Grease Free Bearing Comparison Test on a 300MW Pump Turbine at Dinorwig Power Station

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Introduction:

The turbine guide vane bearings at Dinorwig were designed like most hydro power stations in the late 70's with grease lubricated bronze. But Dinorwig's onerous operating conditions characterised by up to 20 spiral casing pressurisation and 30 mode changes per day resulted in severe wear rates of the guide vane bearings particularly the upper bearing which required replacing every two years. This coupled with the problems associated with frequent pumping of grease which increase operational and maintenance costs and impacts adversely on the environment, led to a review of alternative designs and in particular a move towards self lubricating bearings.

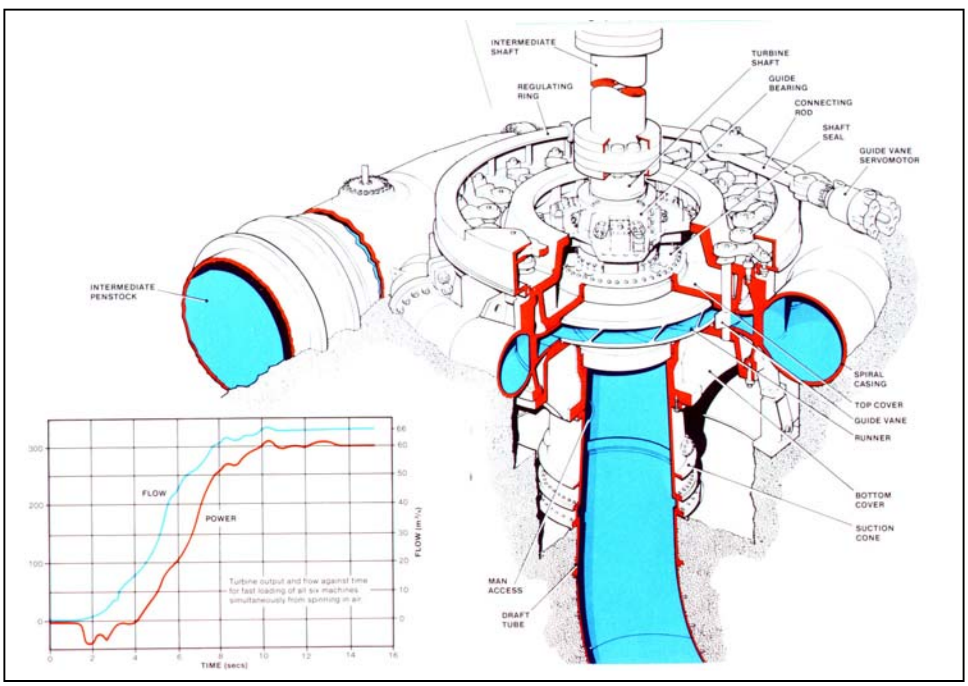

Fig 1 General Arrangement of Dinorwig pump turbine

There is no recognised performance evaluation standard or reliable method for the selection of suitable material for this particular application from the large number of products on the market.

Laboratory scale testing is usually employed to rank the performance of bearing materials for guide vane applications. These tests yield friction and wear data and reduce the time taken for evaluation by carrying out accelerated testing. However, the acceleration of the wear process can introduce wear mechanisms which would not normally be present in a practical situation and may lead to inaccurate conclusions. Great emphasis is placed on friction in laboratory tests, yet there is no correlation between friction and wear. It is possible for material combinations to produce very similar frictional forces but very different wear behaviour.

It was decided to carry out our own real time test for wear data on the upper guide vane bearing. Several manufacturers were approached to provide two samples each for the test. All samples were provided free of charge. All samples were installed on unit 4 and monitored for a period of two years.

Technical details:

The guide vane shaft material is to BS 1630 Grade B stainless steel, 200 HB hardness. Journal size: 207mm. Bearing 207mm ID, 235mm OD. Length 100 mm. Recommended clearance for greased bronze is 0.05 to 0.14mm. The housing material is mild steel 25mm thick.

Service conditions: Load 20N/mm^2 max. Temperature 10 to 15 ^{0}C. Shaft speed 0.625 rpm. Arc of rotation 30^0 .Environment dry and relatively clean with the provision of an O ring to prevent ingress of debris.

Brief description of tested products:

Devatex: A high density fibreglass backing with an integral inside diameter lubricant layer. The bearings were pressed into the housings using a special dye. No onsite machining was carried out.

Lubron AQ: A corrosion resistant bronze alloy embedded with graphite free PTFE solid lubricant. The bearings were supplied oversized on the OD and were machined to the specified interference fit on site and refrigerated overnight prior to installation.

Tenmat Feroform T814: A synthetic fibre reinforced phenolic resin incorporating PTFE evenly dispersed through out the matrix. Tenmat were issued with two housings and the bearings were fitted at their works and delivered to site.

Fiberglide 34 and 64: Bronze alloy with Teflon and Polyester liner. The bearings were press fitted . No site machining was carried out.

Lubrite: Bronze to ASTM B22 alloy 905 with G 10 lubricant. The bearings were supplied oversized on the OD, and machined on site to give the recommended interference fit.

Orkot TXM Marine: A medium weave fabric incorporating solid lubricant within the matrix. The bearings were press fitted after freezing and the bore machined to the manufacturer's instructions.

Tufcot 100 T/G: A fine weave fabric with solid lubricant dispersed in the matrix. The bearings were press fitted. No site machining was carried out.

Kamatics: Fibreglass reinforced resin bush with Karon V liner incorporating Teflon and other elements. Two used bronze bushes were bored out with gramophone surface finish. The Kamatics inserts were glued into the bushes and the bore machined to the recommended size after allowing cure time for the adhesive. Kamatics engineer supervised the installation.

Product distribution:

No distinct wear pattern was found on the upper guide vane grease lubricated bronze bearings removed from No.4 pump turbine after 2 years in service. The wear as can be seen in fig 3 is random, and is probably linked to the grease supply integrity rather than to the guide vane position. The 16 test bearings from the 8 manufacturers were divided into 2 groups. The first group of 8 were instrumented and arranged in 2 clusters of 4 to accommodate the 5 m length of the proximity probe cable. The second group of 8 was installed without any instrumentation. However, each pair of bearings were separated in order to find out if there was any position effect. The position of the test bearing is as shown in Fig. 2.

Fig. 2

PRODUCT	GUIDE VANE NO.	PRODUCT	GUIDE VANE NO.
SET A INSTRUMENTED		SET B	
ORKOT TXM	1	ORKOT TXM	15
LUBRON AQ	2	LUBRON AQ	16
FIBERGLIDE TYPE 64	24	FIBERGLIDE TYPE 34	10
DEVATEX	11	DEVATEX	21
LUBRITE	12	LUBRITE	22
TENMAT T 184	13	TENMAT T184	3
KAMATICS	14	KAMATICS	4
TUFCOT	23	TUFCOT	9
BRONZE BENCH MARK	8		

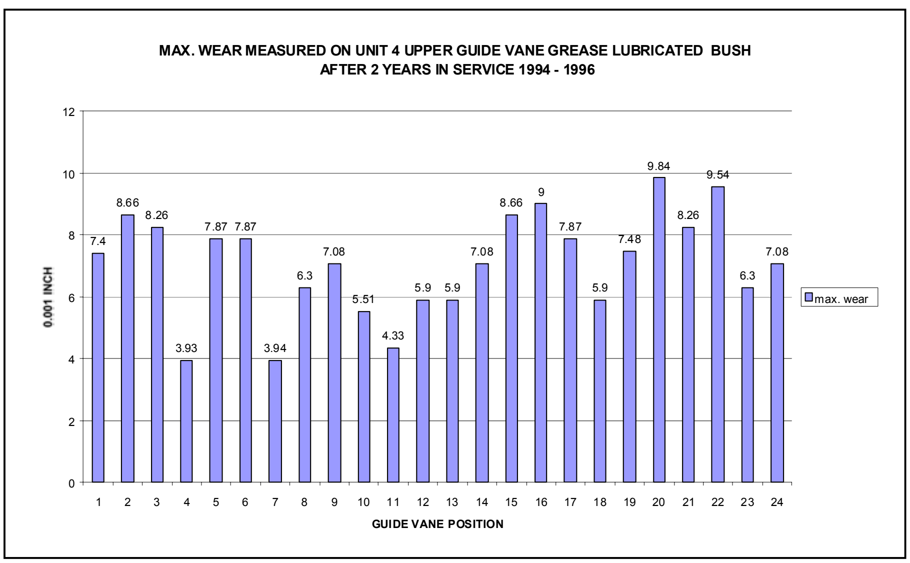

Fig. 3

Instrumentation:

2 proximity probes at 90^0 apart in plan were installed on each of the 9 selected guide vane pots. The probes as shown in fig 4 are tracking shaft movement . The gaps were set at mid range (0.050”) and datum readings were taken when the unit was watered and shut down. The number of spiral casing pressurisation and operating hours are routinely recorded. Bi-weekly readings were taken for the duration of the test.

Top Guide Vane Bush

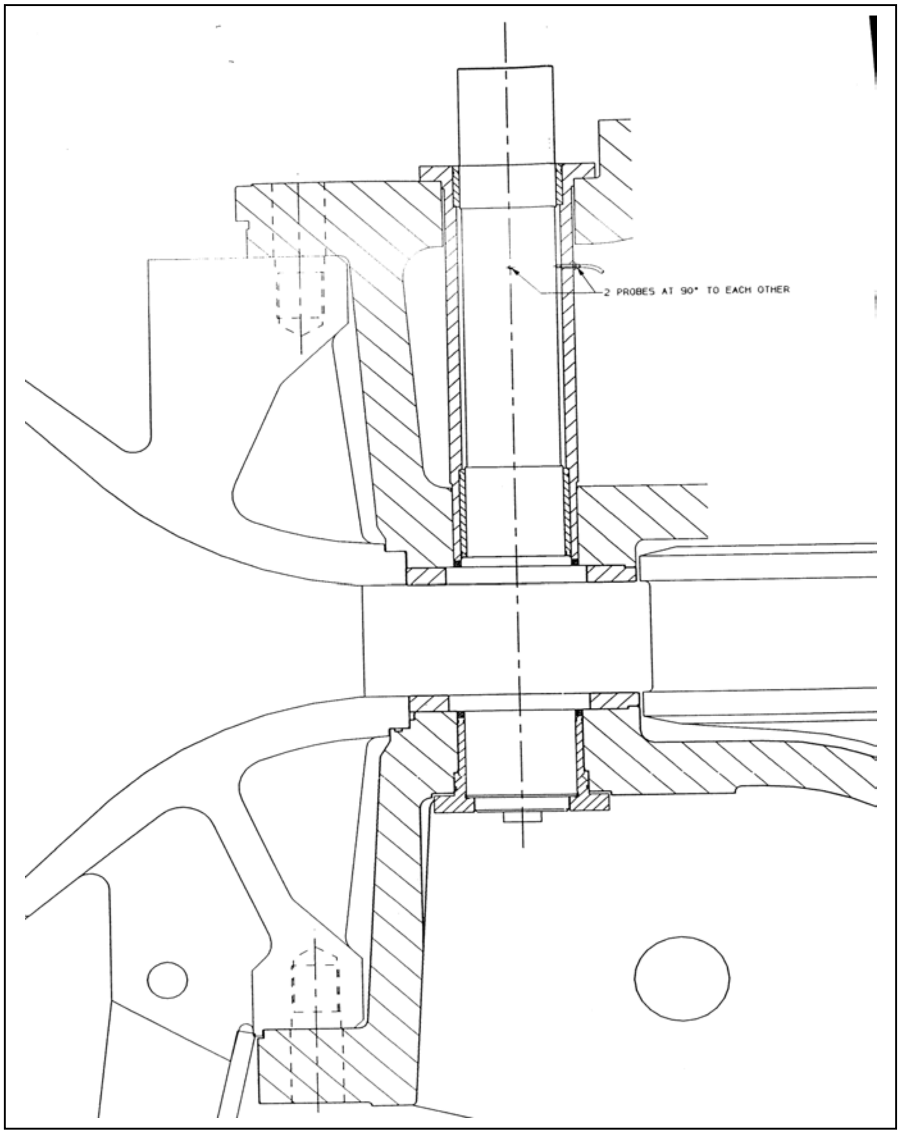

Fig 4 Guide Vane shaft and bearings

Monitoring:

Figs 5 and 6 show typical proximity probe readings when the guide vanes are shut down and 48% open in generation. It is interesting to note that when in generation probe A on the non metallic bearings indicates fairly large negative readings i.e. the shaft is moving away from the probe tip. While both probes on most metallic bearings show a smaller negative movement or remain positive. This behaviour may be significant in that the material is malleable and able to creep under load allowing the shaft and bearing contours to conform with each other or to compensate for non uniform loading present from misalignment. The shaft/bearing contact area is generally larger in non metallic bearings thereby reducing the specific bearing load.

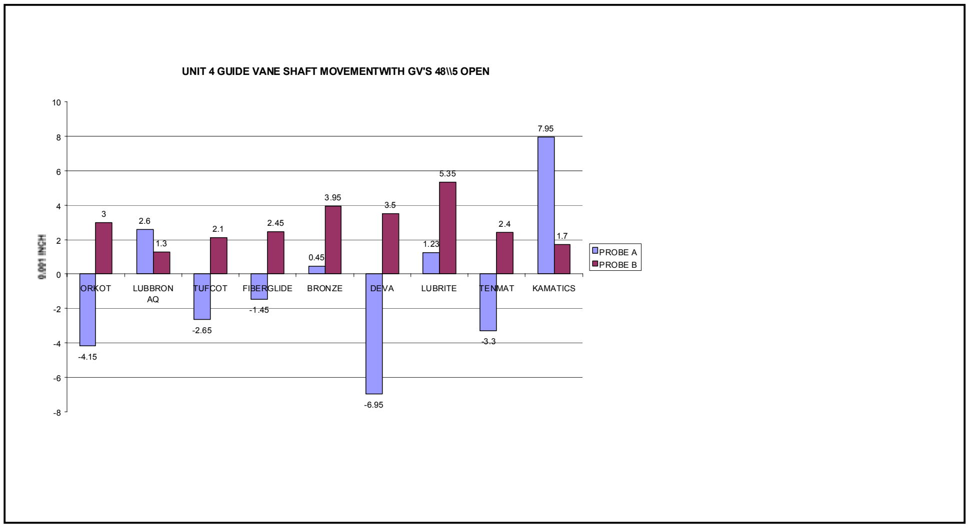

Fig 5

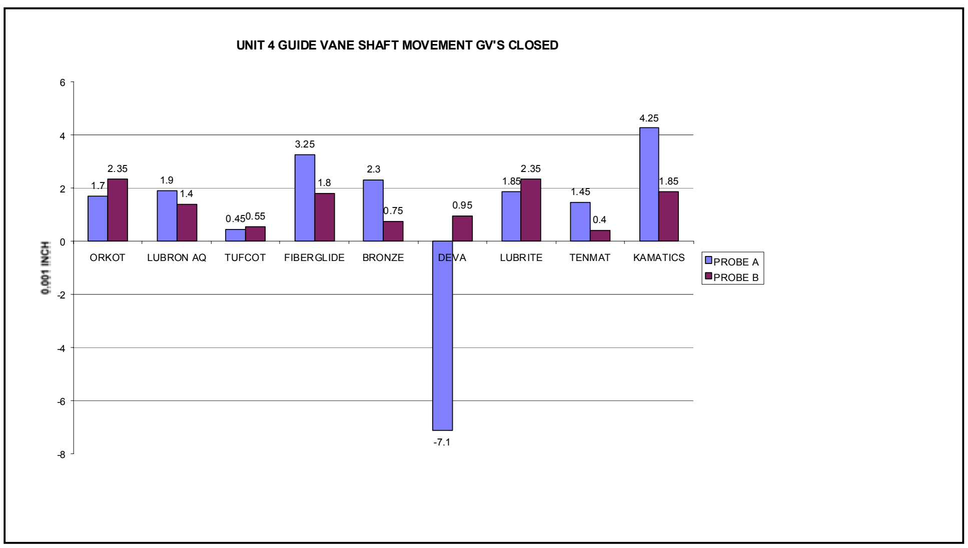

Fig 6

Fig. 7 shows that during the first 2 months all bearings showed accelerated bedding in wear as would be expected , followed by a slow and steady wear rate for Tufcot, Lubron , Tenmat and Orkot which then stabilised without any further significant increase in wear rates after 12 months. The grease lubricated Bronze, Kamatics, Deva, Fiberglide and Lubrite did not reach this stability until 17 months in service.

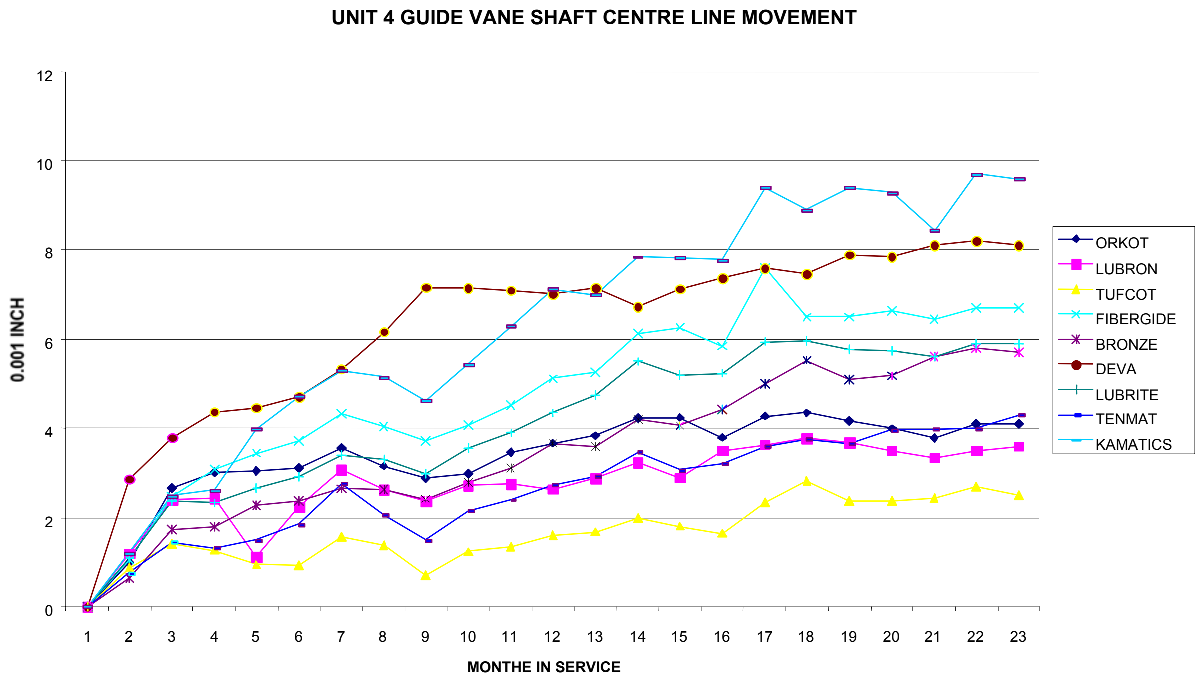

Fig 7

The reason for the apparent good performance of the Tufcot bearing turned out to be due to unexplained expansion in service. The ID was smaller after 2 years in service than when it was installed. There was no water or grease contamination and the manufacturers did not offer any explanation. It is possible that the bearing was not sufficiently oven cured or the resin used expanded in service.

The monitoring gave the operators confidence in the bearing performance and acted as an early warning system for bearing replacement if the probe readings were larger than the allowed max. bearing clearance.

Mid – term inspection results:

After 12 months in service and 6422 spiral casing pressurisation, set B was removed for inspection. The measured wear is recorded in Fig. 8 below.

Fig. 8

PRODUCT	MAX WEAR MM	MAX WEAR 0.001 INCH
KAMATICS	0.125	4.9
TENMAT T184	0.11	4.33
TUFCOT	0.09	3.54
FIBERGLIDE 34	0.14	5.51
*DEVATEX	0.215	8.5
*LUBRITE	0.16	6.3
ORKOT TXM	.04	1.6
LUBRON AQ	.02	0.8
*GREASE LUBRICATED BRONZE	0.175	6.9

* Devatex, Lubrite and Bronze bearings were not returned to service. All other bearings from set B were returned to service for another year.

Final results:

All bearings were removed for inspection after 2 years in service(May 96 to April 98), 11816 operating hours and 10349 spiral casing pressurisation. Results as shown in Fig. 9, 10 and 11 below.

Fig. 9

PRODUCT	GUIDE VANE NO.	MAX. WEAR MM
KAMATICS KARON V	4	0.2075
KAMATICS KARON V	14	0.2375
TUFCOT 100T/G	9	0.16
TUFCOT 100T/G	23	-0.05
TENMAT T184	3	0.13
TENMAT T184	13	0.195
FIBERGLIDE 34	10	0.2125
FIBERGLIDE 64	24	0.165
LUBRON AQ	16	0.015
LUBRON AQ	2	0.015
DEVATEX	21	0.215
DEVATEX	11	0.15
LUBRITE	22	0.16
LUBRITE	12	0.15
ORKOT TXM	15	0.0425
ORKOT TXM	1	0.055

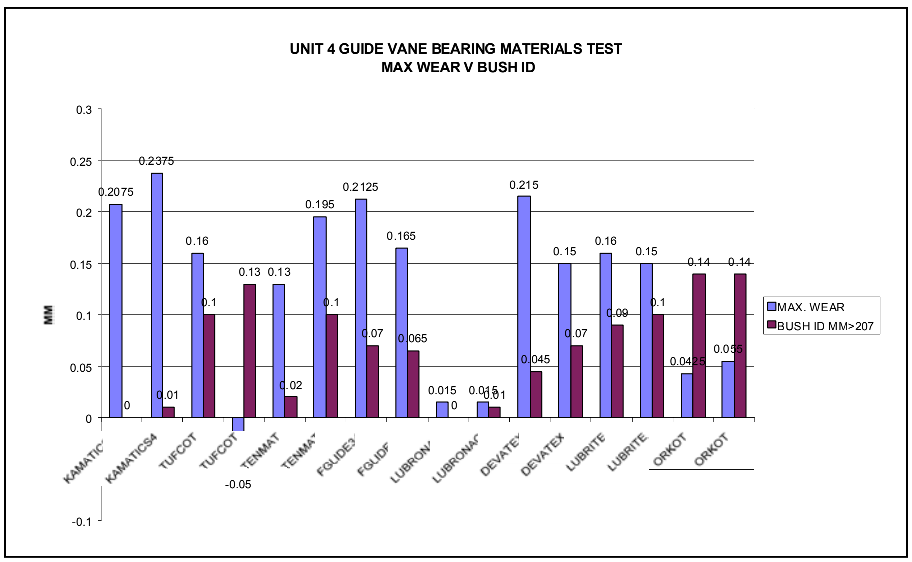

Fig. 10

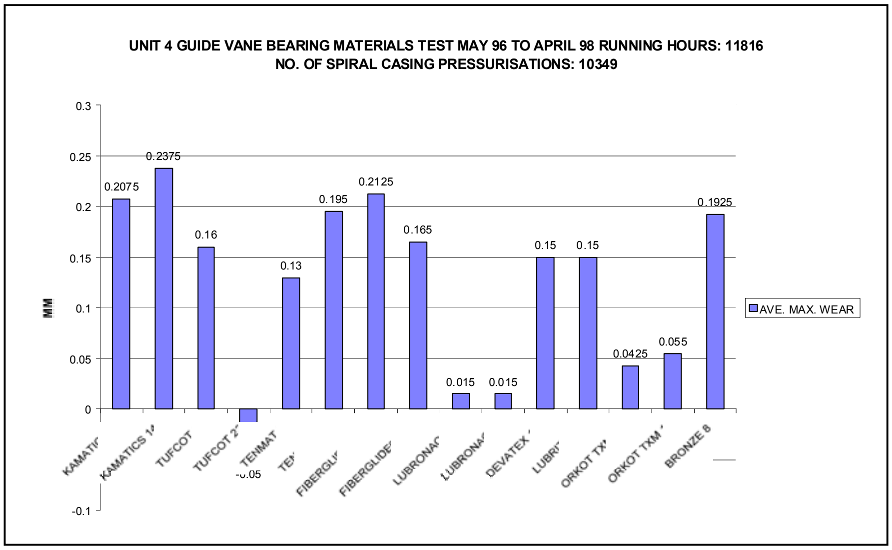

Fig. 11

Further work and future intentions:

A partial test will continue for a further 2 years with self lubricating bearings installed in the upper and intermediate positions. Products to be tested further are: Lubron AQ, Orkot TXM, Glacier 9 P and an improved Kamatics Karon V.

Self lubricating upper and intermediate bearings have been installed in unit 5, the proximity probe monitoring so far has shown lower wear rates than those recorded for unit 4 during an equivalent operating period. This may be due to better load distribution between two bearings with the same properties, where as on unit 4, mixing of grease lubricated bronze intermediate bearing with the polymer type upper bearing may have given rise to a slight misalignment due to varying deflection and subsequently to unequal load distribution, although every effort was made to comply with the manufacturers recommendations and new bronze intermediate bearings were installed on all 24 guide vane pots and the bores finish machined concentric with the upper bearing on a horizontal borer as is the practice at Dinorwig. The average journal surface finish Ra value was 0.68 micron metre.

One pump turbine will be made grease free in the summer of 1999 All 6 units will be grease free by 2004. The regulating ring bearing which is now a complete ring 5.5 m nominal diameter will be replaced by a self lubricating bearing made up of 12 segments forming just over 67% of the existing ring area. The bearing track on the top cover will be covered by a 5 mm thick stainless steel liner and the bearing thickness reduced by an equivalent amount in order to maintain existing levels.

Conclusions:

The test was conducted in order to select a suitable self lubricating bearing material initially for the guide vane shafts, and then to make the whole pump turbine grease free, but the general interest in the test results shown by the manufacturers and operators alike prompts us to make our findings available through this Conference. We must emphasis that the test is primarily relevant to Dinorwig's operating conditions i.e. dry running with frequent stops /starts. Under different operating conditions such as wet running or infrequent stops/starts, lower heads or reduced levels of vibration the tested materials may give different results.

Our test shows that:

- Most of the tested products have outperformed or equalled the grease lubricated bronze for wear rates.
- There was no significant damage on the bearing contact surfaces which were highly

polished on most products. The contact area was 220^0 of arc approximately which is normal for Dinorwig . However, it is thought that the initial contact area would be larger with the polymer type bearing than with the bronze where the contact area will increase with increasing wear.

- ♦ Life expectancy of some tested products could be at least 5 times longer than grease lubricated bronze in the upper bearing position.
- ♦ Self lubricating bearings performance is more predictable than grease lubricated bronze since it is dependent on the consistency and effectiveness of the grease lubricant.
- ♦ Proximity probes are reliable in predicting wear rates
- ♦ The non metallic bearings allow some accommodation of guide vane shaft misalignment by their ability to deflect under load.
- ♦ The importance of quality control on the polymer bearings can not be over emphasised, since there are no equivalent materials certificates to cast bronze, and they do not lend themselves to non destructive testing.
- ♦ There was no correlation between bearing clearance and wear i.e. the concept that a larger bearing clearance leads to reduced wear has not been born out from the test.
- ♦ The cost of non metallic polymer bearings is generally less than bronze bearings.
- ♦ Stopping the use of grease improves the immediate working environment, eliminates the risk of grease ingress into lake water and saves on the cost of grease and grease dispensing equipment.

Biography Details:

William Owen Moss is Mechanical Engineering Manager for First Hydro pump storage plant which includes Dinorwig & Ffestiniog Pumped Storage Power Plants. Educated in Loughborough University, Chartered Engineer and Fellow of the Institution of Mechanical Engineers. Over 20 years hydro experience and 15 years in Nuclear and pulverised fuel power plants.

Burgess Hatem is a Senior Mechanical Engineer for First Hydro. Educated in Nottingham University, previous experience in power and petroleum plants in Syria for 15 years and senior Turbine Engineer in Nuclear power plants for 17 years.