



### SUMMARY

Outlines development of seal design and discusses problems in obtaining long seal life in pumps used in open and closed cooling water systems. Explains importance of controlling foreign matter and corrosion products in the system. Also explains effects of too high concentrations of some inhibitors in the water.

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# Pump Seal Problems in Cooling Water Systems\*

**T**HE mechanical seal, by virtue of its ability to function with no visible leakage at the full range of pressure from complete vacuum to several hundred pounds per square inch with no adjustment or maintenance, has become the most practical method of sealing pumps in open and closed cooling water systems.

However, if pump seals are to function properly and to give satisfactory service life, the water in these systems must be clean. Abrasive particles (either in suspension or formed at the seal faces due to deposition of crystals or other impurities) will cause excessive wear to the seal faces. Also, build-up of deposits on the shaft on the seal's atmosphere side might reduce flexibility of the seal to the point where it cannot function properly.

Before development of seals, mechanical packing was the only means for sealing cooling water pumps. This method is still used by some operators where conditions make the use of mechanical seals impractical, such as on some operation where it is impossible to obtain a clean environment for the seal and where leakage can be tolerated. However, abrasive particles will cause excessive wear to shaft sleeves and require constant adjustment of the packing. Leakage through packing is in direct proportion to the pressure it is subjected to. At a pressure of 250 psi, normal leakage through packing is one pint per minute. Consequently, it is usually necessary that seals be used above this pressure.

#### Development of Seal Design

Most of the early seal designs had certain limitations and consequently were primarily single purpose seals such as the one

shown in Figure 1.

This all-metal seal helped make the first household refrigerator possible by preventing leakage of toxic refrigerants used in those units. Due to lack of synthetic elastomers which could operate in refrigerants and oil, the seal had to be made entirely of metal. The brass bellows provided the flexibility required to allow the seal to compensate for possible shaft axial movement during operation as well as to compensate for wear at seal faces. One end of the bellows is fixed to a flanged member that is clamped to the compressor body; the other end is fixed to the bronze seal face which operates against a ground shoulder of the shaft. The spring generates the force required to maintain contact at the seal faces.

With no production equipment to make optically flat surfaces, the compressor had to be run for several hours until seal faces mated sufficiently to contain the refrigerant gas and oil. Being partially submerged in oil, the seal generates a film of oil between the seal faces for lubrication and also to prevent leakage of gas.

With development of synthetic rubber compounds, seal designs became more flexible and better adapted to production methods so that seals could be produced more economically for a wide range of usage. Figure 2 shows such a seal which can be made from a combination of molded and stamped parts and allows maximum freedom in selection of the materials available today, such as special carbon, ceramics, tungsten carbide, and plastics.

The seal can be made to fit a conven-

tional packing box, or it can be modified to make a more compact design on original equipment. The seal can be easily modified to handle high pressure by replacing the rotating seal face to one of the balanced design, as shown on Figure 3.

The extended rotating seal face is stepped down to reduce hydraulic thrust on the faces by balancing out a portion of effective pressure area of the seal.

#### Problems in Open Systems

In most open cooling water systems where heat is removed by exposing the water to air, sufficient abrasive particles often accumulate to cause unsatisfactory seal life. In addition to particles from the air, excessive amounts of iron oxide are often present, due to corrosion in the system. Only limited treatment generally is used because of the large amount of make-up water required in these open systems.

These fine abrasive particles find their way between the seal faces to cause rapid wear. The mechanical seal depends on a film of fluid to prevent contact between the rotating and stationary seal faces. This film allows the seal to operate over the full range of pressures with a minimum of friction. However, if this film is contaminated with abrasive particles, the seal faces will suffer serious damage.

#### Flushing With Clean Water

Because it is impractical to make a mechanical seal to resist abrasive materials,

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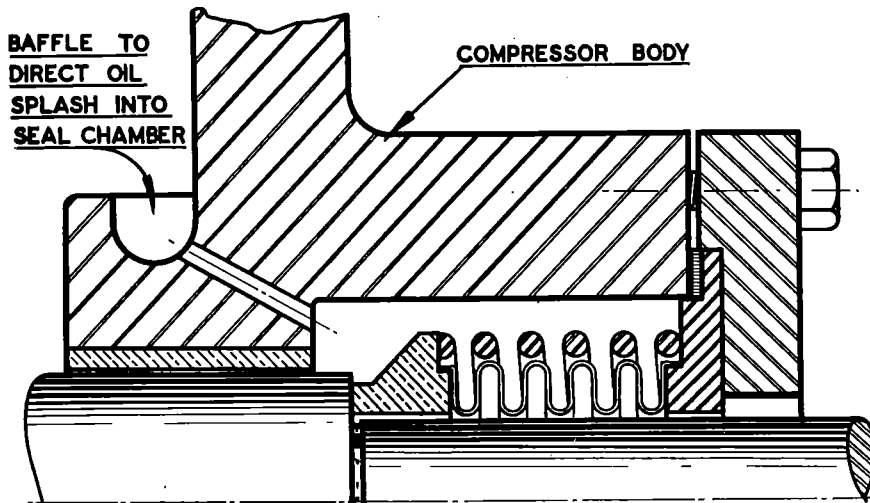


Figure 1—All-metal seal used in early refrigeration compressors because other materials were not available to resist the refrigerant and oil used.

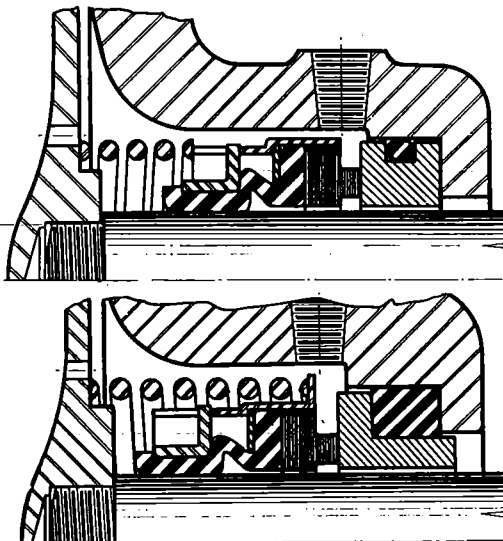
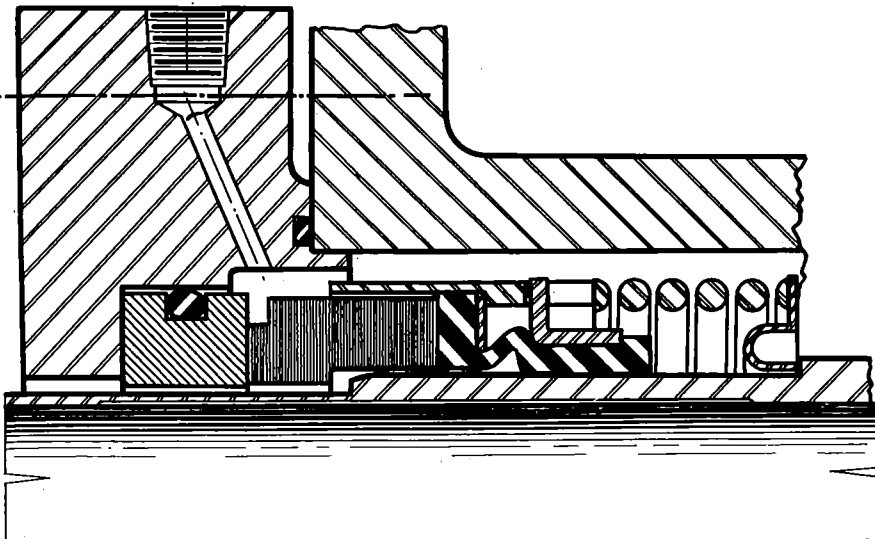


Figure 2—Two types of pump seal designs. Top diagram shows seal designed for limited space between shaft and bore. Bottom design illustrates seal with limited length.

Figure 3—Standard design with slight modification and upgrading of materials allows seal to operate at high pumping pressures.



the next approach is to isolate these particles from the seal. A simple and effective means of doing this on some systems is to inject a portion of the clean make-up water through the seal chamber to insure a clean environment for the seal. As little as 1/4 gallon per minute (gpm) injected into the seal area at a pressure of 10 psi over the pressure on the seal is sufficient to insure clean fluid to the faces.

*Cyclone Separator*

Another effective means of insuring clean fluid to seal faces is by the use of a cyclone separator, as shown in Figure 4. The differential of pressure between the discharge and suction side of the pump furnishes the velocity to make the separator effective. Because pressure in the seal chamber usually is at suction pressure, plus one-half of the developed head of the pump, a portion of the flow can be directed to the seal. This portion is taken from the top of the separator where clarified liquid drawn from the eye of the cyclonic action is relatively free of abrasive particles.

Figure 5 shows the action of the separator in removing abrasive particles from the fluid.

A field test was made recently on a single-stage, double-suction pump handling water containing some solids. In this particular pump, both seals were subjected to suction pressure only; therefore the full developed head was available as a pressure differential across the separator. On this type installation, a small amount of water usually is by-passed from the pump discharge to the seal area to insure lubrication and cooling.

In the line going to one seal, a separator was installed to protect the seal; at the opposite end of the pump, the seal was allowed to operate without any protection. After eight months service, the seal that operated in unclarified water failed due to extreme wear of the carbon washer. Examination of the seal which was protected by the separator showed practically no wear.

*Use of Filters*

One other means of protecting seals is by the use of line filters, but this method requires constant attention to be certain that filters are not clogged. One advantage is that eventually a system can be completely cleaned of all solids, but this applies only to closed cooling water systems.

**Problems With Closed Systems**

On a wide variety of applications in closed cooling water system, mechanical seals have been standard equipment for many years. The first large demand and still the biggest user of seals is in the cooling system of passenger cars and trucks.

A relatively inexpensive seal performs remarkably well in automotive water pumps and as a rule will last from one major engine overhaul to the next. This success

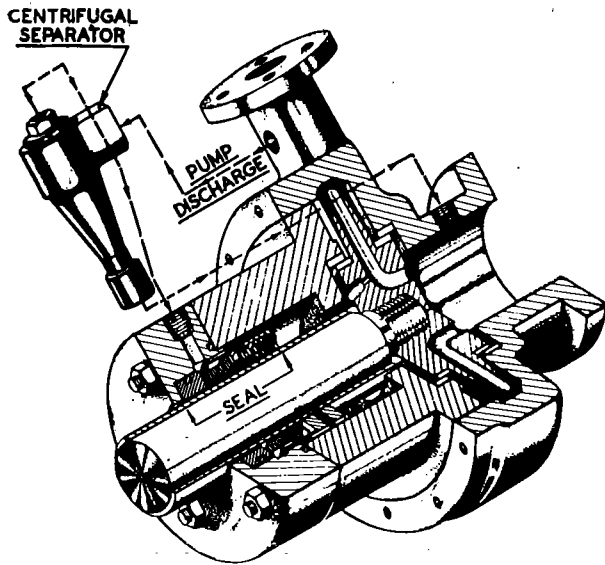


Figure 4—Centrifugal separator can be installed on pumps to eliminate foreign matter and abrasive particles that shorten pump seal life.

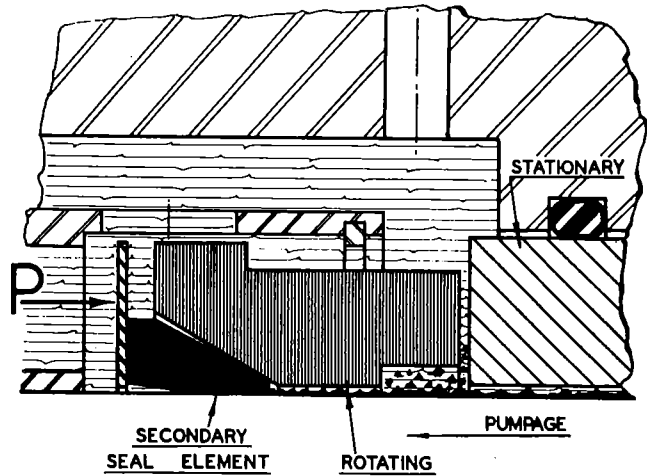


Figure 6—Hang-up area in pump seal where evaporation can occur, resulting in crystals being formed between sealing faces and along the shaft. This condition can cause wear on the seal faces and possibly freeze the seal washer to the shaft.

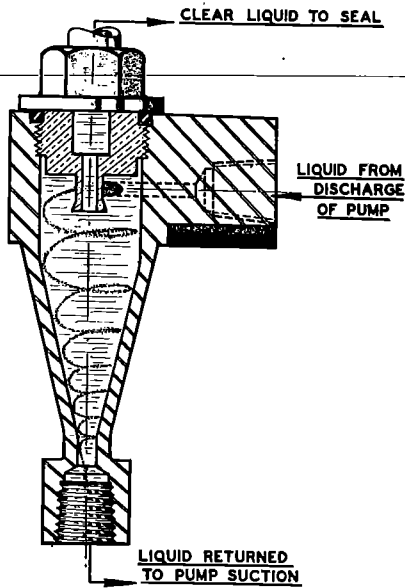


Figure 5—Diagram shows operation of centrifugal separator. Clear liquid is drawn from cyclonic eye at top so that abrasives are eliminated from seal faces.

is in spite of the fact these seals operate in all types of water and anti-freeze solutions that may not be drained and the system not flushed for two or three years. Also, temperatures may vary from  $-65\text{ F}$  ( $-54\text{ C}$ ) at start-up to  $200\text{ F}$  ( $93\text{ C}$ ) in a matter of a few minutes.

Rust inhibitors used in radiator anti-freeze solutions are of the organic type and have no effect on seal performance.

On the other hand, cooling systems of large diesel engines used on locomotives usually are protected with sodium chromate in concentrations of 2000 to 3000 ppm. Sodium chromate treatment at these concentrations contributes to relatively short seal life, but, until a more acceptable method of protecting the cooling system is found, the mechanical seal is preferred over any other means of sealing water in these coolant pumps.

A recent laboratory test of a  $1\frac{1}{8}$  inch seal operating at 1750 rpm and 30 psi in water with 3000 ppm sodium chromate showed 0.0056 inch wear on the rotating carbon seal face in 250 hours. On the basis of this amount of wear, the seal would have failed in approximately 5000 hours—about the average seal life in actual practice. Had this test been conducted on untreated, clean water, the wear would have been less than 0.001 inch. This high level of treatment is not required in large commercial closed cooling systems used for circulating chilled water.

#### Foreign Materials

One of the major problems with seals on large industrial closed systems is due to foreign materials inherent in new piping. Too often, the system is operated without thorough cleaning and flushing.

The following is a recommended procedure for preparing a system for operation to prolong pump seal life:

Clean system with a solution of one of the following: (1) trisodium phosphate, two pounds for each 100 gallons in the system; (2) sodium carbonate,  $3\frac{1}{2}$  pounds for each 100 gallons in the system; or (3) sodium hydroxide, two pounds for each 100 gallons in the system.

Fill, vent, and circulate for eight hours, allowing the water to reach design temperature. Drain and refill with fresh water. The system should be operated again at design temperature for four hours, and a sample from each system be checked for pH which should be between 7 and 8. Any one of three solutions (see above) can be added to the system in quantities necessary to attain the recommended pH.

During the cleaning process, seals will be subjected to water containing high solids concentrations. Some damage can occur. Also, it is questionable as to how many times the system must be cleaned before all solids are removed.

A small percentage of seal failures is considered normal in a large system such as multi-story buildings where cleaning may require considerable time and high pressures.

In commercial buildings, a pump may be operated for several months before the equipment is accepted and must operate for an additional year before the guarantee expires. Some design agencies have specified that spare seals be furnished with original equipment, especially on critical pumps. This eliminates most of the controversy as to responsibility for seal replacements during the guarantee period. Usually, by the time some of the seals need replacing, the system has been thoroughly cleaned and the water properly treated so that new seals will give satisfactory service for several years.

The chilled water system in the Empire State Building in New York is probably one of the best examples of what can be accomplished by complete cooperation of all parties concerned. Because of the height of this building, some pumps are operating with a suction pressure of 560 psi. The pressure on the seals is 600 psi. Because

the pumps are completely insulated and mounted vertically, perfect performance was required from the seals to prevent damage to insulation.

Some difficulty was experienced with the first seals. But after the system was cleaned and treated with 300 ppm of sodium chromate and the design and materials upgraded, these seals are still operating without leakage after four years. There is ample proof in this installation that mechanical seals can handle high pressure applications.

#### *Magnetic Iron Oxides*

Another source of abrasive solids in closed systems aside from original construction impurities is magnetic iron oxides usually found in untreated systems. This material is very fine and extremely abrasive; consequently, seal life can be disappointing. The presence of iron oxide is usually an indication that the system is corroding; therefore corrosion must be eliminated for reasons other than protection of the seals.

Sometimes, in the process of treating a system to prevent corrosion, excessive concentrations of sodium chromate may be used which can seriously affect seal life. Under proper operational conditions, a closed system requires little or no make-up water, and it costs little more to over-treat a system. On the other hand, open systems with large requirements for make-up water are normally treated with 100 to 200 ppm of sodium chromate to maintain a reasonable cost of treatment.

In over 100 tests of various seal materials in various concentrations of sodium chromate, there was little or no deterioration of seals in solutions containing up to 300 ppm. Beyond this concentration, wear was in direct proportion to the increase in treatment.

High concentration of sodium chromate does not appear to have any chemical effect on carbon or aluminum oxide which are the common materials used for faces of mechanical seals in these systems. There is considerable evidence, however, that crystals are readily formed when these solutions are exposed to the atmosphere where the water will evaporate, leaving a residue of abrasive crystals.

Although the mechanical seal functions with no visible leakage, the portion of the film of fluid between the seal faces exposed to atmosphere will dissipate by evaporation. If this film contains an excess of sodium chromate, it will leave a deposit of crystals at the point where evaporation of the film occurs.

Figure 6 shows the area where evaporation occurs in a pump. Some of the crystals are formed between a portion of the sealing faces and along the shaft underneath them. Crystals between the seal faces will cause undue wear to the carbon washer or may become imbedded in the washer, causing wear on the mating seal face. Crystals that form along the shaft can build up to the point that they will fill all the space between the seal washer and shaft and will freeze this member to the shaft. This destroys flexibility of the

seal to the point it can no longer function properly to compensate for face wear or axial shaft movement.

Most operators do not object to reducing treatment levels where seal life has been less than desirable. However, first consideration must be given to corrosion protection of the system. A qualified water treatment agency should be consulted to determine what treatment is required for adequate protection against corrosion. Rarely is more than 500 ppm required for good results, and at this level, there is only slight sacrifice to seal life.



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