

Investigating alternative bearing housing protection devices

Elton T. Krogel

One way to achieve longer mean time between failure is to extend bearing life by reducing the contamination of the lubricant in a pump or agitator bearing housing.

Increasing the mean time between failure (MTBF) of rotating equipment has been the subject of extensive work by the B73 Committee of the American National Standards Institute (ANSI) (1) and by the American Petroleum Institute (2) 610 Task Group. Bearings and mechanical seals have been identified as being responsible for up to 80% of rotating equipment failures. There is a close relationship between the life of these two critical components: The failure of a mechanical seal may cause the bearings to fail, and poor bearing conditions can reduce seal life.

Many papers have been published on the subject of improving MTBF, including recent papers on the effect of seal chamber design on seal life (3), improved bearing design (4), bearing housing design (5), and extending bearing life in the plant by improving bearing housing protection (6).

It is estimated that only 10% of bearings achieve their design life of from 24,000 h to 40,000 h (3-5 years). Rain, product leakage, debris, and wash-down water entering the bearing housing contaminate the bearing lubricant and have a catastrophic effect on bearing life. Very small amounts of water can compromise bearing life; a contamination level of 0.002% water in the lubricating oil can reduce bearing life by as much as 48%. As little as 0.10% water is reported to reduce bearing life by as much as 90%. Oil samples can be sent off-site for debris and water content analysis if contamination is suspected.

Improving bearing housing protection can improve bearing life by reducing contamination of the bearing lubricant. This paper reviews three methods of providing protection to pump, agitator, or other rotary equipment bearing housings:

1. Lip (oil) seals
2. Labyrinths
3. Magnetic seals.

Other factors such as pump and motor mounting, equipment alignment, pipe strain, net positive suction head, and preventive maintenance are not covered in this paper but should also be part of a complete plant program to improve the MTBF.

Lip seals

Lip seals, commonly known as oil seals, are a well established method of protecting bearing housings from water, dust, or steam contamination. There are a myriad of designs available including single and multiple lips (Fig. 1).

Lip seals normally involve a stationary elastomeric lip or lips touching the rotating shaft or sleeve. The elastomer is usually nitrile rubber or Viton* held in place by a metal holder that is pressed into a bearing cap in the housing. The lip may or may not be spring loaded. It contacts the shaft surface at an angle so that contaminants are excluded from the housing. Most lip seals are designed for zero pressure conditions, but many designs are available for special applications.

The temperature limits of lip seals are those of the elastomer used: -54 to 121°C (-65 to 250°F) for nitrile rubber and -40 to 204°C (-40 to 400°F) for Viton.

Advantages of lip seals include low initial cost, availability, and an easily understood technology. New lip seals provide excellent protection in both static and dynamic modes. Some designs involve complex engineering, and applications require a thorough knowledge of the many variables involved.

Disadvantages include short protection life due to wear of the elastomer, which allows the lip to clear the shaft surface and provide a direct opening from the environment to the bearing housing interior. Life expectancy of a common single-lip seal can be as low as 3000 h vs. common L10 life ratings for bearings of from 24,000 h to 40,000 h. While a bearing is designed to last from 3 years to 5 years of continuous operation, the protective lip seal may last only a few months. Actual lip-seal life of 200 h (8 days), with 3-5 months average life, was reported in one plant (6).

Krogel is a pulp and paper specialist at Durametalllic Corp., Kalamazoo, Mich. 49001.

* Viton is a registered trademark of E. I. duPont de Nemours and Co. Inc.

Labyrinths

Labyrinths are defined as devices containing a tortuous path that makes it difficult for contaminants to enter the bearing housing to degrade lubricant effectiveness (Fig. 2). Some labyrinths are incorporated in the bearing housing casting, others are pressed into the bearing cap using the same dimensions as a lip-seal assembly (Fig. 3).

Recent patents detail unique two-piece labyrinths providing improved protection from external contaminants and with added methods for retaining lubricating oil splash inside the bearing housing. Split labyrinths are available as well as designs with enlarged internal collection chambers for near-flooded conditions.

In a common two-piece design, a stationary member is pressed or O-ring mounted in the housing bearing cap with its labyrinth mating with a rotary member mounted on and driven by the shaft. One or more O-rings seal the rotary member to the shaft and provide the driving force.

The advantages of labyrinths are their nonwearing and self-venting features. The new designs work as well in a static mode as in a dynamic, rotating mode. With no contacting parts to wear out, a labyrinth is reusable for an unlimited number of equipment rebuilds and should last for the life of the housing.

Because the labyrinth provides an open, however tortuous, path to atmosphere, the bearing housing vent can be removed and the tap plugged or filled with a temperature gauge. These vents are a prime source of contamination. Bulb-type oilers can be replaced with sight glasses to further reduce contamination. Because the lubricant is protected from contamination and loss, synthetic oils become an economical alternative resulting in further bearing life extension. The most common materials of construction for labyrinths are bearing bronze with Viton O-rings, but many alternative materials are available including stainless steels and nonmetallics.

The temperature limits of labyrinths are limited by the elastomers driving the rotor and holding the stator in place: -40 to 204°C (-40 to 400°F) for Viton.

In cases of extensive lubricant splash, the close-fitting labyrinth may become filled with viscous oil, causing a slight back pressure on a bulb-type oiler. This is another reason to replace the oiler with a bulls-eye sight gauge or a pressure compensating oiler.

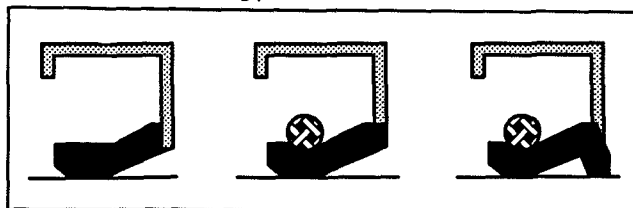
Labyrinths are usually recommended for applications with horizontal shafts. In vertical applications, gravity will cause the lubricating oil to flow out of the bearing housing through the labyrinth channel. Gravity assists in horizontal applications by trapping contaminants in a special internal collection chamber and expelling them to the atmosphere.

The disadvantages of labyrinths include higher initial cost than lip seals and the existence of an open path to the atmosphere which can allow the contamination of the lubricant by atmospheric condensate as the housing chamber "breathes" during temperature fluctuations in humid environments.

Magnetic seals

Magnetic seals are a recent development in bearing protection. These devices use a two-piece, end-face mechanical seal with optically flat seal faces held together

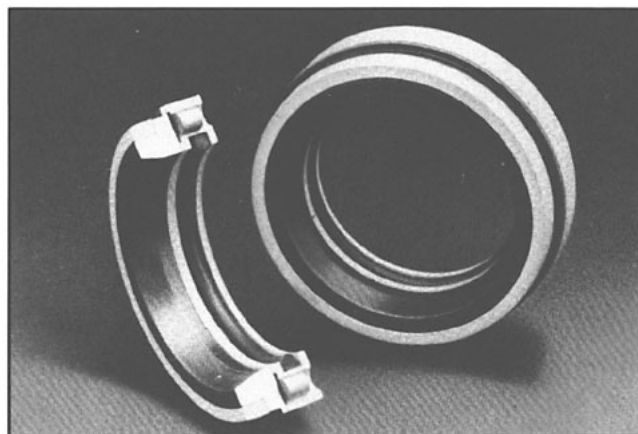
1. Typical lip-seal bearing protectors



2. Labyrinth bearing protection device



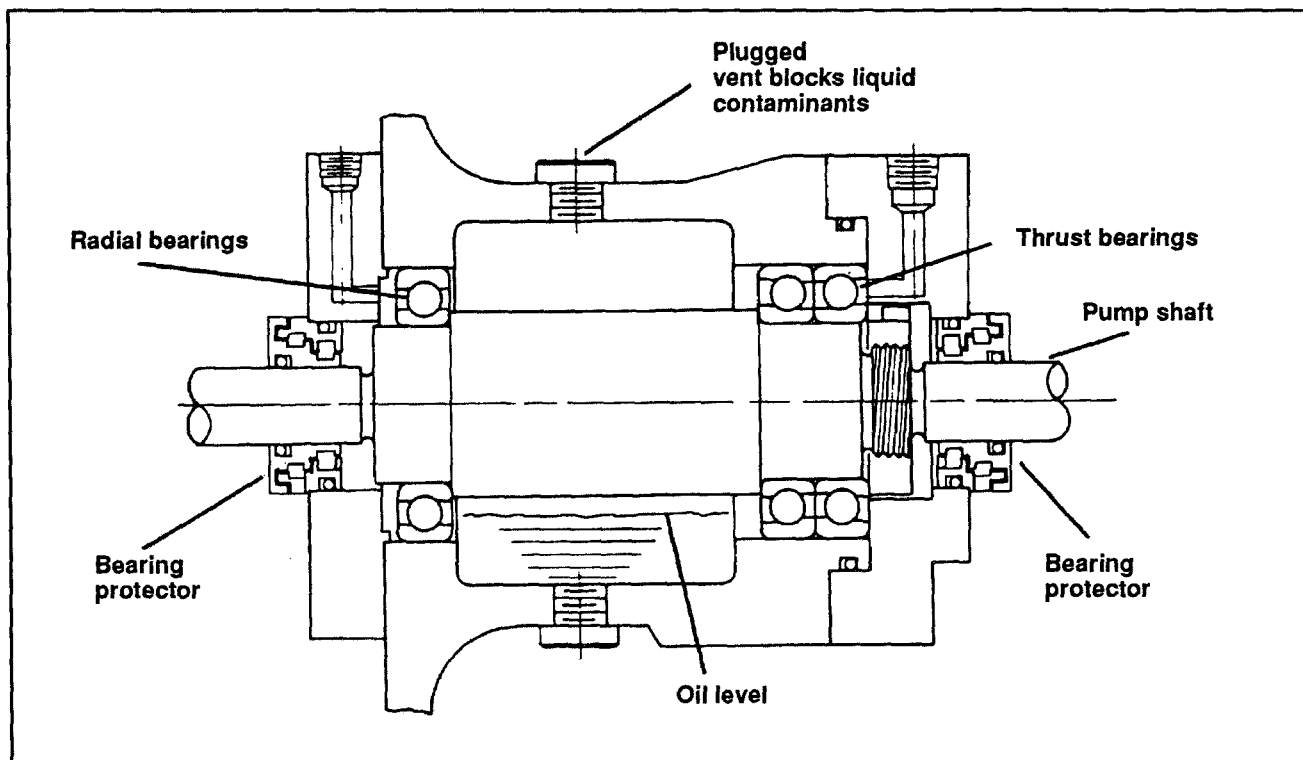
4. Magnetic-seal bearing protection



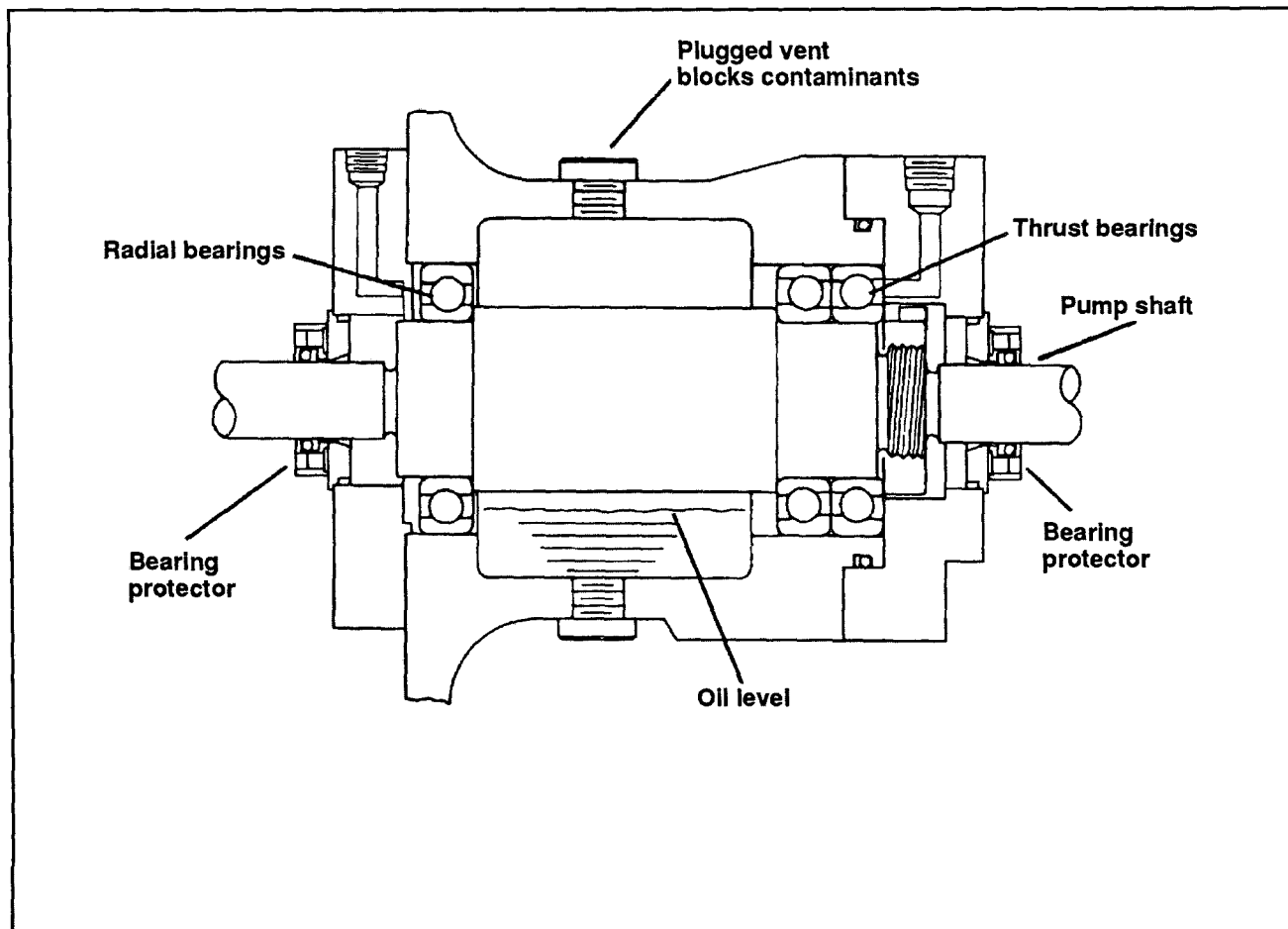
by magnetic attraction (Fig. 4).

Magnetic seals have a design life equivalent to mechanical seals and are repairable. Accurate plant records can allow the use of predictive maintenance programs to replace magnetic seals before lubricant contamination and bearing damage occur.

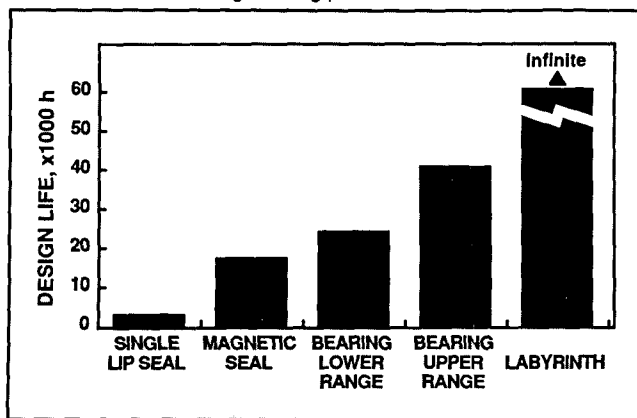
3. Bearing housing with labyrinth protection



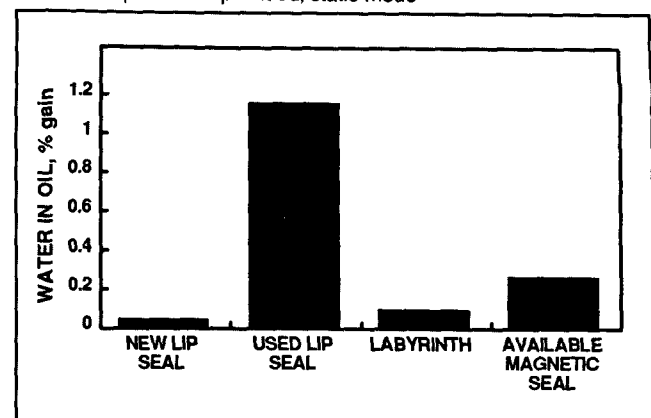
5. Bearing housing with magnetic seal protection



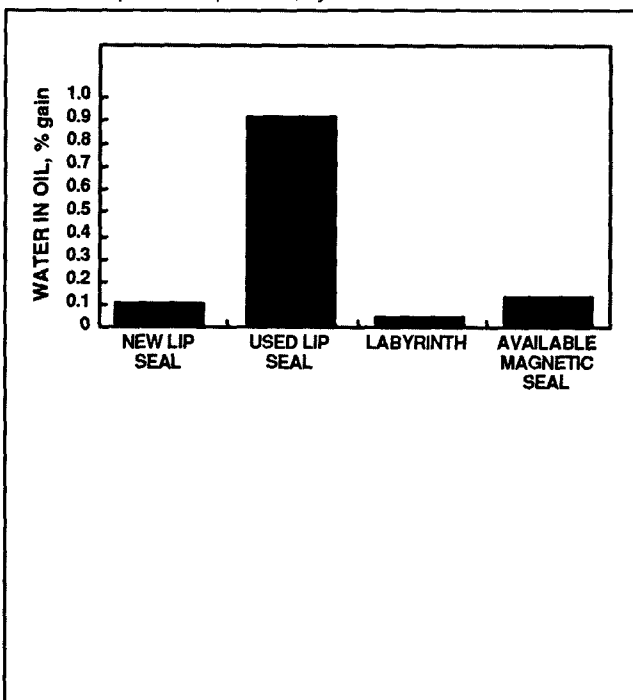
6. Relative life of bearing housing protection devices



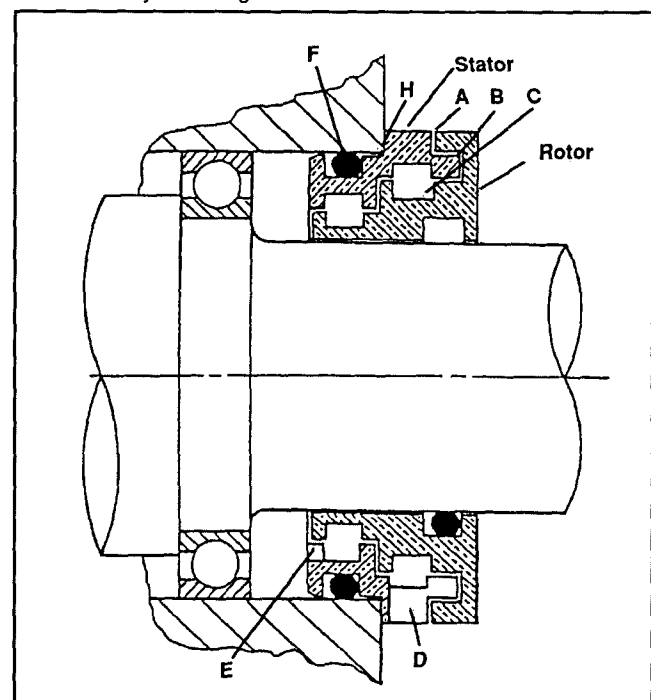
7. Relative protection provided, static mode



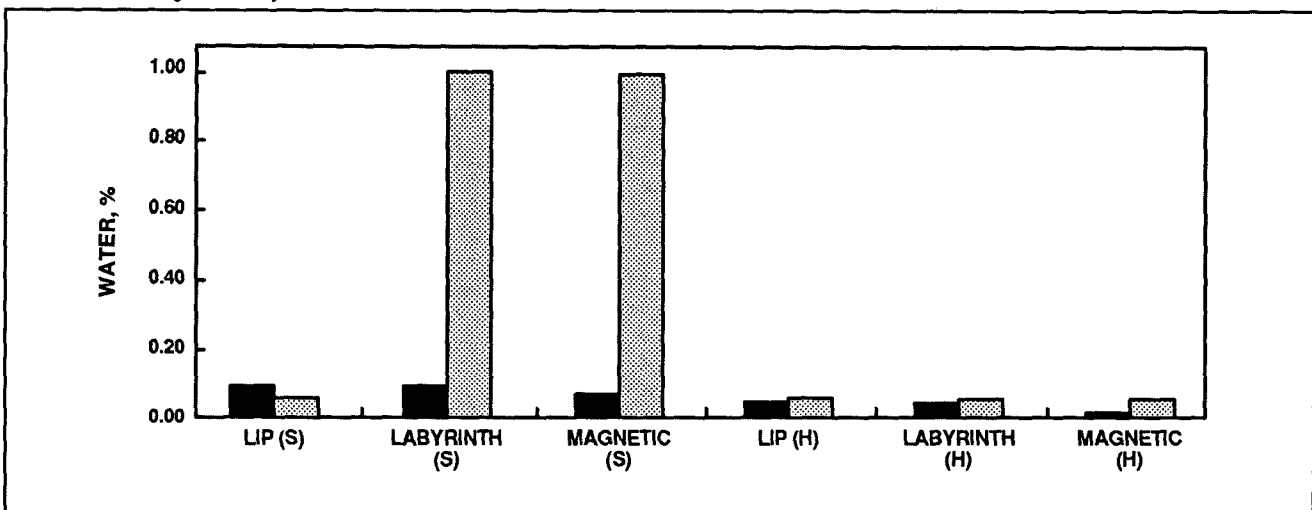
8. Relative protection provided, dynamic mode



9. Critical labyrinth design features



10. Steam and high-humidity tests



The major advantage of magnetic seals is that they hermetically seal the bearing housing (Fig. 5). Because of the positive seal, other arrangements must be made to allow for the "breathing" that results from the expansion and contraction of the air pocket above the lubricant that occurs during normal temperature changes. Conventional bearing housings protected by lip seals or labyrinths constantly "breathe" air in and out of the housing through the breather cap or through the labyrinth. Resultant condensation and debris contaminate the lubricant and shorten bearing life.

Disadvantages of magnetic seals include higher initial costs and a shorter life than the infinite life of a labyrinth.

The stationary piece, sealed with a mounting ring, is pressed into the bearing cap. The rotary is sealed to and driven by the shaft by use of an O-ring. Designs may make the magnetic unit stationary or make it rotate. If the magnet is stationary, it must be insulated from any metal in the bearing cap. The other piece must be magnetic while being rust and corrosion resistant in the plant environment.

Recent patents reveal improved technology to reduce leakage due to distortion of the seal faces by use of special line-on-line coaxial face designs. The inner coaxial face retains the lubricant splash; the outer face excludes debris, water, steam, and water vapor.

The operating temperature limit of magnetic seals is about 120°C (250°F).

In the wet-sump method of bearing housing lubrication, the vent cap on the bearing housing must be replaced with an expansion chamber sized for the volume of the housing and for the expected temperature range. A slight pressure will build up in the housing during warmup which will push oil out of a normal bulb-type oiler. The oiler should be replaced with a bulls-eye sight gauge installed at the design oil level or with a pressure compensating oiler.

With an oil mist lubricant, the magnetic seal can be used, but replacing the vent with an expansion chamber is not recommended. The purge will prevent possible contamination through the vent.

Magnetic seals are generally not recommended for use with a pure oil mist, dry-sump bearing housings, or grease lubricated bearings.

Laboratory, pilot plant, and field test results

Protecting bearings is essential to providing a suitable environment for mechanical seals. In the early 1980s, it became evident from field observations that alternatives to conventional lip seals were necessary to improve bearing life (Fig. 6).

New lip seals, improved lip seals, labyrinths, and magnetic seals were observed in the field to be much more effective than worn, single-lip seals in common use. However, the bearing protection devices on the market left much to be desired with regard to protective qualities, service life, and price.

Laboratory tests were conducted using ANSI-size bearing caps fitted with various protective devices. The results confirmed field observations. New lip seals were effective, but lip seals wore rapidly. Labyrinths and magnetic seals that were then on the market were indeed superior to worn lip seals (Figs. 7 and 8).

Most of the design features being used in labyrinths

marketed in the early 1980s were in the public domain since many of the patents were issued in the 1930s. While there were many claims about the effectiveness of these design features, there was very little documented laboratory or field information available. A matrix design experimental plan was constructed listing all of the known labyrinth design features. From this matrix, bronze ANSI sized prototypes were designed and built that included various combinations of design features. These prototypes were tested in the pilot-plant laboratory using water sprayed from a 500-psi equipment cleaning nozzle at various angles of spray impingement. Results were evaluated by volume measurements of the water passing through the labyrinth and by water content analysis of the lubricating oil. Karl Fisher electrometric titration analyses of the oil were performed by an independent laboratory.

This matrix experimental design allowed the effectiveness of various labyrinth features to be isolated. The study showed that many of the design features of labyrinths marketed at the time did not help protect the bearing housing; they only added to the cost of manufacture. However, the pilot-plant work did indicate that some features are important to the protective qualities of the design (Fig. 9).

These beneficial features include the nose-over feature on the outer rotor labyrinth (A), the inclusion of at least three 90-degree turns in the outer labyrinth (B), an inner chamber designed to collect contaminants passing through the outer labyrinth (C), a slotted cut-water device located in the down position of the stator to expel contaminants caught in the inner collection chamber (D), and an inner mechanism to return oil splash back to the reservoir sump in the bearing housing (E).

The key elements of the labyrinth were found to be the number of turns and the closeness of the fits.

The key element of the oil return feature is the clearance between the inner parts. With high-viscosity oil, a clearance of 0.035 in. was found to be adequate to prevent the escape of the lubricating oil to the atmosphere.

Other design features that were included in the initial pilot-plant work included the mounting of the stator (Fig. 9F). A shoulder stop on the stator was found to be an important feature to ease installation by preventing the stator from being pressed too far into the bearing cap (Fig. 9H).

There are literally thousands of labyrinths now in use in pump and mixer bearing housings and in motors. All of the designs tested provided long-term protection.

As good as labyrinths are, they do leave room for improvement in some applications. They do not protect against condensation of steam or high-humidity air that might enter the bearing housing through vents or labyrinth channels during the normal breathing of the housing caused by temperature changes.

Laboratory tests at a university with ANSI-size pumps confirmed that labyrinths provide erratic protection against steam or condensation when the temperature is cycled (Fig. 10). Two tests were conducted in 2-psi direct impingement steam (S). Two tests were conducted in 90% relative humidity (H). Magnetic seals available on the market at the time of the test did show promising, but also erratic, results.

An analysis indicates that a magnetic seal should include the following design features. If a magnetic stator is used,

it must be insulated from the bearing cap. The seal must be installed properly; if the faces are not in contact there is no protection. Steel components must have a corrosion-resistant coating. The stator should include a shoulder stop for precise depth dimension setting. The rotor should adjust easily for face wear, and direct impingement of water or steam at the seal faces should not cause the faces to open. Line-on-line inner and outer faces should be used to retain lubricant in the housing while providing maximum holding force to keep moisture and debris out.

Pilot-plant work confirmed the superior protection provided when these design features are included in the magnetic seal. Field installations confirm the pilot-plant data.

Conclusions

Proper bearing housing protection devices should be selected for maximum protection of lubricants to increase MTBF of rotary equipment. If lip seals are used they should be engineered for maximum protection and replaced on a regular basis. The replacement of lip seals with labyrinths has been demonstrated to provide savings in excess of \$4,500/year/pump. This resulted in savings of over \$100,000 in two years for one CPI plant (6).

Where additional protection is required against condensation from steam or high-humidity air, the magnetic seal is available. While more expensive initially,

1. Summary of bearing housing protection devices

	Type of protection		
	Lip seal	Labyrinth	Magnetic seal
Wet sump	Possible short life	Acceptable	Preferred
Purge mist	Possible short life	Acceptable	Preferred
Pure mist	Possible short life	Acceptable	Not recommended
Grease	Acceptable	Acceptable	Not recommended
Vertical	Acceptable	Not recommended	Top position only
High-humidity or steam with temperature cycling	Possible short life	Not recommended	Preferred
Direct water impingement	Possible short life	Special design	Preferred
Dirt and dust	Possible very short life	Acceptable	Acceptable

magnetic seals may prove to be very cost effective considering the high cost of turnaround and downtime of critical equipment.

Table I summarizes suggestions for the application of bearing housing protection devices with various types of lubrication systems and environments. □

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