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HANDPUMP TESTING AND DEVELOPMENT

Part 5. The Second Year- Results of Completed and Ongoing Test

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Lund Sweden 1985

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PREFACE

Handpumps have been widely used for a long period of time in rural water supply projects. Although the technology of handpumps is rather simple, the "ideal" handpump has not yet been made.

This can possibly be explained by the sometimes contradictory demands usually put on handpumps, for example:

low cost - long lifetime
low weight - sturdy design
high capacity - easy to operate
high quality - local manufacturing

Thus, there are still improvments to be made. Because of the large number of handpumps in use, even a small improvment could have a considerable impact on pump reliability, maintenance cost etc.

This project is directed, partly towards testing of new designs and partly towards testing of materials, especially materials for cup seals. The report contains the latest results from this laboratory test.

Lund December 1985

Robert Hahn Per Johansson

CONTENT

1. INTRODUCTION

1.1 Background

The Handpump Testing and Development project was started at Lund Institute of Technology in 1982, by Robert Hahn from the Department of Environmental Engineering and Oscar Carlsson from the Swedish Covenant Church (SCC). The project is financed by the Swedish International Development Agency (SIDA) and SCC, which also has initiated a well drilling project and a workshop for Handpump manufacturing in India. Through SCC the results from the laboratory tests can be directly verified and/or implemented in pump production.

Further information on the project is given in the papers:

Handpump Testing and Development

Part 1. Project Description (1982)
Part 2. Interim Report (1982)
Part 3. New Design: Particle Separator, Foot Valve and Rod Guide (1983)
Part 4. The First Year-Results of Completed and Ongoing Tests (1984)

1.2 Project Objective

The objective of the project is to improve handpumps in general and the below-ground components in particular. The test work comprises.

1. Long time endurance test in a test rig, that can operate 12 cylinders in the same time. This will mainly give information on which materials that are most wear-resistant.

2. Testing of new designs. These can be evaluated and compared with conventional designs under the same conditions, in the test rig

2. PROJECT DESIGN

The rig is designed for testing 12 cylinders at a time. It is electrically driven and the well depth is simulated using a pressure tank. A test pressure of 30 meter water column is used as a standard for the endurance tests. The connections to the 12 pumprods are evenly distributed on two shafts so that 3 pistons are started every quarter of a pumping cycle. This supplies an even flow to the pressure tank.

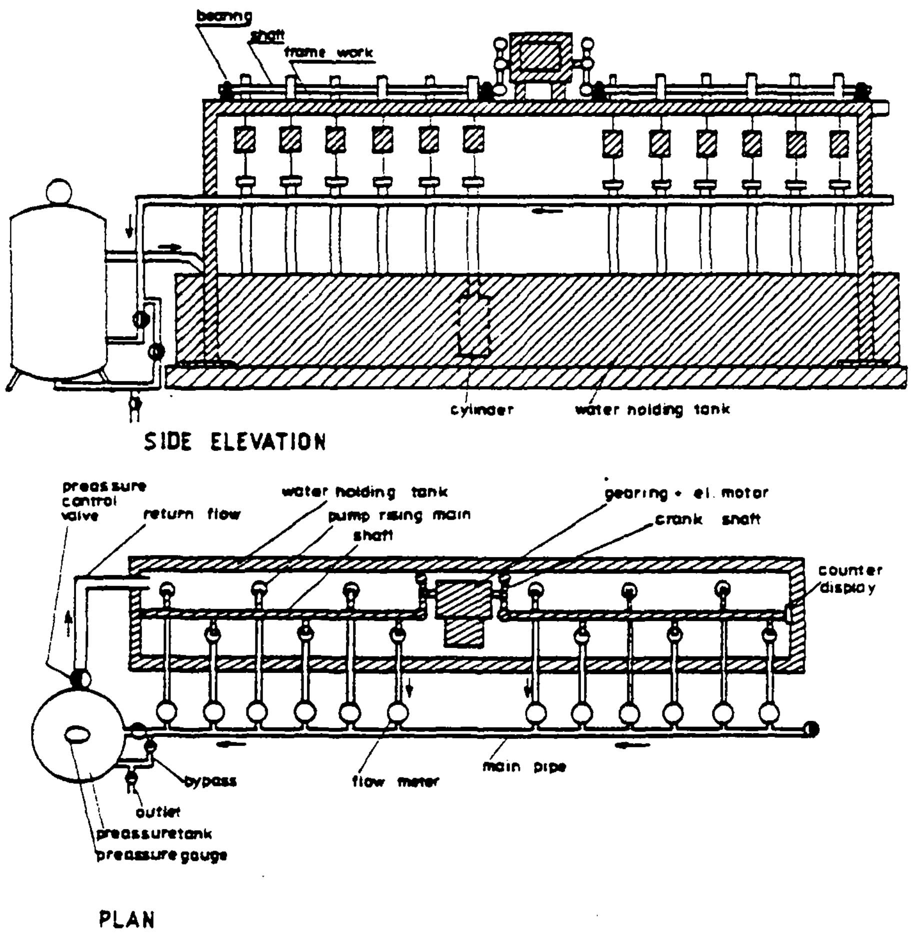


Figure 2.1. Schematic plan of the test rig.

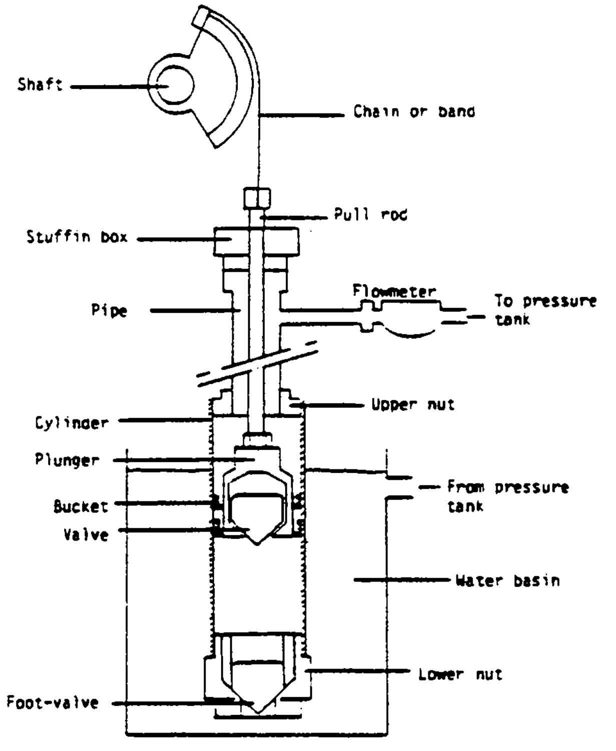


Figure 2.2. Detail of a cylinder set.

The quality of the water which is recirculated in the system is tabulated below. No particles are added to the water, but some suspended matter is continuously accumulated due to wear and corrosion. About 3/4 of the water volume in the system is changed regularly to keep the pollution at a constant level.

Parameter	Min.	Med.	Max.
Temperature (^oC)	14	20	22
Colour (mg Pt/l)	15	35	50
Turbidity (JTU)	-	10	-
Suspended solids (mg/l)	2	4	6
Conductivity (ms/cm)	0.4	0.5	0.6
Chloride (mg/l)	30	40	60
Iron (mg/l)	0.6	0.7	0.8
Calcium (mg/l)	55	60	65
Hardness (mg CaO/l)	110	120	130
(^{o}dH)	11	12	13
HCO_3^- (milliequival./l)	2.6	2.7	2.8

Table 2.1. Variations in water quality.

Measurements

The data recorded are:

- Pressure fluctuations during a pump stroke
- Force required
- Continuous registration of water flow
- Continuous registration of number of strokes
- Calculation of pump efficiency
- Control of water quality

Other data like temperature and atmospheric pressure are checked. Besides regular data recording, special tests for leakage through the cylinder assembly or the plunger, and tests of head loss over plunger and footvalve at different flows are made. The regular check-up of the condition of the different parts of the cylinder assembly is also important. The wear is assessed and measured, when possible, with micro-meters.

3. RESULT

3.1. Connection Handle - Pumprod

Most of the tests in this project are based on the concept of the SWS or the India Mark II pump. The connection between the handle and the pumprod in these pumps is made from a chain and a system with a circle segment, to provide pump rod alignment during pumping.

The sturdy chain presently used in these pumps does not cause any problem. Some wear of the chain and replacement of it after 3-5 years is quite natural. The alternatives of this type of chain tested here were installed since the design of the test rig provided for this opportunity. The object of this part was to find out if other types of chains have an even better performance and if synthetic bands will work as well and last as long as the chain. If so, the band is a better alternative as it is less expensive and easier to install.

3.1.1 Roller Chain 1"

This chain fitted according to figure 3.1 is standard in both SWS and IM II pumps. The chains installed in the test rig showed a tendency to get stiff after a few months. After cleaning and boiling in a mixture of grease and graphite, the chains operated smoothly. Chains installed in new handpumps are treated with grease and graphite boiling, which clearly proved to be necessary.

Figure 3.1 Standard SWS roller chain.

3.1.2 Roller Chain 1/2"

At first this smaller size chain was tried, since the manufacturers data indicated that it would be sufficient for the calculated static and dynamic load. Two chains were tried.

The first one operated in the same way as in the SWS pump, i. e. the weight is carried on the rolls on which the chain is resting. This chain broke after 880. 000 strokes. It was repaired but broke again after another 1.6 million strokes and was then replaced by a 1" standard chain.

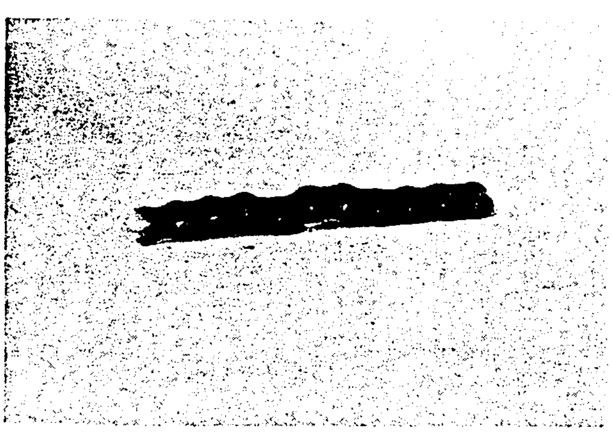


Figure 3.2 The broken 1/2" roller chain.

The second chain was mounted so that the edges of the chain links rested on a polymeric material called Non-fric. This material is sometimes used for protecting chains from wear. The 1/2" chain did not break. However, after 3. 7 million strokes the chain was stiff and therefore replaced with the 1" chain. The wear in the links could be reduced using more grease, but this first test indicated that the Nonfric material would not really be an improvement and this combination was not tested further.

3.1.3 Fleyer Chain

This type of chain has four blades in each link instead of two as in the roller chain. It is designed for lifting. This kind of chain is, for example, used to move the forks in fork-lift trucks. It was therefore found to be interesting in this application, too.

The size, 1/2", proved to be sufficient in this case. The weak point in this type of chain, however, was that heavy wear appeared at the points where the chain rested on the circle segment. The wear at the ends of each link made the chain stiff. The two chains in the test rig had to be replaced after 3. 9 and 8. 5 million strokes respectively. Both of them were very stiff, which can also be seen in figure 3.3.

Figure 3.3 A fleyer chain stiff from wear

3.1.4 Roller - Arm

This device was tried as an alternative to the chain. The roll is attached to the pump rod and the arm to the handle, instead of the circle segment. The form of the track in the arm allows the rod to keep straight during the whole pumping cycle. The idea of this design was that it could be locally manufactured and thus more easily available and at a lower cost.

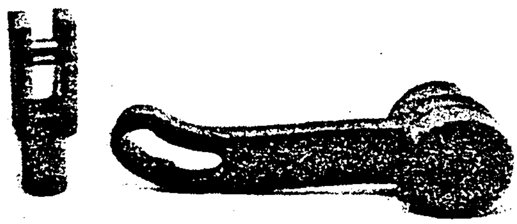


Figure 3.4 Roll and arm

The roller was tested in the rig for 1. 5 million strokes. After that time the pin holding the roll broke, as a result of wear in the arm forcing the roll to shorter and shorter movements during each stroke. The principle proved to be correct, but in practice the device has to be improved. This can be done, e. g. by higher steel quality in the arm and precise machining and possibly also by replacement of the roll with a ball bearing. Then, however, the complexity and the cost of the design increases. As we then come too far away from the basic idea we decided not to continue testing.

3.1.5 Reinforced Rubber Band

This band is manufactured in Sweden, from EPDM rubber with a reinforcement of five thin steelwires. The design load is 800 kg. The band is flexible, but obviously not suited for continuous bending during operation. It broke after 0.8 million strokes. The wires were torn off and on the bottom side of the band the wires began to get visible although from the beginning they were embedded in the rubber. No further testing was done.

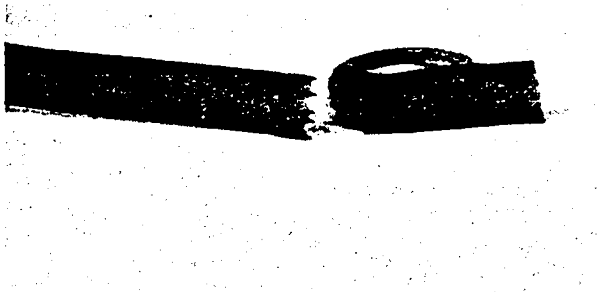


Figure 3.5 Reinforced rubber band broken.

3.1.6 Single Synthetic Band

The single band was tested for 8 million strokes. After that it was still in good shape, but the surface of the bottom side of the band had a tendency to become ragged. Reports from field tests in India during the same time, indicated that a single band would not be sufficient. Some bands had broken, probably due to irregular pumping. This test was, therefore, interrupted; tests using double bands were, however, continued.

3.1.7 Double Band - One Connected.

The change over to double bands was based on the assumption that if the upper band is carrying the load, the band underneath will protect it from wear. The movement from the stretching of the band will be between the upper and the lower band, so that wear from the metal surface of the circle segment will be on the lower band which does not carry any weight.

Figure 3.6 Doubble band

3.1.8 Doubble Band - Both Connected.

In this test the bands are fastened so that both of them carry the load. When the pump rod is in its middle position of a stroke, both bands carry the same weight. In the starting position the load is only on the inner band. In the stop position when the plunger has reached the upper part of the cylinder, the load is only on the outer band. This arrangement will minimize the stretching and subsequent movement and wear of the band.

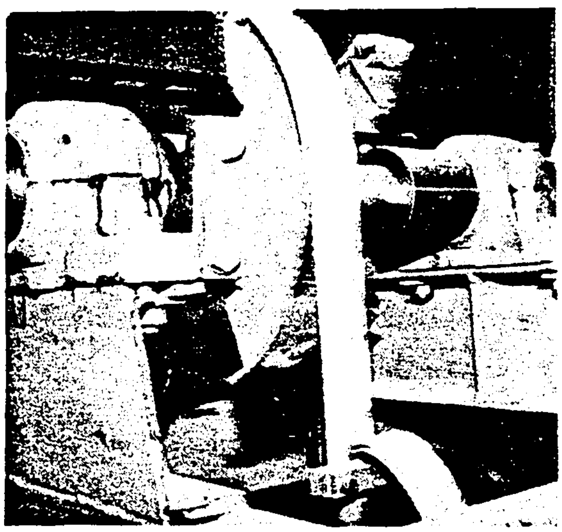


Figure 3.7 Doubble band both operate.

Test	Type	Million strokes	Result
1	Doubble band, both with load on	(36.4)	In good condition
7		(37.2)	-"- -"-
9		(46.1)	Some wear, in operating condition
11		(33.1)	In good condition
5	Double band, one with load on	(49.2)	Worn, but operating
6		(48.9)	-"- -"-
8		(46.9)	-"- -"-
7		11.3	In good condition. Test interrupted
10		35.5	Worn but in operating condition Test interrupted
7	Single band	8.1	In good condition. Test interrupted
5	Reinforced rubber band	0.8	Broken
5	Fleyer chain 1/2"	3.0	Worn stiff
6		8.5	Worn stiff, broken
2	Roller chain 1/2"	2.1	Worn, broken twice
3		3.7	Worn, stiff
2	Roller chain 1"	25.2	Worn stiff, broken
2		(15.2)	Worn, broken
3		19.7	Worn, broken
3		(28.4)	Worn, broken once, operating
4		35.2	Worn, broken
12		(27.6)	Worn, broken
11	Roller-arm	1.5	Broken, test interrupted

Table 3.1 Summary of tests with chains and belts. Figures in brackets indicate that testing is continued.

3.2 Plunger

The plunger should be of a sturdy and reliable design, give a good support to the sealings and contain a well functioning valve. These requirements are met in different ways by the plungers tested here. Generally, all the plungers tested were operating well.

3.2.1 RIMA-Steel Ball Valve

This plunger, from the Swedish manufacturer Holmgrens Armaturfabrik has, like the whole cylinder assembly, a very sturdy design. The plunger, including the valve seat, is made of gun metal and the valve operates with a steel ball. The cylinder is designed for deep wells and was obviously not suited for as high a pumping speed as 50 strokes/minute, which is used in the test rig. The steel ball would not close directly but bounce on the valve seat, the effect being that it did not close entirely before the beginning of the subsequent stroke. As a result, the mean flow was less than from the other cylinders, although the diameter of this cylinder was greater. Since the cylinder did not operate well, the test was not continued. After only a short time of operation, however, wear from the hammering of the steel ball was beginning to show on the valve seat.

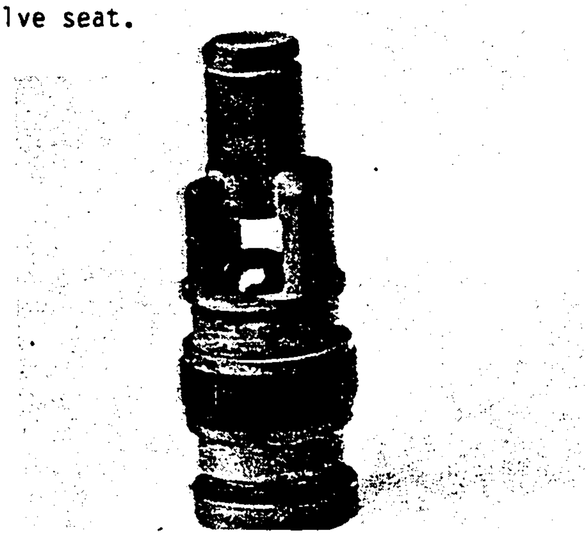


Figure 3.8 RIMA plunger

Test	Type	Description	Million strokes	Result
2	SWS with plastic cone	POM-cone	32.5	Some wear, in operating condition
10		-"-	(48.6)	-"- -"- -"-
4		-"-	(54.6)	-"- -"- -"- Cone o-ring changed after 31.2 Mstr.
9		POM-and PVC-cone	(46.0)	POM cone worn, replaced with PVC after 5.6 MSTR.
7		PVC-cone	(56.6)	Some wear, in operating condition
1		-"-	(33.5)	-"- -"- -"-
2		-"-	(17.2)	In good condition
11		-"-	(33.1)	Some wear, in operating condition
10	Piston with ball valve	Steel ball	1.8	Improper operation, test stopped
5		Rubber ball	(52.6)	Guides worn, ball in operating condition.
12		-"- -"-	(27.6)	In operating condition.
8	India Mark II with poppet	R & C	(46.9)	Operating, poppet nut heavily worn
3		R & C	(48.1)	-"- -"- -"-
6		MEERA	(42.4)	Poppet nut worn, poppet rubber seal worn out totally, operating
12	Test design	All POM	4.5	Test stopped, threads damaged

Table 3.2 Tests of piston. Figures in brackets indicate that testing is continued.

3.2.2 SWS-Rubber Ball Valve

From field experience, we know that the rubber ball in this plunger is sometimes damaged. The reasons for this are related both to the material (the rubber gets worn and can have deficiencies from fabrication) and to the operation (the wear is accelerated by the constant vibration of the ball when pumping). On the plunger tested we also noticed that the gun metal guides for the ball had been worn, however, not to a degree affecting the operation of the valve.

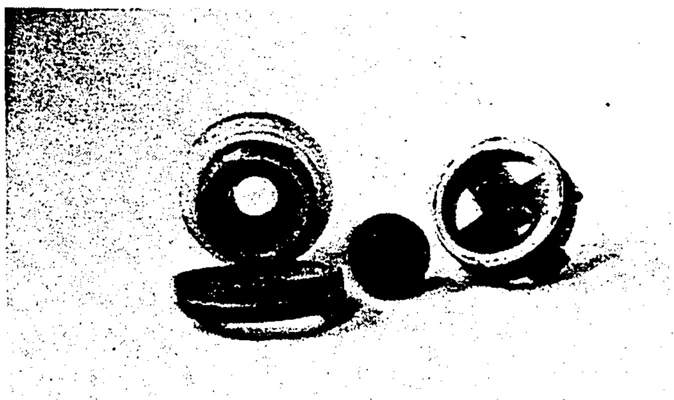


Figure 3.9 SWS plunger

3.2.3 SWS-Plastic Cone

In the plunger, the ball is replaced by a plastic cone which has a better shape considering the hydraulic properties of the valve. It responds rapidly to pressure variations, i. e. opens and closes without delay. The leakage through the plunger valve is reduced by a rubber o-ring inserted in the bottom end of the cone. The o-ring is then pressed against the valve seat in a closed position.

Out of six plungers tested, so far the cone has been worn in only one. In this case, the diameter of the cone was too small from the beginning, allowing it to move sideways during operation. The wear was especially noticeable at the upper and lower ends of the cone.

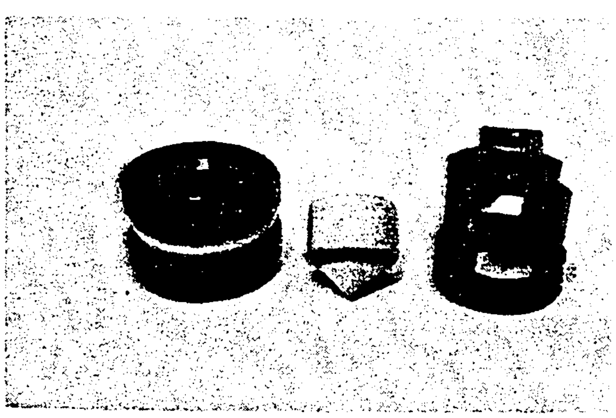


Figure 3.10 SWS new plunger

3.2.4 India Mark II Plunger

All of the three IM plungers tested operate well. Leakage through the valve is low.

One drawback is the relatively complex design. The valve is also exposed to wear, for example on the guides in the closing plate. After this rather short period, all plungers were worn at two locations on the guides, responding to the opened and closed position of the valve. There were also substansial wear on the locknut of the poppet, and in one sample the rubber seal on the poppet was completely worn down.

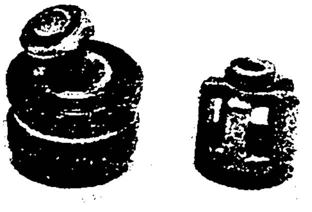


Figure 3.11 Wear on the valve nut.

3.2.5 Head-loss

In all reciprocating pumps a low flow resistance in the cylinder is desirable during the back-stroke, when the piston is going down. "In pumps with a chain" this is necessary since the connection rod-handle makes it impossible to apply any external force to press down the piston. The weight of the pump rod alone creates the downward pressure on the piston.

The downward pressure on the piston is counteracted by,

i) the friction between the cylinder and the piston-seal

ii) the head-loss over the piston, as it moves through the water contained in the cylinder.

If for one of these reasons the piston returns slowly, the operation of the pump is affected, i. e. the capacity of the pump in liters per minute is reduced. The friction during the downward movement is normally low since there is no pressure from the water column acting on the piston-seal. Friction can be high only if the seal has too large a diameter or is too stiff. That means that the head-loss over the piston might very well be a factor limiting the convenience in operation and the capacity of the pump.

The head-loss at constant flow was measured with the laboratory set up shown in figure 3.12.

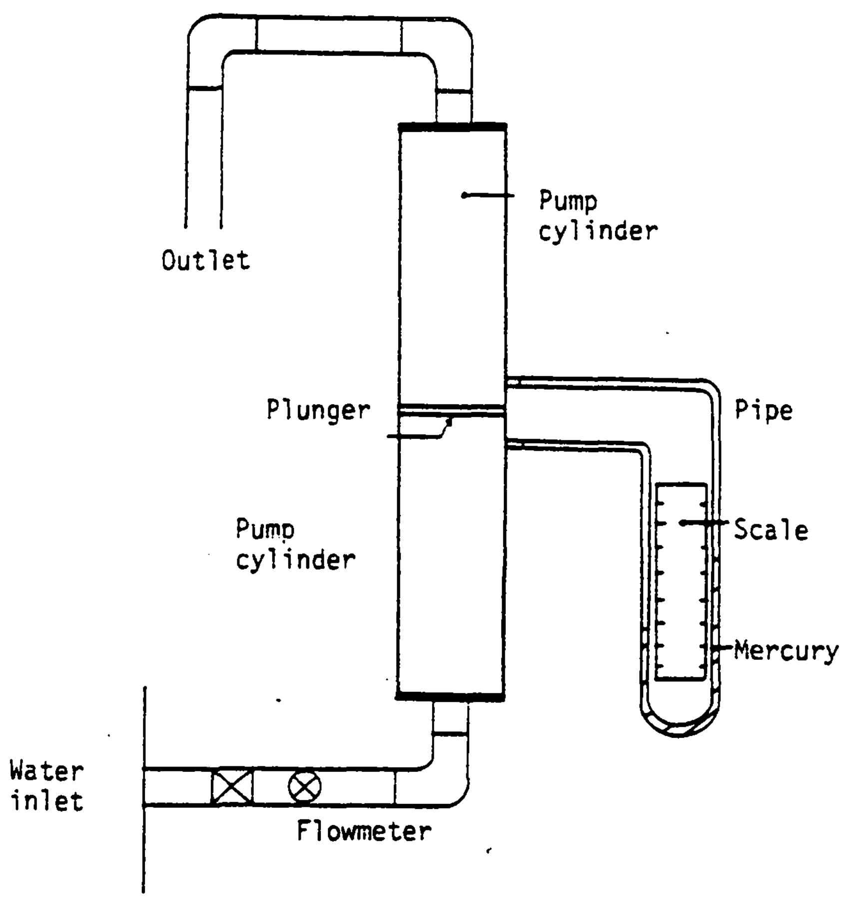


Figure 3.12 Laboratory measurement of head-loss over the plunger.

As shown in figure 3.13, there are only small differences between the plungers tested at high velocities (high flow rate). The rubber ball valve, however, is an exception. The flow induces vibrations in the ball, which may be the explanation for the comparatively poor result. Even if it does not have flow properties as good as other plungers, there is no cause for alarm. Field experience shows that this plunger type operates satisfactorily. It is also interesting to note that the India Mark II plunger valve is relatively heavy and requires a flow of about 20 liters per minute before it opens. The head-loss coefficient is twice as high for this valve compared to the others at low flow rate.

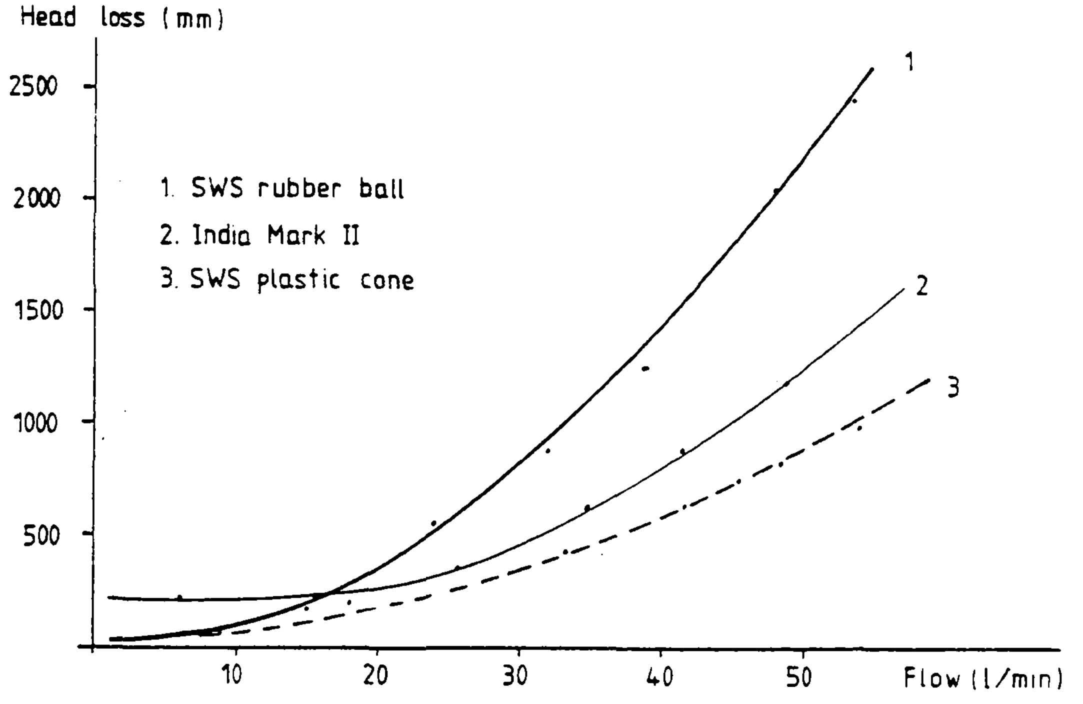


Figure 3.13 Difference in head-loss for the plungers tested.

The head-loss coefficient at stationary flow (Kv) can be calculated according to the formula:

$Dh = Kv\ V^2/2g$, where Dh = head-loss (m)

V = flow velocity (m/s)

$g = 9.81\ m/s^2$

At stationary flow, Kv is constant for a hydraulic structure. The value of Kv will be high at low volume flow, more than 2000, and will decrease as the flow increases. When flow rate reaches about 30 l/min, the valve is entirely open and the Kv value is constant. Vibrations in the ball increase with further flow. The values of the Kv constant are,

SWS rubber ball:	>1000 (not stable)
India Mark II:	180
SWS plastic cone:	50

3.3 Cup Seals

Without any doubt, the cup seals in general are the most sensitive part of the handpump. The reason for taking the pump apart and lifting the rising main and the cylinder assembly is often only to replace the seal. An extention of the lifetime of the material used in cup seals would mean considerable savings in maintenance expenses.

Leather cup seals seems to have the advantage of protecting the cylinder against abrasion by embedding particles within its porous structure. Synthetic materials do not work in this way but they have other advantages. It would be an improvement if all seals produced had exactly the same diameter, thickness, friction-coefficient, swelling properities and wear resistance. This is the case if a synthetic product is fabricated, but it is certainly not the case with leather cup seals. There is presently a tremendous number of different plastic and rubber materials. Some of them ought to have features which render them suitable for this application.

The project incorporates:

1) Comparison of different types of leather seals.
2) Tests of synthetic seals as an alternative to leather.

3.3.1 Leather

A summary of the leather cup seals tested is given in table 3.3. The result still does not allow for determined conclusions, but some interesting indications are shown.

The materials tested are:
- Swedish vegetable-tanned leather with standard paraffin and

carnauba wax impregnation.

- Indian vegetable tanned leather, which is rather soft and therefore easy to install.
- Swedish chrome tanned leather. A very stiff type, which did not operate when mounted with the same diameter as the vegetable tanned. The swelling is believed to cause the seal to be pressed against the cylinder wall.
- Indian chrome tanned leather. These seals were probably impregnated with a mixture of high paraffin content. Swelling did not occur to the same degree as in the Swedish chrome leather.
- Swedish leather from a combined tannage process which produces a stiff strong quality similar to the pure chrome tanned leather. The outer diameter of the cup seal had to be reduced to 60 mm for a 63.5 mm cylinder to achieve smooth operation.
- Indian vegetable tanned leather, rather soft with a special impregnation. This treatment was said to create a surface shield preventing absorption of water. The seal is meant to be tight at the time of installation. When it is later worn down, the surface cover has thus been removed and the bucket will swell. The idea is interesting, but in practise it did not work. When soaked, the swelling was quite rapid and at least equal to other leather qualities.

So far, the best result is obtained with the Swedish combination tanned leather, which has operated for almost 40 million strokes. After this time, both seals are in working condition but the height has decreased and the lower seal, which is more worn, has a thickness of only 0.7 to 3.1 m.m., i.e. unevenly worn.

In general, vegetable tanned leather has shown a slightly better result than chrome tanned leather. There is also a more pronounced difference between Swedish and Indian leather, where the operation time for Swedish qualities is about 80 % higher.

Test	Type	Description	Million strokes	Result
1	Leather, vegetable tannage	SWS, India	(36.4)	Some wear; testing continues
4		SWS, India	16.8	Worn out Upper more worn. Replaced.
4		SWS, India	15.3	Both seals worn out.
6		SWS, India	15.0	Upper seal worn out: Test stopped
10		Sydläder, Sweden	(40.6)	Both seals worn, but in operating condition.
5		Sydläder, Sweden	(52.3)	Upper seal OK. Lower seal worn through at one spot; operating
8	Leather, chrome tannage	Richardsson & Cruddas, India	9.3	Lower seal worn out; both seals replaced
8		Richardsson & Cruddas, India	18.1	Upper seal worn out. both replaced.
8		Richardsson & Cruddas, India	19.1	Both seals worn out.
9		Sydläder, Sweden	(46.1)	Both seals heavily worn.
4			10.9	Both seals worn out.
6	Leather specially treated	MEERA, India	23.3	Only the base plate left of both seals. Replaced.
3		MEERA, India	35.0	Both seals worn down, lower cut off at base. Replaced.
6		MEERA, India	(10.9)	In good condition
11		Sydläder, Sweden	(33.1)	Both seals in good condition.
2		Sydläder, Sweden	(44.0)	Both seals operate lower more worn.

Table 3.3 Summary of tests with leather cup seals.

3.3.2 Synthetic materials

Only two types of synthetic seals have been operated in the test rig. The first one, a composite material Teflon/Graphite is relatively hard but has a low coefficient of friction. This seal wore down rapidly as did other plastic materials tested earlier.

The nitrile rubber seal by Simrit was tested since it has a sturdy design. It is moulded on a textile cord. Unlike the bucket type seals, this one has an inner ring which is fastened by screwing the piston together, and an outer ring that tightens on to the cylinder when subjected to pressure, see figure 3.14.

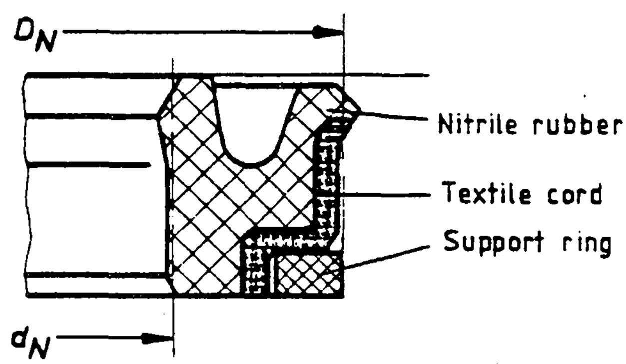


Figure 3.14 Nitrile rubber seal.

The nitrile rubber seal has shown very good results, and another seal of the same type was added to the test to verify this. The operation time at present is given in table 3.4.

Test	Type	Manufacturer	Million strokes	Result
3	Teflon/Graphite	Simrit	3.7	Heavily worn, taken out of operation
12	Nitrile rubber	Simrit	(27.6)	In good condition Some wear on the lower seal
7	Nitrile rubber	Simrit	(56.6)	Heavily worn, but still in operating condition

Table 3.4 Tests of synthetic seals.

3.4 Foot Valve

High reliability of the foot-valve is important. Maintenance and repair of a damaged foot-valve is generally rather troublesome; it requires a special lifting device and is expensive as far as tools, maintenance team and transportation is involved. A break-down of the foot-valve can also happen suddenly without warning, due for instance, to wear on the rubber ball which will later result in a breakdown and could be difficult to discover during regular maintenance. The same goes for the India Mark II valve where the combination of wear and the vibrations in the valve at each pump stroke can cause the closing plate in the valve to unscrew during a relatively short period of time.

Several variations and combinations of materials in a foot-valve of a new basic design are being tested. The results of these tests and a comparison to standard valve types carried out up to now, is shown in figure 4.10.

3.4.1 RIMA, Steel Ball Valve

This foot-valve has the same sturdy design as the RIMA plunger described earlier and, unfortunately, also the same drawback: the bouncing of the ball in the valve seat. The main application of this cylinder assembly is feasible in rather deep wells where pumping is done in cycles with a low frequency. Changes in material or design might broaden the field of application.

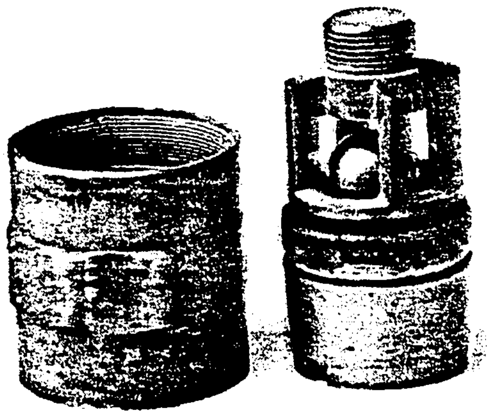


Figure 3.15 RIMA foot-valve

Another interesting feature of this cylinder, besides the sturdy design, is the design of the lower nut. The inside of the nut is cone-shaped and, likewise, the lower end of the foot-valve. To keep the valve in place and to prevent leakage, a leather seal is inserted just above the cone, see figure 4.24. The open-type cylinder, provided it is fitted to a rising main with a large diameter, then allows for a lifting of the footvalve by screwing the plunger in to it and pulling, i. e. there is no need to lift the pipe and the cylinder.

3.4.2 SWS, Rubber Ball Valve

This standard valve type has been tested to compare with new valve types and has performed well in the laboratory. From field experience, we know that breakdowns occur, often as a result of wear and damages of the rubber ball. The risk for such a breakdown is increased by the pressure peaks induced at the end of each pumpstroke. Another reason for changing the design is the rather high head loss and the vibrations of the ball, which can disturb the functioning by cavitation.

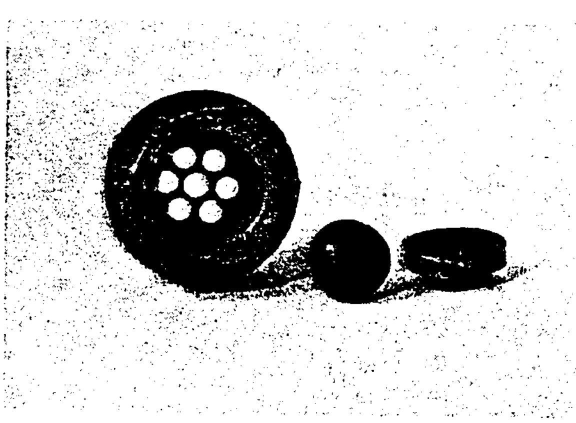


Figure 3.16 SWS rubber ball valve

3.4.3 New Design Iron Valve

The unprotected iron valve very soon proved to be a bad design. After only two month of operation the guides for the plastic cone were almost completely destroyed, due to the combination of wear and corrosion.

In the valve with corrosion protective paint, the guides were intact after the relatively short testing period, but the valve ceased to operate since the guides had cut almost right through the cone, see figure 3.17.

Figure 3.17 Painted iron valve

The iron valve with a plastic cover on the inside has performed very well. Two samples with a Rilsan cover, a polyamide-based thermoplastic, and two with Slitan, a two layer plastic cover, are being tested. Only in one case has the test been interrupted, the reason being corrosion underneath the cover, which destroyed the holes for the stop pin.

3.4.4 New Design Gun Metal Valve

This valve has a design similar to that of the iron valve, but the material allows it to be smaller and have thinner walls. In this case corrosion is no problem. There seems to be an unlucky combination between gun metal guides and a plastic cone.

3.4.5 New Plastic Valve

The valves of this type were all machined in thermoplastics, POM and PVC. Both types showed very good wear resistance. The reason for going over to plastics is that it allows for production by extrusion moulding at a rather low cost.

The POM valves all operated well. The PVC valves, however, were all broken down during the test. Cracks occurred at the valve seat or at the threads.

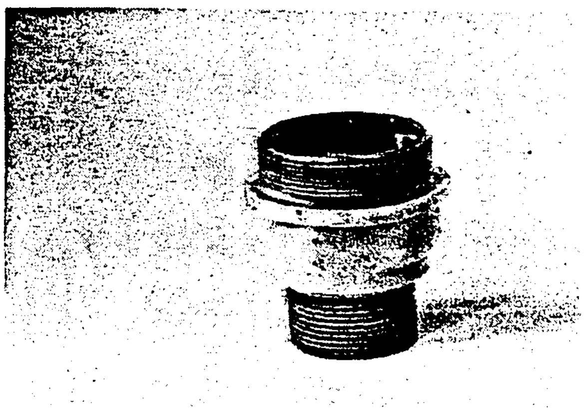


Figure 3.18 The POM valve

3.4.6 India Mark II Valve

Both the R & C and the MEERA valves are operating in the test rig and after about 30 million strokes, are in good condition. The foot-valve has a better design than the plunger in the sense that the upper lock nut cannot be damaged. The opening is restricted by a ring in the lower end of the guides. Field experience has indicated a weakness in the design of the nut. If it is heavily corroded, the sheer forces in the threadings might induce a crack in the nut when trying to unscrew it. It seems like the wall is too thin below the threaded part of the valve nut.

3.4.7 Head-loss

Three types of foot valves were tested at stationary flow:

- SWS rubber ball valve
- India Mark II valve
- New design plastic valve

The same equipment was used as that in the plunger test described in section 3.2.

As expected, there was only a slight difference between them. An addition of one meter of water column at the most will be the effect if a rubber ball valve is used instead of the new type of valve with a plastic cone. This difference, however small, can be of interest if a design for extractable foot-valves, like the RIMA valve, is to be used.

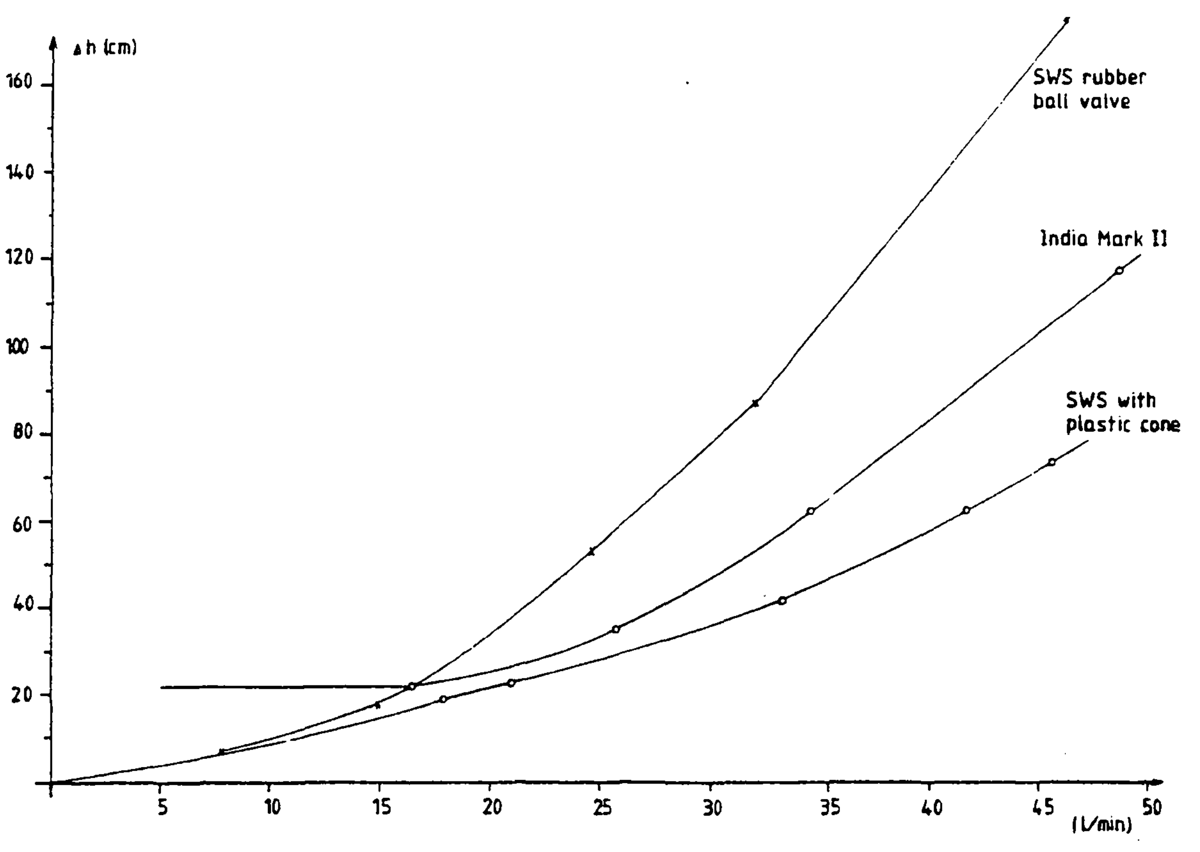


Figure 3.19 Head-loss over the footvalve at stationary flow.

The performance of the rubber ball was, in this case, better than that of the plunger valve. It could be that the guiding of the ball is better in the footvalve and, therefore, the vibrations are not allowed to be as rigorous as in the plunger valve. Except the head loss, another reason for trying to keep these vibrations as low as possible is the wear and tear of the rubber ball, which will otherwise be the inevitable result.

The relation between the India Mark II valve and the new valve type with a plastic cone is similar to the previous test. The head loss over the plastic valve is somewhat lower and the opening pressure of about 0. 2 m required to lift the poppet in the IM II valve is the same as determinated earlier.

4. DISCUSSION

4.1 Connection Handle-Rod

According to principle the transfer of the force from the handle to the pump rod in piston pumps, can be done in two ways; by using some kind of linkage with bolts or bearings, or by using a chain or a belt on a circle segment. Other kinds of power transmission, rotation or hydraulic devices, are less suitable for reciprocating pumps.

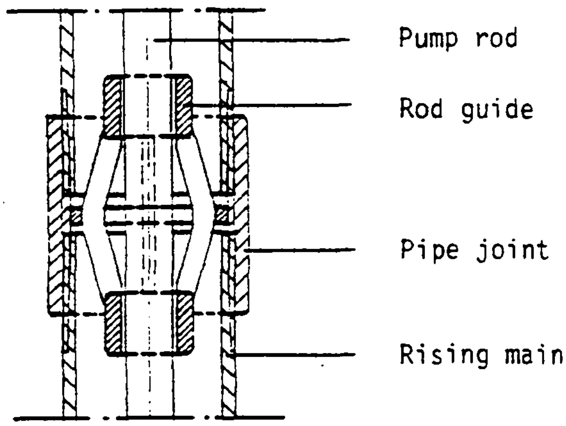
The advantages of the circle segment are :

- The operation will be smooth, even though some time is needed for the piston to move back to starting position.
- The alignment of the pump rod is good, which decreases the risks of breakdown of the rod or the rising main.
- The end of the main can be tightened with a bush, preventing corrosion of the pump head and making possible the use of the pump as a force pump.

The obvious disadvantage of the use of a chain or similar is that the pump has to be mounted on at least a 10 m deep well, which means that the prinicple is not suited for shallow well pumps.

If a linkage system is used, the risk of damages to the rod, coupling or main, can be decreased by the use of a rod guide, see figure 4.1. The disadvantage of the guide is that the friction will increase both in deep wells where the main and the rod are often somewhat curved, and in shallow wells, where the effect of the movement of the rod with the linkage will be more pronounced. This increase can substantially increase the pumping work.

In a deep well, the combination of a force transfer with a chain, or similar, and a controlled number of rod guides can be expected to work efficiently. In a shallow well, it is important to have the cylinder installed in the bottom of the well. Hereby, the risk of polluting the well during priming of the pump is avoided. In this case, a type of direct action pump without a handle, similar to the Tara pump, seems to be both simple and efficient. Thus, the principle of the circle segment is seen as a good alternative for deep well handpumps. The results of the laboratory tests, figure 4.2, indicate how to design and what materials to use.



Figures 4.1 The SWS rod guide.

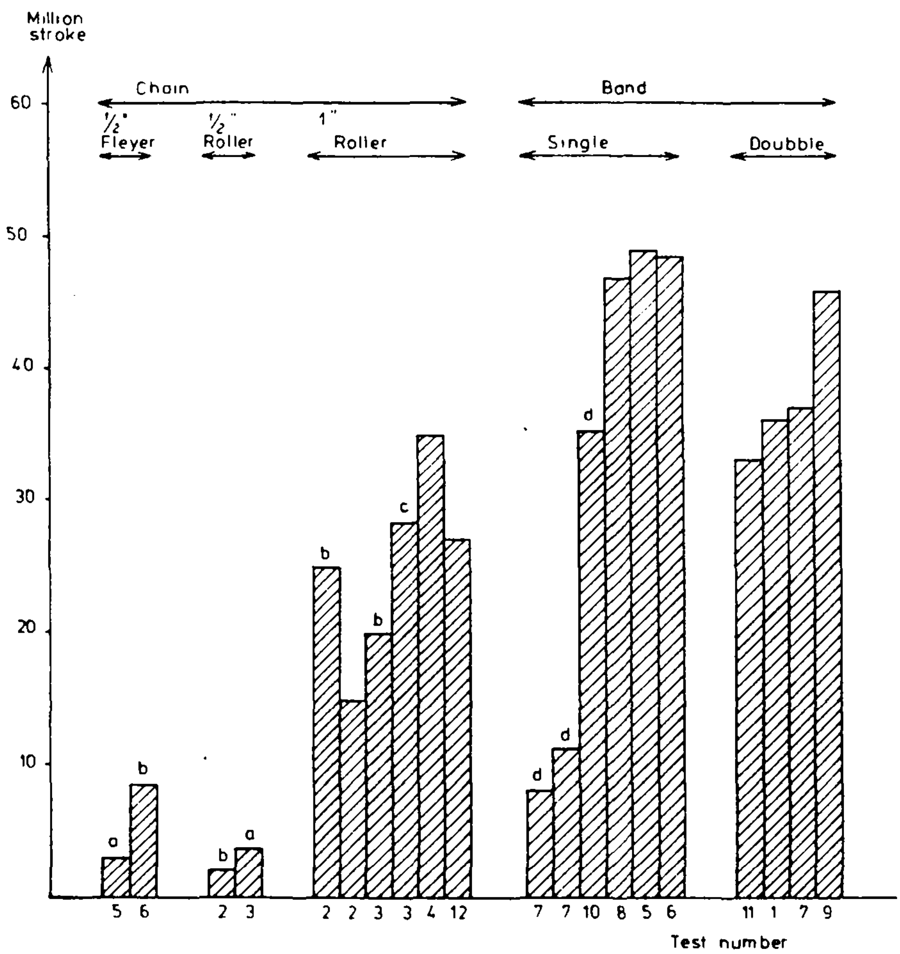


Figure 4.2 Result of tests with chains and belts.
a: Worn and stiff
b: Worn and stiff, broke.
c: Broken and repaired.
d: In operating condition, test interrupted.

Bars open at the top indicate that testing is continued.

Other mechanical devices, like the roll and arm described in section 3.1.4, have proven to be alternatives to designs based on a circle segment. Mechanical arrangements are, however, believed to require higher material quality and more precise machining. The tests have, therefore, concentrated on chain/belt design, which is easily adapted to manufacturing in developing countries.

All the chains tested operated well. However, the wear resistance of the chains having a smaller dimension was not satisfactory. Although sufficient, according to manufacturer´s specification, the 1/2" chains broke after only a short period of operation. The test with fleyer-type chains proved negative, as well as tests with a low-friction polymeric material used in support of the roller chain.

As expected, the 1" chain, standard in the India Mark II pump, was more reliable. It is essential that the chain is properly greased, preferably by boiling in a mixture of grease and graphite. Chains not treated in this manner began to stiffen after only a month of operation in the rig.

After about 20 million strokes, the chains are considerbly worn. This corresponds well to field experience showing that the chain can be expected to operate well for about 4-5 years. It is worth noticing that in spite of the comparably smooth operation in the test rig, 3 out of 6 chains have so far broken. The 1" chain is robust, but when worn, it is not fully reliable.

Of the 6 synthetic bands tested, not one has broken even though the operation time is well over 30 million strokes. Two tests with single bands were interrupted after about 10 million strokes because other arrangements with the bands were more interesting to try. Both of these bands were in good conditon.

As an alternative to the single band, which did not operate quite as well in the field, a double band was tried, tests 5, 6, 8 and 10. Here, the outer band carries the load and the inner band hangs loose or is fastened to the circle segment. This arrangement was expected to increase the lifetime of the band, since the wear from the steel support will be on the unloaded band.

After 30 million strokes it was obvious that the basic idea was correct; the lower band in contact with the steel surface was worn. There is, however, an elastic stretching of the outer band with each stroke, which also induces wear between the two bands.

A sample of this kind of band (test 10) was taken out of operation and the load carrying capacity was tested. The band, which had operated for about 35 million strokes, was loaded with successively increasing weight. The increasing tension could be seen by an elastic deformation, but the band was intact up to a load of 580 kg. The fibers then started to break one by one and the strength was rapidly reduced.

A new band of the same kind was also tested. It was loaded with up to 1250 kg without any signs of breakage. A higher load could not be applied in this case since the band started to loosen in the end couplings.

The remaining capacity of 580 kg, after a corresponding field operation time of 6 to 7 years, should be compared to the actual load. In a 30 m deep well the static and dynamic load would normally not be more than 100 kg (weight of water column and pumprod, friction and acceleration force). Thus, in this case the remaining strength of the band exceeded the required strength with a factor of 5.

To further improve the band installation a double coupling was tried where both bands are carrying the load, figure 4.3. The advantages of this arrangement are that:

- The total elastic deformation is less since the load is divided between two bands. The wear from stretching between the bands is expected to be reduced.
- If one band breake, the other one will serve temporarily until the pump is repaired. The risk for total breakdown is reduced.

When pumping, the load is first mainly born by the inner band. In the middle position, when the piston has moved half of its upward stroke, both bands are equally loaded. The outer band then takes over successively during the rest of the stroke.

Replacement is simply made by unscrewing two bolts, see figure 4.4. To adjust the band properly, the pump rod should be fixed, e. g. with a clamp, in its middle position with the piston half-way up. Both bands being equally stretched can then be fastened to the handle, also held in the middle position.

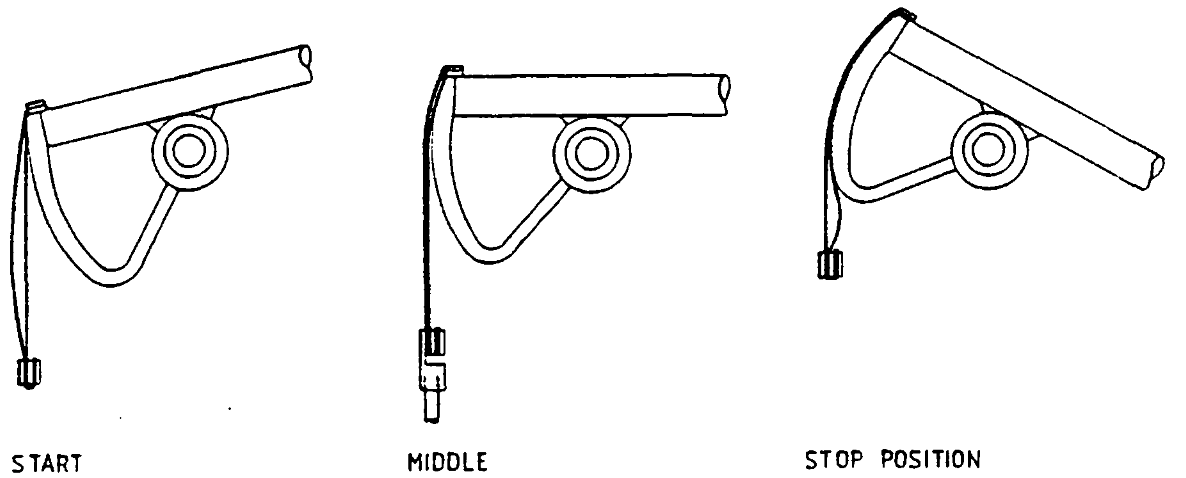


Figure 4.3 Operation with the doubble band.

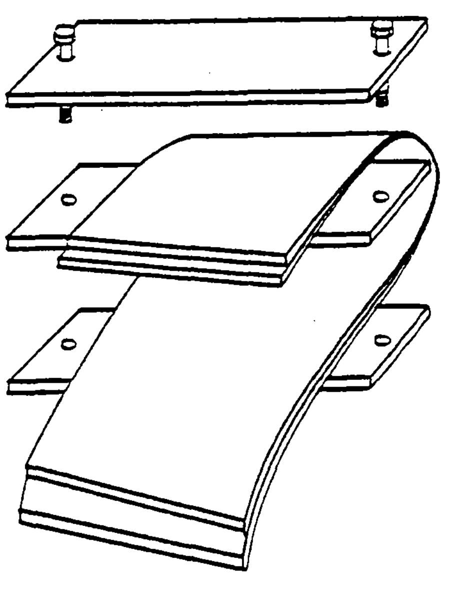


Figure 4.4. Principle of the band coupling.

The cost of the band is considerably lower than that of the 1" chain. Even if the lifetime seems to be longer, spare band can be stored in the village and can be easily changed by a local caretaker.

4.2 The Plunger

The plunger with a poppet valve, used in the India Mark II pump, has operated well in the test. Exept the relatively high head-loss, there are, however, some disadvantages with this design. One problem is the lock nut on the top of the poppet. At each pump stroke the nut bounces to the valve cage, which will result in rapid wear of the nut. If the pump rod is screwed too deep into the valve cage, it can moreover speed up the wear. The risk is then obvious that the poppet will unscrew and hinder operation of the pump. There has also been a rather heavy wear on the flat rubber seal in the poppet. In one plunger, this seal was completely worn out after about 25 million strokes.

The conventional SWS plunger with a rubber ball valve is functioning rather well. The main disadvantages are the rather high flow resistance (figure 3.13) and the tendency of the ball to vibrate, which will increase the wear and the risk of cracking the rubber material which will split the ball.

The new plunger design with a cone of thermo-plastic instead of the ball has been found to be a good alternative. A total of 10 plungers have been tested in the rig and some general information can be extracted from this test.

Hydraulically, this plunger operates very well. The head-loss is minimal and the cone rapidly reacts to pressure variations, i. e. firmly opens and closes.

Considering manufacturing, the cone should be of thermo-plastic. It can then be produced at a low cost by extrusion moulding. Except fore single tests with polyamide and some high density polyethylene materials, the test cones are all made of POM or PVC.

PVC was chosen because the price is low and the availability good. The test, however, indicated that in general PVC was more subjected to wear than was POM. Serveral POM-cones have operated for 30-40 million strokes without any visible signs of wear.

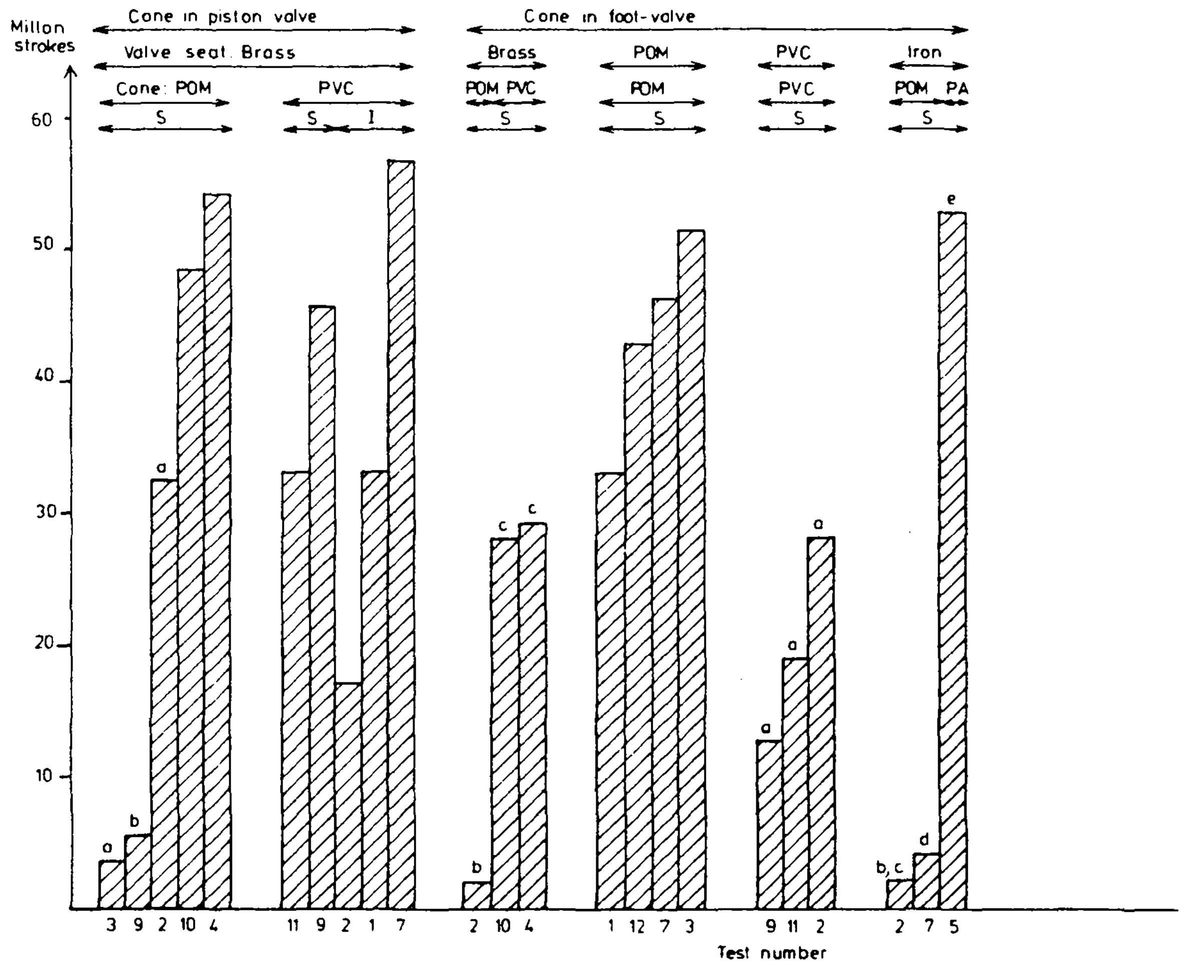


Figure 4.6 Comparison of test result of plastic cones in plunger and foot valve.

S = Swedish a : Cone in good condition, test interrupted.
I = Indian b : Cone damaged, too small initial diameter.
c : Cone damaged, rough guides.
d : Cone in good condition, guides damaged.
e : Plastic coated iron valve

Basically, rapid wear is caused either by an extremely rough surface of the brass guides in the valve or by an extremely high initial distance between the cone and the guides. In either of these two cases the cone is rapidly worn, see for example test 9.

The Indian PVC was of a harder quality than the Swedish PVC used in this test. The Indian cones also showed less signs of wear. If available, however, POM should be selected.

The valve seat and the guides in the plunger are made of brass. In the foot valve, the design of the valve seat and the guides is identical, but other materials beside brass have been tested.

The best result is obtained with plastic valves. Both with POM and PVC the wear on the cone was hardly visible. However, the PVC valve cage did not have sufficient strength, see below. The brass foot-valve unexpectedly tore the PVC cones quite hard. After 30 million strokes the cone got stuck in both test samples due to damages.

The reason for this difference between the brass plunger and the brass foot-valve, seems to be the roughness of the guides, which is somewhat more pronounced in the foot-valve.

The same type of wear occurred in iron valves. The cone lated million strokes. In the untreated iron the corrosion in combination with wear also destroyed the guides completely. The iron valve in test 5 has an inside plastic cover which explains the improved result in this case.

When the cone is made of proper material and has the right diameter, the only weak point is the wear of the o-ring. These problems are believed to be caused by either:

- Too loose tension when mounted, i.e. the inner diameter of the ring is too large. Wear will result from the movement of the ring in the track.
- Too wide cone track, so that the ring cannot hold a fixed position.
- Too low rubber quality.

The ideal form of the track cannot be made when machining the cones, and moulded cones must be made in two pieces in order to obtain the best track form. Sufficient results can, however, be achieved by retaining the correct track diameter and by selecting a high rubber quality. A flat deformed o-ring is furthermore no threat to the operation of the pumps. In most cases, the level in the rising main will sink overnight when the pump is not in use. An o-ring which is beginning to deform after, say, 5 years, can easily be replaced when the pump is maintained for other reasons, such as change of cup seals.

4.3 The Cup Seals

The test has verified that leather is a comparatively good material for cup seals. With proper selection of raw material, tannage and impregnation the leather seal will last as long as high quality nitrile rubber, and much longer than many plastic materials tested earlier. The reasons for using leather are primarily:

- The porous structure allows particles to be embedded, thus preventing wear of both the seal itself and the cylinder wall.
- Good leather seals could be manufactured locally in most countries.
- Leather seals with comparatively long lifetime can be manufactured.

The dimensions of the leather bucket for a 63. 5 mm. cylinder are shown in figure 4.7. Exact figures cannot be given for the outer diameter and the thickness since they depend on the swelling properties of the leather quality used. The sealing edge should be cut at an angle of about 30° in order to direct particles in the water away from the cylinder surface. As much material as possible should, however, be kept, i.e. the angle of the piece cut away should not be more than about 45°.

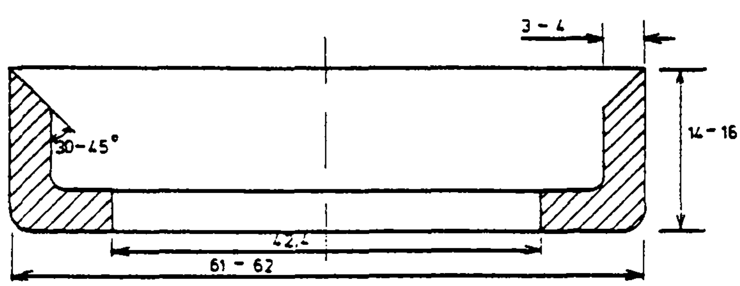


Figure 4.7 Cup seal dimensions (mm).

It is of the outmost importance to select leather from high quality hides. This is illustrated in figure 4.8, where the mean value of the operating time is about 80 % higher for Swedish leather than for Indian, excluding the type of tannage. The quality depends on the type of cattle. For example, buffalo hides are said often to be more soft and porous structure. The age of the animal and the climatic conditions of its environment also contribute to the leather quality. Highland cattle, for example, are said to give more dense and stable leather.

If there is not much to choose from in this respect, it is, however, important to select the best portions of the hide, such as the butt and shoulder leather. This should eventually be controlled by specially licensed manufacturers since it is almost impossible to confirm if soft pieces of leather have been used, after impregnation of the bucket.

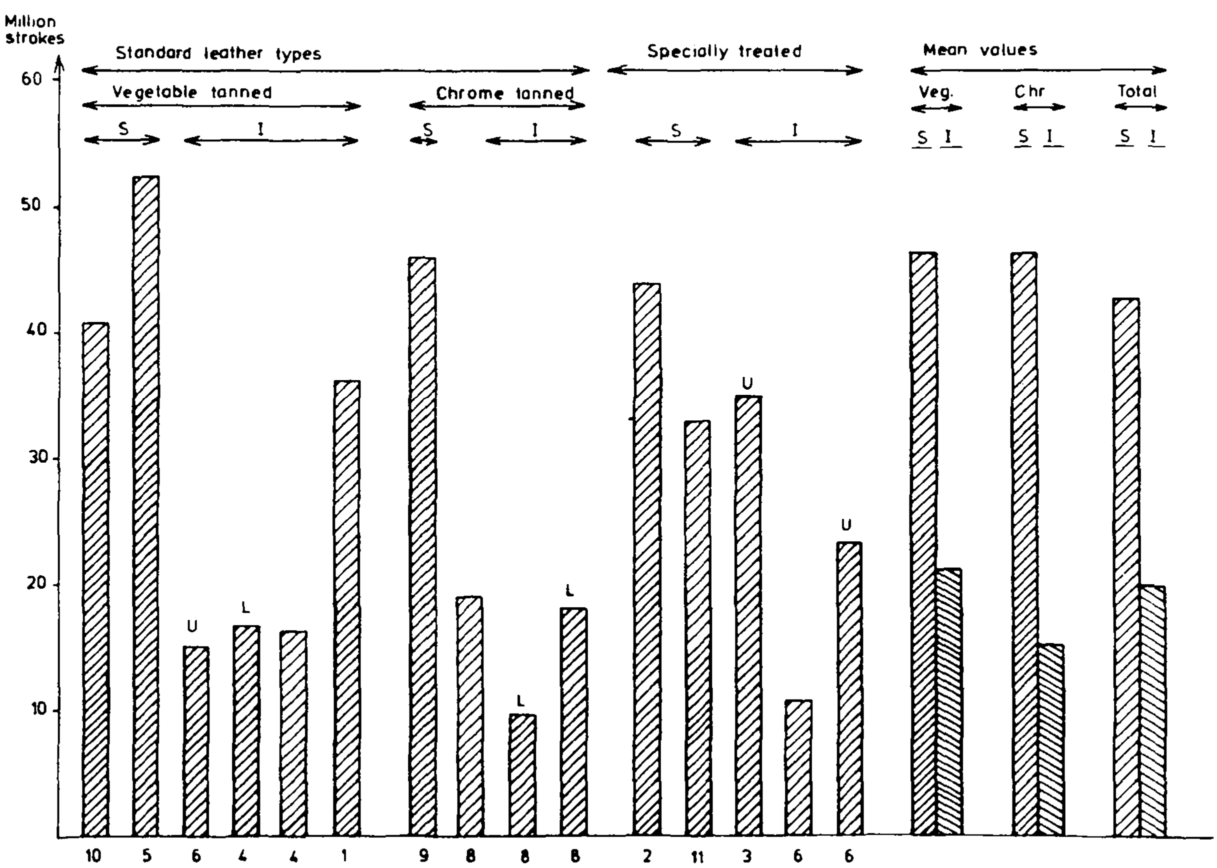


Figure 4.8 Summary of the result of cup seals tested.
S= Swedish leather, I= Indian leather
U= Upper, L= Lower Cup Seal.

In regards to the tannage process, it appears that chrome-tanned leather has two advantages: Firstly, it will probably be of a more even quality, not being dependent on where it is manufactured. The quality of vegetable-tanned leather is dependent on where it is manufactured, due to the variety of tannage processes available. Secondly, chrome-tanned leather will be rather stiff. The test result gives reason to believe that a stiff bucket will last longer since it is not deformed, as shown schematically in figure 4.9. Instead, the wear will take place at the upper edge of the cup so that its height will decrease with time.

The soft cup seals which have been worn down, test numbers 3, 4, 6:1 and 6:2, were all cut off just above the base plate where, due to deformation, the seal is pressed hard against the cylinder wall. Another reason for reluctancy to vegetable-tanned leather is that such cup seals are relatively easy to form. In the tests done by MAWTS, Mirpor Agricultural Workshop and Training School in India (Journey -83), the cups were formed after 20 minutes of soaking in cold water. The effect is simply that a cup which is easily formed is also easily deformed!

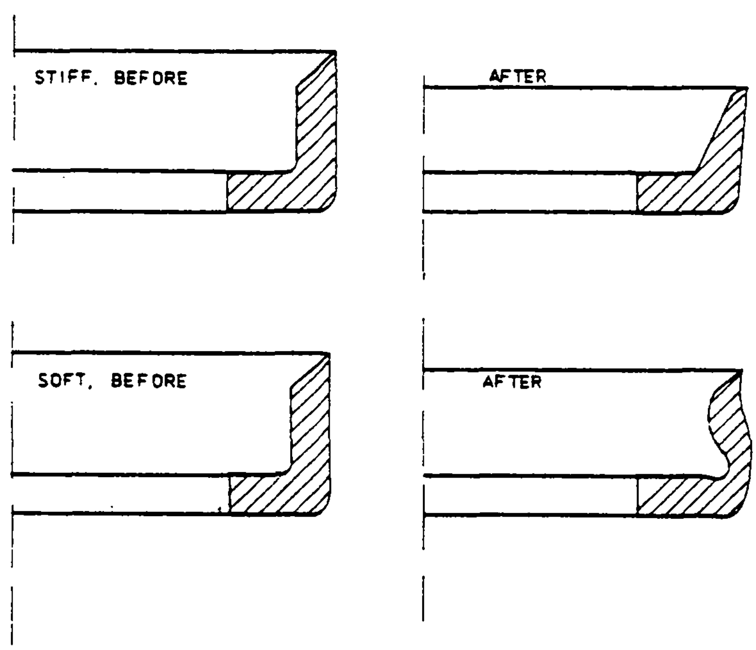


Figure 4.9 Difference in deformation and wear between soft and stiff cup seals.

On the other hand, if chrome-tanned leather is used, it must be of a quality which allows formation by pressure without prior soaking in water.

During the test it was found that if the cup seal is stiff from the beginning, it is also very sensitive to swelling. The outer diameter of the chrome-tanned cups had to be reduced from 63 to 60 mm, before they would operate as intended, i. e. allow the piston to move downwards in the cylinder by gravity. Thus, it is important to be able to adjust both the diameter and the leather thickness to the swelling properties of the leather used. The thickness is controlled by splitting the hide to a thickness of 3-4 mm, leaving the hair side intact.

After formation of the cup, impregnation is made by soaking it in hot carnauba wax. This wax is rather expensive, and an acceptable impregnation is achieved using a mixture of wax and parrafin. However, the leather must be completely dry before impregnation. Otherwise, the water will boil and coagulate the proteins in the leather cells, thereby reducing the stability of the cup. MAWTS has recommended an addition of 10 % linseed oil to the impregnation mixture. This will probably make the cup more pliable and thus easier to install and to operate initially.

Contrary to MAWTS's suggestion, the hairside should be turned inwards when forming the cup. It is true that in some cases, for example with hydraulic seals, the cup seal is made with the hair-side outwards to obtain as smooth a surface as possible. In the type of cylinders used in handpumps, however, the cup seal will in any case get a polished smooth surface rather quickly. The reason for turning the hair-side inwards, is that the leather in this layer is more dense and stable. If, after some time of operation and subsequent wear this layer remains, the cup will maintain its stability.

In a test report from Consumers Association (CATR -84) it is stated that two cup-seals are not necessary ; one is sufficient since the lower does not operate as long as the upper does. This test indicates the contrary. Of the 12 cup seals being tested and the 6 that have been worn out, the lower seal is more worn in about half of the test samples (cf. figure 4.8). The reasons could be variation in leather quality, impregnation and cup manufacturing and, eventually, excentricity in the mounting of the cup on the piston. As long as these variations cannot be perfectly controlled, it is not possible to predict which cup seal will last longest. However, if one cup seal will last longer than another, the total operating cycle of the pump (before maintenance is required) is thereby prolonged.

Another explanation for the result that the lower cup is heavily worn in some cases, is that it is, in fact, operating. If both seals are flexible, so that they are pressed against the cylinder wall more during the up-stroke, the upper seal will be pressed slightly outwards/downwards at the start of each pumpstroke. Since water is an incompressible fluid, the lower seal will be correspondingly affected at the start of a stroke, if positioned tight against the cylinder. The result is that both seals cooperate in taking up the hydraulic pressure. If they in this way take up a portion each of the pressure, the friction between each seal and the cylinder will be lower than if only one seal was used. The wear can be expected to be correspondingly reduced with the reduction in friction. Hence, the lifetime of two cup seals is longer than that of one.

Even if CATR is correct in stating that the lower cup does not operate, this is no reason for using only one seal. The lower seal will come into operation later on when the upper cup ceases to function. Thus, the total lifetime is prolonged. To conclude; it seems wise to use two cup seals in the piston, disregarding how they operate together or their variations in quality.

Of the synthetic seals tested, only the type with nitrile rubber on a textile cord has shown good results. These results are, in fact, the best of all seals tested at present. After 3.5 million strokes the v-shaped lip at the upper part of the sealing ring (see figure 3.14) is completely worn down. The seal still operates with little leakage and will probably continue to do so for quite some time. The obvious advantages with this seal are that:

- It is manufactured with precision and has an even and predictable quality.
- It has high resistance against wear and its shape gives no possibilities for particles to be trapped between the seal and

the cylinder.

- Even after it is worn it continues to operate with acceptable efficiency for quite some time, i.e. no sudden break down, as is the case if a soft leather cup is cut off at the base plate.

The drawback is the fairly high price of the seal, which has to be imported and which can be difficult to supply as spareparts. Still, it is a good alternative if leather cups of proper quality cannot be produced locally.

4.4 The foot-valve

Most of that which is said concerning the plunger valve is also true for the foot-valve. One exception is the India Mark II foot-valve, which is performing better than the plunger. The problem with wear of the rubber seal at the poppet has not occurred here. The poppet design is also altered so that a ring at the bottom end of the guides stops the poppet when the valve opens. Therefore, there is no risk for damages of the lock nut at the top of the poppet.

As mentioned in section 4. 2, the valve design with a plastic cone proved to be reliable, but some unexpected results have also emerged. The first design with an iron valve was not at all successful. Damages of both the cone (test 2) and of the guides (test 7) occurred. A surface treatment by coverage with a wear-resistant plastic material made it possible to overcome this problem. Four tests with plastic-covered iron valves show a positive result (test 2, 5, 9 and 10).

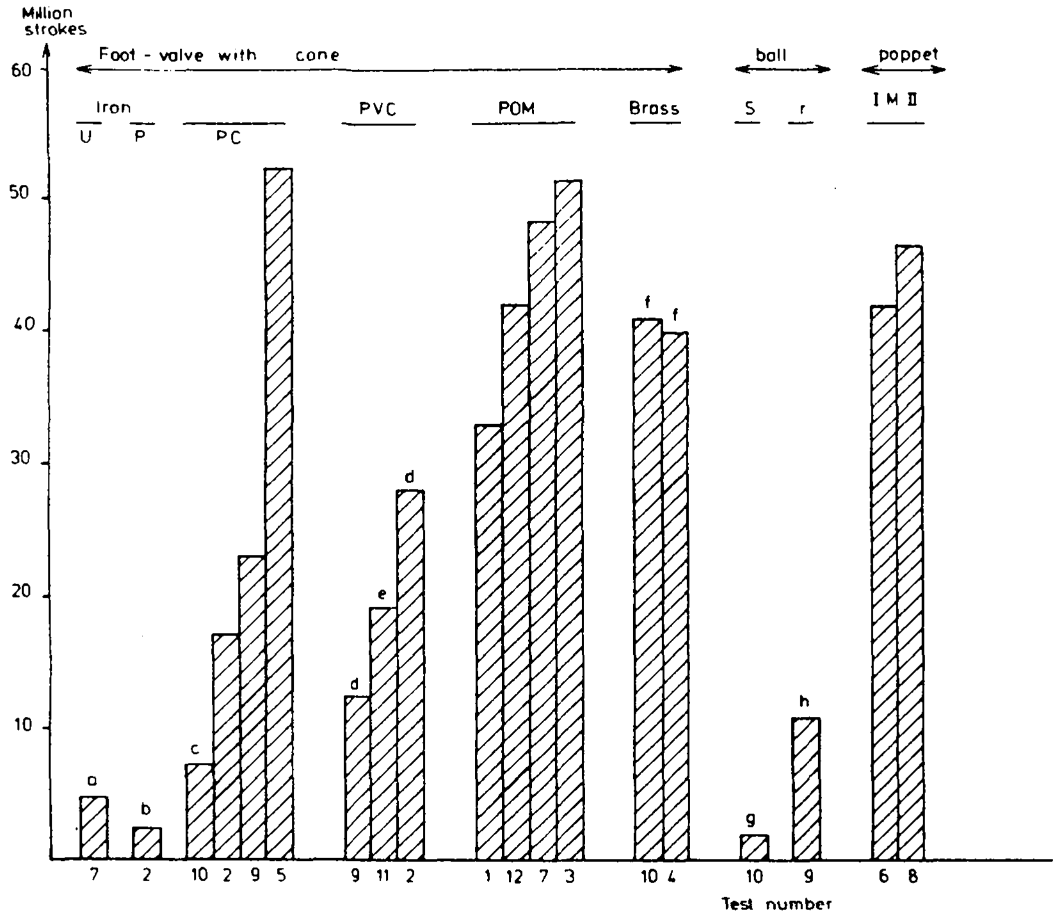


Figure 4.10 Result of test of foot-valves.

u : unprotected s : steel

p : painted r : rubber

pc : plastic cover

a : Guides destroyed by corrosion

b : Cone damaged by rough guides.

c : Test stopped. Corrosion in hole for stop pin.

d : Valve cracked during operation

e : Valve cracked during demounting

f : PVC cone worne out, replaced

g : Test stopped, unsatisfactory operation.

h : Test stopped for other reason

In one case, the holes for the stop pin corroded. This can, however, easily be avoided if the treatment is standardized. The plastic material is not very easy to apply. One type melts on by heating the iron to 400^{o}C. The other one has to be applied by spraying in two layers with special equipment. Neither of these methods are adjusted to manufacturing in developing countries, at least not the spray method.

The plastic valves all worked very well in respect to hydraulic operation, tightness and wear. Both PVC and POM cones had very few signs of wear after operation in a plastic foot-valve. The reason for testing plastic materials in this case is primarily because a high-quality valve can be produced at a very modest price (down to about 2-3 USD) when using an extrusion moulding process.

Two problems appeared when using thermo-plastics. One was elastic deformation of both PVC and POM. This resulted in a tendency of the inside guides to bend together when the valve was screwed on to the cylinder hard. The problem is not so pronounced when the wall of the valve is thicker. On the other hand the moulding process does not allow for a very thick wall. Problems do not arise if the valve is only screwed on by hand. For field conditions, however, it must be able to withstand "rougher" methods. A design which incorporated a metal support ring inside the threaded part of the wall of the valve did help, but the problem was not totally overcome.

Another problem occurred with the PVC valves. The strength of this material is obviously not sufficient for the present valve design. All three of the test samples were cracked in the wall or the bottom. In one case, the crack occurred during unscrewing for valve maintenance.

At present, it seems that the brass foot-valve is the most successful design. As could be seen in figure 4.10, it is, however, important to make sure that the guides are smooth and have no rough edges. The PVC cones in the two test samples of brass valves were worn out too soon, after 30 million strokes. If this valve is to be put into production, the cone must be of a POM quality or possibly of a plastic type called Orlon, which is also being tested.

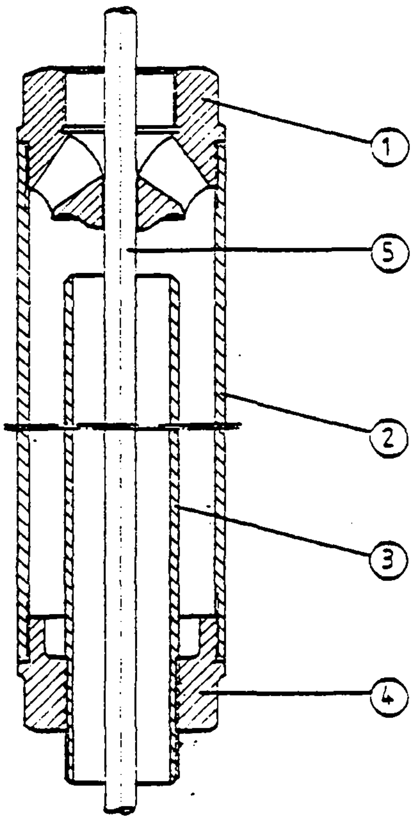
5.5 The Cylinder Assembly

In general the India Mark II cylinder assembly has an attractive design in that it is easy to maintain. It is sturdy and heavy duty tools can be used. The flat seals in both end caps of the cylinder make opening and closing easy without screwing too hard. The main disadvantage is that the whole assembly is subjected to heavy corrosion both outside, especially after the paint cover has been damaged during maintenance, and inside the top-nut and the foot-valve.

The SWS cylinder assembly has the advantages of being light and easy to handle and is not subjected to corrosion to the same extent as the Mark II cylinder. Still, the rust which builds in the top nut often makes loosening of the brass cylinder difficult. Damages are then likely to occur on the cylinder, if it is screwed hard when installed. The maximum outer diameter is 90 mm, which makes this cylinder hazardous to install in a conventional 4 inch borehole.

The SWS cylinder can now be made with the particle separator, see part 3 of the project report papers. The separator has proven effective in field installations. Mounted directly in connection to the cylinder, figure 4.11, it will remove particles through settlement in the water column which stands in the rising main. Heavy particles which would settle during pumping are unlikely to get in through the foot-valve. The separator mainly protects the cylinder assembly from particles which settle during idle periods, especially during the nighttime. It is assumed that this arrangement will substantially lengthen the lifetime of the cup seals. Without the separator, the particles will be stopped by the piston and a fraction will be trapped in between the seal and the cylinder wall, thus increasing the wear. The top nut of the separator may have to be redesigned. Clear signs of wear occured both on the nut and the rod after only 8 million strokes in a laboratory set up.

The separator can be installed in all types of piston pumps. It can be fitted to the rising main, usually a 1 1/4" pipe and a special connection to each type of cylinder is therefore unnecessary.



1. Separator nut
2. Pipe 2 1/2"
3. Pipe 1 1/4"
4. Separator lower nut
5. Pump rod

Figure 4.11 The particle separator mounted directly on the rising main.

The only restriction is that it cannot be used in an open-type cylinder, i.e. together with an extractable piston. Since a vast majority of pumps already in operation today are closed-type piston pumps, the separator can be used widely.

The concept of the VLOM pump has formed the strategy and aims in pump development in many ways. One aspect frequently discussed is the need for an extractable piston. With a rising main of the same diameter as the cylinder, or larger, the piston can be taken up without removing the cylinder. The advantages are obvious:

- Maintenance will be radically simplified. At present, certain lifting devices are required in many cases to take up the whole main with the rod, often also filled with water. Screwing the main and rod apart is time-consuming. With an extractable piston, a village caretaker can easily change cup seals alone.
- The distance from the rod to the wall of the main is farther. Some "snaking" of the rod can be accepted without any risk for breakdown. Hereby, the need for rod guides is also eliminated.
- The volume in the main is substantially higher and the flow velocity during pumping lower. Since the head-loss is related to the square of the velocity, pumping will actually consume less energy as the efficiency increases.

Now, if the main is to be a large diameter pipe, it is an advantage to use plastic pipes since they are both easier to handle and usually less expensive. If a plastic pipe is used, it will, however, be difficult to take it up, since it will have glue-joints or will be in one piece. It is therefore desirable to be able to also extract the foot-valve for purposes of maintenance.

With a main of the same diameter as the cylinder, and possibly also of the same material, the extractable foot-valve must be of the same diameter as the piston, which is shown in the new design suggestion in figure 4.12. Here, the piston is also used as foot-valve. Two reasons for this can be identified:
- The foot-valve will be as easy to extract as the piston.
- Less parts will be needed to design, produce and, most important, keep in stock locally.

The design in this case uses exactly the same piston. The only modification is an o-ring inserted in the lower bucket to increase stability when the valve is in place. To lift the foot-valve the piston is lowered and attached to the foot-valve by screwing (clockwise so that the rod-couplings do not unscrew). This principle has been successfully utilized before, for example in the RIMA valve described above.

In figure 4.12 the foot-valve is fixed by an end support designed to be fitted to an end joint with a flange. This is because it is to be tested on a PEX pipe, a polyethylene pipe with a molecular cross-structure which gives the material an improved strength and wear resistanc. The surface roughness of this pipe is very low. In test 1, the PEX pipe is used as cylinder. The vegetable tanned leather cups are almost not worn at all after 20 million strokes. The same types of cups were totally worn out in the same period of time when operating in brass cylinders (test 6 and 4), see figure 4.8.

The use of some sort of plastic rising main thus presents an interesting perspective. There might not be any need to use a special cylinder; the plunger can operate directly in the main. If the part of the pipe where the plunger moves is worn after a few years, the pump rod has only to be shortened 10 cm so the plunger is positioned higher up in the pipe.

1. Support ring
2. Bolt
3. Cage
4. O-ring
5. Valve seat
6. Cup seal
7. Bush
8. O-ring
9. Cone
10. Valve cage
11. Cylinder wall
12. Pump rod

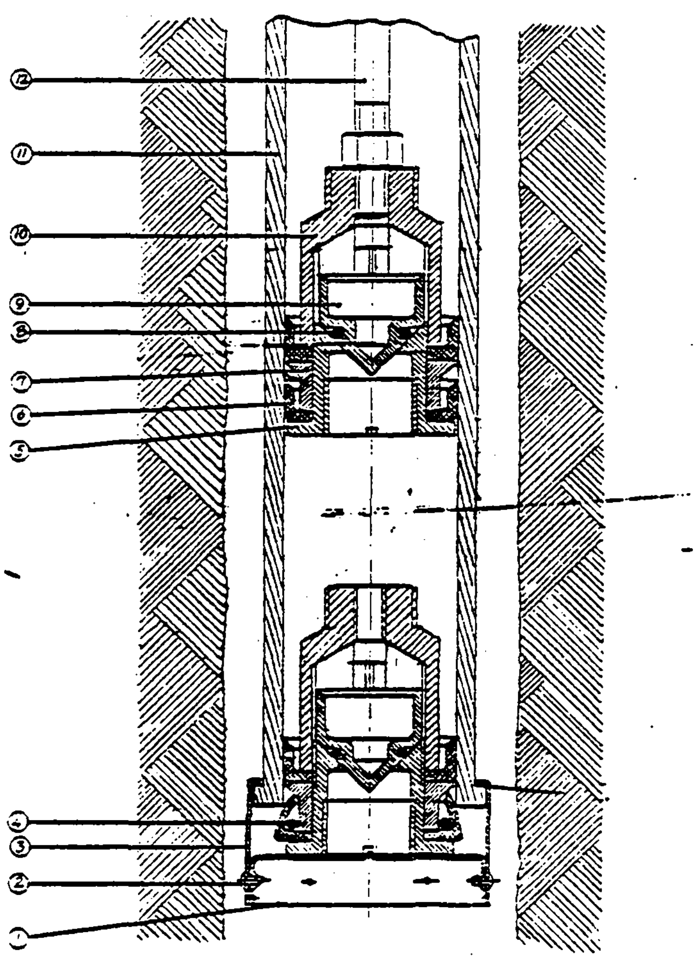


Figure 4.12 Design suggestion for open-type cylinder with extractable piston and foot-valve.

There are, obviously, possibilities to improve the design in many aspects, of which the above suggestion is only one. With new materials and simplified design the installation and maintenance will be easier, which will make handpump systems more reliable. With a standardized and simple design it is likely that the total cost will also be reduced in the future.

ABBREVIATIONS

CATR	,	Consumers´Association Testing and Research Laboratory
CIDA	,	Canadian International Development Authority
IDWSSD	,	International Drinking Water Supply and Sanitation Decade
IRC	,	International Reference Center
IST	,	Indian Standards Institution
ITDG	,	Intermediate Technology Development Groups
MEERA	,	Pumpmanufacturer in India
MEP	,	Minimum Evaluation Procedure
Mp	,	Madhya Pradesh
O&M	,	Operation and Maintenance
PEX	,	Polyethylene crossbounded
PHED	,	Public Health Engineering Department
POM	,	Polyoxymethylene (Acetal plastics)
PVC	,	Polyvinylchloride
R&C	,	Richardson and Cruddas
RWS	,	Rural Water Supply
SIDA	,	Swedish International Development Authority
UNDP	,	United Nations Development Program
UNICEF	,	United Nations Childrens Fund
VLOM	,	Village Level Operation and Maintenance
WDP	,	Water Development Project
WHO	,	World Health Organization
LWF	,	Lutheran World Federation
SWS	,	Sholapur Well Service