Pumps on transcontinental pipe lines, where conventional mechanical packing meant tolerating rather excessive leakage which resulted in a serious problem of repumping that leakage into the pipe lines.

On pumps in petroleum refineries, where conditions present a host of problems, pump manufacturers today are recommending seals on every conceivable type of unit in the processing industry.

Speed-reducer manufacturers have long felt the need of freedom from gland leakage, and most progressive manufacturers are now using the mechanical seal.

Manufacturers of agitators and vacuum-processing equipment find the mechanical seal a solution to many of the problems which have troubled them previously.

The use of seals on the coolant pumps on internal-combustion engines is an important development. Today, with but one or two exceptions, every automobile builder uses seals to the comfort of many automobile owners.

The Diesel-engine manufacturers are making wide and increasing use of seals on coolant and oil-transfer pumps, reducing "in-shop" time and making for cleaner and more efficient operation. Frequently the adoption of mechanical seals results in considerable construction savings, eliminating parts and expensive gland construction. Mechanical seals permit full streamlining and enable important space-saving requirements to be made.

Summary

Construction is important, and every interested prospective user should acquaint himself fully with the desirable factors and necessary requirements for his particular job and insist that the seal used possess all of the desirable factors that go to make up a good seal.

Application of the proper seal to the job is the answer to successful performance. Submit application problems to a qualified manufacturer before they are too far advanced in construction details. Follow closely the layout submitted and approved for the particular job under consideration, and thus assure a successful seal application.

Utility is unlimited, and the prospective seal user would do well to deal only with a manufacturer competent and capable of analyzing the specific problem and willing to work with the equipment manufacturer toward a successful solution of the problem involved.

Discussion

C. L. Pope.[2] The author refers to the ability of the mechanical seal to prevent leakage. It is our opinion that a mechanical seal must permit leakage if it is to run as a lubricated surface. If the seal is not lubricated, wear will result. It is granted that under the right conditions wear is low and relatively long seal life can be obtained. Seals should last indefinitely if a seal controls oil leakage so that the surfaces are at all times lubricated.

P. C. Stein.[3] Exception must be taken to the inference that dry-running of mechanical seals is not possible. Dry seals have been run and are being run on commercial machines at rubbing speeds far in excess of the limits which the author gives for liquid seals. The author states: "No combination of materials has yet been discovered that can tolerate dry rubbing for more than a few minutes' duration." Certainly, he is aware that motor and generator brushes have been able to tolerate weeks of continuous operation with dry-rubbing contact since well over a half century ago. This example goes somewhat afield from mechanical sealing devices, but it is one which is commonplace in everybody's experience. Without question, dry-rubbing contact per se at substantial speeds is possible.

The writer has designed and has been associated with the manufacture and testing of well over a hundred dry seals which have given satisfactory service in the field, some at high rubbing speeds. Several typical applications are given in Table 1.

Leakage measurements were not made on the applications given in Table 1 beyond determining that seal performance was satisfactory from an operational standpoint, with the exception of applications Nos. 2 and 3. In application no. 2, for which 54 seals were furnished, leakage test results were below 4 cfm free air per seal at the operating pressure. Application no. 3, which was in a compressor for a supersonic wind tunnel, did not have a direct leakage test for the seals after installation, but a test indicated that leakage into the enire tunnel, including leakage through the compressor casing, valve stems, piping flanges, and gaskets at the working-section entry ports under full vacuum, as well as through the two seals, was less than 0.4 cfm of free air.

In general, leakage of dry seals can be held to almost any reasonable minimum by refinements in manufacture and workmanship. In most applications, the additional expense incurred to obtain very low leakage is not justified. In application No. 8, which is a shop experimental installation, it is consistently possible to have the leakage per seal less than 0.75 cfm of free air at 100 psig internal pressure. This installation has been operated at speeds of 19,000 rpm with test durations extending over several days.

Experimentally, the writer has operated a 10-in-diameter seal intended for dry operation on a gas-turbine dummy piston at speeds up to 8800 rpm (rubbing speed of 23,000 fpm). The tests were being conducted in an effort to test seal performance at 15,000 rpm (rubbing speed of 39,200 fpm), but bearing and coupling failures terminated the test on every attempt to attain the desired speed. Seal performance under 60 psig air pressure before mechanical failure of the testing machine was always good.

[2] Lubrication Engineer, Eastman Kodak Company, Rochester, N. Y.

[3] Consulting Engineer, The Kuchler-Huhn Company, Inc., Sharon Hill, Pa.

TABLE 1 APPLICATIONS OF DRY SEALS

Application no.	Seal diam, in.	Rpm	Rubbing speed, fpm	Type of machine	Medium sealed	Pressure sealed	Ambient temp, deg F
1	6 3/8	4000	6660	Compressor	Air	45 psig	260
2	6 7/8	4000	7180	Compressor	Air	75 psig	375
3	7 1/4	4660	8830	Compressor	Air	—27 in. Hg to +12 psig	...
4	6 3/8	8300	13820	Compressor	Air	—27 in. Hg to +12 psig	...
5	2 1/2	1800	1180	Autoclave	Air	250 psig	300
6	1 1/2 and 5 5/8	1800 and 3600	706 to 5290	Centrifuge	Volatile Vapor	Nominal	...
7	4 5/8	1000	1210	Textile draw-roll	Steam	400 psig	448
8	3 1/2	19000	17400	Experimental	Air	100 psig	80

The speed limitations given by the author for liquid seals are far below what has been attained to date even in commercial service. The writer has designed and has been associated with the testing of liquid seals for high-pressure compressors which are in service with rubbing speeds well in excess of the author's limitations. He has also conducted tests of similar seals at rubbing speeds of roughly twice the upper limit given by the author.

In the present state of the art of seal design, it is rash to venture an opinion of the possible upper limits of rubbing speed for either dry, nonlubricated, or liquid-lubricated mechanical seals. The limitations of a given design are determinable, but recognition of the mechanism and properties which cause the limitations will often extend the regions of operability of a mechanical seal.

Author's Closure

Mr. Stein overlooks entirely the type of sealing that is being discussed in the author's paper. In the first instance, let us consider the rather thinly drawn analogy to motor and generator brushes. It has been the consensus of opinion of electrical engineers that there exists between the brush and the armature an air film which serves to prevent excessive friction, wear, and heat. The correctness of this air-film theory is rather well borne out by the fact that unlimited difficulties were experienced in high-altitude flying where the air film was of low degree, which resulted in rapid wear, excessive friction, and the generation of considerable undesirable heat.

The seals discussed in the author's paper are such that the loss of even 0.4 cfm would be unthinkable and intolerable. It can be appreciated readily that if leakage amounting to 0.4 cfm existed, it would be impossible to live in a room where an ammonia compressor was in operation. There are many other toxic problems where such losses could not be tolerated.

The seals primarily discussed and considered in the author's paper are those wherein the losses of oil in refrigeration compressors, for example, must be held well below 10 grams per 1000 hr of operation. The author does not deny the possibility of operating a seal on an air or gaseous film at relatively high speeds, provided losses such as Mr. Stein proposes are not objectionable.

In order to hold leakages to extremely low limits (which is understood to be of such a low order that the gas is not detectable by conventional means), the imposition of considerable spring loading is required. This, in the opinion of the author, makes it impossible to run dry. Innumerable tests of various designs and construction with innumerable material combinations have proved the impracticability of attempting to operate dry. It is the opinion of this author that high speeds with dry running are possible only when relatively high leakage can be tolerated.

If Mr. Stein will take into consideration the difference in sealability of the seals discussed in the writer's paper and those brought forth in his discussion, he should agree readily that the arguments he advances have little or no bearing on the precision type of low-leakage seals covered in the author's paper.