# ROTARY OIL SEALS

BY

LIEUTENANT-COMMANDER W. H. BAWDEN, M.B.E., R.N.

Until the invention and large scale production of oil resisting synthetic rubber, the main material used for oil seals was leather. Oil resisting synthetic rubber has now, to a great extent, displaced leather as the material for the sealing member not only of rotary oil seals but also of seals for reciprocating shafts of hydraulic equipment, in industry generally. The reasons for this are :—

(*a*) Rubber seals are more efficient, allowing less leakage and causing less friction.

(*b*) They generally run satisfactorily at higher peripheral speeds than leather seals.

(*c*) They are more flexible at the sealing lip, allowing a greater ovality or eccentric rotation to the shaft to occur before leaking excessively.

(*d*) They have a longer shaft life than leather seals.

It is on account of this last consideration that rubber seals are being adopted for naval ordnance equipment.

An early type of leather oil seal, known as the ' Gits ' seal, consists of a metal case containing the sealing member, which is held in place by a coned washer and finger springs. The case is closed by a plate, held in place by swaging the edge of the case. A section of such a seal is shown in FIG. 10.3 of B.R. 292—*Manual for the Maintenance of Naval Ordnance and Gunnery Equipment*. Leather seals can also be fitted with garter springs to hold the sealing member to the shaft. Such a seal is shown sectioned in FIG. 10.4 of B.R. 292.

It is the intention of the Director of Naval Ordnance to introduce synthetic rubber rotary oil seals for use in naval ordnance equipment and in order that suitable seals may be used, a programme of tests is being carried out at the Admiralty Engineering Laboratory, West Drayton.

## THE BRITISH STANDARD ON ROTARY OIL SEALS

The multiplicities of the combinations of seal housing diameter, seal width and shaft diameter have in the past been so thoroughly explored by engineering individualists, that in 1947, the British Standards Institution, in an endeavour to limit the ever-increasing number of sizes available, produced B.S. 1399—*Rotary Shaft Oil Seal Units* (*Related Dimensions*), in order, in their own words, ' to co-ordinate supply and demand '. This standard gives guidance on a number of aspects, the most important of which are mentioned below.

### Sizes of Oil Seals

A table, in three sheets, gives a series of 85 recommended shaft diameters, ranging from ¼ in to 7 in, together with a choice of 2, 3 or 4 alternative housing diameters for each shaft diameter. For each housing/shaft diameter combination there is a choice of four housing widths, depending on the type of seal. Altogether there are 1,024 recommended combinations of dimensions.

Of the 85 shaft diameters listed, the 53 most commonly used have been selected by the Director of Naval Ordnance as his ' preferred ' range of sizes, and with his ' preferred ' housing diameters, have been published in D.N.O. Standard 7724. The housing diameter selected is, for each shaft size, the smallest shown in B.S. 1399. Four choices of seal width are given in B.S. 1399, and these are also given in D.N.O. 7724, which therefore gives a choice of 53 combinations of shaft and housing diameter, or 212 combinations of shaft diameter, housing diameter and seal width. (Seals for only one range of seal widths—Single Wide—are being tested at A.E.L.).

The 'preferred' range of oil seal sizes given in D.N.O. 7724 has been accepted by all Admiralty Departments and is promulgated in B.R. 1943 (53) as S.D.M. (N) 22/2 and seals from this range should be used if possible in new designs, to simplify the supply of spare oil seals. As an example of the very large number of different sizes of seals which could intrude if growth was left unchecked, it is of interest to note that one manufacturer catalogues over 1,150 combinations of shaft and housing diameters between $\frac{1}{4}$ in and 7 in shaft diameters.

The four widths of seals referred to above are :—Single Wide, Single Narrow, Semi-Dual and Dual. For most purposes the single wide housing is used, and the majority of manufacturers make a large range of seals for this width of housing. Single narrow seals are used where space limitations preclude the use of single wide housings. The lip of a narrow seal is not as flexible as that of the wide seal. Semi-dual and dual housings are for seals employing two wiping lips, the former when one lip only is fitted with a garter spring, and the latter when both lips are so fitted.

It is unlikely that large scale adherence to the sizes recommended in B.S. 1399 will be achieved for very many years, because of the expense of changing seal sizes in industries using mass production. No single manufacturer at present has the moulds for making all the 53 sizes preferred by D.N.O., even in the single wide range.

**Shaft Sizes and Limits on Housings**

An ample tolerance is provided for each shaft diameter, the whole of which would never require to be adopted for any particular application. Tests so far conducted at the A.E.L. indicate that the position of the shaft diameter within its limits of size (0·994 in to 1·006 in for a shaft of 1 in nominal diameter) makes no difference to the leakage or friction of the seal. This range of tolerances extends to $\pm$ 0·010 in for shafts of $5\frac{1}{8}$ in diameter and larger.

The shaft end over which the seal is mounted must be chamferred, to avoid damage when fitting the seal. The chamfer angle recommended is 20 degrees to the axis, and the chamfer length between 0·200 in for $\frac{1}{2}$ in diam. shafts and 0·35 in for 7 in diameter shafts.

Compared with the tolerance range allowed for shaft diameters, the range allowed for housing diameters is very small. For the seals being tested at the A.E.L., having housing diameter of 1·625 in the limits are 0·0 in to + 0·001 in and this is increased to 0·0 in to + 0·003 in for the largest seals dealt with in B.S. 1399.

A limit is set to the size of the corner radius allowed in the housing, and to the minimum length of the chamfer at the entrance to the housing. This chamfer is recommended to be 30 degrees to the housing axis.

The only limitation imposed on the seals is that the sealing lip shall not contact the shaft nearer to the front of the seal than a certain minimum distance.

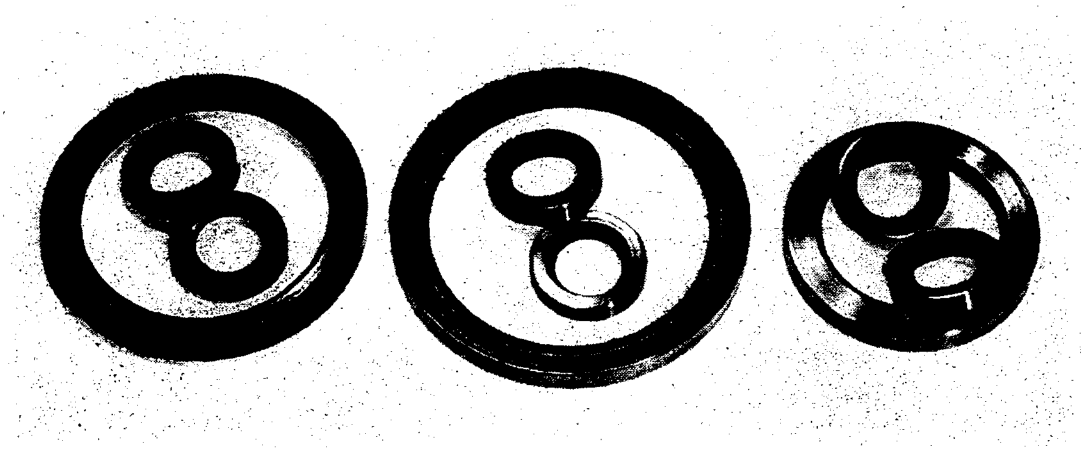

FIG. 1
Left : Metal Insert Seals
Centre : Metal Cased Bonded Seals
Right : Metal Cased Built-up Seals
The Largest One has a Leather Sealing Element

THE SEALS

## Types of Rotary Seals

Leather was originally used as a sealing material, and it was supported in a metal case by springs, the various parts being held together by swaging the case edge over the front plate. Such seals were known as built-up seals, and had one advantage over other types of seal, for the front or closing plate makes it most unlikely that the garter spring will be displaced when fitting the seal over the shaft. Synthetic rubber, unlike leather, could be bonded to the metal case, as a bonded seal with no closing plate. A third type was the metal insert seal, in which the outside metal was sunk beneath an outside layer of rubber. There are several advantages to this type of seal :—

(*a*) It is less liable to allow leakage round the outside, because of the flexibility of the rubber case.

(*b*) It is easier to press into its housing, requiring only a quarter of the force for a metal cased seal.

(*c*) Except for the garter spring, which can economically be made of non-corroding metal, it has no exposed metal parts to corrode.

On the other hand, when fitted to badly designed housings, having an inadequate chamfer, or to correctly designed housings with the outside of the seal ungreased, the rubber casing over the seal can be torn back.

The three types of oil seal are shown in FIGS. 1 and 2.

## Limitations on Use

Fluid pressure and temperature, material, surface finish, speed and whip of the shaft all impose limits on the application of these seals. Generally, the performance has been found to be much better at low fluid pressures—up to 15 lb/sq in, than at higher pressures. Peripheral shaft speeds up to 3,000 ft per min will not cause trouble, particularly if the ambient oil temperature is not high, and the shaft is true. If the shaft is bent, excessive leakage may be expected. An investigation into this effect will shortly be made at the A.E.L. to determine which seals are most effective on a bent shaft.

The most suitable material is mild steel. A case-hardened surface is preferable as it makes damage to the seal land during assembly of the equipment very

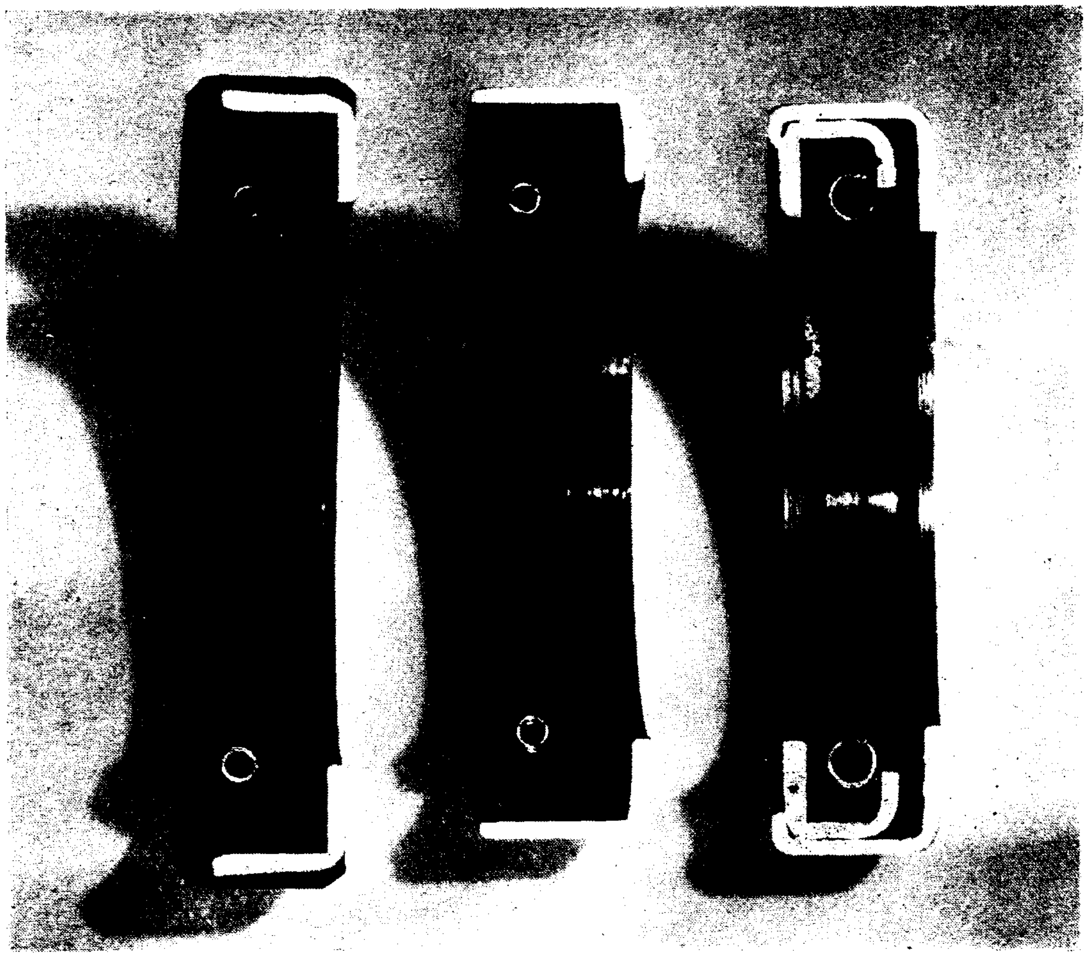

FIG. 2

Left : Metal Insert Seal
Centre : Metal Cased Bonded Seal
Right : Metal Cased Built-up Seal

unlikely. If shafts are chromium-plated, the deposit should be thick and of good quality. Thin or poorly bonded deposits will flake off and cause damage to the seal.

The better the surface finish of the shaft, the better will be the performance of the seal. Good quality grinding producing a surface finish of 6 to 10 micro inches centre-line average will be quite suitable for rotary seals. In applications where a rotary seal is fitted outside a ball or roller bearing, it is usually good policy to make the seal land about 0·002 in smaller than the bearing land, so that the bearing is not forced over the seal land, causing leak-producing scratches on its surface.

## CARE AND USE OF SEALS

### Mounting and Fitting

Synthetic rubber seals should be stored in the packets in which they are supplied, and the packets should be kept airtight and in darkness. They should not be stored near electrical machinery, as the ozone produced reduces their shelf life. Seals should never be stored loose in a bin or storage rack, nor strung on a piece of wire or string. Synthetic rubber tends to harden with age and hence the oldest seals should be used first. Before fitting, a new seal and its housing should be examined to see that they are both clean, and that the housing and the outside of the seal are undamaged. The housing and the

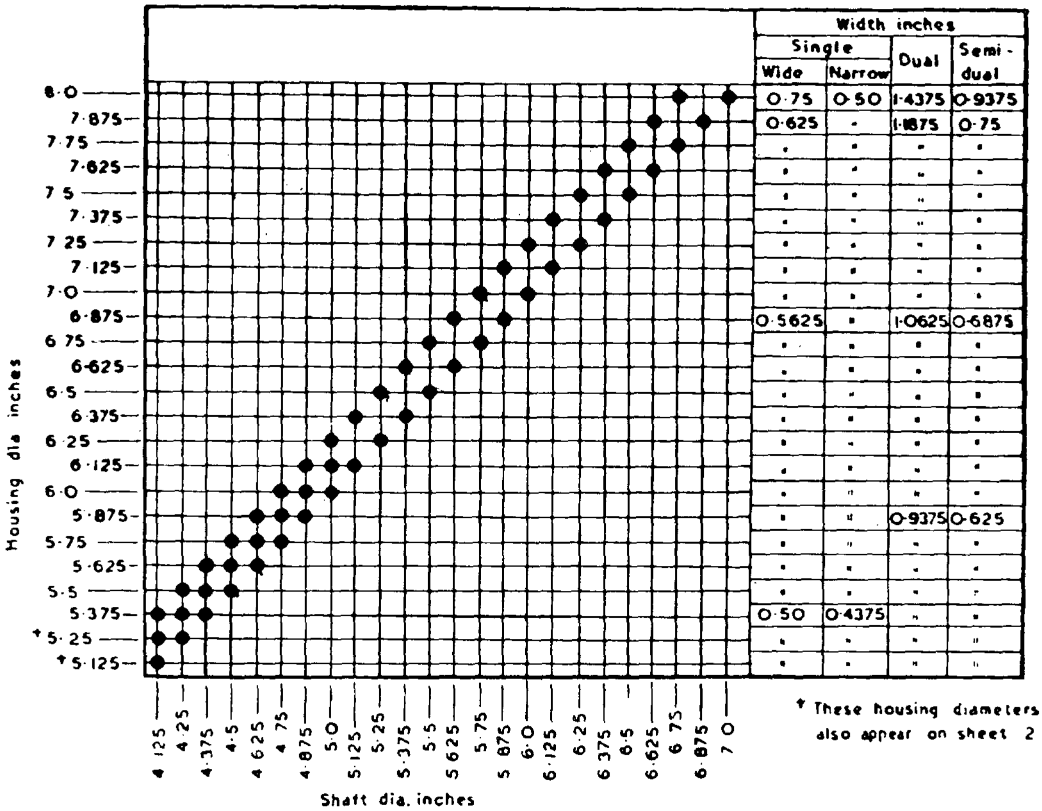


FIG. 3—A SPECIMEN PAGE FROM B.S.1399 : 1947
*(This illustration is reproduced by permission of The British Standards Institution, 2, Park Street, London)*

outside of the seal should be smeared with grease before assembly. This is most important for metal insert seals. Vaseline or lanoline are the most suitable greases for mounting seals, but any mineral grease will be found satisfactory.

When fitting a seal on to a shaft which has a keyway or splines, it is essential to protect the sealing lip from damage by means of a taper sleeve on to which the seal can be drawn. The taper sleeve can then be pushed over the splines or keyway, and the seal eased off on to the plain portion of the shaft. The surface of the taper sleeve and shaft should be lightly coated with oil to prevent damage to the sealing lip.

Seals require considerable forces to insert them into their housings, which range from about 250 lb for a metal insert seal to over 1,000 lb for some makes of built-up metal cased seals, for 1 in diam. shafts. Forces for larger seals are, of course, greater. The seal must be pressed evenly into its housing, and never put in with a hammer and drift. In some cases it is possible to remove the shaft and, placing the whole unit on a lathe, press the seal into place by use of the tail stock. Where the unit cannot be moved, it may be possible to make up a tool to exert the necessary even force. In some cases, where the shaft cannot conveniently be moved, consideration should be given at the design stage to fitting detachable housings, located preferably by taper pins. Seals can easily be fitted to, and removed from, detachable housings which can easily be taken to a press or lathe. These housings have the great advantage that, if they become damaged, they can easily be renewed. Whenever a seal is pressed into its housing, a mandrel should be used. This mandrel should not be more than 0·012 in less than the housing diameter. If the mandrel is too small, the seal, particularly a metal insert seal, may be damaged.

Great care must be taken when returning a detachable housing, with seal fitted, to its working position, not to allow the weight of the housing to press the seal lip on to the shaft. If this does occur, the seal lip may be damaged.

It should not normally be necessary when stripping an equipment for servicing or repair, to remove seals from their housings. If metal cased seals are so removed, they should not be replaced, as the initial interference fit cannot be achieved again. Metal insert seals can achieve their initial interference fit again, but it is not advisable to re-insert them into their housings once they are removed.

Further tests on rotary seals of this type will be made at the A.E.L. and these will include tests on seals for $3\frac{1}{2}$ in diam shafts at temperatures down to −40 degrees F. Tests so far have been conducted on seals for 1 in diam. shafts running at 950 r.p.m. for 500 hrs. Shafts thus revolve 28,500,000 times during the test. A motor car back axle performs approximately one million revolutions per thousand miles run. Several metal insert seals fitted to a 90 mm. diam. shaft on a test rig at the A.E.L. have already performed about 30,000,000 revolutions at speeds up to 1,000 r.p.m. and show no signs of damage or deterioration.