DEVELOPMENTS IN MAIN PROPELLER SHAFT WATER-LUBRICATED BEARINGS

BY

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Introduction

Water-lubricated main propeller shaft bearings are wonderful things, when they work! Most LEANDER Class MEOs would be hard-pressed to remember their last 'A' bracket bearing change as the bearings will generally outlive at least four MEOs and then probably not need changing for another five years; nuclear submariners are sufficiently confident of their tailshaft bearings for only one of the two to be fitted with wear-measuring facilities. When they perform as intended, water-lubricated (WL) bearings are simplicity themselves: they require no external services, are simple, robust, easy to replace, and need no servicing other than wear measurement. When they are troublesome, a fact to which an increasingly large number of Type 42 and Type 22 MEOs will testify, they can be responsible for unscheduled dockings, operational limitations, and frustration and nuisance when MOD requires 'just one more set' of poker readings before allowing yet another dispensation over BR3001 limits.

The engineering advantage of a successful WL bearing design for R.N. propeller shafts is beyond challenge. What is equally clear, however, is that existing designs are no longer adequate in an increasingly large number of cases. MOD has been aware of this for some time, the *Invincible* story[1,2] being the most blatant example of it. A vigorous development programme has been under way for over three years now and has recently culminated in a number of sea trials and significant design decisions for new ship classes.

The purpose of this article is to explain what has been happening in recent years in order to bring about the changes needed to match designs to current and future requirements.

Origins of Existing Designs

FIG. 1 illustrates a typical 'partial' arc type of WL bearing. Variants of this bearing are fitted to all submarines except the O and P Class, and to all major modern surface warships, in 'A' bracket and/or stern tube positions. Differences between classes generally only relate to the bearing lengths, chosen in order to maintain the contact pressure within the specified limits, or minor differences in features of the geometry which will be discussed below.

This design of bearing was conceived in 1955 against the background of dissatisfaction with the rubber or lignum vitae staved bearings then in general use. Length to diameter ratios (L/D) of up to 7:1 were then the norm in order to keep within the very low load capacity of these materials. With such a bearing length, shaft to bearing misalignment is an inevitability at some point along the bearing, the natural bend of a shaft over this sort of length being of the order of 0.25 inches. Rubber staved bearings gave poor start-up characteristics (they tended to stick to a shaft if left idle for long periods), and they had a tendency to de-laminate from their backing. Strategic

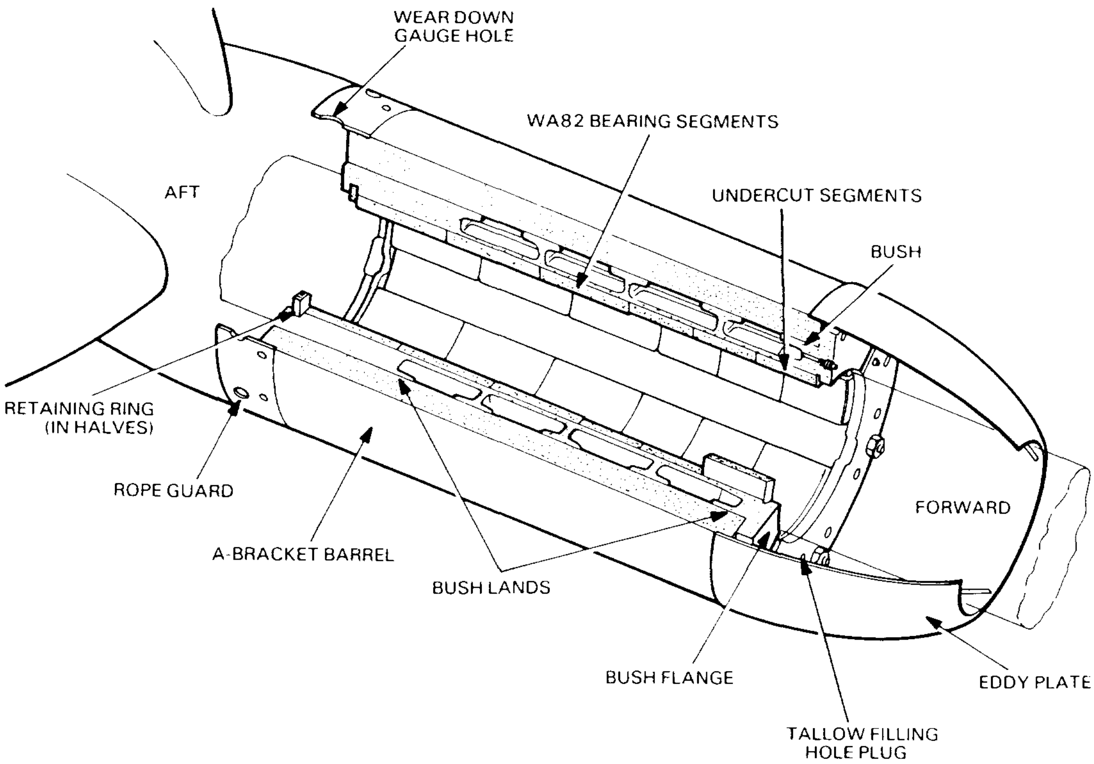


FIG. 1—TYPICAL PARTIAL ARC BEARING

supplies and quality control of lignum vitae made this material increasingly difficult to support. A specific case in 1946 reported to the author was of runaway wear after installation of new lignum vitae staves with the wood grain running the wrong way during a docking of a cruiser in the East Indies.

A typical development programme followed over the next two years comprising small scale material screening, full scale laboratory tests, and finally sea trials in H.M.S. *Cumberland* in 1958. The aim of these trials, carried out by PAMETRADA* in their Wallsend-on-Tyne research station, are virtually identical to today's aims, namely 'to provide a bearing which would be free from trouble under starting conditions, have a low wear rate, and be impervious to sand and coral particles in the seawater, and also to marine growths, and be relatively insensitive to malalignment'. In 1987 the only significant differences would arise out of the knowledge of the risks from cathodic chalk, more of which later, and the lack of a Pacific Fleet.

Whilst it is debatable whether the eventual sea trials proved that these requirements had been met fully, they certainly showed that a bearing with an L/D ratio as low as 1:1 would perform satisfactorily and give acceptable wear rates for the docking intervals of the era. The PAMETRADA trials[3] were generally very thorough and covered a wide range of tests which the MOD has only recently acquired the capability of repeating.

The Need for Change

The designs evolved from PAMETRADA bearing (FIG. 2) have been fitted to over sixty ships and submarines since the late 1950s. Wear rates have consistently averaged 0·008 – 0·01 inches per 1000 miles, which compares well with the *Cumberland* trials where 0·01 inches per 1000 miles was

*PAMETRADA: Parsons and Marine Engineering Turbine Research and Development Association.

measured. A Type 42 typical wear rate is 0·006 inches per 1000 miles for the main 'A' bracket bearing (MAB) and 0·008 inches per 1000 miles for the intermediate 'A' bracket bearing (IAB).

However, there are four factors which underly the need for change: consideration of material and health and safety at work, changing basic requirements, the influence of shafting dynamics, and the spasmodic and unpredictable occurrences of runaway wear.

Material

The material in commonest use in partial arc bearings is manufactured by Railko Ltd., of High Wycombe. It carries the designation WA82, and is an asbestos weave impregnated with phenolic resin. By its nature a water-lubricated main shaft bearing can only operate at best in conditions of boundary lubrication. Sea water is a good lubricant but requires high speeds, a very tight control of bearing surface finish, and close control of the shaft to bearing alignment. None of these can be guaranteed in a WL shaft bearing, and shaft to bearing pad contact and wear are inevitable. The selected material has to be able to withstand these conditions without degradation and with a tolerable wear rate. WA82 and other Railko asbestos-based products, such as AL11, are excellent provided that the journal material is correctly chosen, and that there are no abrasives present. This topic is discussed further later. However, under the Health and Safety at Work regulations, machining of bearing pads in these materials requires specially controlled conditions and is generally contracted out or done during 'unsocial hours'. Both ways add to cost and time and interfere with Dockyard working practices, and there has been pressure to find a non-asbestos alternative.

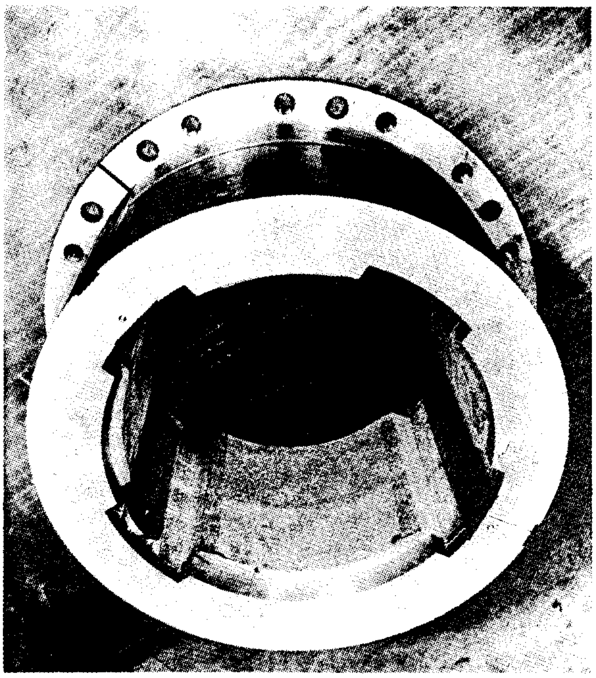


FIG. 2—'A' BRACKET BEARING FOR SEA TRIALS IN H.M.S. 'CUMBERLAND' (MINTEX M.6 MATERIAL)
Reproduced from a 1958 report[8]

Changing requirements

Two requirements have changed in recent years: docking intervals and minimum continuous operating speeds. As under-water coatings have improved and the drive to improve operational availability has become more pressing, docking intervals have extended. As a consequence the number of unscheduled dockings and loss of operational time directly attributable to poor bearing performance has increased. Water-lubricated bearing performance now has high visibility in certain classes, notably Type 42. In new classes the change in requirement has been twofold: firstly to provide a bearing with a life adequate to meet the extended refit intervals, and secondly to take account of the need for much lower continuous operating speeds.

Shaft Dynamics

It has long been known that warship propeller shafts are very flexible and have bending and vibratory characteristics which are a function of the interaction between shaft, propeller, and hull, and also have a significant influence on the latter through the 'A' bracket struts. There have been several recent sources of information, both sea trials and analysis. The *Invincible* report[1] described in detail the effect of propeller loading on shaft bending moments and the impact of these on bearing reactions, particularly at the IAB. FIG. 3 illustrates this connection, but, in the case of *Invincible* the concern was to explain a vibratory phenomenon and rapid wear, and the shaft movement was considered only in the vertical plane. Faced with numerous incidences of Type 42 rapid wear and unscheduled dockings, this class also was subjected to analysis and sea trials.[4,5] In this case, however, there was no associated shaft vibration nor the possibility of the IAB unloading, even if the IAB pads completely wore away, since in the Type 42 the distribution of bearing loads and bearing influence numbers is quite different to that in the CVS. Hence, the mechanism posed for the CVS failure would not work for the Type 42. The examinations of worn bearings and the analysis uncovered two facts which were not previously known. Firstly the Type 42 IAB reaction doubles in magnitude between static and full load conditions under the action of the propeller induced bending moment, and secondly it moves outboard to a point where it no longer sits on the bottom bearing pad (see FIGS. 1 and 4) but across the waterway between side and bottom pads. This latter conclusion was full supported by the very careful measurements of bearing wear scars taken by RAE Pyestock (FIG. 5) and reported[6,7]. In fact it was the very careful and painstaking 'detective' work performed there which first led the analysis in this direction.

Both the increase in bearing reaction and the sideways movement are a direct result of offset propeller thrust whose magnitude and direction depends on shaft speed and direction of rotation. As the IAB reaction rises the MAB decreases and these effects, together with the position of the shaft within the IAB, go a long way to explaining why the IAB wears faster than the MAB in most classes.

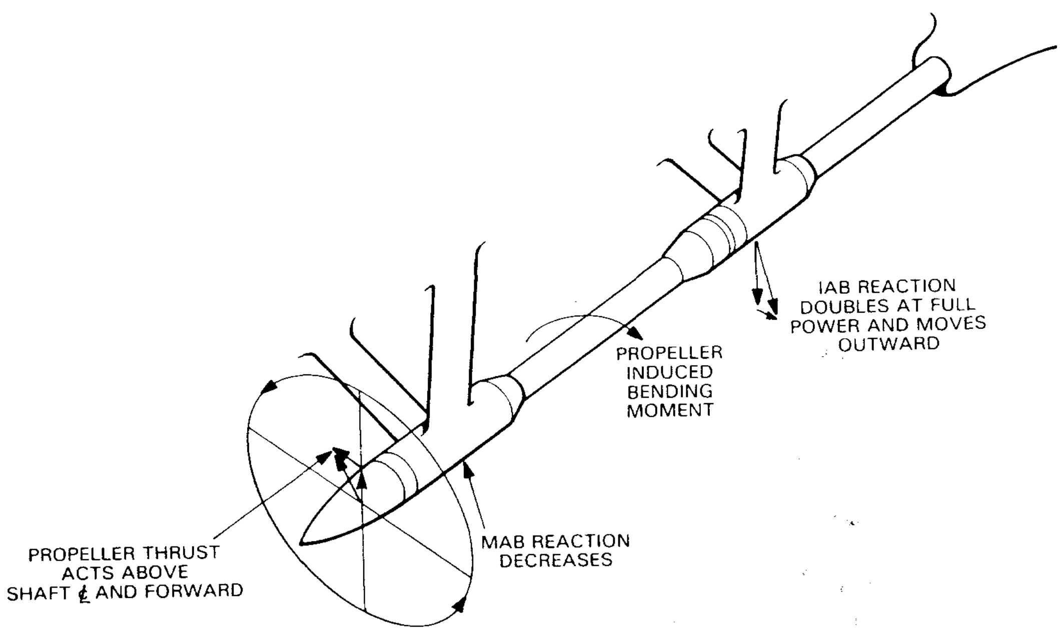


FIG. 3—EFFECT OF PROPELLER THRUST ON BEARING REACTIONS
IAB: intermediate 'A' bracket bearing
MAB: main 'A' bracket bearing

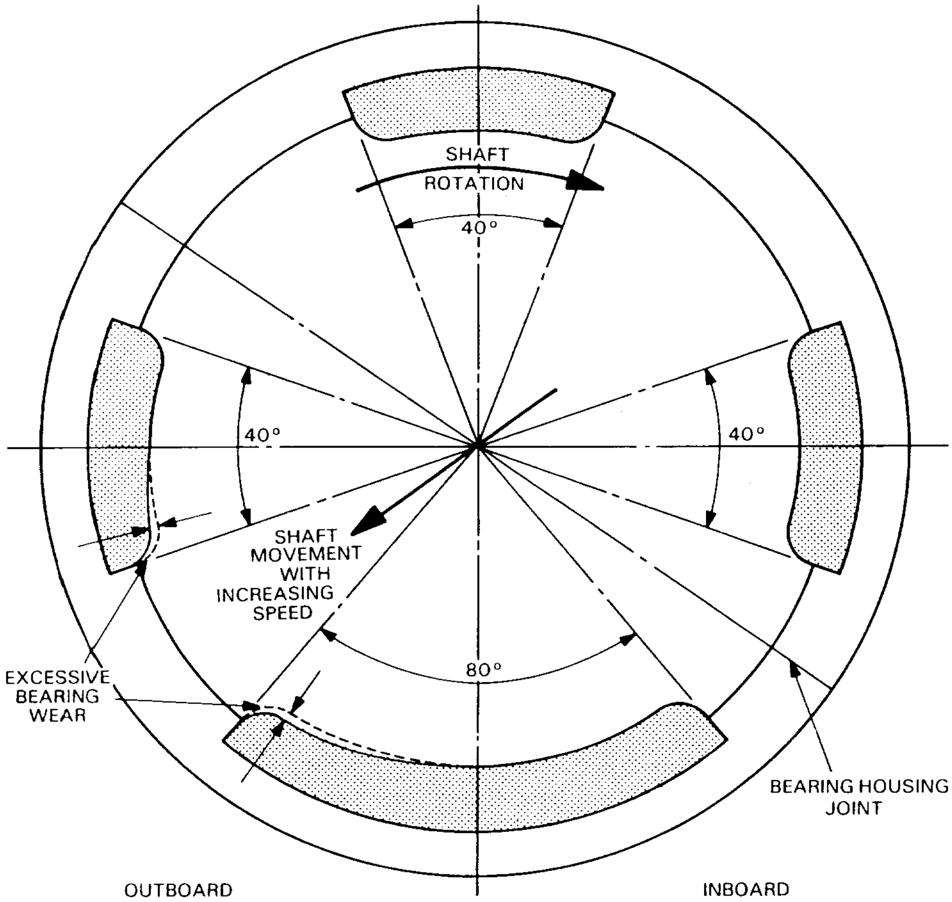


FIG. 4—TYPICAL TYPE 42 INTERMEDIATE 'A' BRACKET BEARING WEAR PATTERN, LOOKING FORWARD

Trials were carried out in two Type 42s to verify normal shaft vibratory behaviour[4,5] and to check that static alignment was correct. One of the YARD conclusions, before the analysis described above had been carried out, was that the IAB was probably running non-hydrodynamically. RAE Pyestock, as a result of their wear scar measurements, had already calculated that the net bearing pressure on the edge of the bottom IAB bearing pad under full power conditions was between 200 – 300 lb/in^2, thus almost guaranteeing that hydrodynamic lubrication could not take place.

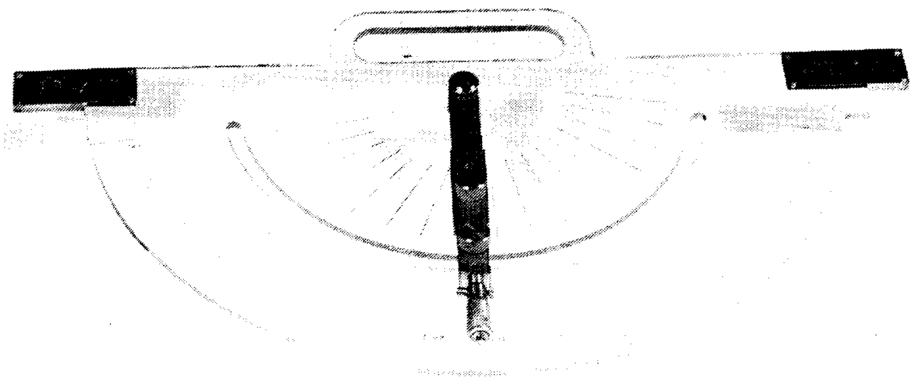


FIG. 5—RAE PYESTOCK WEAR MEASURING DEVICE

Whilst this mechanism cannot provide the total answer to why some ships of the class suffered runaway wear, it did point very clearly to the need to give much better circumferential support to the shaft journal within WL bearings in order to cope with the migrations of load line. In the worst cases of wear there had to be additional influences at work and these are described in the next section.

Submarines have also provided information which has greatly influenced current thinking on bearing design. Submarine stern seal performance is critically dependent on accurate location of the tailshaft, which in turn is dependent on the performance of the adjacent forward stern tube bearing. It was not uncommon to find this bearing completely worn out at refits (it is top loaded in SSBNs and most SSNs). Extensive measurements at sea and analysis of the interaction between the hull and the shaft has provided a wealth of data to explain what is happening and to define the needs of the shaft alignment and WL bearing performance. The detail of this whole area could provide the basis of at least two more articles but it is sufficient to say that it has made clear the fact that the existing design of partial arc bearing will no longer meet the design requirements of at least the forward stern tube bearing in submarines.

Nature of Wear

Within the limits of the means of measurement available in R.N. warships—the poker gauge—most ships follow a fairly uniform trend, albeit that a lot of readings are needed over a long period to be certain of the trend. Wear measurement is discussed in more detail below. Those that do not follow the trend (one Type 42 has suffered two emergency dockings in the last one and a half years and is due for another in the next six months) are extremely difficult to explain with any great certainty. Exceptional cases do arise from time to time—obvious journal damage for example—but in most cases the relationship between cause and effect are circumstantial at best. H.M.S. *Sheffield* provided an excellent example in 1980. She showed wear of abnormal proportions within four months of emerging from refit and a long period stationary in Portsmouth. Scrapings were taken from her journals, the deposit having been felt to be rough, and were analysed as 'cathodic chalk', a product of the hull protection systems. It forms on all exposed metal surfaces which act as the cathode, provided that they are left undisturbed for long enough. A perfectly justifiable connection was made in the *Sheffield* case between these deposits and the wear, and this phenomenon has carried the blame for many subsequent cases of rapid wear, though very rarely is a rough film detectable on the journals of such bearings. Devonport ships, stern tubes, and staved bearings appear to be immune from this phenomenon.

Cathodic chalk has been heavily researched by CDL[8] and RNEC Manadon[9]. Its nature, its cause, and the existence of ideal conditions within 'A' bracket bearings have all been established, but what has not been proven is the effect that it has on the material employed in WL bearings—WA82—despite almost a year of trying on one of the WL bearing test rigs at RAE Pyestock. This work has just been completed and the results are not fully analysed but what was very clear was that chalk whose chemical and physical appearance was to all intents and purposes identical to that found in *Sheffield* caused no acceleration of the wear in samples of WA82 run against a chalked journal. However, the circumstantial evidence remains and *Sheffield* is just one of several ships in which evidence of chalk has been abundant following rapid wear.

This has led to consideration of the features of the current bearing design and the conclusion that a great improvement can be made by reducing the aspect ratio (width/length) of the waterways. Chalk grows less easily inside relatively long, thin, passages such as those found in staved bearings, or large partial arc bearings with narrow waterways. Rubber staved bearings are fitted in LEANDERS whose wear record is excellent and they appear to be free from any evidence of chalking. However, they are also largely based in Devonport whose water is thought to contain 'humic compounds', washed down from Dartmoor, and which has been shown to interfere with pH conditions within the typical 'cathodic' cell [9]. Evidence is also available from foreign navies, and the trend towards low wear rates and absence from chalk in rubber staved bearings is well supported, though generally in bearings whose L/D ratio is much greater than in R.N. practice.

In spite of the confusing evidence surrounding cathodic chalk there are several preventative measures which can be taken in service, few of them, regrettably, without practical problems which would render their use fairly unpopular with the operational authorities, but they are listed below for completeness:

(*a*) *Water Flow*. It is known from the behaviour of stern tube bearings and from laboratory work that a steady, very low, flow of water will interrupt conditions within the bearing waterways and prevent the polarization of the water and thus the deposition of chalk. Precisely what this flow would have to be is not certain but evidence from stern tubes would suggest that normal stern seal cooling flows are sufficient (5 *l*/min approximately).

(*b*) *Grease injection*. Elimination of the sea water from the bearing would eliminate the basic raw material required to complete the cell. For ships about to emerge from dry-dock this is widely practised but for those already afloat it is fairly impractical as suitable temporary seals would have to be devised and fitted to retain the grease. This method has been attempted but the principal result was pollution of Portsmouth Harbour.

(*c*) *Inhibiting agent*. Use of a dissolvable inhibiting agent is attractive as it is easy to fit and does not interfere with notice for sea. This has been tried in the form of dissolvable glass impregnated with polyphosphates. It is expensive and its use was called for before any laboratory trials have really proved its effectiveness. However, the ships in which it was used have not suffered rapid wear or obvious chalking after periods immobile alongside in Portsmouth.

(*d*) *Shaft turning*. All the above methods are intended for use if the shafts cannot be turned but there is no doubt that turning in accordance with standing instructions is the most practical and beneficial. Hardness of the chalk film is proportional to the length of time left undisturbed, and weekly turning will rub off the chalk while it is still very soft.

Whilst the relationship between chalk and bearing wear is circumstantial, that between the wear of WA82 and abrasives is certainly not. Laboratory tests have shown quite conclusively that sand and grit have a drastic effect on both the gunmetal journal in R.N. WL bearings and the WA82 bearing material. Proof of this as the cause of the cases of rapid wear experienced in recent times is very difficult as the evidence generally disappears as soon as it has done its work. There are exceptions where the abrasive lodges in the Railko pad and acts as a grinding surface on the journal but overall the laboratory evidence simply points the way clearly towards the need for a revision of the material pair to one which is far more tolerant of abrasive material and in which wear preferentially attacks the bearing and not the journals.

The Test Programme

As stated earlier the current development programme has remarkable similarities to that undertaken by PAMETRADA in 1955. The aims are similar, as are the methods of proceeding. Regrettably the progress has not been as rapid as desired, for a variety of reasons, not least of which has been the need to direct resources towards the day-to-day problems in the Fleet. However, the elements of the programme are described below.

Material Screening Tests

Most of the bearing testing to-date has been conducted on a rig known as the '200 mm' rig (Fig. 6). This rig is installed at RAE Pystock and essentially comprises a 200 mm diameter shaft journal immersed in a sea water tank. A variety of materials and bearing shapes can be accommodated up to an L/D ratio of 2:1, with the bearing housing being loaded against the journal to a maximum load of 9000 lb*f*. (This allows testing up to the common bearing

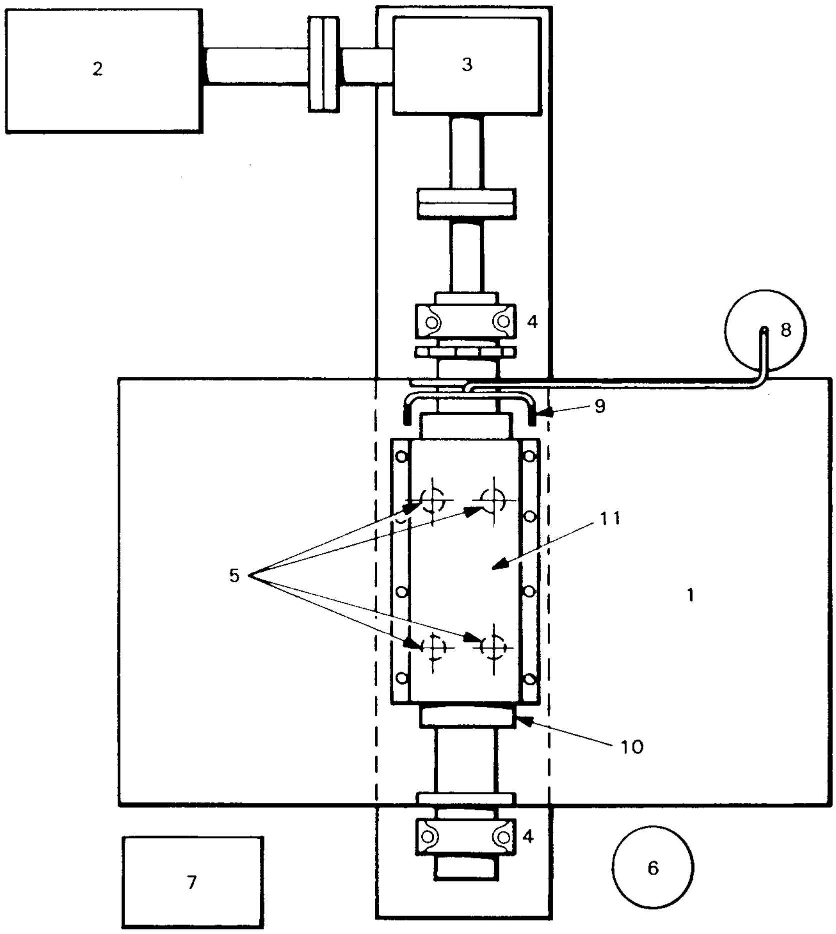


Fig. 6—Layout of 200 mm bearing test rig
1. seawater tank
2. thyristor controlled motor
3. gear box
4. bearings
5. hydraulic jacks
6. accumulator
7. replenishment tank
8. filter
9. spray pipes
10. test journal
11. test bearing

material limiting pressures). Screening tests to date have been primarily aimed at finding a non-asbestos replacement to WA82. The candidate materials are run through a standard test programme representative of a frigate operating profile and ranked according to their wear and friction performance. The programme would have continued by running the same materials in a low speed and abrasive test regime and a certain amount is complete; but for a variety of reasons the programme has been delayed—a step change in basic testing philosophy, the need to give priority to the cathodic chalk rig tests and in service problems, and latterly a decision by CERN* to give up this area of work and hand it over to the Sea Systems Controllerate to arrange a suitable contractor to continue the work and run the development programme.

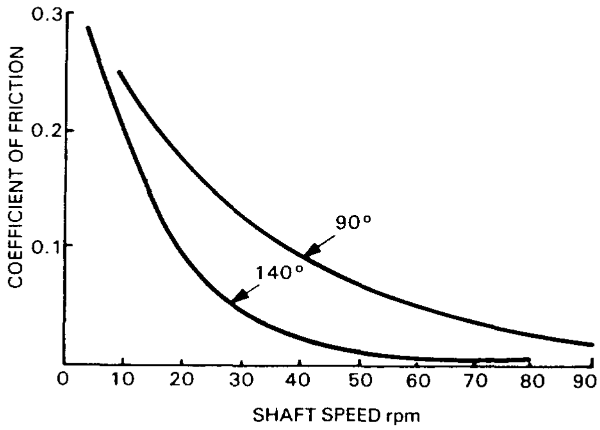


FIG. 7—COMPARISON BETWEEN FRICTION OF TYPICAL 90° AND 140° PARTIAL ARC 200 MM TEST BEARINGS
N.B. 50 R.P.M. ON TEST RIG GIVES THE SAME JOURNAL SURFACE SPEED AS ABOUT 20 R.P.M. ON FULL SIZE TYPE 42 SHAFT

However, sufficient work had been completed to establish two important facts. Firstly, a suitable non-asbestos alternative to WA82 had been established—another Railko product, NF21; and secondly, in direct contradiction to the PAMETRADA conclusion that the limiting arc length for a partial arc bearing was 90°, a 140° arc bearing was found to have superior performance. It had been thought that above 90° it was not possible to have a continuously converging pair of faces, i.e. journal and bearing. The differences are shown in FIG.7 and as a result TRIDENT, UPHOLDER, and the Type 23 frigate will all be fitted with 140° partial arc bearings.

It was recognized that the tests which led to this selection had important limitations. The lack of knowledge about the effect of abrasives and low speed has already been mentioned, though the lower hydrodynamic speed of the 140° bearing would improve low speed performance. In addition the means of load application, always uniformly distributed along the bearing length, and the scale of the tests could well influence the conclusions, particularly in light of the data gathered from the sea trials and analysis described above. RAE Pyestock has made great improvements in the quality of testing in the last two years by upgrading the 200 mm rig instrumentation to the extent that it is now possible to plot the hydrodynamic pressure wedge under the bearings on test and correlate this with friction measurements and temperature distributions in the bearing material. This enabled the performance of the various material options arc lengths to be compared with much more certainty, but scale and loading patterns were still of great concern and in 1983 it was decided that a full scale test rig was required in order to give the final confidence necessary to underwrite the design choices for the new ship and submarine classes.

* CERN: Controller R & D Establishments, Research and Nuclear

Full Scale Test Rig

A full scale test rig has now been procured and commissioned at Pyestock. FIGS. 8 and 9 illustrate the rig whose essential features are a casing of 'A' bracket proportions and stiffnesses, a 550 mm journal, a loading system capable of moving its point of application along the bearing (and in the future of supplying a varying load), and a water supply system. It is a sophisticated rig in its concept and instrumentation and the fact that it sets out to model 'A' bracket conditions has introduced practical handling difficulties arising from the mass of the casing. Nevertheless, after teething troubles with the loading device, it runs well and has shown itself to be capable of producing good results. Unfortunately its arrival at RAE Pyestock almost exactly coincided with CERN decision to withdraw from the water-lubricated bearing test programme and little useful testing has been accomplished beyond the commissioning results. It will shortly be re-sited with the 200 mm test rig at the British Marine Technology (BMT) site at Hythe, in Hampshire, and set to work with a 140° partial arc bearing installed in order to allow full scale verification of the design choices already made. Opportunity is being taken during the transfer to improve the flexibility and capacity of the rig.

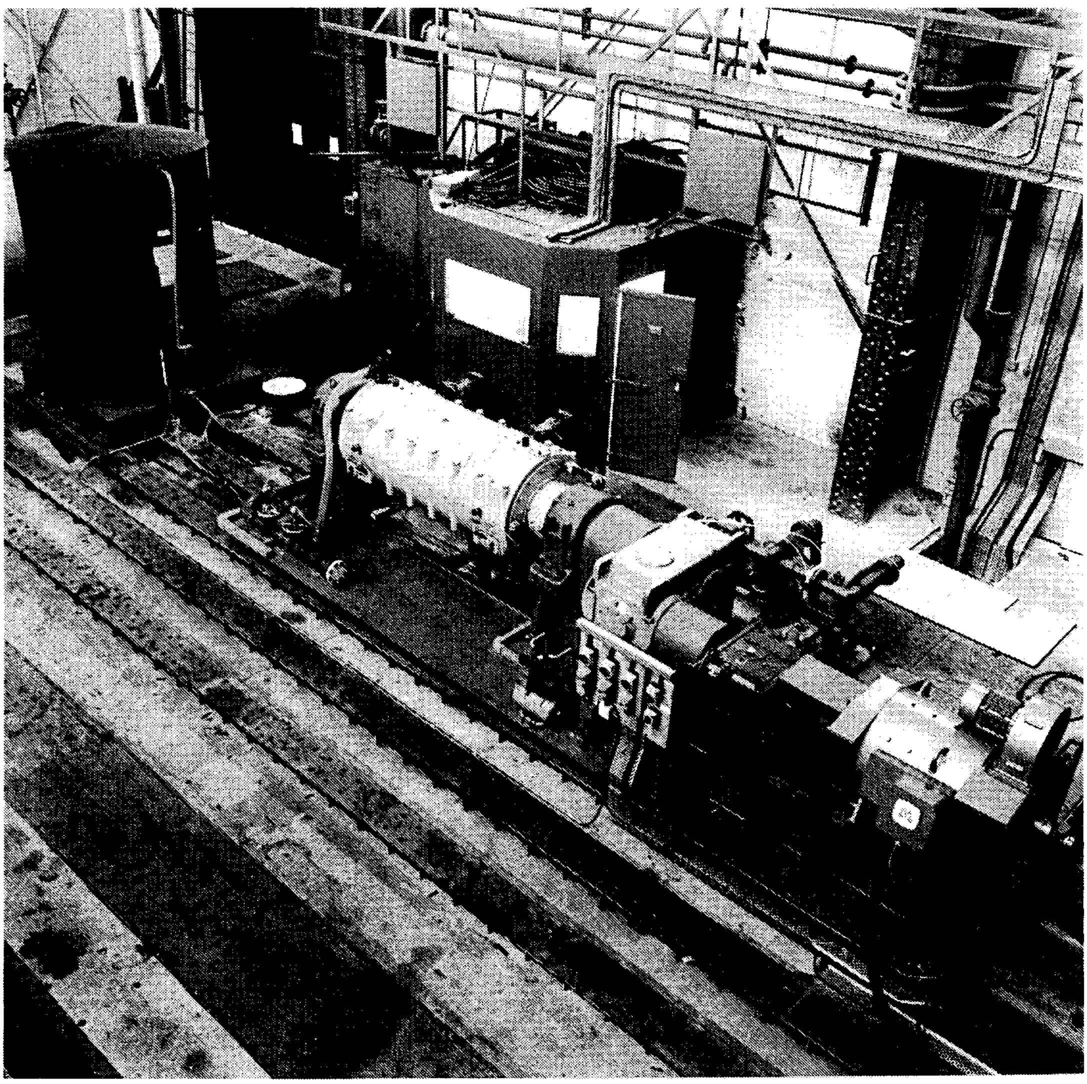
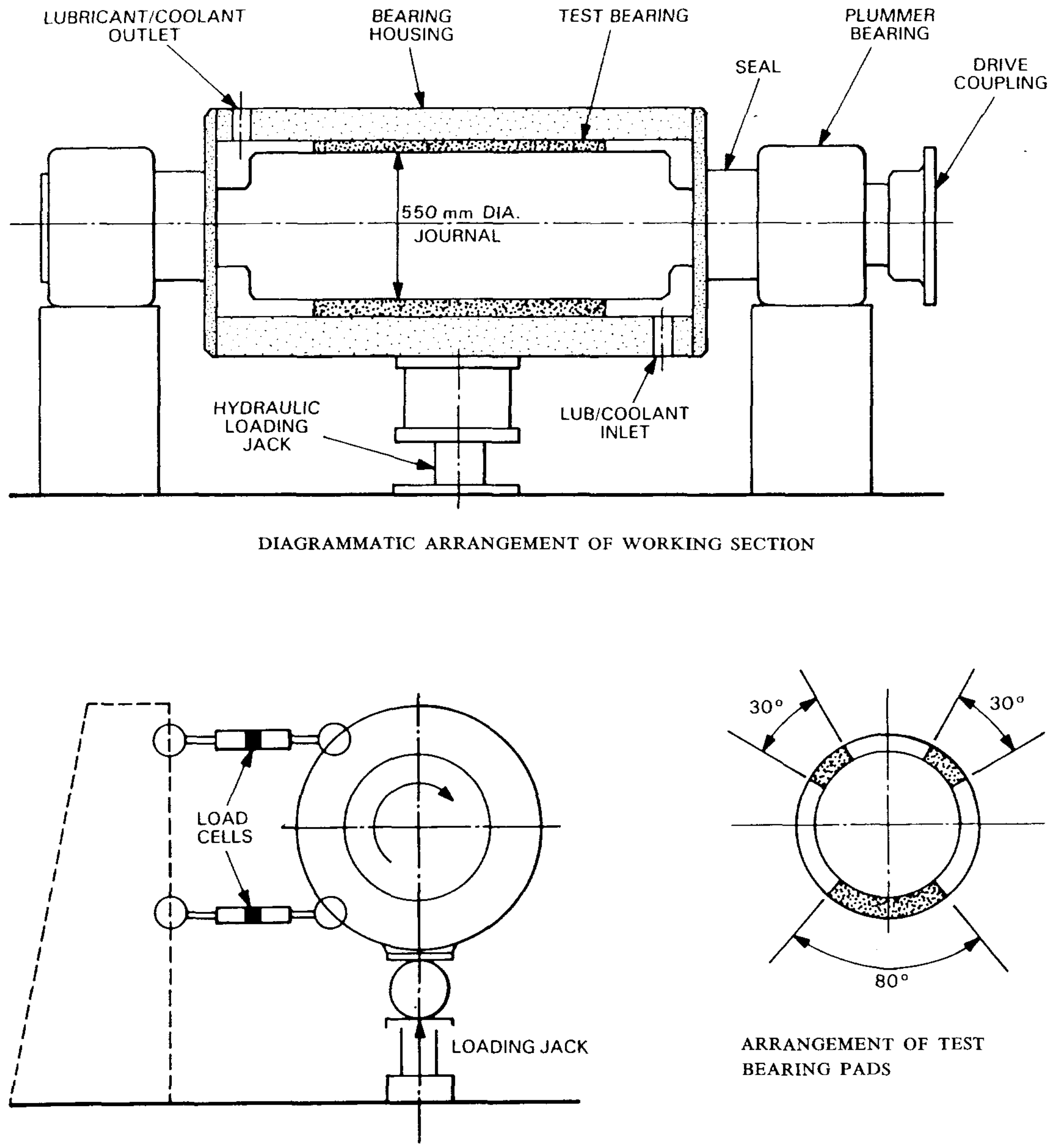


FIG. 8—550 MM BEARING TEST RIG



DIAGRAMMATIC ARRANGEMENT OF WORKING SECTION

ARRANGEMENT OF TEST BEARING PADS

TORQUE MEASUREMENT ARRANGEMENT

FIG. 9—550 MM BEARING TEST RIG

Sea Trials

Although some areas of the laboratory testing are incomplete, sea trials have become necessary in order to speed up the process of finding a solution to the current Fleet problems as well as to assist in the verification process referred to above.

Railko NF21, as a straight replacement for WA82, has had a total of six ship-years' worth of trials in Types 42 and 22 frigates and an O & P Class submarine; and H.M.S. *Invincible* is being totally outfitted with this material during her refit. Whilst it was selected as a solution to the asbestos problem this material has also been found to have a wear rate of only 70% of that of WA82, and a modification to introduce it as the standard material in partial arc bearings will be initiated this year. This represents a very low cost improvement in bearing performance.

It is recognized, though, that more radical changes are necessary if bearing life is to be brought up to meet modern requirements. Change to a 140° partial arc is also a relatively cheap and beneficial change and should reduce the tendency to chalk, provide much better support for the shaft, and improve low speed performance. It can be fitted into existing housings after widening of the dove-tails and re-orientation of the housing in the 'A' bracket barrel. It is more expensive than the straight change to NF21 but less than the cost of a rubber staved bearing, for backfit application. Although laboratory tests are incomplete the rubber is thought to have the best potential for reducing wear because of its greater tolerance of abrasives, the evidence from other navies, and the fact that Pyestock small scale tests showed quite clearly that modern products can sustain bearing pressures of up to 80 lb/in^2, in stark contrast to 1955 when 30 lb/in^2 was the maximum. This means that a rubber staved bearing can be fitted within the same length as the existing partial arc types and one such bearing has already done over 6 months running in a Type 42 IAB with very encouraging results to date. It is planned to fit a second such bearing in the same ship this year. At the same time a 140° partial arc is now fitted to another Type 42 and it is intended to attempt to draw some conclusions from all these trials early in 1988.

Whilst the options for the IAB are reasonably straightforward, the MAB requires rather more attention. These bearings, from the evidence seen of the way in which they wear, require more resilience than an IAB because of the misalignment, both static and dynamic, between the shaft and bearing, under the influence of the propeller and hull movement. Early on in the test programme it was thought that the best way of providing this was by use of a tilting pad bearing with pivots allowing full freedom of movement. These pads would have been lined with a Railko product and would have had the unique facility of being capable of underwater change. A small scale programme at GEC laboratories in Whetstone had some success but it became clear fairly quickly that it would have been a very expensive bearing with some difficult problems to overcome to allow backfit. In its place a rubber staved bearing, with a more or less conventional housing but with a limited degree of flexibility, is being developed and it is hoped that it will be available for a sea trial this year.

Bearing Wear Measurement

Considerable criticism has been directed towards the method in regular use for measuring bearing wear, the poker gauge. Poker gauges have an appealing simplicity and 'technology' which well matches WL bearings. But as every MEO knows they are a potential source of misinformation and confusion unless great patience and persistence is exercised. The author is only too aware from bitter personal experience.

Unfortunately, there is no readily available, practical, and reliable alternative. Several have been considered and two very similar schemes are under close scrutiny right now. The most promising is being developed by Vickers Shipbuilding and Engineering Ltd. for TRIDENT, where the forward stern tube bearing weardown is fairly critical to the shafting alignment. A rubber staved bearing is already specified, with expectation of long life, but there are practical problems in the use of a poker gauge in this bearing. (Current submarines have no means of measuring the wear of this bearing between refits). The device is very similar to that fitted in car disc pads with sensing heads located at various depths in the bottom stave, and each sensor has its associated wires led away through the adjacent pressure hull to an instrument panel. The difficulty that all devices of this type suffer is the 'mixing' of technologies. It is not possible to fit the instrument after the pad is installed and so it has to withstand the normal fitting procedures used for these bearings which are 'robust' to say the least. In a surface ship there exists the additional problem of finding a suitable route for the cables from the 'A' bracket to the ship's hull. A very similar device has been proposed by RAE Pyestock and is under consideration for evaluation in the full scale test rig.

Radiation has been considered as a measurable parameter. In certain difficult applications a small irradiated plug can be fitted in the path of rubbing surfaces and the degree of wear assessed by measuring the decrease in radiation strength. In an 'A' bracket situation this could, in theory, be done by a diver carrying a geiger counter or by fixed instrumentation. Such a proposal was ruled out on practical grounds. The size of radiation source used for such systems is little more than a luminous watch and, apart from having a half life too short for the normal life of a WL bearing, is likely to be masked by the massiveness of an 'A' bracket and would require too much precision in the placing of the geiger counter to be capable of being done underwater.

Detachable blocks at the ends of the bearing, with their surfaces in contact with the journal, are a possibility. These could then be taken to the surface and the thickness of the bearing material gauged by the identical thickness of the adjacent block. They would require access holes in the rope guards and fixing arrangements capable of handling by diver in low visibility. Caliper measurements between the shaft journal and a fixed reference point on the bearing housing provide the same information without the need for additional equipment.

It is the belief of the author that poker gauges offer the most practical method of measuring wear, augmented by the use of feeler gauges, and caliper measurements where doubt exists. However, it has to be recognized that poker gauges do not necessarily measure bearing wear. They indicate the shaft position within the bearing and in relation to whatever is the limiting criterion, whether this is rotor to stator, stern seal, or bearing clearance. This position can be a result of bearing and shaft wear and none of the above methods can discern the difference if the shaft is sitting firmly on the bottom of the bearing. Neither can the poker gauge indicate when a shaft is not sitting on the bottom of the bearing. However the author is aware of no ships in service where this can now happen since the shaft will carry on wearing the bearing away until it meets metal and then still be firmly seated on the bearing bottom. If suspected this can only be verified by feeler gauges though it is very difficult to be sure that the gauge is inserted at the bottom of the bearing or that the shaft is actually dead centre in the bearing, if the ship is afloat.

The key to faith in poker gauge readings is to obtain firm wet and dry readings, with a good original dry feeler in addition, and as many readings as can be practically obtained to ensure that trends can sensibly be deduced. This is particularly important during the early stages of a bearing's life when 'running-in' takes place and periods alongside and basin trials can take their toll.

The Future

Improving the bearings in 'A' brackets is only solving half the equation. It is known from the small scale trials at GEC that abrasives have a drastic effect on the wear of journals, particularly on the gun-metal in common use in R.N. warships. This is supported by the evidence of shafts in service which invariably have to have their journals reclaimed during shaft refurbishment. It is equally known, from small scale tests again, that hard coated journals (e.g. cermet, detonation gun or plasma spray coatings) do not wear and provide excellent bearing surfaces. Work is underway now to devise a way to fit such a scheme on to the journal of a warship tailshaft and, given success, it is very likely that this and rubber staved bearings will become the favoured combination for many years to come.

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