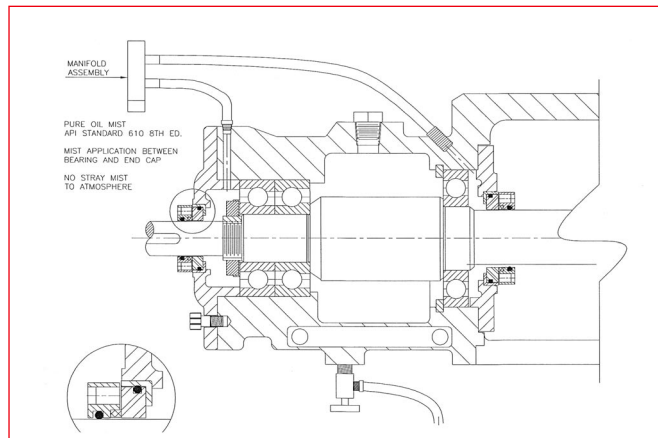


Fig.8: Magnetic seal hermetically sealing-in oil mist applied to modern centrifugal pump bearing (Source: Isomag Corporation, Baton Rouge, LA; isomagcorp@aol.com)

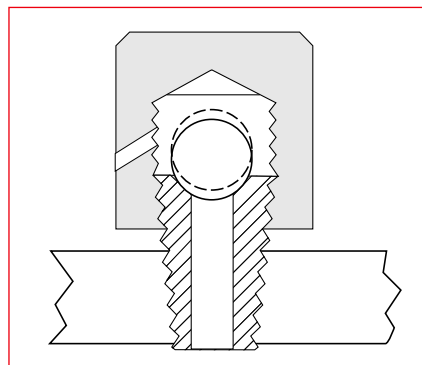


Fig.9: Pressure relief poppet valve

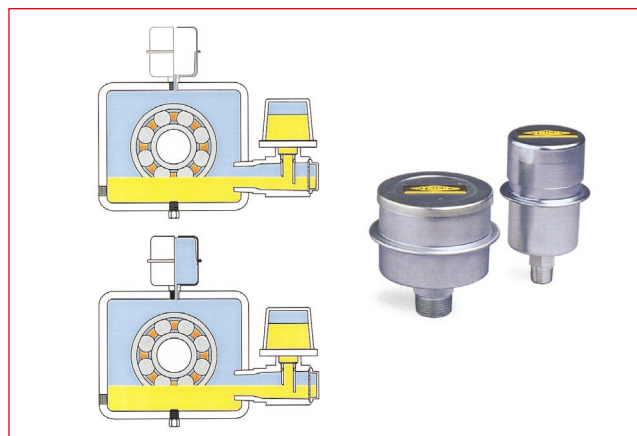


Fig.10: Bearing housing expansion chamber (Source: Trico Mfg. Corp.; Pewaukee, WI; www.tricomfg.com)

There are compelling reasons, then, to adhere to the old dictum: "An ounce of prevention is worth a pound of cure." We have the means and the knowledge to reduce the risk of bearing failure. Superior constant-level lubricators prevent pressure-driven oil loss. Hermetically sealing the bearing housing is feasible, and prevents the intrusion of water and airborne dust. Expansion chambers protect certain hermetic seals against pressure-induced decreases in anticipated life. Desiccant-based means of moisture removal and costly moisture monitoring devices will not be needed once the well-known water entry passageways have been closed (in a proven manner, which duplicates the sealing action of literally hundreds of millions of mechanical face seals). However, moisture monitoring and removal are important reliability-improvement measures in equipment where moisture intrusion cannot be prevented by economic means. ■

Heinz P. Bloch, P.E., is a consulting engineer and ASME Fellow with offices in Montgomery, Texas. He advises industry world-wide on reliability improvement and maintenance cost-reduction issues, and continues to teach in-plant courses on all six continents. Before retiring from Exxon in 1986 after over two decades of service, Mr. Bloch's professional career included an assignment as Exxon Chemical's Regional Machinery Specialist for the United States, as well as machinery-oriented staff and line positions with Exxon affiliates in the USA, Italy, Spain, England, The Netherlands and Japan. He is the author or co-author of thirteen texts and over 200 technical papers and articles. In his spare time, he functions as the

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(Editor's Note: This excerpt is adapted from "Constant Level Lubricators and Other Bearing Protection Devices: Smart Retrofits will Improve Equipment Reliability," by Heinz P. Bloch, P.E.)

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