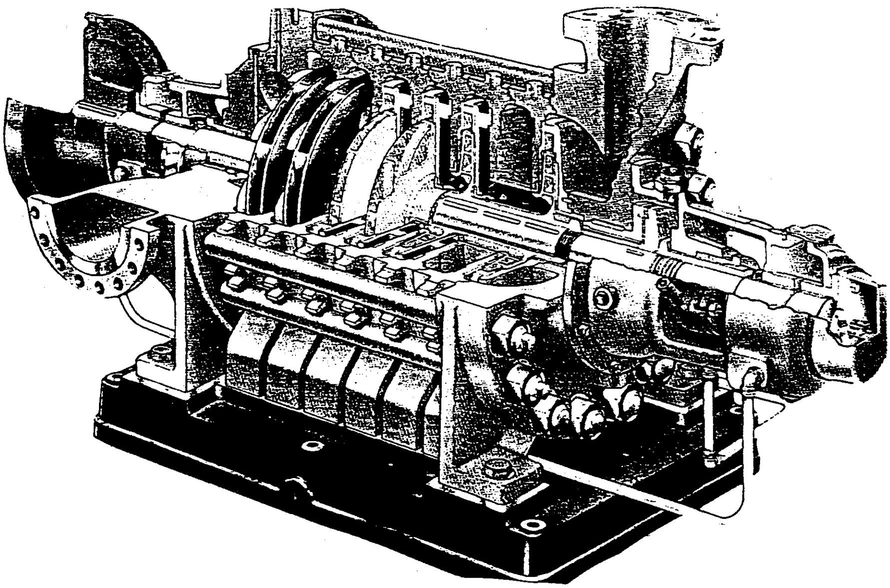
Advances in Mine Dewatering Pumps



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ADVANCES IN MINE DEWATERING PUMPS

1 CURRENT STATUS

2 PRODUCT DEVELOPMENT

2.1 HYDRAULIC DEVELOPMENT

2.1.1 EFFECT OF RUNNING CLEARANCE ON PUMP EFFICIENCY AND PUMPING COST.

2.2 MECHANICAL DEVELOPMENT

2.2.1 WORN PUMP : INCREASE AXIAL THRUST.

2.2.2 CALCULATION OF HYDRAULIC AXIAL THRUST.

2.2.3 BALANCING PRESSURE :

2.2.3.1 OPERATION OF THE BALANCING DISC.

2.2.3.2. INDICATOR OF INTERNAL PUMP WEAR.

2.3 NEW MATERIAL DEVELOPMENT

2.3.1 BACKGROUND.

2.3.2 SURFACE COATINGS.

3 CASE STUDY :

3.1 TESTS CARRIED OUT AT KLOOF GOLD MINE IN SOUTH AFRICA.

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1. CURRENT STATUS

Almost 1200 SULZER mine dewatering pumps valued at approximately R 132,000,000 have been sold to the Southern African Mining Industry, of which +- 130 units are currently installed in the Zambian Copper Mines. It is clear that the mine dewatering pump can be seen as a mature product which it is.

Over the years, demands on the pumps have increased :

- higher pumping head combined with corrosive water and sometimes high contents of suspended solids have resulted in unacceptably short service life for certain applications.

Further, since pumping is not the primary objective of mining the considerable effect of pump wear and the resulting low efficiency on power demand in mines has been largely neglected.

The established pump manufacturers have not been seriously challenged from the market and were slow to react to the new situation.

The purpose of this presentation is to discuss the major opportunities in product improvement and a resulting reduction in the <u>cost per cubic meter of water being pumped.</u>

It is then also the objective of the Pump Division of SULZER SOUTH AFRICA to provide the mining industry with mine dewatering pumps and product support services so as to minimise the cost per cubic meter of water pumped.

2 PRODUCT DEVELOPMENT

2.1 HYDRAULIC DEVELOPMENT

Hydraulic development for mine dewatering pumps has over the recent years focused mainly on :-

- Power concentration
- Improving pump efficiency
- Reduction of instability in pump head characteristic
- Simplification of hydraulic shapes to allow lower manufacturing costs

Since mine dewatering pumps are highly standardized, there is a strong need to minimise the variety of pump sizes and pump parts in order to reduce the level of stockholding. To achieve this, SULZER has focused on the above by fitting modern hydraulic designs into existing pump sizes, whenever possible.

A typical example of this is the fact that the SULZER HPH 54, HPH 58 and HPH 60 have one common mechanical design, therefore a variety of duties can be accommodated by replacing only the hydraulic components.

Appendix 1 - illustrates this variety of duties that can be achieved.

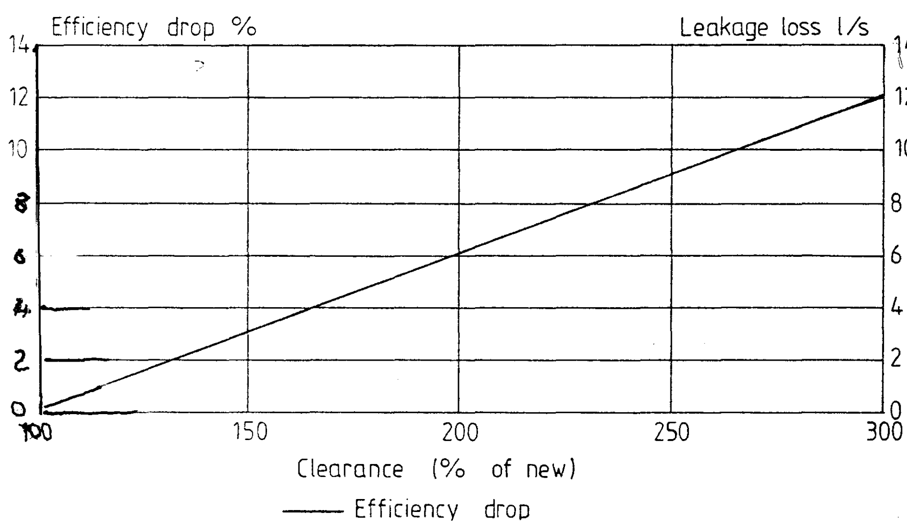
As an example of improved stability and efficiency Appendix 2 shows the difference in performance between the old HPH 48 and the new HPH 50. The results are based on actual comparison tests. The new HPH 50 has an increased efficiency between 2 to 5% depending on the operating duty and when retrofitted into existing HPH 48 pumps will considerably increase the pumping rate without overloading existing motors.

2.1.1 Effect of running clearances on pump efficiency and pumping cost

Since pumping is not a primary objective in mining the power consumption of mine dewatering pumps is normally not closely monitored.

The internal pumps wear depends primarily on the corrosive/erosive properties of the pump media, the relative velocity between media and wear surfaces and on the physical and chemical properties of the materials.

Pump efficiency versus wear ring clearance



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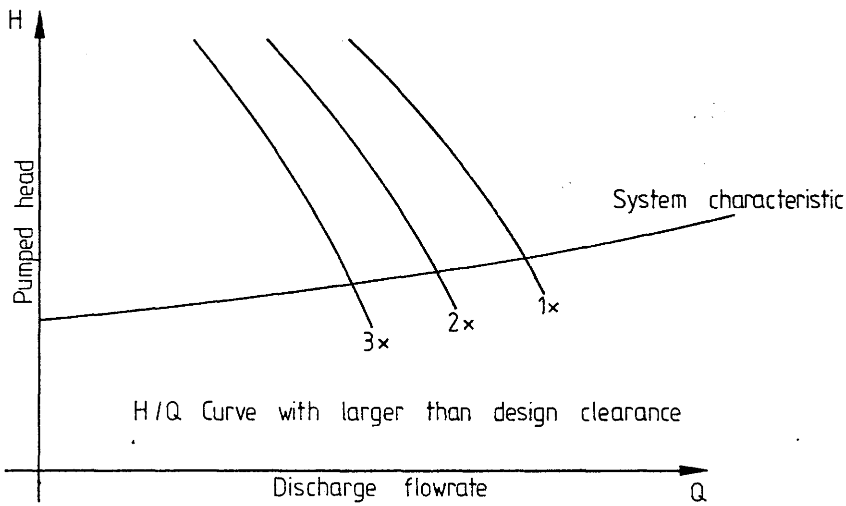
2.2.3.3 Monitoring of Internal Wear Rate

The total flow pumped by the impeller consists of the discharge flowrate plus the internal leakage flowrate. As the internal clearances increase so will the leakage rate increase and hence a reduced discharge flowrate will be experienced.

Due to the fact that the system characteristic in a mine dewatering application is fairly flat, we can assume that the discharge pressure will remain constant with a marginal reduction in flowrate.



The monitoring of the balancing pressure is therefore carried out by measuring the pressure and plot this measured value as a ratio of the actual discharge pressure.

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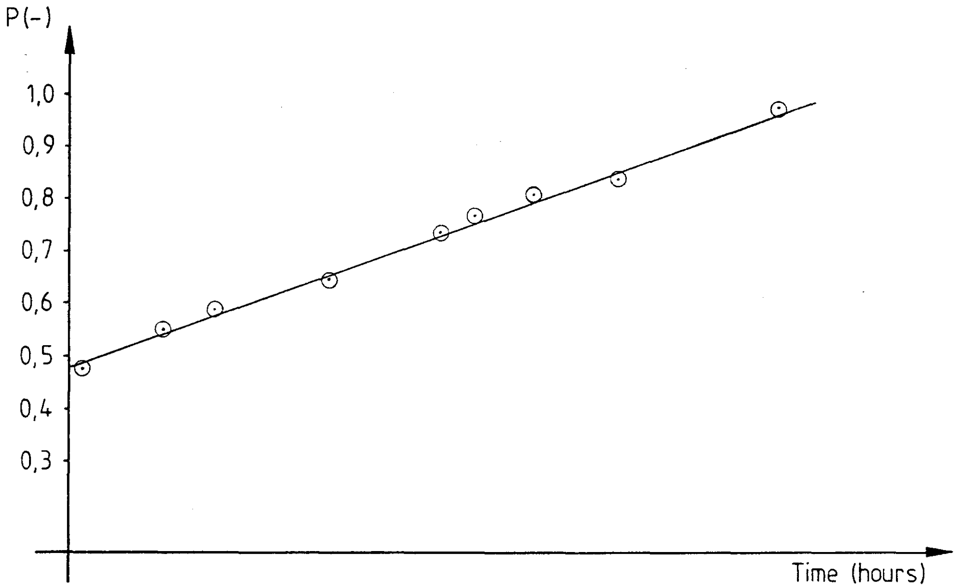
P = Balance Pressure / Discharge Pressure



As already explained, the increase in axial thrust due to internal wear will result in an increased balance disc pressure and hence an increased ratio "p". The balancing pressure can increase up to a maximum value approximately equal to the pressure generated by the pump (i.e. when P = 1,0). At this point, if the internal clearances of the pump gets larger, the axial thrust increases, and there is not enough pressure on the balancing disc to open the wear faces and allow water to flow. This condition will result in metal to metal contact and consequent destruction of the rings. Replacing the wearrings under this situation will have no effect and result only in destroying the new rings.

Based on actual experience, it is found that the practical limit for "p" is around 0,9. The economical limit however lies between 0,7 and 0,9 depending on the actual design. This limit can be determined for each specific pump installation.

2.3 NEW MATERIAL DEVELOPMENT

2.3.1 Background

Against the background of complaints relating to problems experienced with short running hours and high maintenance cost, SULZER has carried out extensive tests using various alternative material combinations to improve the situation.

Materials tested are summarised in Appendix (7).

In addition, as a result of a particular problem, a highly abrasion resistant material combination was tested. This combination was specifically developed and tested by our subsidiary in West Germany for large boiler feed pumps. The stationary wear rings were made in a very high chrome content alloy steel whilst the rotating surface on the impeller was chrome plated. Although very promising results were obtained, some practical problems arose due to the fact that the high chrome alloy steel is extremely brittle and results in fractures if not handled carefully.

The latest development in this area is along the lines of a suitable surface coating.

2.3.2 Surface Engineering Technology

Whist the value of thermal coatings for protection of mine drainage pumps against corrosion and erosion has now been established, the full potential has yet to be realised. As a result of experience over the last decade, a pattern of requirements for mine drainage pump components has been established, with regard to the type of coatings and processes best suited to enhance their performance. Thermal coatings are used in the rehabilitation of expensive, hard-to-replace components, and the enhancement of the performance of new components are achieved by the application of high technology coatings ranging from oxides to chrome steels to tungsten carbides.

2.3.2.1 Standards of Quality

While the mechanism of adhesion and intercoating structure is still being investigated, experience in thermal coating practice has established factors that are mandatory for the attainment of high integrity deposits.

2.3.2.1 Standards of Quality (cont)

The surface chemistry of both the substrata and the impacting media have been shown to have a significant effect on the physical and mechanical properties of the subsequent surface layers. It will therefore be appreciated that the strictest standards of quality control must be observed with respect to the quality of the consumable material used, thermal coating equipment selection, as well as service facilities such as compressed air, process gases and fume and dust extraction.

2.3.2.2 Selection of Process and Consumable Materials

A number of metallic and ceramic coatings have proven track records for a myriad of industrial repairs. However, the choice of materials and processes are, more often than not, governed by experience. Fortunately, similar service environments are common to a number of different operating units and these provide a basis for new applications. Still, careful analysis is critical.

Listed below are some of the materials and their applications for the repair and maintenance of mine drainage pump components.

a) Alumina/Titania :

An Alumina/Titania coating produces a hard bearing surface with low coefficient of friction which is highly resistant to abrasion, erosion and cavitation. Can be finished ground to 12-14 micro inches rms. The coating is deposited by means of a high velocity Plasma Coating System.

Typical Application :
- Impeller neck rings and landings
- Shaft sleeves
- Over-flow pieces
- Large Protection Plates

b) Tungsten Carbide :

A composite coating combining the hardness and wear resistance of chrome carbide in a matrix material providing excellent bonding characteristics. The coating has a dense structure and provides wear resistance from hard surface sliding over the coating and in applications where there is fretting caused by non-intended motion. This coating is deposited by means of the H.V.O.F. System (High Velocity Oxygen Fuel System).

b) Tungsten Carbide : (cont)

Typical Application :
- Diffusers
- Impeller Shrouds, and inlet and outlet vanes
- Small Protection Plates

c) Cobalt Nickel :

A composite cobalt based powder producing a coating with excellent metal to metal wear properties, impact and corrosion resistance with a hardness of 56 - 61 RHC. The coating is deposited by means of the Spray Fuse Process.

Typical Application :
- Balance Valve Wear Rings.

2.3.2.4 Typical Cost Saving :

A recent study of the estimated cost of pump losses due to progressive wear over a period of 6 000 hours was conducted by Prof. E.A. Bunt of the Rand Afrikaans University. Components of a six stage pump were coated and the pump assembled and run alongside a standard uncoated unit. The performance of the pumps was monitored and the information gathered was passed on to Prof. Bunt to analyse.

Calculations were made of flow losses of the multi-stage pumps operating under a head of 98m and at a speed of 1 480 rev/min. The difference in flow loss between the two pumps was recorded and translated into an estimate of increased operating costs over this period. Using an assumed cost of electricity, the extra net operating cost per stage was found to be over R10,000.00 while the volumetric shortfall was 687 030 cubic metres.

At the end of the test period the pumps were disassembled and it was found that the coated units were still in good condition with no measurable changes in the critical dimensions. The uncoated pump components, however, showed evidence of severe erosion and the critical dimensions had worn, opening up the clearance to more than 3mm. The original radial clearance was 0.2mm.

3. CASE STUDY

3.1 TESTING AT KLOOF GOLD MINE

3.1.1 Background

Complaints were received from Kloof Gold Mine with regards to problems experienced with short running hours and high maintenance costs occurring on the SULZER HPH 58 - 10 Stage Multistage Pump Units.

The main cause for concern was the high incidence of balance disc wear ring replacement and balance disc failure.

The situation at Kloof was not expected at all by Sulzer as the same standard pumps with identical number of stages have a service life between 13,000 and 20,000 hours before needing a complete overhaul, about 10 times more of what is achieved at Kloof (Appendix 3).

When advised of the high replacement rate of the wear rings to the balancing device, the cause was considered to be a too high axial thrust due to excessive wear on the eyes and bosses of the impellers. At that time it was not possible to take these pumps off line in order to check the internal clearances. As a preliminary measure it was decided to increase the balancing disc area by 15% which has increased the life of the balancing disc wear rings and reduced part of the problems.

3.1.2 Site Test 1

The main purpose of the first site test was to study the wear pattern of the pumps, i.e. the increase of axial thrust with time.

At the start of the test the pump condition was as new: all clearances were as per drawings. The pump was of standard design except for the balancing disc (area increased by 15%).

In these tests, the following data was recorded :-

- suction pressure at pump suction branch
- discharge pressure at pump discharge branch
- balancing pressure with the help of a special tapping point
- balance water quantity
- shaft displacement
- running hours
- the replacement dates of the wear ring to the balancing discs

Appendix 4 shows the change of balancing pressure, balancing water quantity, wear of balancing disc, exchange of balancing disc wear rings and throttling bush.

3.1.3 Conclusions of Site Test 1

The main conclusions from these first tests are summarised below :-

a. As predicted by the theoretical calculation, the axial thrust (pressure acting on balancing disc) increases with time (wear).

b. The rate of axial thrust increase depends on the water quality.

c. The effect of the balancing disc size can also be explained with the help of the graph (see Appendix 8). The starting point (value p at zero hours on the graph) shifts up if the balancing disc is smaller or down if it is bigger for a given axial thrust.

   Increasing the balancing pressure area by 15% reduced p from 0.575 to 0.5.

d. The balancing pressure can increase up to a maximum value approximately equal to the pressure generated by the pump

   (i.e. when p = 0.9 on Appendix 4).

e. By monitoring the balancing disc pressure, it is possible to "predict" (as long as the water quality stays fairly constant) when a pump will require a general overhaul.

3.1.4 New Material Development

The first tests showed that the rapid increase of axial thrust was due to the unusually fast opening of impeller clearances resulting in a relatively short service life for the pump.

In order to improve service life we decided to introduce some highly abrasion resistant materials and test them.

We selected the following material combination. The casing wear rings to the impeller were made out of 1.4138 soft-nitrated alloy (instead of phosphore bronze) to run against hard chrome plated surfaces (instead of aluminium bronze) on the impeller.

3.1.5 Second Site Tests

In order to determine how the proposed new materials would perform, it was agreed to test two pumps operating in parallel (ensuring that both would pump the same water quality). One pump is called the test pump (with modified internals as described above) and the other the standard pump (with standard internals) as a reference pump.

A second series of tests was started on the two pumps.

Here again, the change of the balancing pressure versus time has been plotted on Appendix 5. In this figure the balance disc wear has been recorded. The balancing water versus time is indicated in Appendix 6.

3.1.6 First Conclusions of Site Test 2

From these series of tests one can draw the following conclusions:-

a. Both pumps had the same balancing pressure at the beginning of the test..

b. The increase of axial thrust (balancing pressure) is much quicker for the standard pump than for the test pump with new materials.

c. The balance disc wear is also higher for the standard pump. The balancing water flow diminishes with increased axial thrust and therefore the gap between the two balance disc wear rings is reduced with resultant faster wear.

5. CONCLUSION

At a time when the Mining Industry is coming under increasing cost pressure, the considerable waste in parts, reconditioning and energy cost for mine dewatering pumping is largely neglected.

Resulting from a situation at the Kloof Gold Mine, where HPH 58 pumps from SULZER supplied in standard execution encountered extreme operating conditions resulting in unacceptably low component life, a close cooperation between SULZER and the Mine has developed to overcome the problem.

This exercise has led to the development and enhancement of our product, especially relating to the use of superior materials.

The method of monitoring and predicting the most effective intervals for reconditioning has been introduced on all SULZER HPH pumps and has proved to be very effective.

One of the most important result of this development is the fact that the running hours of the pump between maintenance have increased considerably with the original efficiency being maintained for much longer periods. This naturally has a direct impact on the energy cost and consequently the cost per cubic meters of water being pumped.

ACKNOWLEDGEMENTS

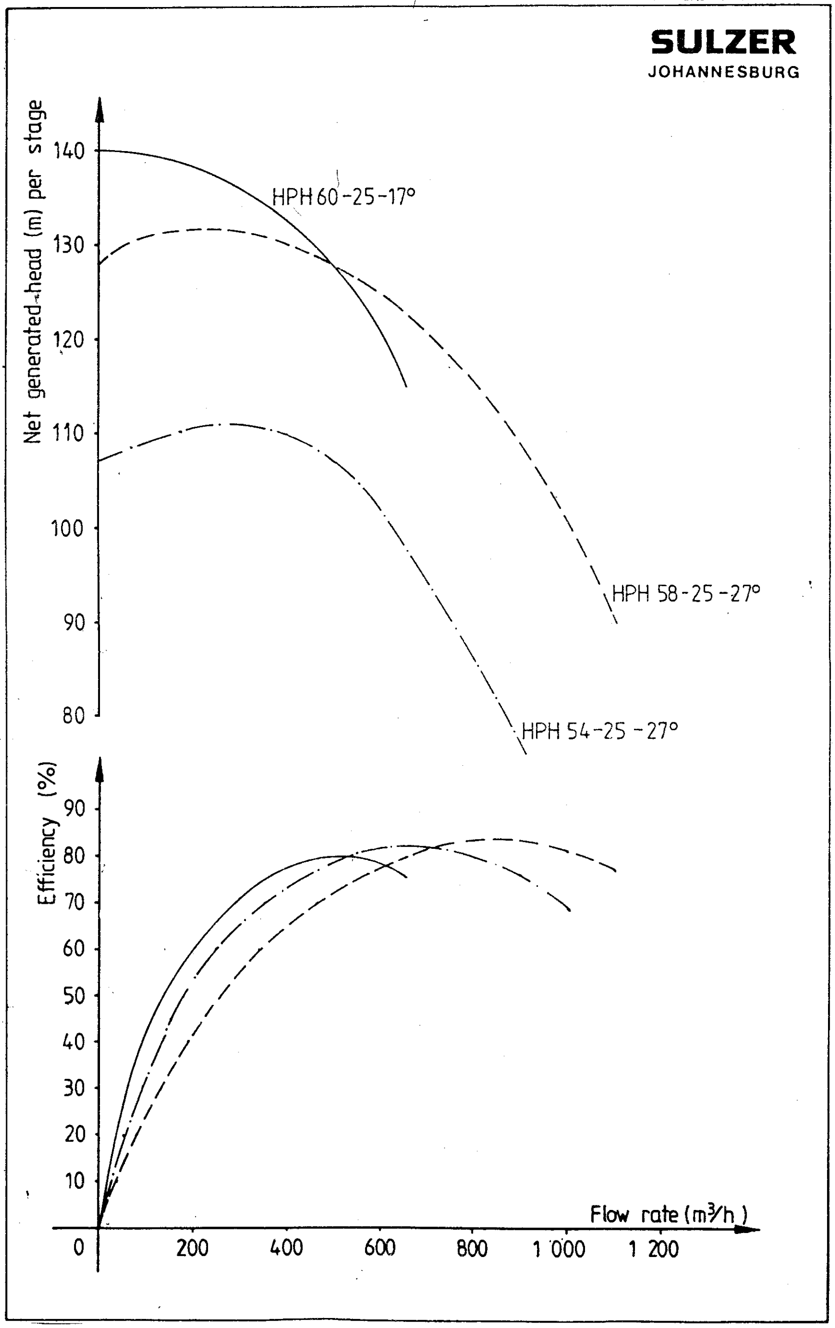
1. "Mine Dewatering Pumps ; A Critical Review"
   R. Vach and J. de Salis

2. Kloof Gold Mine in South Africa
   for the extensive tests carried out.

3. R.A.R.E. (Proprietary) Limited ;
   Surface Engineering Technology

4. Prof. E.A. Bunt ; Rand Afrikaans University
   "Estimate of Cost of Pump Losses due to
   Progressive wear over a period of 6000 Hrs."

APPENDIX 1


SULZER
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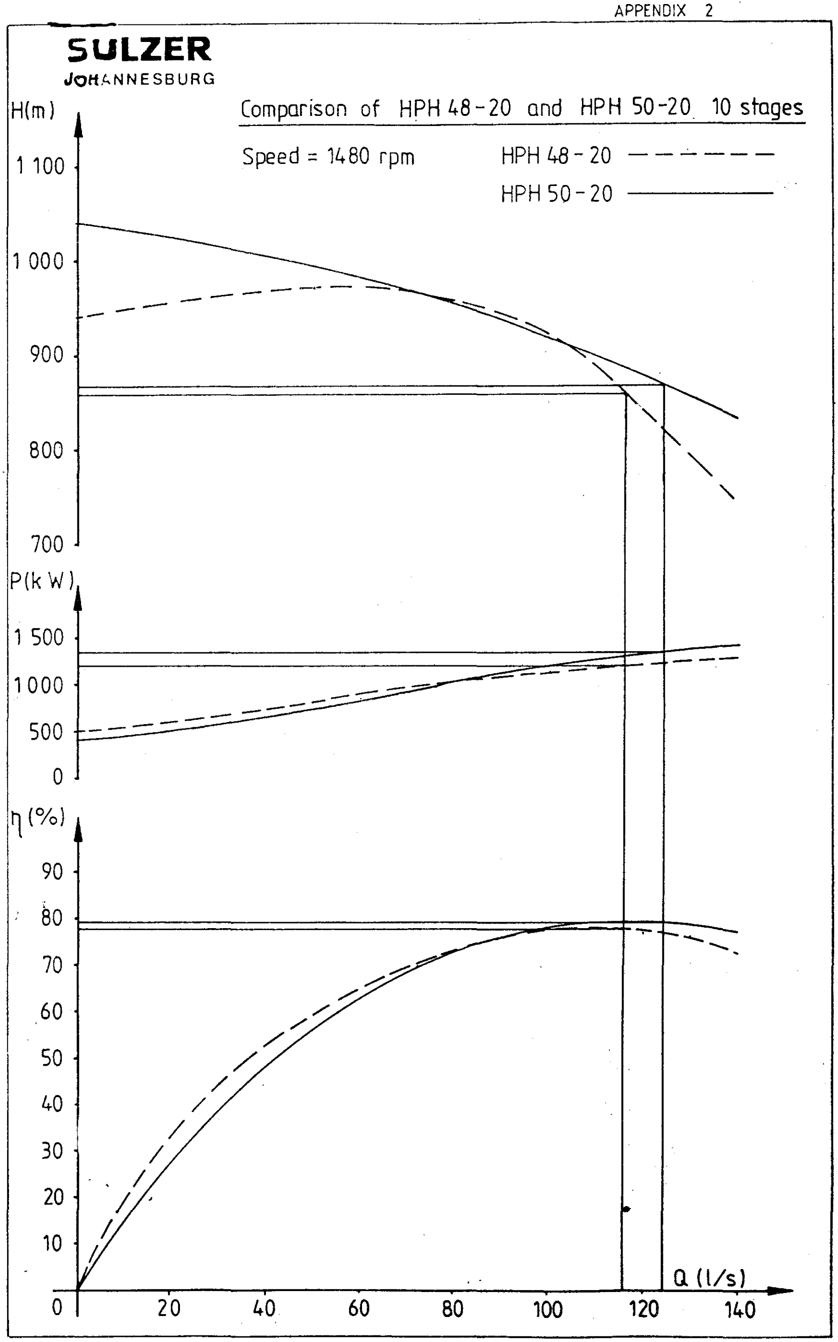
Net generated head (m) per stage
140
130
120
110
100
90
80
HPH 60-25-17°
HPH 58-25-27°
HPH 54-25-27°
Efficiency (%)
90
80
70
60
50
40
30
20
10
0
200
400
600
800
1 000
1 200
Flow rate (m³/h)

APPENDIX 2


SULZER
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Comparison of HPH 48-20 and HPH 50-20 10 stages
Speed = 1480 rpm
HPH 48-20
HPH 50-20
H(m)
1 100
1 000
900
800
700
P(k W)
1 500
1000
500
0
η (%)
90
80
70
60
50
40
30
20
10
0
20
40
60
80
100
120
140
Q (l/s)

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APPENDIX 3

RUNNING HOURS

RUNNING HOURS FOR HPH 58-25 PUMPS

WESTERN AREAS GOLD MINE - NORTH SHAFT

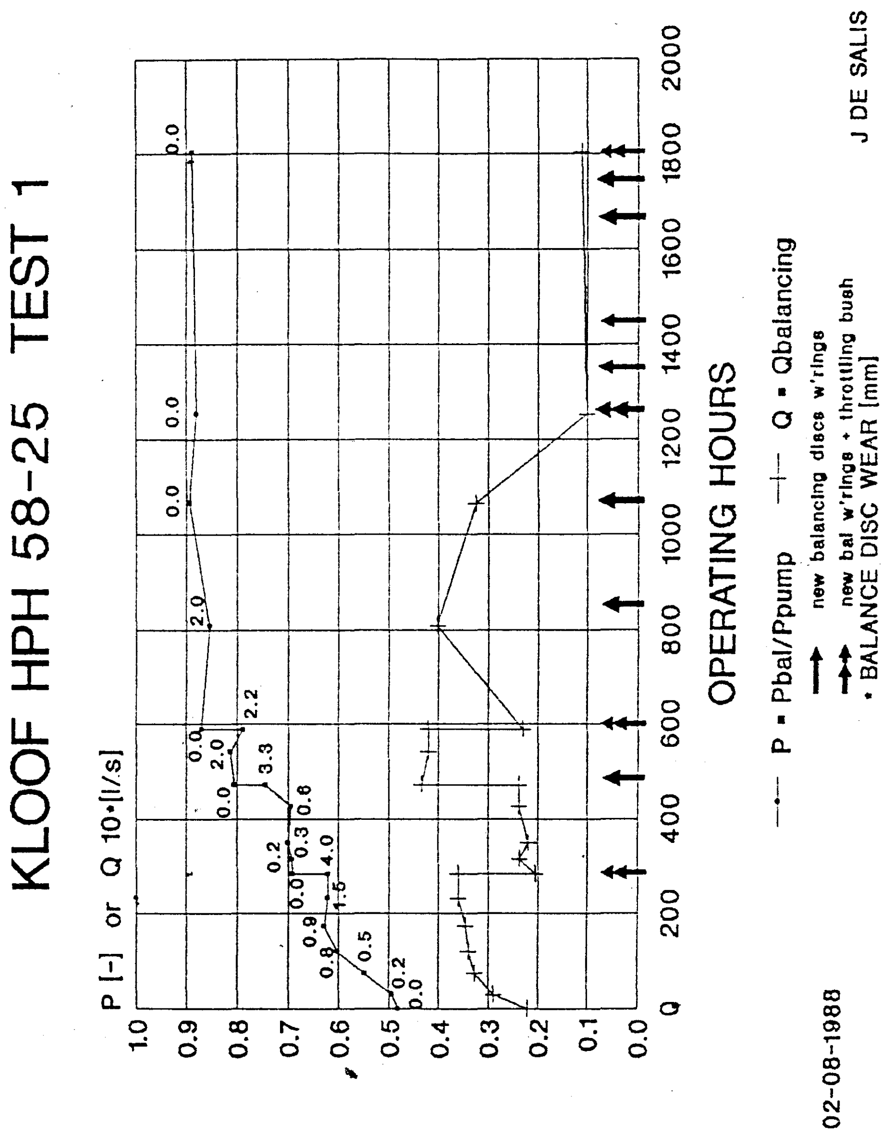
Running hours end of April 1988

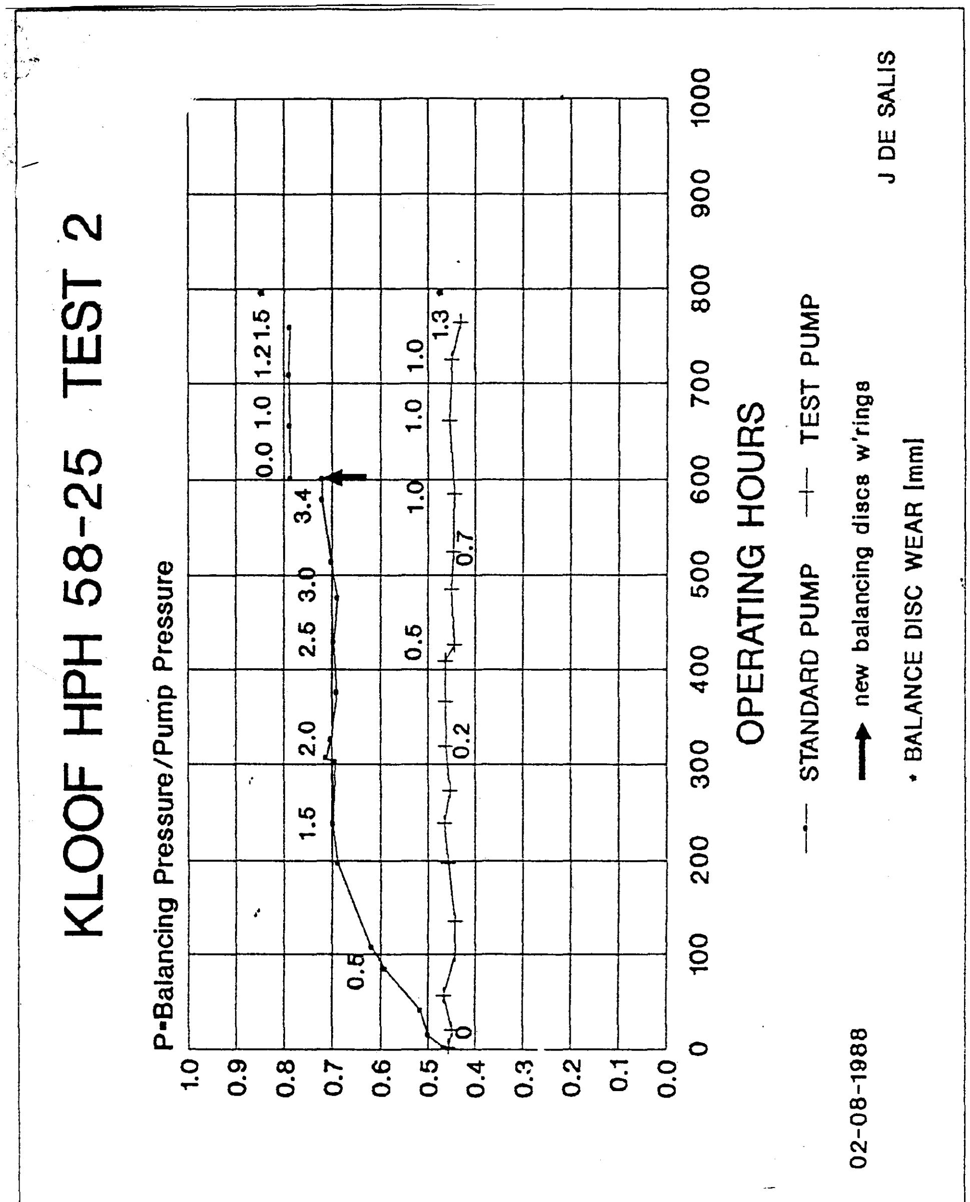
PUMP NO. 1	:	20 523	HOURS
PUMP NO. 2	:	12 957	HOURS
PUMP NO. 3	:	14 809	HOURS
PUMP NO. 4	:	16 445	HOURS

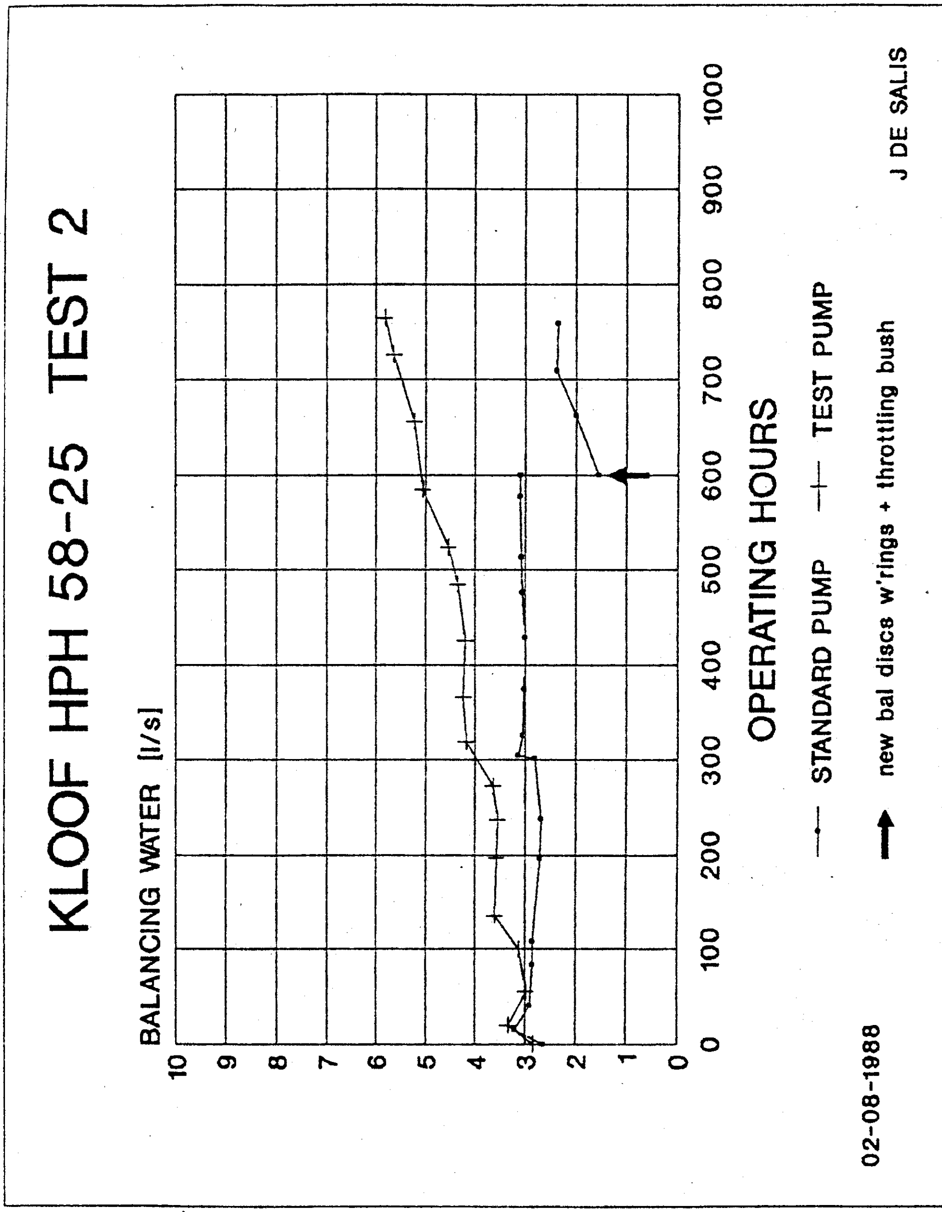
PUMP NO. 3 WAS RECONDITIONED AND IS RUNNING

6 805 HOURS SINCE THEN

ABOVE PUMPS HAVE 10 STAGES


KLOOF HPH 58-25 TEST 1
P [-] or Q 10•[l/s]
OPERATING HOURS
P = Pbal/Ppump
Q = Qbalancing
new balancing discs w'rings
new bal w'rings + throttling bush
* BALANCE DISC WEAR [mm]
02-08-1988
J DE SALIS


KLOOF HPH 58-25 TEST 2
P=Balancing Pressure/Pump Pressure
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
100
200
300
400
500
600
700
800
900
1000
OPERATING HOURS
STANDARD PUMP
TEST PUMP
new balancing discs w'rings
• BALANCE DISC WEAR [mm]
0.5
1.5
2.0
2.5
3.0
3.4
0.0
1.0
1.2
1.5
0
0.2
0.5
0.7
1.0
1.0
1.0
1.3
02-08-1988
J DE SALIS


KLOOF HPH 58-25 TEST 2
BALANCING WATER [l/s]
0 1 2 3 4 5 6 7 8 9 10
0 100 200 300 400 500 600 700 800 900 1000
OPERATING HOURS
STANDARD PUMP
TEST PUMP
new bal discs w'rings + throttling bush
02-08-1988
J DE SALIS

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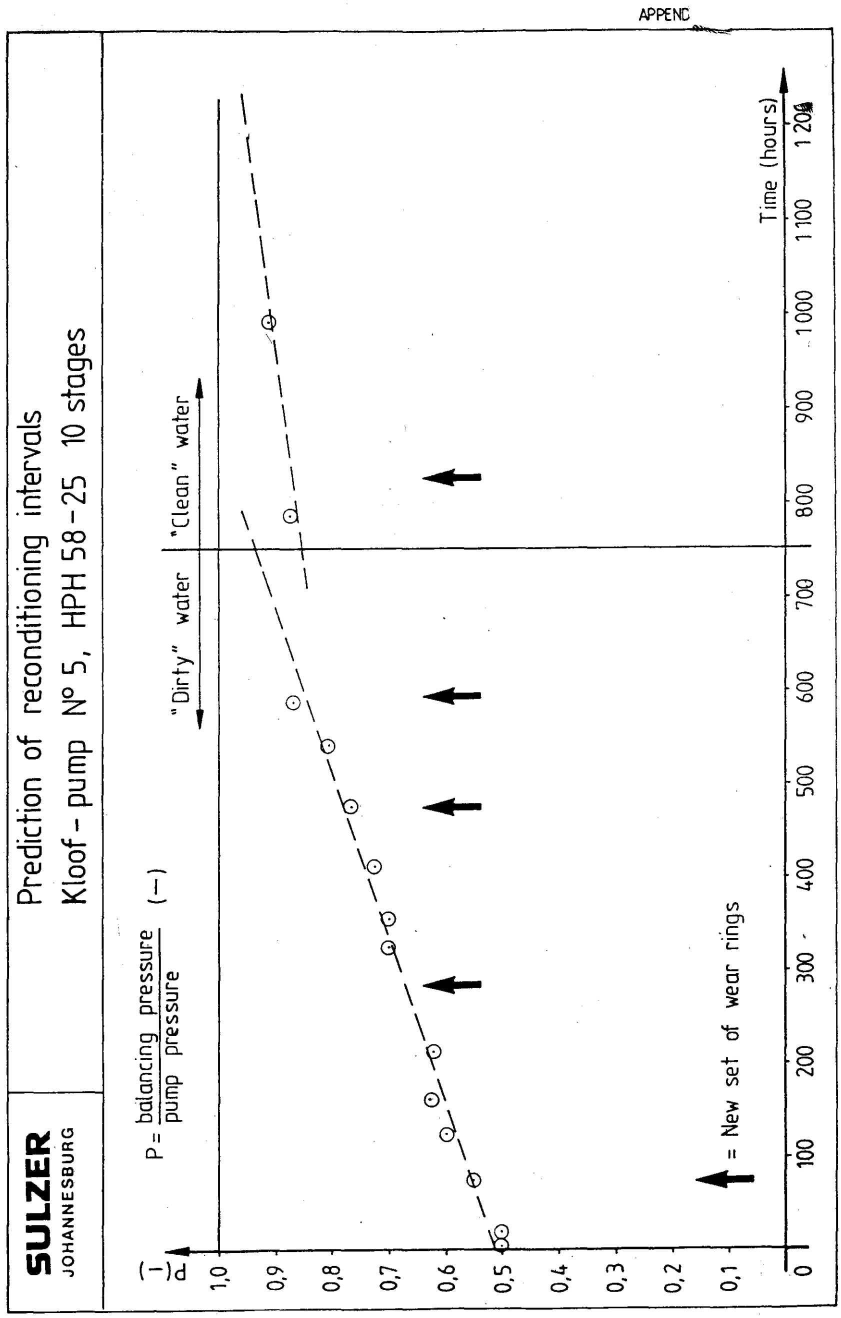
APPENDIX 7

MATERIALS SELECTION CHART

STAGE	IMPELLER	PROTECTION PLATES		WEARING RINGS	
		LARGE	SMALL	CASING	SMALL
1	P B I	P B I	-	0,6025	RCH 1000 (yellow)
2	A B I	P B I	PB 7 + Ceramic	RCH 1000 (Yellow)	PB 2
3	P B I	P B I	PB 7	PB 2	PB 2 + (Ceramic)
4	P B I : Wrg.areas Ceramic	A B I	PB 7	PB 2 + Ceramic	PB 2 + tuCarbide
5	P B I : Wrg.areas tu.carbide shrouds etc.Covac	A B I	A B I	PB 2 + tu.carbide	0,6025
6	L G 3	L G 4	BELZONA	0,6025	L B 2
7	L G 3 Wrg.areas Electro-less Ni Shrouds etc tu.carbide	VESCONITE	BELZONA	L B 2	VESCONITE
8	L G 3: Wrg.areas Ceramic Shrouds etc hard Cr.	VESCONITE	P B 7	VESCONITE	P B 2 +
9	P B I : Compl.hard Cr.	RCH 1000 (White)	RCH 1000 (White)	P B 2 + 19300	P B 2 + 19222
10	P B I Compl.electroless Ni	L G 4	P B 7	P B 2 + 19222	L B 2
11	P B I	L G 4	A B I	L B 2	0,6025
12	A B I	RCH 1000 (White)	RCH 1000 (White)	RCH 1000 (Green)	-


APPEND
SULZER
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Prediction of reconditioning intervals
Kloof - pump N° 5, HPH 58-25 10 stages
P = balancing pressure / pump pressure (–)
P (–)
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
"Dirty" water
"Clean" water
= New set of wear rings
100
200
300
400
500
600
700
800
900
1000
1100
1200
Time (hours)

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APPENDIX 9

LIST OF SYMBOLS AND UNITS

a	(mm)	balancing disks gap
b	(mm)	fixed throttling gap
c	(m/s)	velocity
Com	(m/s)	velocity
F	(N)	force
g	(m/s^2)	gravity constant
H	(m)	delivery head
p	(Pa)	pressure
Q	(m3/s)	quantity (flow)
R_2	(m)	impeller outer diameter
R_S	(m)	wear ring diameter
r	(m)	radius
ω	(l/s)	angular velocity
π	(-)	pi = 3.14
ρ	(kg/m3)	specific weight of water
ξ	(-)	friction co-efficient

Main subscripts :

ds	:	discharge side
ss	:	suction side
l	:	leakage