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DEPARTMENT OF
ENVIRONMENTAL ENGINEERING
Lund Institute of Technology
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# RURAL WATER SUPPLY IN DEVELOPING COUNTRIES

## -Field and Laboratory Studies with Emphasis on Handpump Technology

Robert Hahn
Lund 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.

Therefore, the handpump testing project has been of encouraging to work with. I would like to thank Mr Oscar Carlsson, who initiated the project, and my collegaues and others who have supported the project during the past years.

This paper is based partly on new results from laboratory tests of handpumps and partly on results presented earlier in the following reports.

Hahn, R. et al (1981) Village Water Supply in India. An Evaluation Study of the E.L.C. Water Development Project in Betul M.P., India.
Hahn, R. (1982) Handpump Testing and Development. Part 1. Project Description.
Hahn, R. (1982) Part 2. Interrim Report.
Hahn, R. (1983) Part 3. New Design; Particle Separator, Foot Valve and Rod Guide.
Hahn, R. (1984) Part 4. The First Year - Results of Completed and Ongoing Tests.

Lund July 1985

Robert Hahn

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## 1. INTRODUCTION

In order to achieve benefits from development, i.e. improved basic conditions for the poor, two things must be assured;

- efforts to stimulate development, in agreement with the existing situation and the causal mechanisms within the society
- access to essential public services for the target groups.

Water supply and waste disposal are among these essential public services. In the 1970's, the awareness of water - related problems gradually increased, along with the ambition to solve them. Water as a basic human need was discussed at a number of UN conferences during this period:

1972 The conference on the environment in Stockholm. The fresh water resources of the world were discussed as well as their importance for the environment and survival.

1973 The conference on population in Bukarest. The limitation of water resources was discussed in relation to the increase of population and the demand for a higher standard of living.

1974 The conference on food products in Rome. Problems dealing with water resources were emphasized since it was pointed out that an increase of agricultural irrigation is one of the best ways to attain an improved supply of provisions in the world.

1976 The HABITAT-conference in ~~Toronto~~ Vancouver. The subject for discussion was water resources and human habitation, i.e., the water supply of the community. It was stated that a thousand million people in the world lack adequate drinking water. Thus, it was recommended that the decade 1981-1990 should be called "The Drinking Water & Sanitation Decade", and that great efforts should be made to bring about an improvement.

1977 The water conference held at Mar del Plata. The main purpose of the conference was to discuss the utilization of global water assets and the appropriate technology in the struggle against the increasing water demand. It was recommended that the decade 1981-1990 should be designated the "International Drinking Water Supply and Sanitation Decade" (IDWSD). Each country should set up specific targets, taking into consideration its sanitary, social and economic conditions.

The following quote summarizes the idea behind the Water Decade (Unesco -81). "1981 marks the start of the International Drinking Water Supply and Sanitation Decade, a worlwide co-operative effort to provide clean water and adequate sanitation for all by the year 1990. The Decade has been decleared by the United Nations General Assembly in response to a human tragedy of enormous proportions: more than half the men, women and children living today have no ready access to clean drinking water, and fewer still have facilities for sanitary waste disposal. Over the next ten years many groups will join forces to remedy this situation, which gravely affects human health and productivity and severely impedes development progress. Participants will include governments of both developing and industrialized countries, non-governmental industry, schools and colleges, the media and several United Nations agencies".

The prospected situation of the water decade 1981-1990 is illustrated in figure 1. 1 and 1. 2. The access to an adequate water supply is currently substantially lower in rural areas than in urban areas. The general goal was complete coverage by the year 1990, however, most nations have later taken a less ambitious and more realistic planning approach.

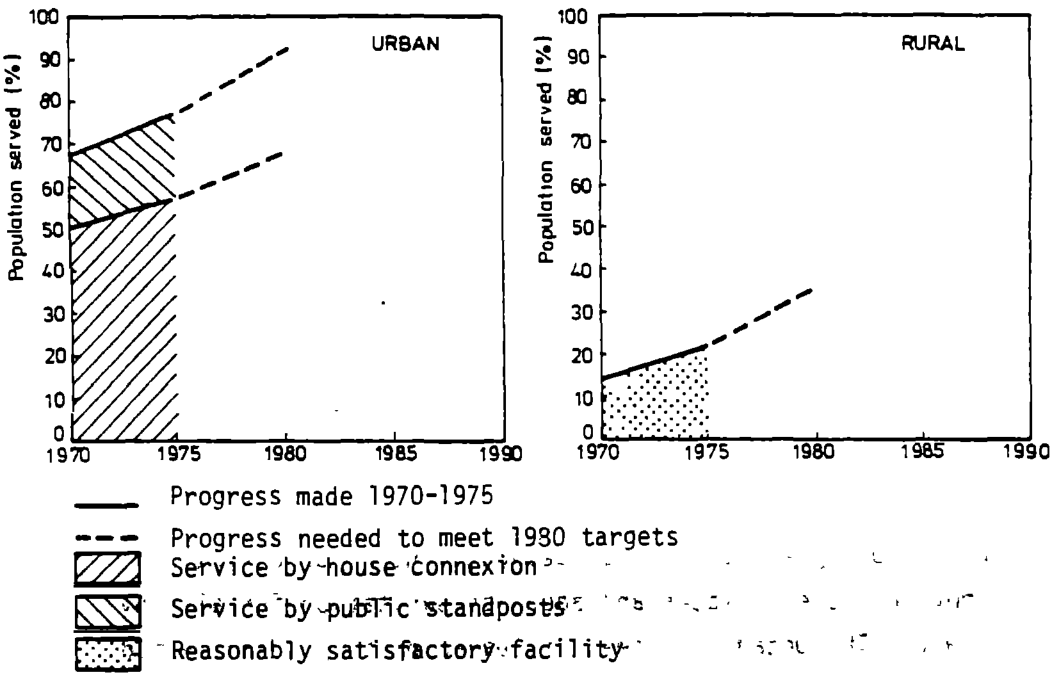


Figure 1.1 Community water supply in the developing countries. Percentage of population served (Hahn et al -81).

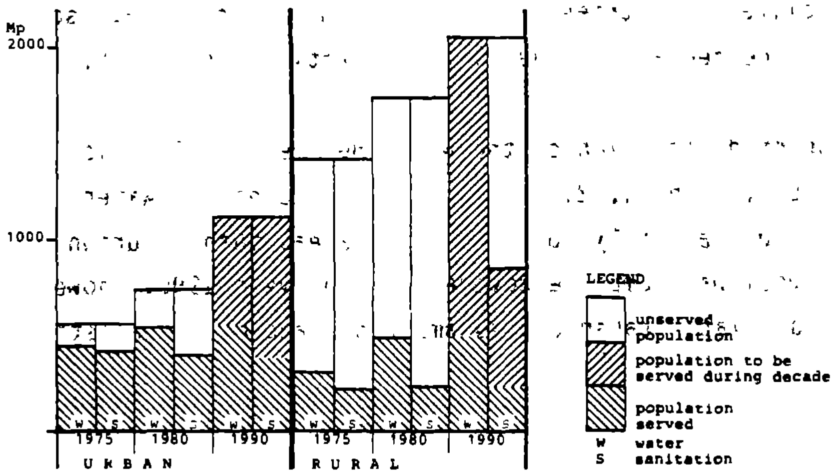


Figure 1.2 Population coverage during the IDWSSD, 1981-90 (Falkenmark -82).

A frequently cited estimate of the service level to be reached during the Decade, was made by the World Bank (Unesco -81). This option is also based on less sophisticated technology. Still, the total annual cost is calculated at approximately USD 30. 000 million. The coverage is estimated at:

| | | | |
|---|---|---|---|
| Urban | Water supply | 40% | house connection |
| | | 40% | stand pipe |
| | Sanitation | 25% | sewerage |
| | | 15% | septic tanks |
| | | 40% | latrines |
| Rural | Water supply | 10% | house connection |
| | | 30% | stand pipe |
| | | 40% | handpumps |
| | Sanitation | 10% | sewerage |
| | | 70% | latrines |

The strategies for the Decade involve support of national Decade programmes, through technical co-operation, generation of dynamic self-sustaining programmes, promotion of technical co-operation among developing countries and encouragement of the flow of external funds into national Decade activities. Several UN organizations, e. g. UNICEF, WHO, and the World Bank take part in planning and implementing the water supply activities.

From the table above it is seen that handpumps are expected to be used in the majority of rural installations. A breakdown of the figures on population to be covered shows that about half a million people a day have to be served. Other estimates on the number of handpumps to be installed have ended up with about 20 million during the decade.

As the Decade advances, it is becoming clear that the withdrawal of groundwater by means of handpumps is likely to be the most important option for provision of an adequate water supply for the rural population in most of the developing countries.

## 2. SCOPE OF WORK

This paper deals with appropriate technology for rural water supply in developing countries. The term "appropriate" is here used only in regard to technical aspects of water supply.

The work is limited to systems involving handpumps for the withdrawal of water from tubewells or dug wells. As mentioned in the introduction, handpumps have lately also been given much attention in tests, development work and donors support. Still, much remains to be done, as discussed below, before this technology is ready to meet the high demands set by the hard conditions under which it must operate.

The paper is based on two projects related to this subject. One is an evaluation study of a water development project in Madhya Pradesh, India. This study (Hahn et al -79) was made to evaluate the result of ten years of operation of a drilling programme. Some of this material illustrate the practise of drilling and pump installation and related problems in rural areas in developing countries. The other project deals with laboratory tests and technical development of handpumps (Hahn -81, -82, -83, -84). The parts of this project which relate to test procedures and test results are discussed in detail in chapters 4 and 5.

## 3. WATER SUPPLY IN DEVELOPING COUNTRIES

### 3.1 Technical Options

Basicaly three sources of drinking water exists:

1. Precipitation
2. Surface water
3. Ground water

Rainwater catchment has been practised for a long time in many parts of the world. Roof run-off can be collected on a smaller scale. In larger schemes, the surface run-off can be collected either in dams for direct use or by earth banks on gentle slopes. In the latter case, the water collected is normally used indirectly as groundwater recharge through extended infiltration.

Small-scale collection can be a way to provide an adequate water supply, but it usually isn't. Some reasons for this are:

- It is often difficult to find a surface large enough for the collection, larger than the roof.
- Good tanks with sufficient volume are required.
- If the water will last the storage period out, you may not be sure that the quality will last.
- The system is not reliable since both the intensity of the rainfall and the length of the dry season will vary.

Large-scale collection by embankment or dam construction may be efficient for community water supply. Being a local construction, it also provides a possibility for public participation and thus the capital cost can be lowered and the maintenance later on can partially be a local responsibility. Generally, however, the drawbacks of large dam constructions are:

- The high investment required.
- The need for geological and construction expertise.
- The change in water quality with time, by contamination, bacterial and algae growth, etc.

The use of surface run-off for drinking water supply in developing countries is not too common simply because of the relatively low availability of surface water (lakes, rivers and streams). To this we can add that surface water in arid and semi-arid regions is often of poor quality; high solids content related to erosion during flow peaks, high micro-biolic activity related to climate and/or eutrophication related to pollution. Increased use of surface water, where sufficient quantites of water are available the whole year round, will require:

- Water treatment by particle separation and disinfection.
- A water distribution system.
- Improved water pollution control.

There are, however, reasons for trying to extend the use of surface water, both from a hydrological point of view, considering the water balance, and also with respect to installation costs. A surface water system can be arranged at a comparably low cost since simple treatment like slow sand filtration can give a sufficient quality of treated water.

The primary reasons for utilizing groundwater are that:

- The availability is good. Sufficient quantities for household supply can be found almost anywhere.
- The quality of the water is good and it can normally be used without prior treatment.
- In areas with densely populated villages, one well or more will give sufficient service so that piped supply system will not be required.

On the negative side, we have, of course, the relatively high drilling cost, the need for rather sophisticated drilling equipment and problems related to pump installation and maintenance. This will be discussed in more detail below.

To summarize, the reasons for improving a water supply system can be expressed by four key-words; quality, quantity, proximity and reliability. As presented in WHO-83, these factors might be used as indicators for the level of service provided by a water supply, i. e.

Another activity within the project is field tests. Eighteen developing countries have been selected and local organizations are responsible for the follow-up of some pump types. A report from the field study will soon be available. The project also involves the promotion of the VLOM concept which has been given a lot of attention, especially from private pump manufacturers.

In India, handpump installation has been successfully promoted by UNICEF, who are responsible for the quality control and the manufacturing of the India Mark II handpump. At present there are 35 licensed manufacturers producing pumps for 11 states covered by the UNICEF programme. By the end of the Decade there will be about 1 million Mark II pumps in Indian villages.

A testing project is organized by UNICEF in the state of Tamil Nadu, in collaboration with the Water Supply and Drainage Board and the companies Richardson & Cruddas and WAVIN. Eighty pump are installed in Coimbatore district. The objective is to develop better pumping elements. Existing components are modified where necessary. The existing stock of spares should be able to incorporate in succeeding generations of pumps. Experimental components are;

- An extractable check valve made from the piston assembly.
- A grappling device attached to the piston, to be used to lift the check valve assembly.
- A brass cylinder slieve in PVC rather than cast iron casing.

The components are to be used togheter with a large diameter rising main. The test is expected to be completed in 1984.

In Bangladesh, where the groundwater table is at an average depth of about 6 m, over 500,000 suction handpumps have been installed over the last 10 years. The most common one is the Bangladesh No. 6 handpump.

| Make | Manufacturer | Cost | Suitable for community drinking water supplies? | Manufacture in developing country? | Reliability | Packaging quality |
|---|---|---|---|---|---|---|
| **Deep well pumps** | | | | | | |
| Abi-Vergnet ASM | Groupement Abidjan Industrie<br>SNE Mengin<br>BP 343 Abidjan | $836 to 20m | if pumpstand improved | no | pumpstand very unreliable<br>Below ground element good | reasonable |
| Atlas Copco Kenya | Atlas Copco<br>Terratest Enterprise Rd,<br>PO Box 40090, Nairobi,<br>Kenya | $669 (1981) | has potential | pumpstand yes<br>below ground no | likely to need maintenance | good |
| Briau Nepta | Briau SA<br>BP 0903, 37009 Tours,<br>Cedex France | $656 to (1982) 20m | has potential | no | would be robust if spring designed out | good |
| Funymaq | Funymaq<br>Honduras. CATS supplied by Georgia Inst of Technology, Atlanta, Georgia, USA | N/A | has potential | yes | foot valve easily damaged | very poor |
| Jetmatic | Sea Commercial Co<br>3085 R Magsaysay Blvd.<br>Cor V Cruz St, Manila 2806<br>Philippines | $32 (1982) without connecting rod & rising main | no | not ideal design | poor | good |
| Kawamoto Dragon No 2 | Kawamoto Pump Mfg Co.<br>11 39 4-Chome, Ohsu.<br>Naka-Ku, Nagoya, Japan | $362 complete (1982) | only upto 15 people | has potential | wears with intensive use | excellent |
| Korat [illegible] | [illegible] | [illegible] | has potential | has potential | [illegible] | [illegible] |
| Maldev | [illegible] | N/A pumphead only [illegible] | yes | yes | good although rising main needs attention | good |
| Moyno 1W2.6 | Robbins & Myers<br>Moyno Pump Div<br>1895 Jefferson St<br>Springfield<br>Ohio 45501 USA | $552 (1982) Pump only<br>$739 (1982) to 20m | not ideal; poor delivery rate | no | generally reliable but field maintenance costly and difficult | good but may deteriorate in wet conditions |
| Nira AF-76 | Vammalan Konepaja<br>38200 Vammala, Finland | $[illegible] (1982) | has potential | no | robust if design changes made | reasonable |
| Petro | WellDrill Systems AB<br>Tagenevagen 21, s-425<br>90 Hisings Karra, Sweden | $465 to 20m | pumpstand yes<br>pumping element no | has potential | needs design change | reasonable |
| Sumber Banyu | PT Celco Ind Co<br>43A JL Jendral, Gatot,<br>Subroto, Bandung,<br>Indonesia | $85 (1981) | no | no | poor | sturdy but awkward |
| VEW A 18 | Vereinigte Edelstahlwerke<br>Franz Josefs-Kai 51<br>A 1011 Vienna, PO Box 56,<br>Austria | $1,583 (1982) to 20m | only if skilled maintenance available | no | poor | good but awkward |
| Volanta | Jansen Venneboer<br>Industrieweg 4, Postbus 12<br>8130 AA Wijhe<br>The Netherlands | $[illegible] to 20m | has potential with modification | has potential | [illegible] reliable but design since changed — no new test report available | poor |
| Bandung | IWACO BV<br>PO Box 183,<br>3000 AD Rotterdam,<br>The Netherlands | $54 (1981) | no, needs priming | has potential | susceptible to accidental damage | unsuitable but manufacturer says carrier changed packaging |
| **Shallow well pumps** | | | | | | |
| Ethiopia Type BP50 | EWWCA<br>PO Box 1922, Addis Ababa,<br>Ethiopia | $[illegible] (1981) | yes | yes | reliable and easy to maintain; not very robust | good |
| New No 6 | Engineers Works<br>Steel Industries<br>67 Tejgaon I/Area,<br>Dhaka 8, Bangladesh | $[illegible] (1981) | not very, needs priming | yes | sturdy and simple but could wear considerably with heavy use | reasonable |
| Rower | Mirpur Agric Workshop Training School<br>c/o World Bank<br>222 New Eskaton Rd<br>PO Box 97, Dhaka,<br>Bangladesh | $33.50 in Bangladesh | not suitable but good for low lift irrigation | yes | likely to wear but parts easy to replace, a true VLOM pump | no data |

Table 3. 1. Summary of CA test findings (World Water Sept.-84). Pumps in shaded sections are those from which CA might expect the choice to be made.

The Rower pump has also been developed in Bangladesh. The pump gets its name from the operating action which is similar to rowing a boat. It lifts water up to a maximom of 5 m, through a 65 mm ABS plastic cylinder. The complexity of the pump is reduced since it works without a pivot.

Another new type is the TARA pump. A "third generation" non-suction low-lift handpump was developing during 1981-83. The pump is a direct drive pump wich lifts water from down to about 15 m. Fifty TARA pumps have also been sent to UNICEF in Sri Lanka for field testing. In rural Bangladesh a sample of 200 experimental TARA pumps will be mounted during a period of 3 years, starting january 1984. This test project is founded by CIDA through UNDP.

In Sri Lanka, a handpump field test is managed by the German Technical Cooperation organization. Sixty pumps of four types are currently monitored. They are:

-The AID/Batelle deep well pump
-The Sihalese deep well pump
-Two versions of the India Mark II type
-The second generation TARA pump.

In Nigeria, the U. K. company Consallen will install 2000 handpumps with extractable pistons. An ABS plastic rising main is used. Consallen was the only company to meet the special requirements in this case.

Another U. K. company, the March May, is manufacturing a deep well handpump from glass-fibre composites. The pump weighs about 40 kg, complete with 20 m drop pipe, and is claimed to meet the VLOM concept. The pump cylinder is PTFE-lined and the composite piston has an o-ring seal of nitrile rubber.

The plastic direct-drive handpump, manufactured in Canada by PEK, is also said to satisfy many of the VLOM requirements. The design is similar to the Ethiopia type BP50 pump tested by CA. The positive displacement pump balances the weight of the rod and the cylinder, not through levers or counterweights as on most other handpumps, but by using a buoyant rod (Aluminium or PVC).

In Thailand, 121 sites have been selected for field tests of handpumps. There are some difficulties in finding sites with a low enough static water level since the country has severe flooding problems more than four months a year. In the Philippines, 160 pumps are installed for field tests, mostly in new tube wells. Some of the wells, as in Thailand, are equipped with the Roboscreen.

In Papa New Guinea, handpumps are installed in wells with depths down to 45 m. Most wells are drilled with the handauger sludger method.

In the Peoples Republic of China,(PRC) a total of 166 pumps of foreign origin and 137 Chinese-made pumps will be tested. The Chines pumps are all of metal, since the PVC industry in PRC is not developed for products to be utilized for water supply. At present no deep well handpumps exist in PRC.

A laboratory in Beijing is being equipped for tests of 30 handpumps and another laboratory in Changsha will accomodate the testing of 16 shallow well pumps. China was also the host of the latest workshop on the state of the art and application of handpumps, August 1984.

Totally, in the East Asia and Pacific region, about 700 handpumps will be installed for laboratory or field tests in 1984. Some 36 % of these pumps are of foreign origin. A breakdown of the field trials are shown below.

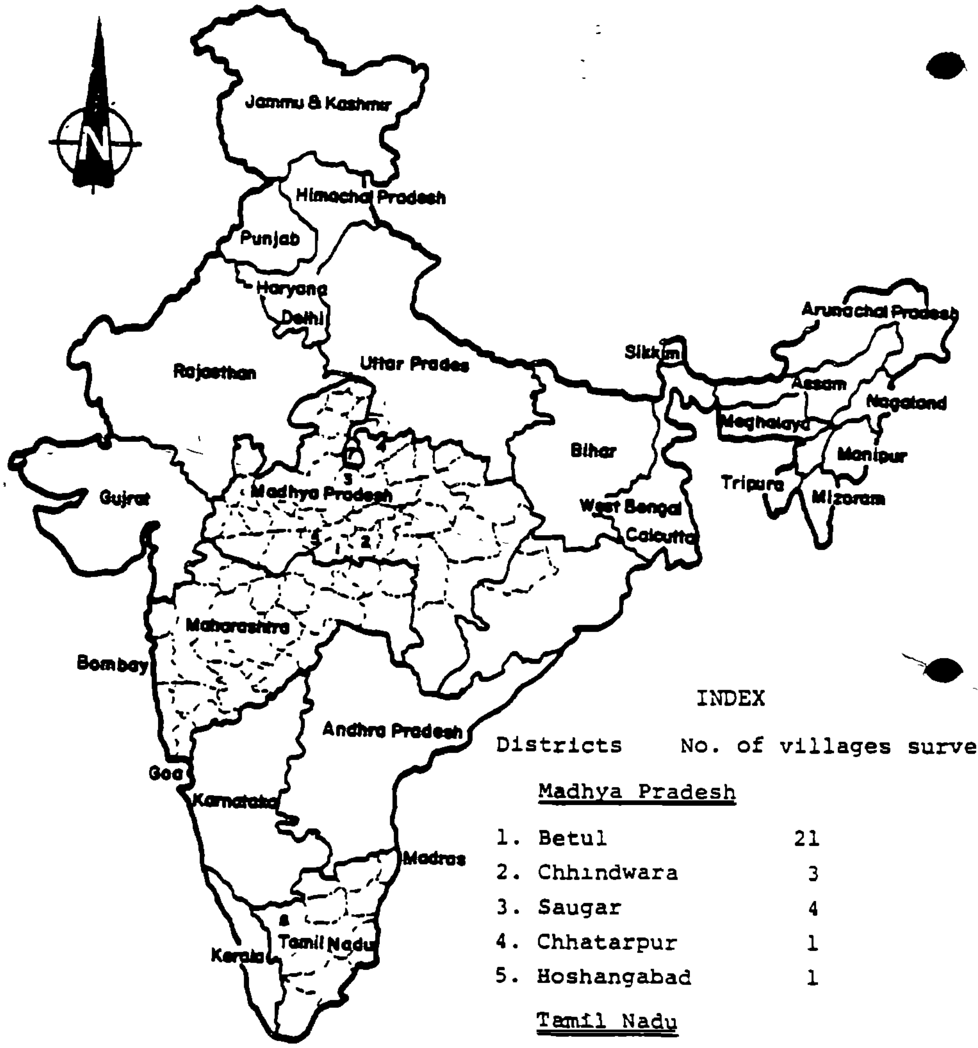
| Pumpmake | Nos. |
|---|---|
| India Mark II | 49 |
| Maldev | 69 |
| Tara | 45 |
| Blair | 35 |
| Consallen | 10 |
| Preussag Turni | 10 |
| Preussag Kardi | 10 |
| Rower | 3 |
| Treadle | 1 |
| TOTAL | 235 |

| Pumpmake | Nos. |
|---|---|
| Chinese | 137 |
| Thai | 110 |
| Philippines | 110 |
| Papa New Guinea | 67 |
| TOTAL | 424 |

## 3.3 EXAMPLE 1: Drilling of Tubewells in India

### 3.3.1 General

The following example of work with drilling of tubewells and installation of handpumps is taken from an evaluation study (Hahn et al -81) of Water Development Project (WDP) in Betul, M.P., India. WDP is run as an independent project within the Evangelican Lutheran Church in Madhya Pradesh. After ten years of operation of the project, an evaluation of the same was requested by its Swedish project manager as well as by the main donor, the Lutheran World Federation.



INDEX

| Districts | No. of villages surveye |
|---|---|
| Madhya Pradesh | |
| 1. Betul | 21 |
| 2. Chhindwara | 3 |
| 3. Saugar | 4 |
| 4. Chhatarpur | 1 |
| 5. Hoshangabad | 1 |
| Tamil Nadu | |
| 6. Coimbatore | 22 |
| Uttar Pradesh | |
| 7. Jhansi | 3 |

Figure 3.2. Map of India with the districts dealt with in the survey.

## 3.3.2. The Design of the Project

The present design of the project is described by the organogram in figure 3.3, to which the following comments refer.

The Synod is through its Council responsible for the activities within the church. WDP is, however, economically independent. The donors can influence the Project only through their power to accept or dismiss different project proposals from WDP.

Capital for starting up the Project and later for additional equipment was raised primarily by Lutheran churches in West Germany, USA, Canada and Sweden. The donations were canalized through the Lutheran World Federation (LWF). Other donors are e.g. the International Development Authorities in Canada and Sweden.

The Project is designed to be self-sufficient, in regards to running costs by means of income mainly from tubewell and extension drilling. Additional external funds are necessary, however, due to the organisation's involvement in other activities that are free of charge, such as geological investigations, water quality control and pump repair, and because of the relatively low drilling charge and a few free or subsidized bores.

| | Personnels | Daily Labours | Man hours per year | Total value of investments | Capital invested 80/81 | Running costs | Income | Grants for projects | Grants for running costs | Donations recieved in kind |
|---|---|---|---|---|---|---|---|---|---|---|
| Office | 12 | - | 25.440 | 1.145 | 350 | 696 | 41 | | salaries<br>147 | spares from abroad<br>900 |
| Store | 3 | 1 | 8.480 | stock value<br>1.400 | - | - | - | marginal farmers scheme<br>232 | | |
| Workshop | 6 | 4 | 21.200 | 112 | 100 | 227 | 18 | | | |
| GID and TRT | 8 | 2 | 21.200 | 200 | 50 | 217 | 37 | | | |
| Well Test | 9 | 1 | 21.200 | 300 | 30 | 213 | 11 | | | |
| Tubewell drilling | 20 | 5 | 53.000 | 2.500 | 100 | 2.512 | 2.508 | staff quarters<br>232 | | |
| Extension drilling | 4 | 2 | 12.720 | 218 | 141 | 153 | 76 | | | |
| Pump repairs | 7 | 3 | 21.200 | 50 | 15 | 287 | 35 | | | |
| T O T A L S | 69 | 18 | 184.440 | 5.925 | 786 | 4.305 | 2.726 | 464 | 147 | 900 |

Table 3. 4. The situation in the financial year 1980/81.
Figures in 1000 rupies, which equals USD 115 in 1981 exchange rate.

The Project Advisory Committee was appointed with the intention of improving the contact and the exchange of information between the Church and WDP. The committee consists of three delegates from the Synodical Council and two from WDP, the project director and the project manager. The project director is chairman of the committee. He also has the right to appoint another two delegates as consulting experts on special issues.

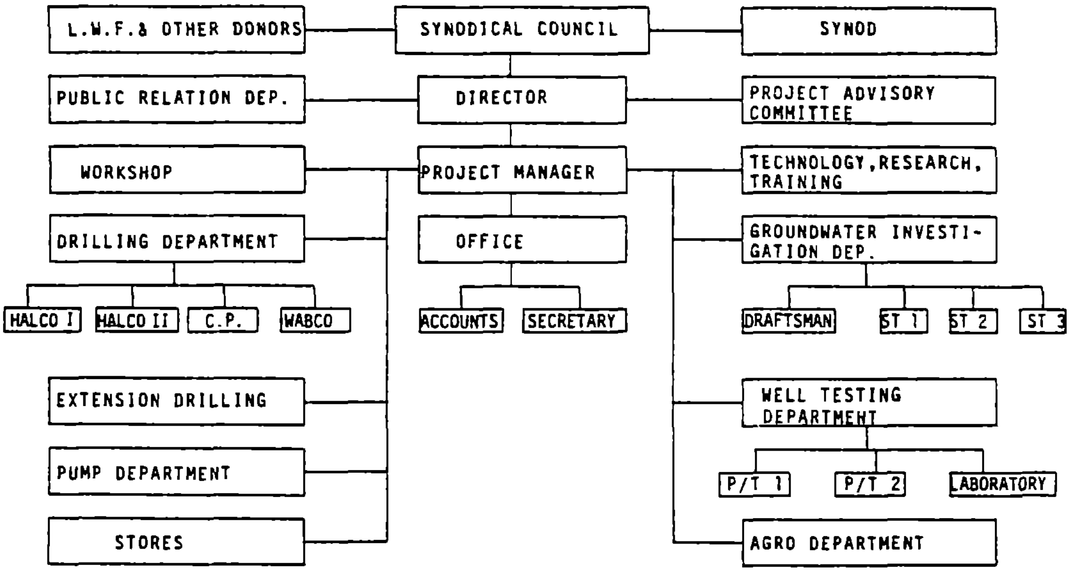


Figure 3.3. Present organization of WDP.

At the time, the Director was responsible for the overall leadership of the Project and the contact with clients, donors, etc. The Project Manager was responsible for the operation of the departments and also directly responsible for the drilling activities. All these duties are now the responsibility of one person, i. e. the directoral and managerial services have been combined.

At present, the Public Relations Department employs only one person. Part of its work has to do with public relations, but most of it is administrative. The department arranges inspections of vehicles and deals with licences, etc.

About 200 surveys are made each year. When drilling is done without a prior survey, a geologist goes along with the drilling team to select a proper site.

The resistivity survey has proved effective, especially in crystalline rocks. About 90 % of the wells were successful when a geophysical survey was made prior to drilling. In basalt and sandstone the rate of success is lower, about 56 %.

The Well Testing Department runs to units for test pumping of wells. A simple yield estimation is always made with a V-notch, as the bore is pumped clean. A constant rate test and/or a step-drawdown test is made in order to select a suitable pump, when a powered pump is to be installed.

The step-drawdown test is generally made in five steps of about 100 minutes each. The constant rate test usually consists of 12 hours pumping and 12 hours recovery. The water level is measured with an electric water level indicator and the discharge rate with an orifice plate.

The department also has a small laboratory for chemical water quality analyses. Most of the analyses are made spectrophotometrically with a Hach field kit, and some are made titrimetrically, e.g. fluoride. The precision of the measurements could be estimated to be about ± 5%. which is not very high, but quite enough for the purpose.

Equipment for bacterial quality analyses with a membrane technique (Millipor) is available, but has not been used since 1976. These analyses could, when needed, be made in Naghpur, about 180 km away from Betul.

The WDP has, since 1976, been trying to form an Agricultural Department, (AGRO) but due to lack of skilled staff, it did not come off the ground to 1980, when one agriculturist was employed. Since then, the "marginal farmers scheme", which was started in 1976, has also come off the ground and the first ten wells were drilled in 1981. At the same time a Rural Community Development, prepared in 1978, was stared.

The aim of the Marginal Farmers Sceme (MFS) is to introduce more profitable farming techniques to farmers with small land-holdings in the Betul area. Primarily this will involve better irrigation techniques, which will chiefly be achieved by provision of tubewells.

The MFS is implemented in the following way:

A. A groundwater potential study of an area is conducted by TRT and GT.

B. The agriculturist contacts the farmers in the area and identifies them by four criteria:

   I. Land-holding of not more than 10 acres

   II. The area is electrified

   III. The land is suitable for agricultural purposes

   IV. The farmer is interested in development.

C. The farmer is introduced to a bandk which undertakes to finance the development of the farm.

   The WDP deposits 25 % of the loan as security with the bank.

D. The WDP carries out the work, including drilling, testing and installation of the pump and charges the farmer a subsidized cost (at present 30 % of the drilling cost is subsidized through grants from LWF). After checking the work, the bank pays out the money to WDP.

E. After the irrigation system has been installed on the farm, the WDP agriculturist continues to help the farmer with agricultural and financial advice, etc.

The workshop was put into full operation during the second year of the Project, and has developed under the leadership of the works manager, Anselm Gonsalves. All necessary equipment, lathe drill, power hacksaw, welding set, gantry, etc, are in use.

The Project has a fairly large number of vehicles and other equipment at its disposal (see table 3.5 below). To maintain a high working capacity, it is important to minimize machine downtime.

A comprehensive stock of spare parts is imperative, for two main reasons. The equipment is, to some extent, technically highly sophisticated and in many cases of foreign origin, which means that spare parts are not available in India. Furthermore, the Project is located in a remote area of Madhya Pradesh so even Indian spare parts can be difficult to obtain within reasonable time.

Orders for spare parts are made well in advance to maintain a minimum stock level. It takes, for instance, about 6 months from the date of order for spare parts to reach the store in Betul. Most of the foreign goods are sent via the aid organization War-on-Want in London.

The store is organized on a Kardex system according to the parts catalogues for the different machinery. The information listed contains stock position, location of spare parts in the storeroom, value of particular items and the minimum stock level.

The Drilling Department employs crews for tubewell drilling. Each crew consists of a site supervisor, a driller, two helpeers and a cook.

The two oldest "down-the-hole hammer" -type machines have been in work from the very start of the Project. These machines are mounted on 20-ton Leyland trucks. A 100 psi Brommwade compressor, powered by a 200 hp diesel engine, is used for the air supply to the drilling mast unit.

Ashok Leyland Comet trucks are used as support vehicles for the drilling machines. Mounted on these vehicles are diesel and water tanks and a tool box. Drill tubes and casing pipes are carried on either side of the tanks. The equipment allows the crew to work outside the base for two weeks at a time.

The Pump Department plays an important role. To quote one of the annual reports of the Project: "A well without a suitable pump or without an operating pump is nothing but a hole in the ground".

The team, 10 men, undertakes the installation and repair of hand, diesel and electric pumps, as well as the construction of platforms and drainage. As PHED increasingly carries out pump installations within their own organization, most of the contracts with PHED presently involve concrete constructions.

A lot of equipment is required to run the project. The following list gives an overview of the vehicles and other equipment utilized by the different departments.

| Department | Vehicles and Equipment |
|---|---|
| GID | 3 Land Rover with survey equipment |
| TRT | 1 Jeep for field work |
| AGRO | 1 Motor cycle for extension work |
| Extension drilling | 1 Bedford truck with hoist<br>1 Atlas Copco VT 250 compressor<br>1 CPT 300 compressor |
| Tubewell drilling | 2 Halco 625, for hard rock<br>Capacity. depth max. 100 m<br>diameter 100-150 mm<br>pressure 100 psi<br>air volume 600 cfm<br>2 Ashok Leyland Commet, support trucks<br>1 CP 700, combination rig for soft as well as hard stratas<br>Capacity: depth max. 300 m<br>diameter 150-300 mm<br>pressure 250 psi<br>air volume 825 cfm<br>1 Ashok Leyland Hippo, support unit<br>1 Land Rover, for supervision<br>2 Holemaster 1500, for alluvium<br>Capacity. depth max. 100 m<br>diameter max 400 mm<br>2 Ford Super 400, tractor for towage<br>1 Tractor with trailer, for support<br>1 Land Rover 109, for supervision |
| Well testing | 2 Ashok Leyland Commet, with generator set and a range of submersible pumps for yield testing<br>Capacity: max 75 $m^3/h$ at 150 m pumping depth |
| Pump repair | 1 Bedford pick- up for light transports<br>2 Land Rover pick-up<br>1 Mahindra jeep, for supervision |
| Workshop | 1 Scammel, recovery vehicle<br>1 Mahindra pick-up, for light transports and emergensy purpose |
| Office | 2 Land Rovers |

Table 3.5. Equipment used by WDP.

## 3.4 EXAMPLE 2: Handpump Installation in India.

### 3.4.1 General

The following example is taken from the same evaluation study as example 1 (Hahn et al -81). The data presented were collected from a field investigation of 55 randomly-selected handpumps in the area. All villages visited were documented in a questionaire (appendix I). As shown in the result from this investigation, e. g. regarding localization, the outcome was not quite as expected at the time when the questionaire was prepared. This clearly illustrates the importance of testing the methodology and the materials, forms, etc. before the investigation is performed on a larger scale.

### 3.4.2 Condition of platforms and drainage.

In the village investigated, only 31 % of the handpumps had a good and firm foundation while 22 % had no platform constructed. Significant differences between the districts could be noticed. Tamil Nadu had platforms constructed at all wells and also a higher percentage of platforms in good condition. In Betul Districts a majority of the wells had platforms in "fair" condition, ranging from slightly damaged to bad, with broken and cracked concrete, leaking and loosely-fitted pumps.

About 70% of the platform constructions were made with an arrangement for drainage, but only in 50% of the wells was the drainage in order. Tamil Nadu also had a higher percentage of drainage in good condition. It was, however, generally not more than 1 m in length. It could be argued whether or not that is sufficient. In Betul District the mean length was 3.0 m and in other districts 2.0 m.

Only in a few cases could a soakage pit be seen functioning. Generally, the pit was too small or no arrangements at all had been made for infiltration. Stagnant water on the surface around the platform and/or after drainage was the rule.

The local PHED engineer stated that new constructions and reconstructions of platforms are to be made in the near future, according to UNICEF instructions. UNICEF prescribe a circular platform with a diameter of 1. 6 m. Experience at WDP and inspections of such platforms indicate that even larger dimensions would be appropriate.

### 3.4.3. Condition of handpumps.

The selection of villages for the questionnaire (appendix II) was based on handpumps. Fifty-five handpumps were chosen at random, stratified after type of pump and year of installation. Of the chosen handpumps a large number were found to be located in Betul District and in the state of Tamil Nadu. The remaining pumps are located in Uttar Pradesh (3) and in M. P. in the districts of Sangar (4), Chhindwara (3), Chhatarpur (1) and Hoshangabad (1). Their location is shown in figure 3.2.

| Area | In good condition | In fair condition | Out to order | Total |
|---|---|---|---|---|
| Betul District | 7 | 11 | 3 | 21 |
| Tamil Nadu | 10 | 4 | 6 | 20 |
| Other districts | 7 | 1 | 4 | 12 |
| Total | 24 | 16 | 13 | 53 |

Table 3.6 Number of handpumps distributed according to condition and location.

To test the hypothesis that the condition of the handpumps is the same in Betul, Tamil Nadu and other districts, the Pearson Chi-square Test of Homogeneity was used. The deviation from the null-hypothesis of equal distribution in all cases was found to be in significant. Consequently, there could not be said to be any differences between the areas according to the condition of handpumps.

A point estimate of the proportion of handpumps out of order is, for the total material, 13/53 = 0.25. At a 95% confidence level, 25% of the handpumps do not work and the interval of confidence is given to be [13, 36] .

| Type of pump | In good condition | In fair condition | Working | Out of order | Total |
|---|---|---|---|---|---|
| Mahasagar | 1 | 3 | 4 | 2 | 6 |
| Jalvad | 1 | 5 | 6 | 4 | 10 |
| Sholapur | 0 | 2 | 2 | 0 | 2 |
| India Mark II | 22 | 6 | 28 | 7 | 35 |
| Total | 24 | 16 | 40 | 13 | 53 |

Table 3.7 Number of handpumps distributed according to the condition and type of pump.

A test corresponding to the above was made. But in this case it concerned different types of pumps according to the distribution of "working" and "non-working". It gave a non-significant result which means that no difference in this aspect between the types of pumps could be found.

If, instead, the condition ('good', 'fair' or 'not working') is tested in the same way, a significant difference between the pump-types is found. The hypothesis that the first three older pump-types have the same distribution could not be rejected. Accordingly, a test of the hypothesis that the share of pumps in good condition is equal, in regards to the class 'India Mark II' and the class 'other pump types', gives a significant deviation on the level of 99.9%. This proves that there are more pumps of the India Mark II type which are in good condition than there are of the other pump types

A point estimate and a 95% confidence interval for the share of pumps in good condition gives the following results:

| Type of pump | Share in good condition (%) | Interval |
|---|---|---|
| India Mark II | 63 | [46,79] |
| Other types | 11 | [0,34] |

As the intervals do not cover each other, the differences between the two classes are obvious.

### 3.4.4 Maintenance of handpumps

Of the 13 handpumps found out of order in the survey, 2 had damages on the pump head (the above-ground mechanism), 8 on the below-ground mechanisms and 3 on both, i. e. breakdowns in the below-ground mechanism seem to dominate in about 70% of the cases. Other investigations on the nature of repairs, report that 65-70% breakdowns of this type, e.g. wear and tear of cylinder assembly, rod and pipe cut or falling.

These 13 pumps had been out of order for a period of time ranging from 1 day to about 3 years.

| Time out of order | No.of pumps | Precentage |
|---|---|---|
| 0-15 days | 2 | 15 |
| 15-30 days | 2 | 15 |
| 1 month or more | 9 | 70 |

In four cases the breakdown had not been reported; in one of these cases the villagers did not know whom to contact and in the rest there was probably a lack of interest. In two cases the fault was reported but nothing had happened so far. The remaining seven villages had reported and a repair-team or a mechanic had tried and failed. The reason for the failure was said to be lack of tools, spare parts, etc. or poor training.

At present WDP carries out maintenance work only occasionally, when asked for. PHED is building up a control system for pump repair. The system, which is partly similar to the three-tier system suggested by UNICEF, is based on regular inspections of the handpumps, depending on village density, every two months.

The repair work is done by the mechanic alone, or with the help of an assistant. He is equipped with simple hand-tools and, hopefully, a bicycle. Heavy work, such as removal of cylinder assembly and transport, is done with the assistance of villagers or with the help of staff from the center in Multai.

The percentage of handpumps found in working condition in this survey indicates an improvement compared with statistics for the year 1979.

On the other hand, the fact that most of the handpumps were found out of order and had been so for a long time would indicate the opposite. Anyhow, no maintenance system can arrive at good results without the participation of the community. Thus, any repair system, however effective, will fail unless the villagers themselves are informed about the advantages of using handpump water and are taught the proper use of handpumps.

### 3.4.5 Localization of handpumps

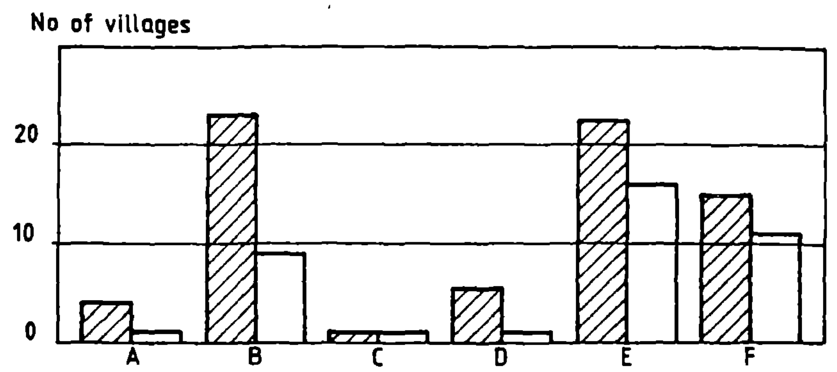
Out of the 55 villages in the survey, 31 % had the tubewell centrally located. A location outside the villages was decided up on chiefly because of hydrological aspects or the existence of passable roads for the drilling equipment (figure 3.4 ). In 11 of the 15 cases where accessibility had been decisive for the location of the tubewell, it was placed outside the village.

In all cases the tubewell was accessible to all inhabitants of the village, irrespective of caste, social position or other differences between groups of the population. The water could also in each case be used free of charge, as the tubewell is financed by the authority responsible for community water supply (Engineering Department or Water Board).

In 27% of the villages in the survey, only water from the tubewell was used (15 villages). In the remaining villages, some households used the traditional water source, an open well or a stream.

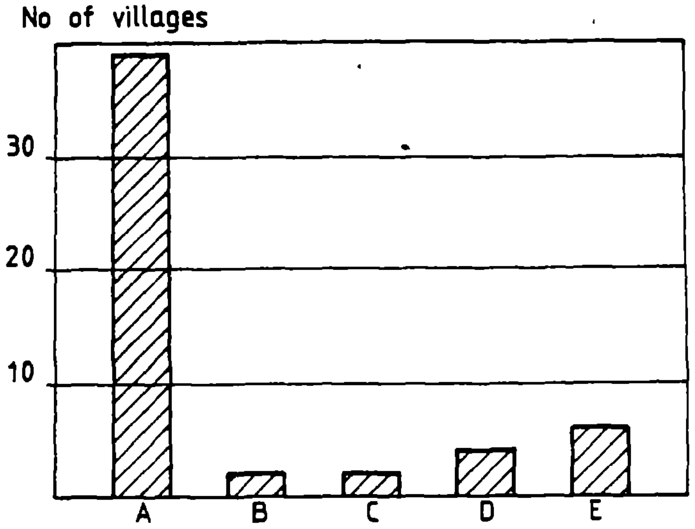
The reasons why not all households use the tubewell are given in figure 3. 5. The predominant motivation is "inconvenient situation". As can be seen in figure 3. 6 , this could not be the total explanation.

Only in two of the villages where open wells are also used besides the tubewell, is the distance to the tubewell considerably farther (6% of the villages). In the remaining villages, 94%, the distance was about the same to both sources or was even much farther to the open well.



A. Population/household density
B. General opinion in the village
C. Opinion of influential aspects
E. Hydrogeological aspects
F. Existence of passable roads etc.

Figure 3.4. Reasons given in the survey for the localization of the tubewell in the village. (Hatched bars show the distribution for the total number of villages (55) and the open bars the distribution for villages where the tubewell has been placed outside (32).)



A. Inconvenient situation
B. The water is not accepted as suitable drinking water
C. General disinterest
D. Low yield
E. Other handpump in the village

Figure 3.5. Answers in the village survey, motivating the fact that the tubewell is not used by the whole population (40 villages out of 55).

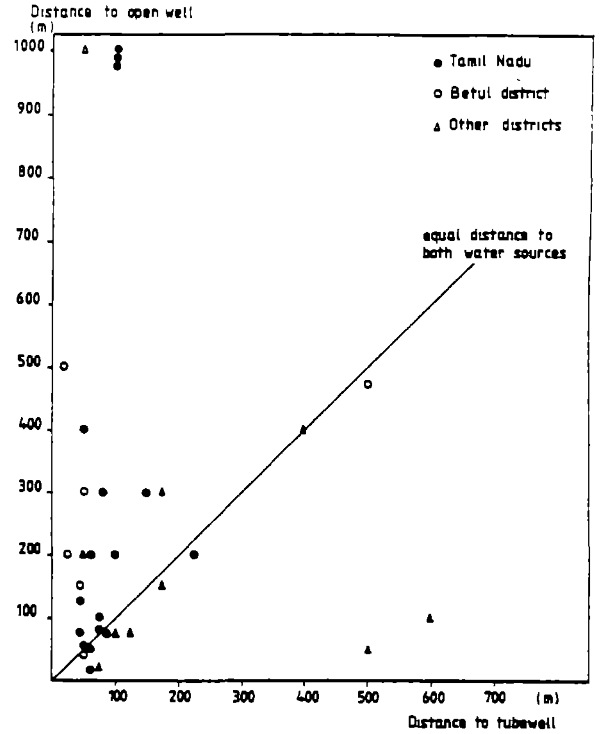


Figure 3.6. Distance from nearest house to tubewell and to open well in the villages in the survey where 'inconvenient situation' of the tubewell is said to be the reason why some households prefer the traditional water source.

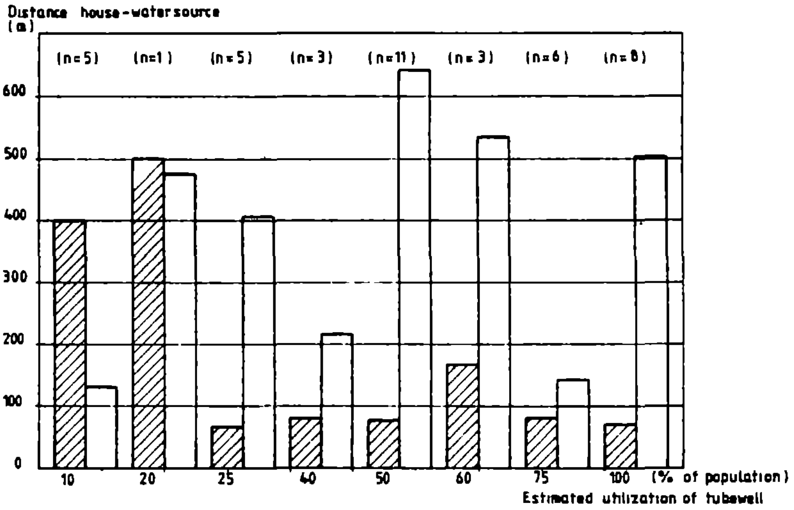


Figure 3.7. Percentage of households in the villages that use the handpump (hatched bars) in relation to distance between the nearest house and the watersource. The bars give the mean value for the villages with the same degree of utilization of the tubewell. Open bars represent the mean distance to the alternative source (the open well) at the given percentage utilization of the tubewell.

Thus, 'inconvenient situation' could not be the only reason why only part of the population used the tubewell, but probably different sorts of 'inconveniences' must be taken into account.

One factor contributing to low utilization of the tubewell could, for instance be that pumping is experienced as hard work, compared with lifting a bucket of water from an open well.

Another form of inconvenience is that pumping is more time consuming and could only be done by one person at a time. Current standards prescribe one handpump per 250 persons. If each person uses 25 l per day and if pumping gives 10 l per minute, withdrawal of half the daily supply would require about 5 hours. Thus it is not possible for all the villagers to fetch water within the same limited period of time, morning and noon.

Even if distance is not the only decisive factor determining the choice of water source, it is an important one. Figure 3.7 indicates that if the distance to the tubewell is comparatively farther than to the open well, only a small percentage of the households in a village use the tubewell. When 50% or more of the households use the tubewell, the distance to the traditional source is much greater than to the tubewell.

# 4. HANDPUMP TESTING AND DEVELOPMENT

## 4.1 Handpump Design

This section is meant to give a very short introduction to the design of handpumps, for readers not too familiar with this kind of technology. Among more extensive descriptions, the IRC publication "Hand Pumps" Technical Paper Series No 10 ( McJunkin -82) can be strongly recommended.

The basic technique of pumping by hand dates back to the sixteenth century. Over the years several different technical handpump principles have been applied.

- The reciprocating, positive displacement pump, which operates with a piston in a cylinder.
- The rotary pump, which consists of two rotating gears meshed together in a housing.
- The helical rotary pump, often termed the progressive cavity pump, which consists of a single-thread helical stator. The best known pump of this type is the British "Mono"pump.
- The diaphragm pump, which employs an elastic membrane as the pumping element.
- The chain pump, of which several models have been used. An endless chain which carries the water up to the well top and empties it into the spout by centrifugal action or by gravity if small buckets are attached to the chain. A rope has simply been used in handmade versions.
- The hydraulic ram, which uses the kinetic energy of flowing water to pump a portion of it to a higher level.
- The ejector pump, in which a portion of the water pumped is used to force a larger volume of water to the surface.
- The peristaltic pump, where peristaltic action on a flexible hose is used either as a pumping element or to induce pumping by hydraulic action to another pumping element.

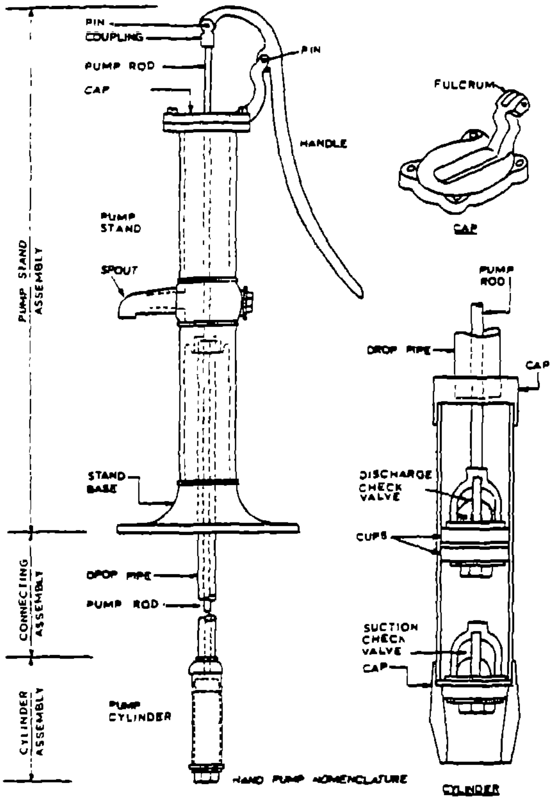


Figure 4.1. Handpump nomenclature (Mc-Junkin -82).

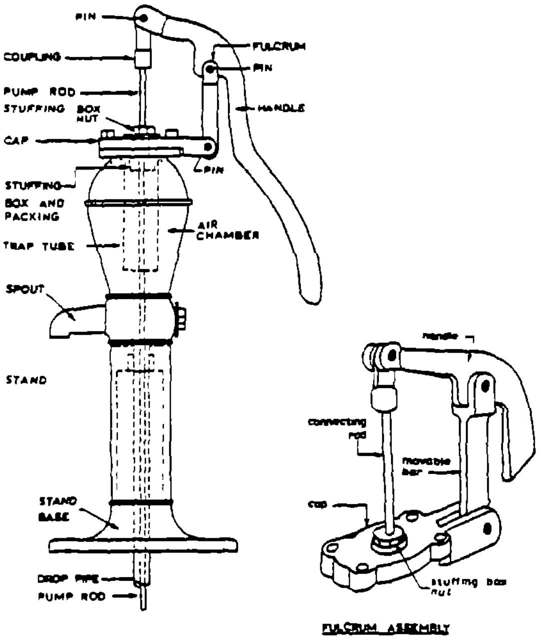


Figure 4.2. Handpump with stuffing box for use as a force pump. (Mc Junkin -82).

Apart fromn the mechanism of the pumping element, the pump design can vary in regard to the operation of the pump. The most common arrangement is to use a lever-type handle in order to obtain a mechanical advantage. Smoother operation can be adopted using a fly wheel and a crank-shaft to lift the pump rod. Some recent pump designs apply hydraulic transfer of the force down to the pumping element. For hygienic reasons, the hydraulic media used is clean water from the well. The pump can also be foot-operated as in the "Kangeroo-pump", in which the water is lifted by a spring, compressed by the body weight of the person pumping. Another foot operated design uses the pedal drive as in a bicycle to gain an ergonomically improved operation.

The most common type is the single action, reciprocating, positive displacement pump. With this straight forward design, a fairly energy-efficient operation can be maintained. Morever the construction is not too complicated and thus well-adapted to local manufacturing in developing countries. The large number of this type of pump already installed is also a good reason for trying to improve the design and finding better materials for the cylinder assembly and other components, which is the major objective of the pump test described below.

The basic components of the positive displacement pump (or the piston pump) is shown in figure 4. 1. By definition we can distinguish between:

- The shallow-well pump, where the plunger and its cylindere are located above the ground (in the pump stand) or 1-2 meters below ground if protection against freezing is required. The design relies on lifting by atmospheric pressure, which in practise limits the operating depth to about 7 m.
- The deep-well pump, where the cylinder assembly is located below the static water level. The maximum pumping depth is dependant on the human motive power, the cylinder and rising main diameter and the mechanical advantage. This means that conventional constructions are limited to depths of down to about 200 m.
- The force pump, where the top of the pumpstand is sealed with a

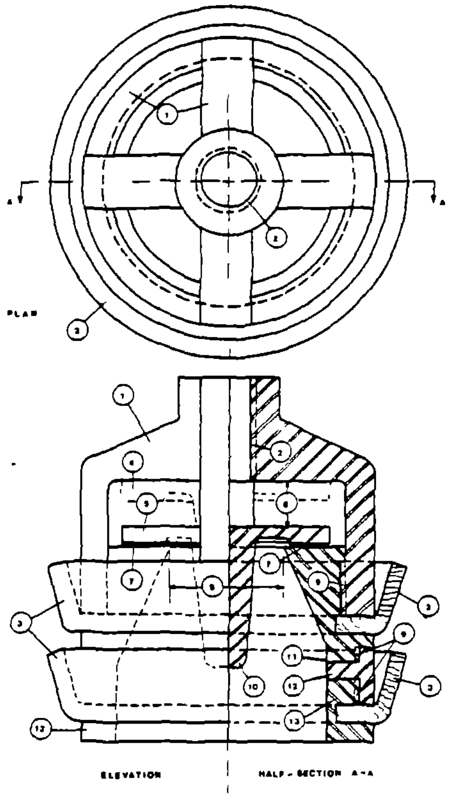


Figure 4.3 Detail of plunger assembly (Mc Junkin -82).

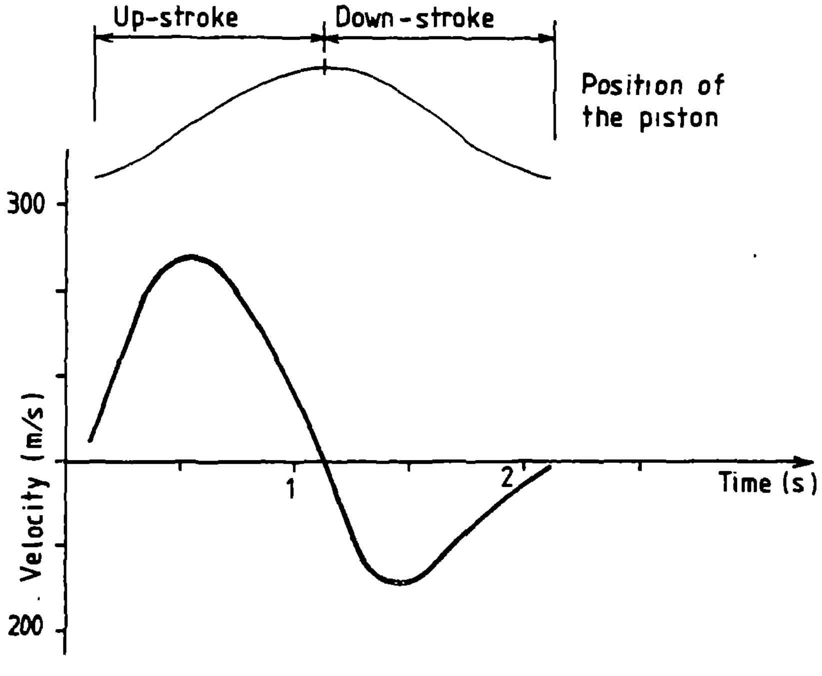


Figure 4.4 Movement of the piston during a pumping cycle.

stuffin box. With this arrangement water can be forced up higher than ground level, i.e. to an elevated storage tank. Both shallow and deep well pumps can be used in this application.

When operating the piston pump the plunger is accelerated from its bottom position up to the middle of the cylinder, ideally to the half-way point of the stroke length. Then the piston is retarded to zero at the upper turning point, where it is either pressed down by force or let down by gravity to complete the pumping cycle. The velocity during the cycle is shown in figure 4.4.

The required pumping force can roughly be calculated as:

$$F = mg = \gamma \, H \, A \, g = \frac{1}{4} \gamma \, H \, \pi \, D^2 \, g \approx 7.7 \, HD^2 \text{ (kN), where}$$

m = Mass of water column (kg)
H = Static head (m)
D = Cylinder diameter (m)

To this force the work to lift the pump rod, which has a weight of about 1 kg/m, must be added if it is not fully balanced by the weight of the handle. Further more the pumping efficiency is reduced by different losses,L, consisting of:

L = Ls + Ll + Lf + Lm, where

Ls = Headloss during pumping
Ll = Capacity reduction due to leakage through cup seals and valves
Lf = Losses from friction between the seal and the cylinder wall
Lm = Losses from mechanical friction in the pump.

The combined effect of theoretically required energy to lift the water, the added work to lift the lifting device (pump rod) and the effect of different losses are shown in the figure below. The increase of the effect of losses with increased pumping depth is principally dependant on the factors Ls and Lf.

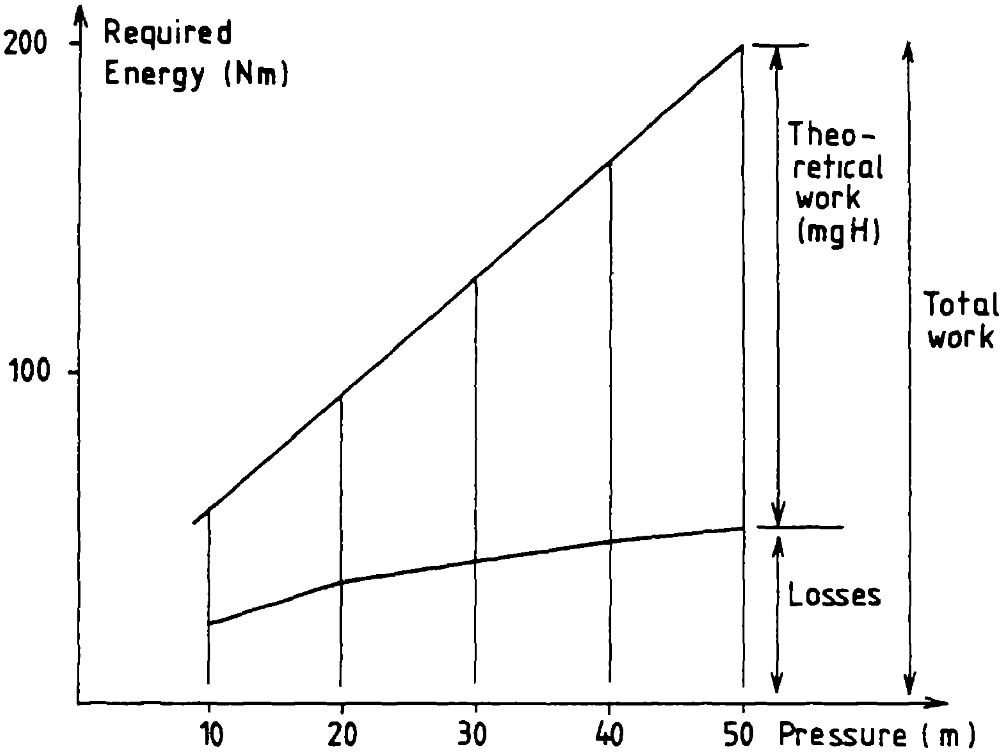


Figure 4.5 Required energy at different depths.

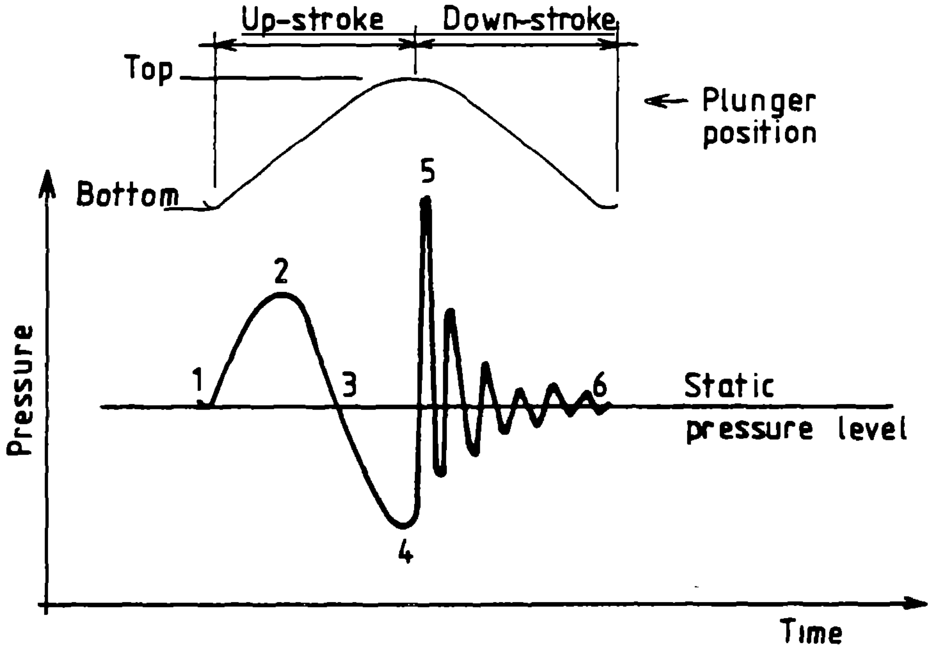


Figure 4.6 The pressure in the cylinder, above the piston, during a pump stroke.

The calculated force can be seen as the average over the pumping cycle. Actual pump tests will show that peak forces occur which are two to three times the calculated force. This means increased load on couplings, valves and other equipment, which has to withstand these peak stresses. An understanding of the variation in force, or as shown below, internal pressure, will also be of guidance in design of proper valves and other devices in order to minimize such variations:

The rapid pressure variations during a pumping cycle are of two kinds: One slower alteration due to the force required to accelerate the mass of water retained in the rising main and later the effect of the kinetic energy given to this mass.

One rapid pressure wave induced by the closing of the foot-valve at the end of the cycle.

These variations are shown schematically in figure 4.6.

1. The plunger starts to accelerate.
2. The acceleration of the plunger and the above mass of water reaches its maximum, at about 1/3 of the upward stroke-length.
3. The kinetic energy given to the water column has reduced the pressure, since the piston is now slowing down, at about the middle of the stroke-length.
4. The pressure drops below the static level if the water column has been given enough velocity. When this low pressure is maintained for some time the (hydraulic) pumping efficiency will exceed 100 %, since the capacity in l/stroke will be higher than theoretically given by the cylinder volume. This occur at about 2/3 of the upward stroke-length.
5. The piston has now reached its top position. The water column slows down and when the flow direction alters (or just before depending on the density of the poppet), the foot-valve closes. If the water has turned down-wards, the closing will give a hammering effect.

6. The pressure transients have declined during the downward movement of the piston. The pressure can protrude since the piston valve is open during the down-stroke. A new cycle can start.

To conclude, there are still design improvements to be made on handpumps. Construction improvements and evaluation of proper materials can increase the energy-efficiency and reliability. New design and new materials can also bring the pump of the piston pump closer to the VLOM - concept. This concept states basically that pump manufacturers should aim at producing a pump which allows for Village Level Operation and Maintenance. The stress is on maintenance, i. e. spare parts should be locally available and/or manufactured and parts the pump should be easy to install and repair.

## 4.2 Project Objectives

The handpump testing and development project described below was started at the Department of Environmental Engineering, Lund Instute of Technology in 1982. The project was a result of problem identification and discussion made during the work with the evaluation study reviewed here in section 3.3 and 3.4

The major objective of the testing project is to improve the design of the handpump by;

- comparative tests of handpump components, especially cylinder assembly,
- test and evaluation of new designs.

The test work is done solely in the laboratory. The project is financed by the Swedish Covenant Church, which is particularly interested in these technical issues since its Mission in India has established a wokshop for the manufacturing of handpumps and tubewell drilling, Sholapur Well Service(SWS). The tests have been done in close cooperation with Mr Oscar Carlsson, who at present is stationed at SWS in India.

Contact is also kept with other testing projects, such as the laboratory tests conducted by the Consumers Association in England and different field investigations promoted by the World Bank and/or UNICEF, often in cooperation with projects supported by national development agencies. This exchange of information is vital and will prevent unnecessary misstakes or duplicated work.

Most of these other testing programmes are directed towards the investigation of complete fullscale pumps from various manufacturers. In this project the efforts are concentrated on the comparison of different pump components. As such, it is seen as a valuable complement to field tests. Since all devices tested are operated under equal conditions, the results are directly comparable. Local variations which will occur in a field test, such as differences in water quality, pump utilization, etc, will not disturb the interpretation of the result. A component that performs badly in the laboratory has not to be tested further, while a good result in the laboratory ought to later be verified in a field study.

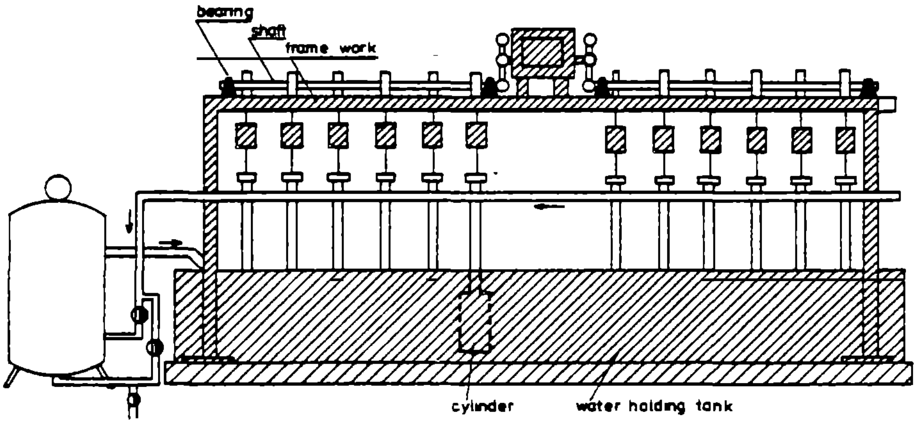
The present state of the project is reviewed in this context. Further information and details of the test work is found in the project reports, see the reference list ( Hahn - 82a, - 82b, - 83a, - 83b, - 84 and Veturlidason - 83 ).

## 4.3 Test Equipment and Procedure

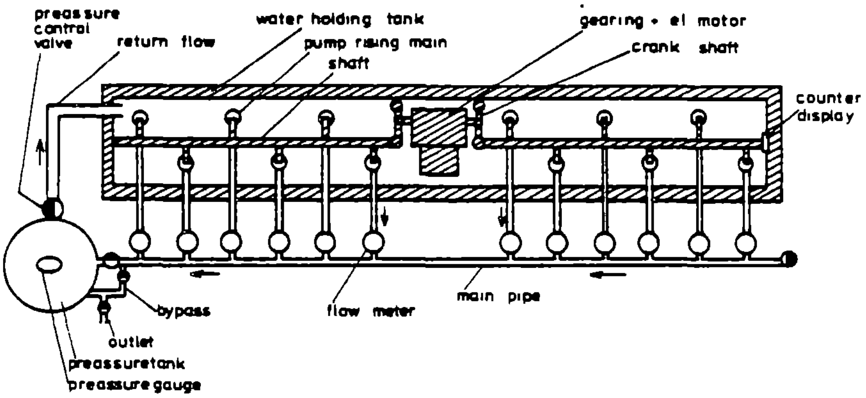
After about half a year of planning and construction, the test rig described below was put into operation in June 1982. By the end of 1984 the rig had operated for about 50 million pumpstrokes, which is equal to just over two years of continuous operation.

A common standard is one handpump per 250 people. If 25 liters per person and day is used for household supply and the pump gives 0.35 liters per stroke, the pump will be operated for about 18.000 strokes a day. Each pump in the test rig works continuously at 50 strokes per minute, which makes 72. 000 strokes per 24 hours. A result from the laboratory test is thus produced at least 4 times faster as compared to field trials. The two year time of operation in the rig can therefore be compared to 8 to 10 years of field operation.

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.



SIDE ELEVATION



PLAN

Figure 4.7. Schematic plan of the test rig.

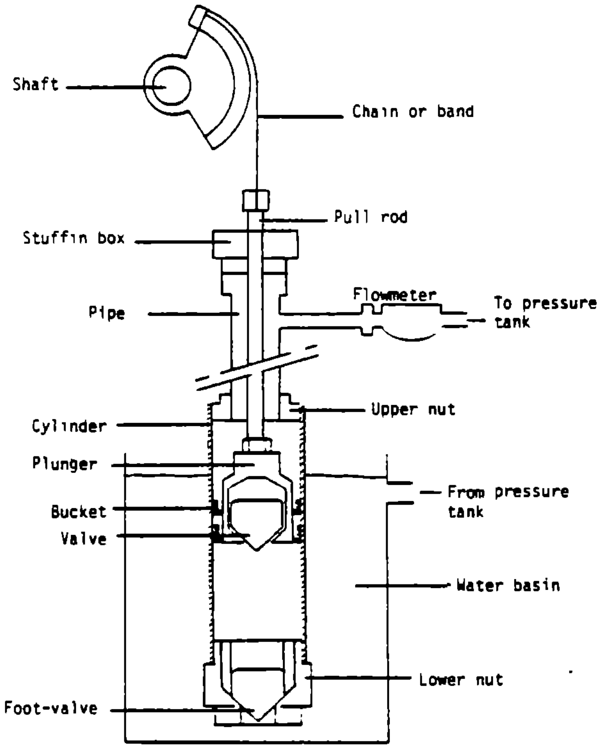


Figure 4.8. Detail of a cylinder set.

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 (°C) | 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 |
| (°dH) | 11 | 12 | 13 |
| $HCO_3^-$ (milliequival./l) | 2.6 | 2.7 | 2.8 |

Table 4.1. Variations in water quality.

At the start of the project, a SWS pump was mounted in the laboratory with the pumping depth of 7 m. This pump was used for detailed measurements, to obtain reference of the performance of the same cylinders in the test rig, i.e. a calibration of the test rig. Using the pump in comparison was of great value since the simulation in the rig was more difficult to obtain than expected.

It was found that force and pressure variation measurements not be made in the first rig without great difficulties, due to disturbances from the other cylinders operating at the same time as the cylinder being studied. To obtain higher accuracy of measurements, a second rig was put into operation. The design was similar to the rig described above, but only one cylinder was run at a time.

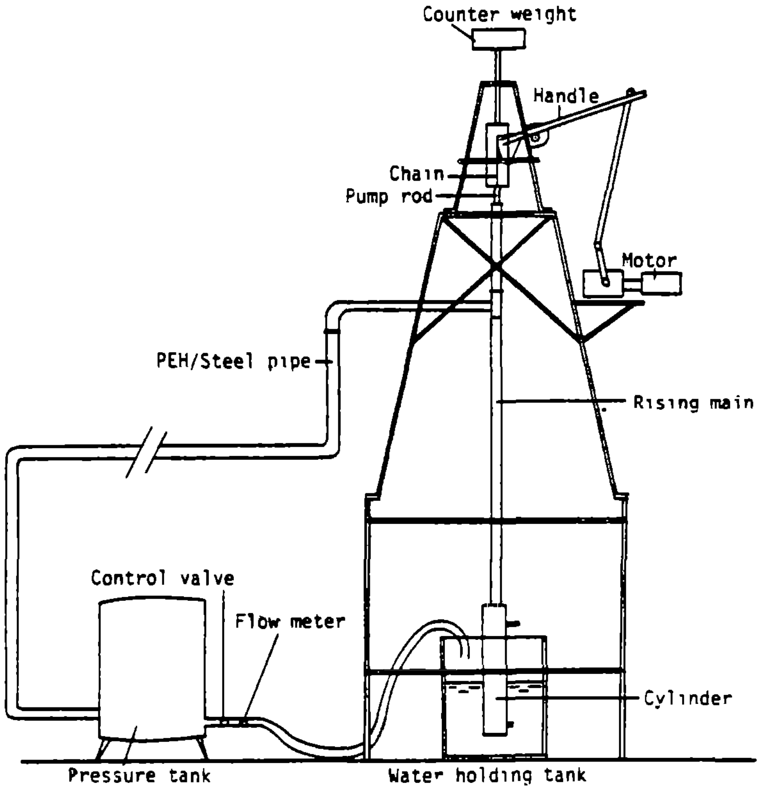


Figure 4.9. Test rig for detailed studies.

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

The data are stored in an ABC 80 micro-computer. The same computer also registers signals from instruments used in pressure and force measurements and makes the required calculations. Diagrams from these data are drawn automatically by a Hewlett Packard plotter.

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.

## 4.4. Result

### 4.4.1. 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.

#### 4.4.1.1 Roller Chain 1"

This chain fitted according to figure 4. 10 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 4.10 Standard SWS roller chain.

#### 4.4.1.2 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 4.11 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.

#### 4.4.1.3 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 4.12.

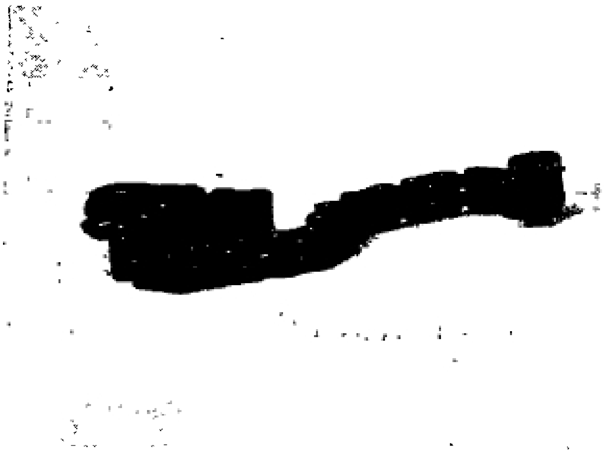


Figure 4.12 A fleyer chain stiff from wear

#### 4.4.1.4 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 4.13 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.

### 4.4.1.5 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 4.14 Reinforced rubber band broken.

4.4.1.6 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.

4.4.1.7 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 4.15 Doubble band

### 4.4.1.8 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.

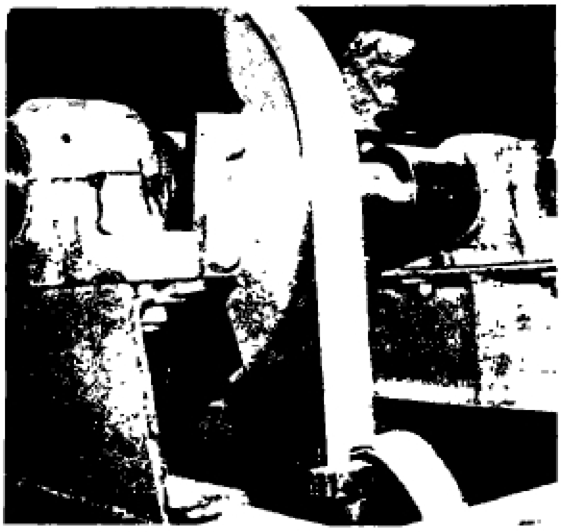


Figure 4.16 Doubble band
both operate.

| Test | Type | Million strokes | Result |
|---|---|---|---|
| 1 | Doubble band, both with load on | (24.1) | In good condition |
| 7 | | (24.1) | -"- -"- |
| 9 | | (32.9) | Some wear, in operating condition |
| 11 | | (20.0) | In good condition |
| 5 | Double band, one with load on | (35.8) | Worn, but operating |
| 6 | | (35.8) | -"- -"- |
| 8 | | (33.8) | -"- -"- |
| 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 | | (4.2) | In good condition |
| 3 | | 19.7 | Worn, broken |
| 3 | | (15.3) | Worn, broken once, operating |
| 4 | | (29.7) | Worn, but operating |
| 12 | | (17.9) | -"- -"- |
| 11 | Roller-arm | 1.5 | Broken, test interrupted |

Table 4.2 Summary of tests with chains and belts. Figures in brackets indicate that testing is continued.

### 4.4.2 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.

#### 4.4.2.1 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.

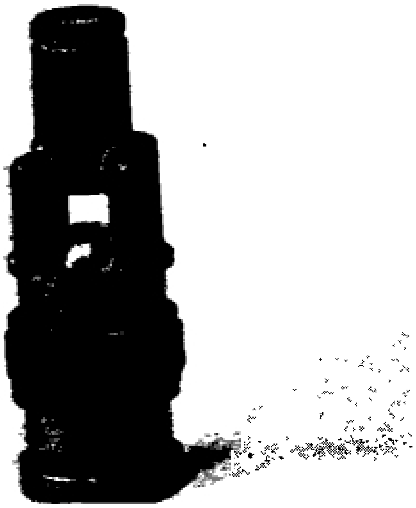


Figure 4.17 RIMA plunger

| Test | Type | Description | Million strokes | Result |
|---|---|---|---|---|
| 2 | SWS with plastic cone | POM-cone | 32.5 | Some wear, in operating condition |
| 10 | | -"- | (35.5) | -"- -"- -"- |
| 4 | | -"- | (44.3) | -"- -"- -"-<br>Cone o-ring changed after 31.2 Mstr. |
| 9 | | POM-and PVC-cone | (33.0) | POM cone worn, replaced with PVC after 5.6 MSTR. |
| 7 | | PVC-cone | (43.5) | Some wear, in operating condition |
| 1 | | -"- | (21.0) | -"- -"- -"- |
| 2 | | -"- | (6.0) | In good condition |
| 11 | | -"- | (20.0) | Some wear, in operating condition |
| 10 | Piston with ball valve | Steel ball | 1.8 | Improper operation, test stopped |
| 5 | | Rubber ball | (39.5) | Guides worn, ball in operating condition. |
| 12 | | -"- -"- | (16.5) | In operating condition. |
| 8 | India Mark II with poppet | R & C | (33.8) | Operating, poppet nut heavily worn |
| 3 | | R & C | (35.0) | -"- -"- -"- |
| 6 | | MEERA | (29.3) | Poppet nut worn, poppet rubber seal worn out totally, operating |
| 12 | Test design | All POM | 4.5 | Test stopped, threads damaged |

Table 4.3. Tests of piston. Figures in brackets indicate that testing is continued.

#### 4.4.2.2 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 4.18 SWS plunger

4.4.2.3 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 cove 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 4.19 SWS new plunger

### 4.4.2.4 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.

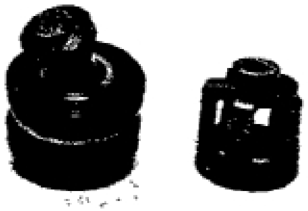


Figure 4.20 Wear on the valve nut.

### 4.4.2.5 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 the India Mark II-type 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 4.21.

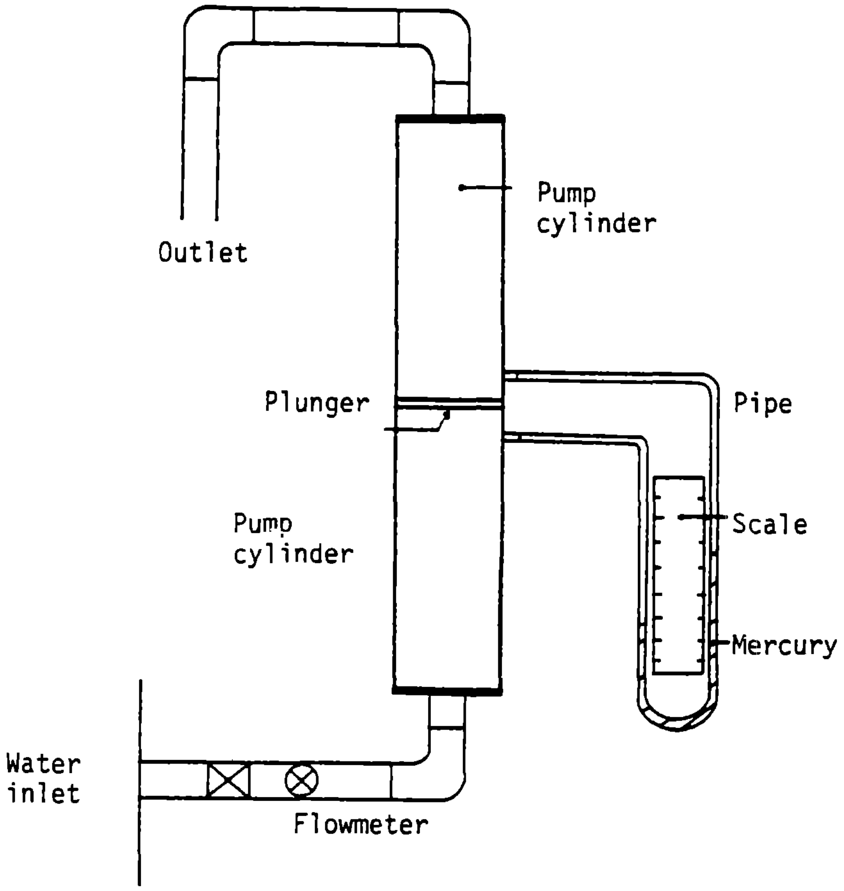


Figure 4.21 Laboratory measurement of head-loss over the plunger.

As shown in figure 4. 22, 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.

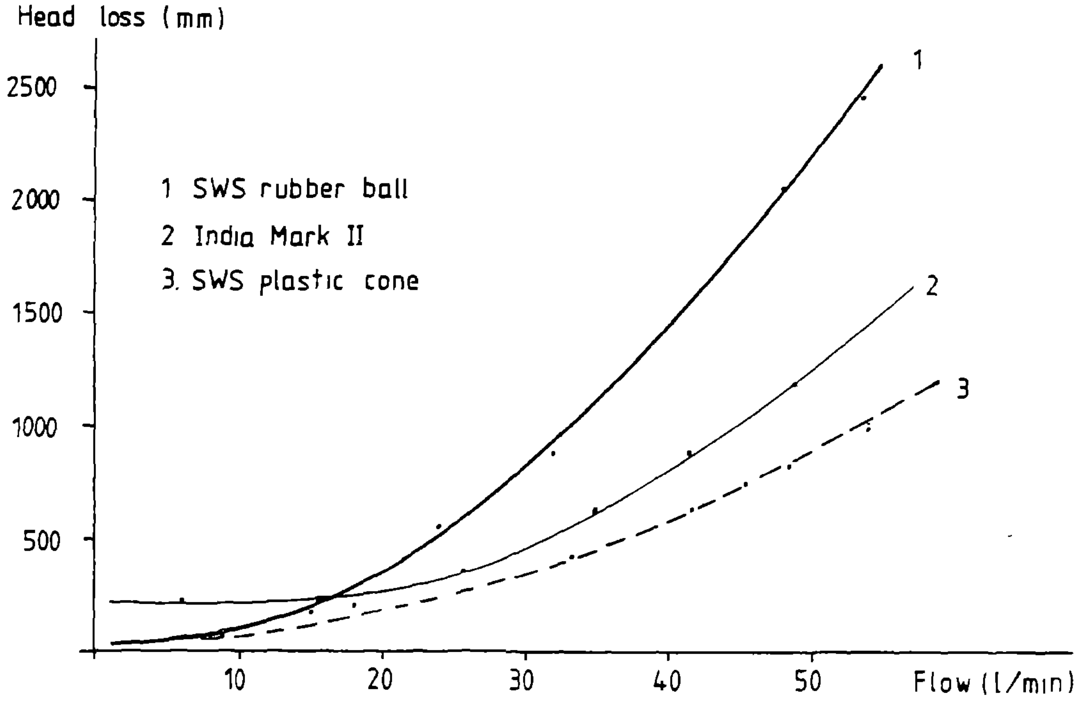


Figure 4.22 Difference in head-loss for the plungers tested.

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

### 4.4.3 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.

#### 4.4.3.1 Leather

A summary of the leather cup seals tested is given in table 4.4. 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 | (24.1) | Some wear; testing continues |
| 4 | | SWS, India | 16.8 | Worn out<br>Upper more worn. Replaced. |
| 4 | | SWS, India | (6.0) | In good condition |
| 6 | | SWS, India | 15.0 | Upper seal worn out: Test stopped |
| 10 | | Sydläder, Sweden | (35.5) | Both seals worn, but in operating condition. |
| 5 | | Sydläder, Sweden | (39.5) | Upper seal OK.<br>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 | (6.0) | In good condition |
| 9 | | Sydläder, Sweden | (33.0) | Both seals worn in upper edge, still operating. |
| 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 | (6.0) | In good condition |
| 11 | | Sydläder,Sweden | (20.0) | Both seals in good condition. |
| 2 | | Sydläder, Sweden | (38.5) | Both seals operate lower more worn. |

Table 4.4 Summary of tests with leather cup seals.

#### 4.4.3.2 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 4. 23.

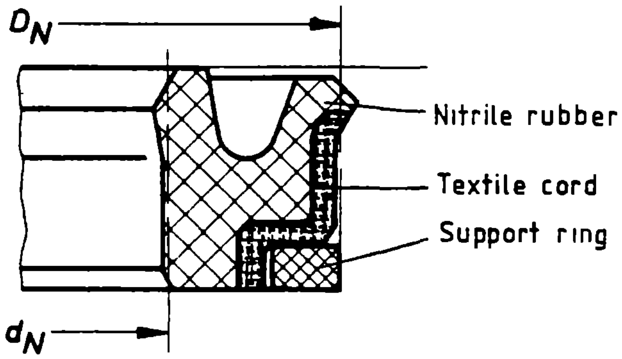


Figure 4.23 Nitrile rubber seal.

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 4.5.

| Test | Type | Manufacturer | Million strokes | Result |
|---|---|---|---|---|
| 3 | Teflon/Graphite | Simrit | 3.7 | Heavily worn, taken out of operation |
| 12 | Nitrile rubber | Simrit | (17.9) | In good condition<br>Some wear on the lower seal |
| 7 | Nitrile rubber | Simrit | (43.5) | Heavily worn, but still in operating condition |

Table 4.5 Tests of synthetic seals.

### 4.4.4. 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 5.10.

#### 4.4.4.1 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.

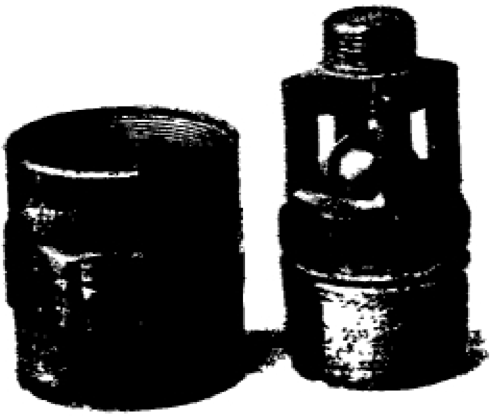


Figure 4.24 RIMA foot-valve

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.

### 4.4.4.2 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.

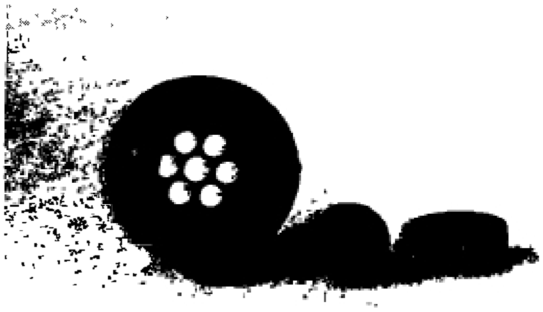


Figure 4.25 SWS rubber ball valve

### 4.4.4.3 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 4.26.

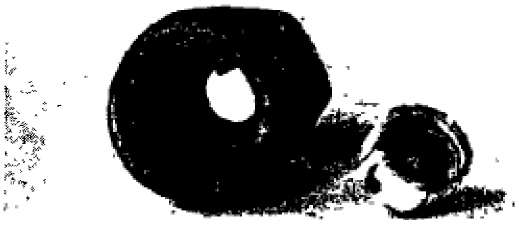


Figure 4.26 Painted iron valve

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.

### 4.4.4.4 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.

### 4.4.4.5 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 4.27 The POM valve

### 4.4.4.6 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.

### 4.4.4.7 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 4.4.2.

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.

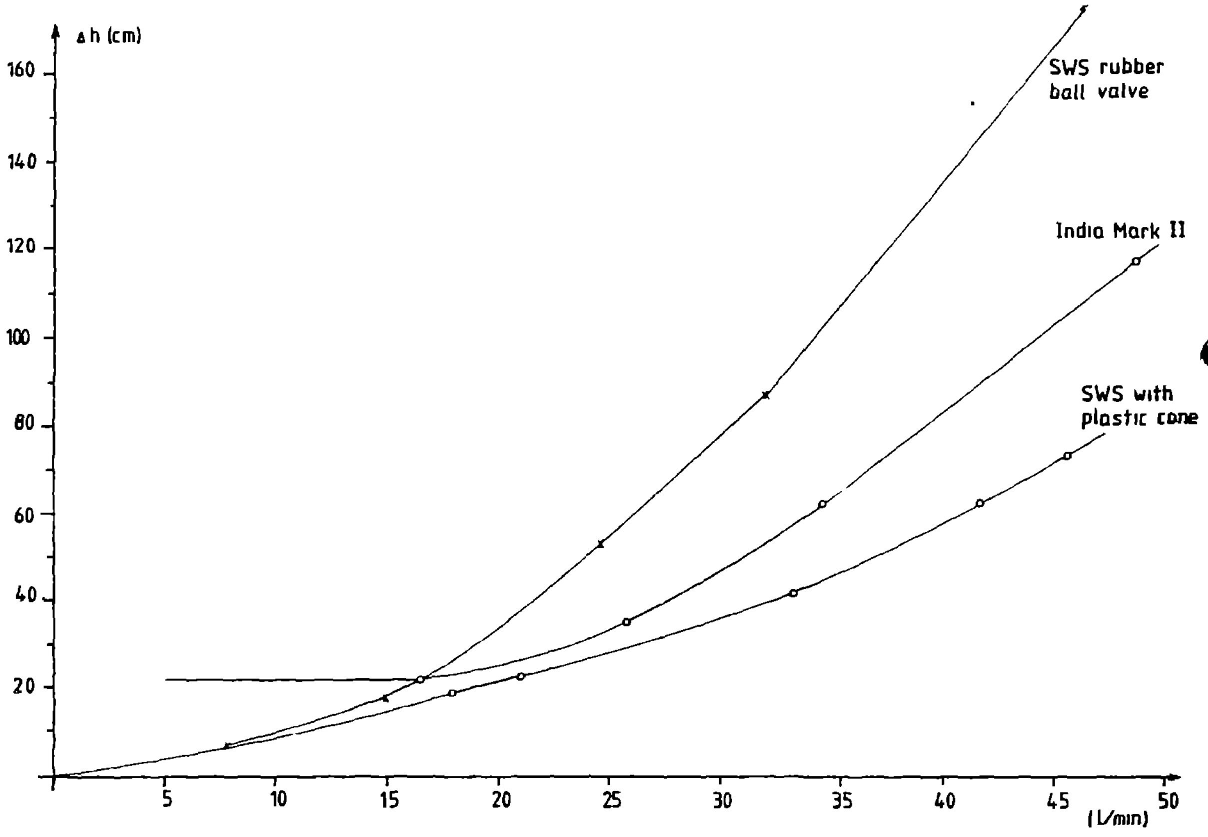


Figure 4.28. Head-loss over the footvalve at stationary flow.

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.

# 5. DISCUSSION

## 5.1 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.

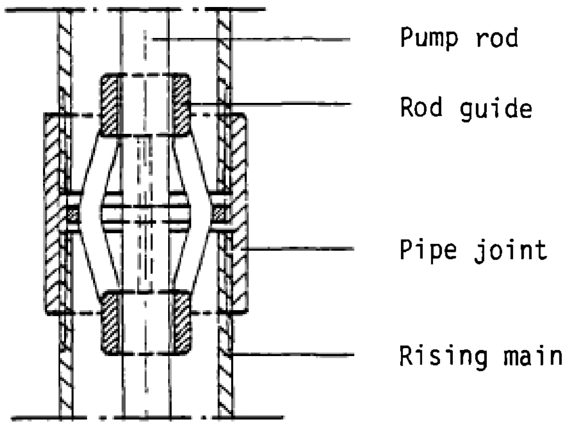
The advantages of the circle segment are :

- 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 5.1. 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 5.2, indicate how to design and what materials to use.



Figures 5.1 The SWS rod guide.

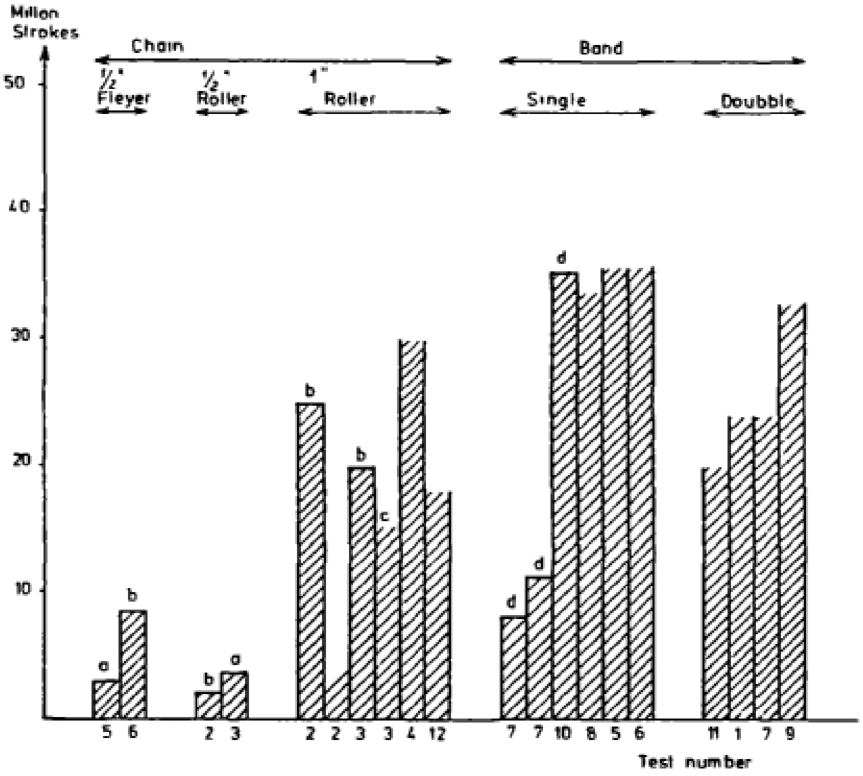


Figure 5.2 Result of tests with chains and belts.
a: Worn and stiff
b: Worn and stiff, broke.
c: Broken and repaired.
d: In operating condition, test interrupted.

Bars open at the top indicate that testing is continued.

Other mechanical devices, like the roll and arm described in section 4.4.1.4, 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.

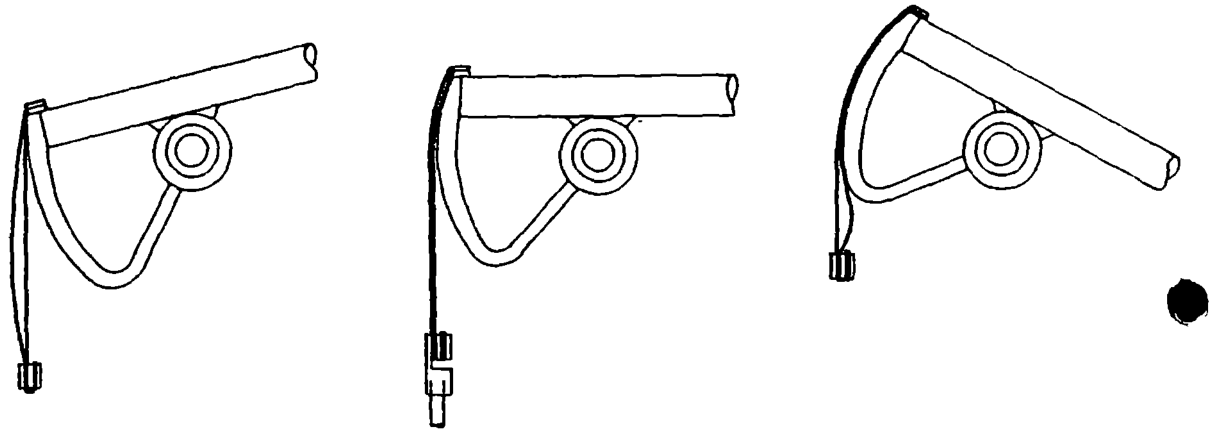
The remaining capacity of 580 kg, after a corresponding field operation time of 6 to 7 years, should be compared to the actual load. In a 30 m deep well the static and dynamic load would normally not be more than 100 kg (weight of water column and pumprod, friction and acceleration force). Thus, in this 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 5.3. 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 5.4. 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.



START MIDDLE STOP POSITION

Figure 5.3 Operation with the doubble band.

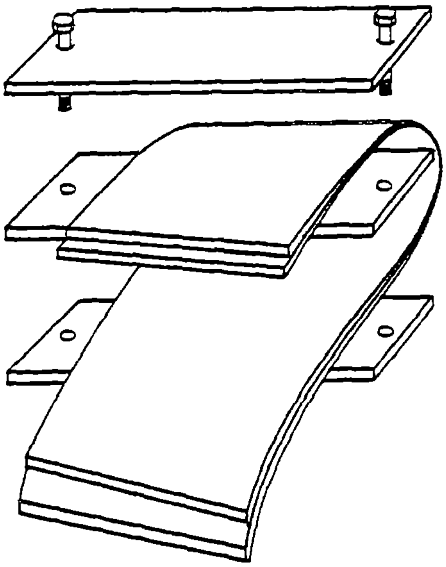


Figure 5.4. Principle of the band coupling.

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.

## 5.2 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 4.22) 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 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.

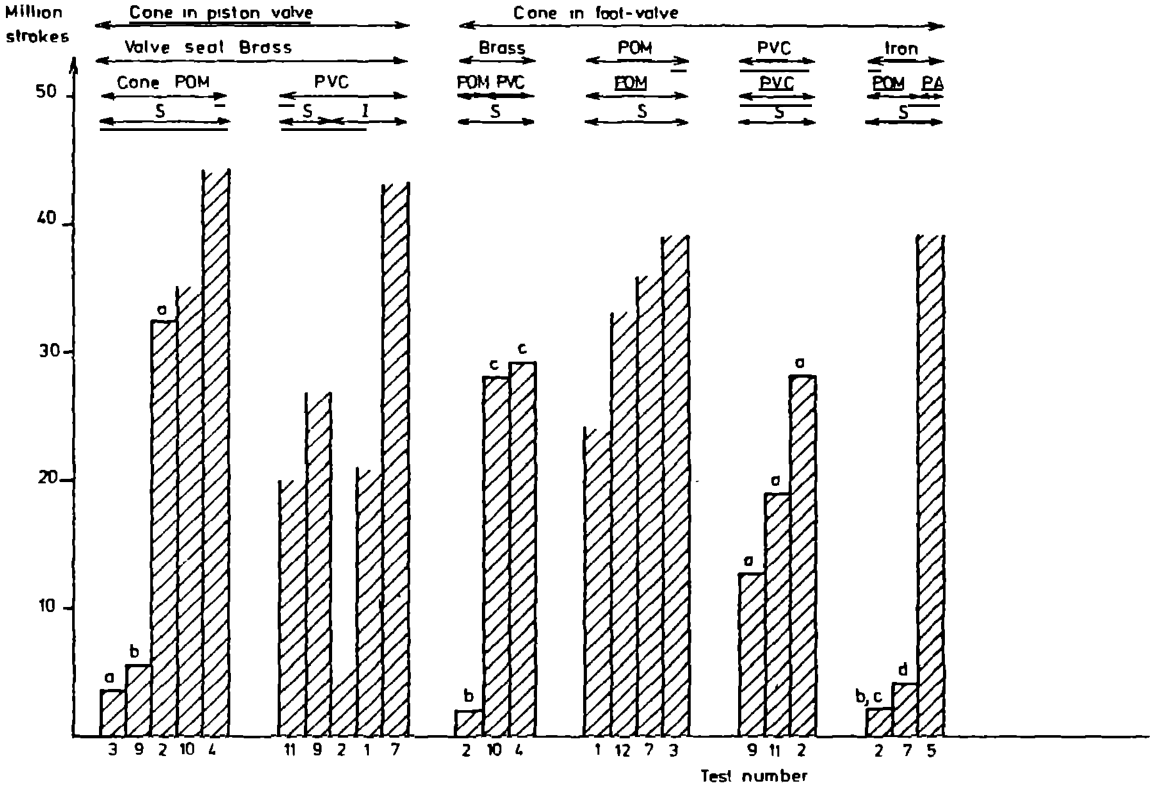


Figure 5.6 Comparison of test result of plastic cones in plunger and foot valve.

S = Swedish
I = Indian

a : Cone in good condition, test interrupted.
b : Cone damaged, too small initial diameter.
c : Cone damaged, rough guides.
d : Cone in good condition, guides damaged.

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.

## 5.3 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 5.7. 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°.

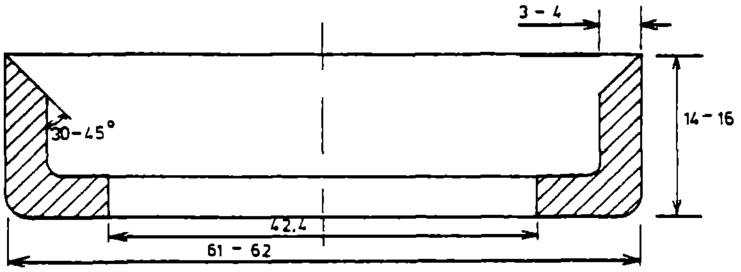


Figure 5.7 Cup seal dimensions (mm).

It is of the outmost importance to select leather from high quality hides. This is illustrated in figure 5.8, 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 often have a more soft and porous structure. The age of the animal and the climatic conditions of its environment also contribute to the leather qualilty. 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.

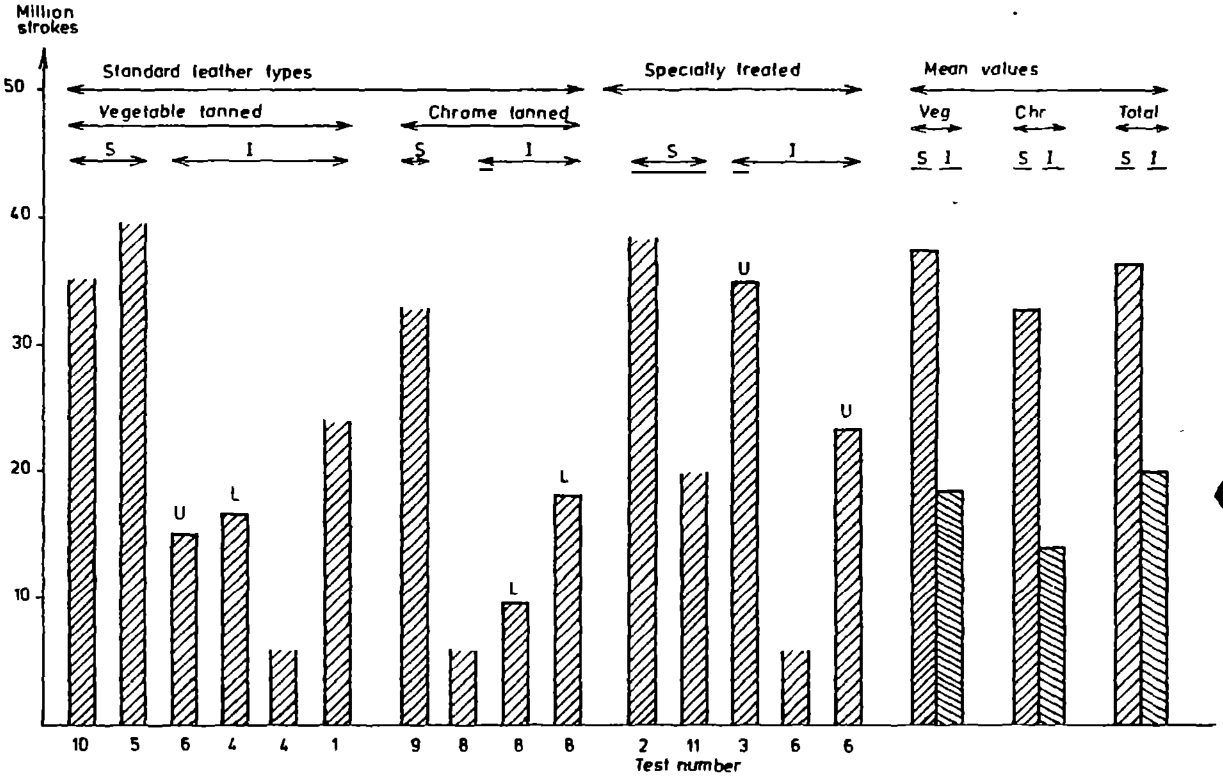


Figure 5.8 Summary of the result of cup seals tested.
S= Swedish leather, I= Indian leather
U= Upper, L= Lower Cup Seal.

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 5.9. 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!

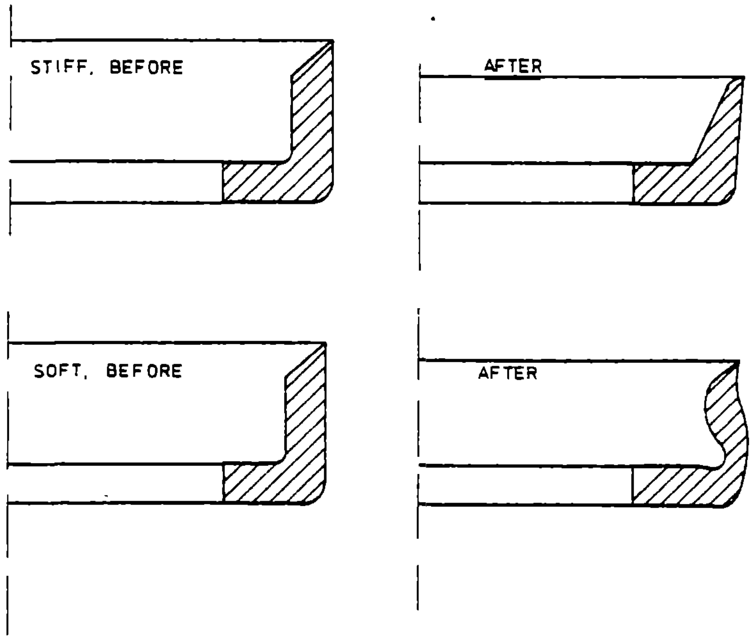


Figure 5. 9 Difference in deformation and wear between soft and stiff cup seals.

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 5.8). 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 4.23) 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.

## 5.4 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 5. 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).

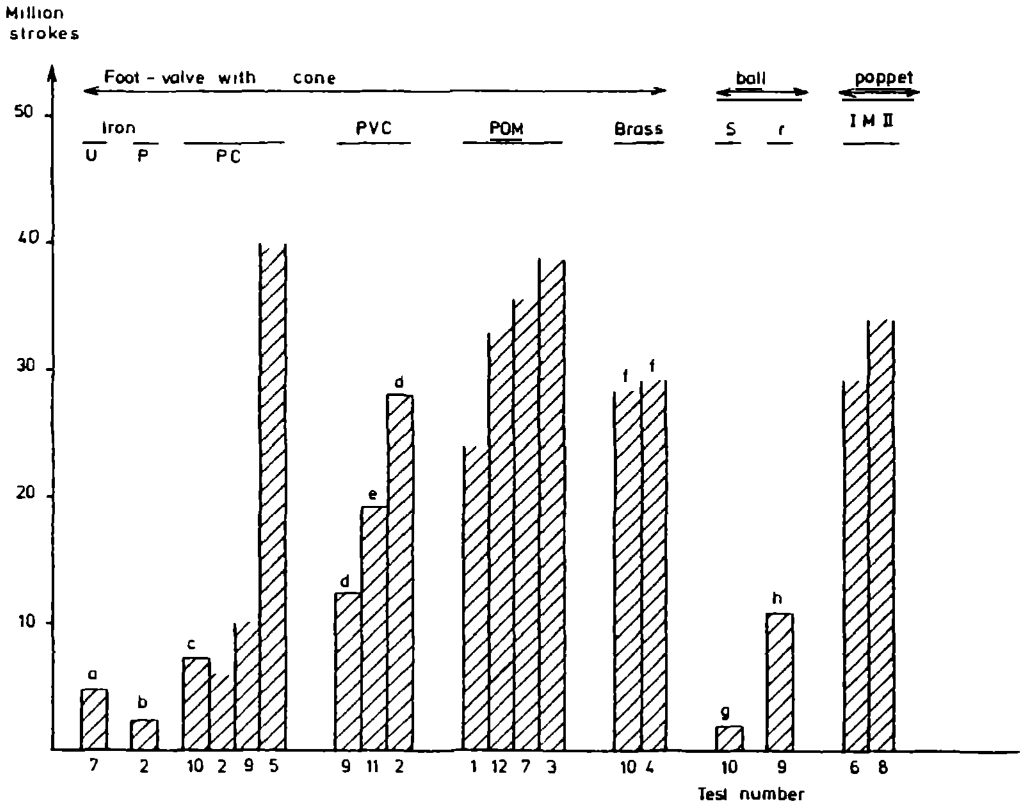


Figure 5.10 Result of test of foot-valves.

u : unprotected

p : painted

pc : plastic cover

s : steel

r : rubber

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°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 5.10, 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.

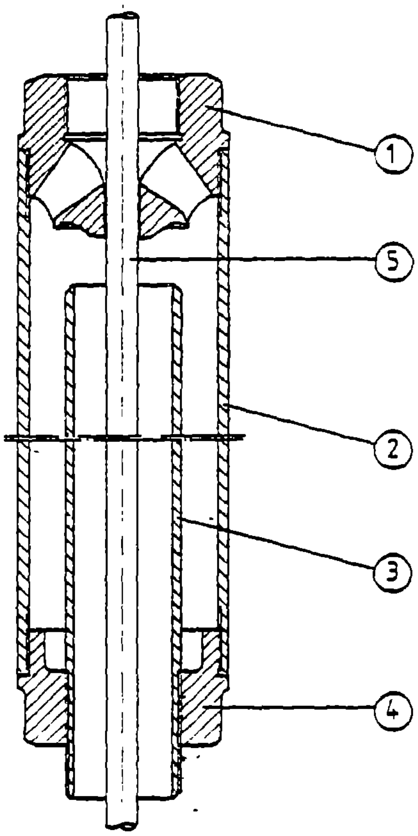
## 5.5 The Cylinder Assembly

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 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 5.11, 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 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 5.11 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 5.12. 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 5.12 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 5.8.

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

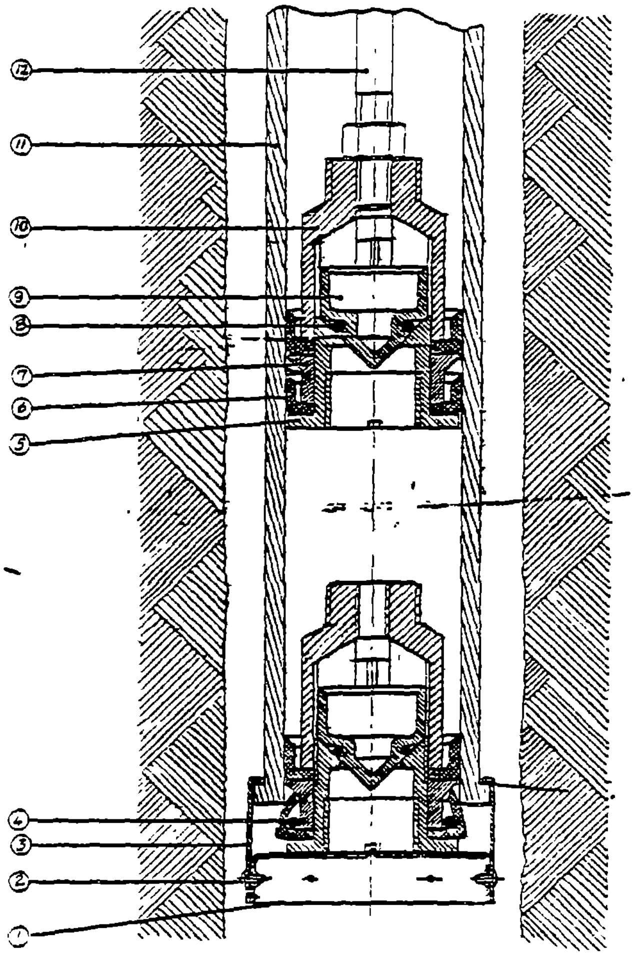


Figure 5.12 Design suggestion for open-type cylinder with extractable piston and foot-valve.

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.

## 6. HANDPUMPS IN WATER SUPPLY PROJECTS

As previously discussed in section 3.1, several different techniques can be applied in most rural water supply projects. This paper has only dealt with one technique, the utilization of groundwater by means of handpumps. To optimize the water supply system, the handpump technology has to be assessed against other alternatives. In other words, answer the important question "When is it appropriate to use handpumps?". The need of an instrument or a methodology to carry out such an assessment is pointed out below.

In general terms, we can say that the type of technology selected for a water supply project is a function of a few basic factors as indicated in figure 6.1. The process of selecting the appropriate technology can schematically be divided into two steps: Firstly, to technically identify the feasible alternatives. For the comparison of the quality criteria in each case with existing raw water sources, a set of requirements for water treatment can be identified which will be linked to a certain degree of treatment or certain techniques. Secondly, these alternatives have to be assessed and compared with local prevailing conditions and available resources.

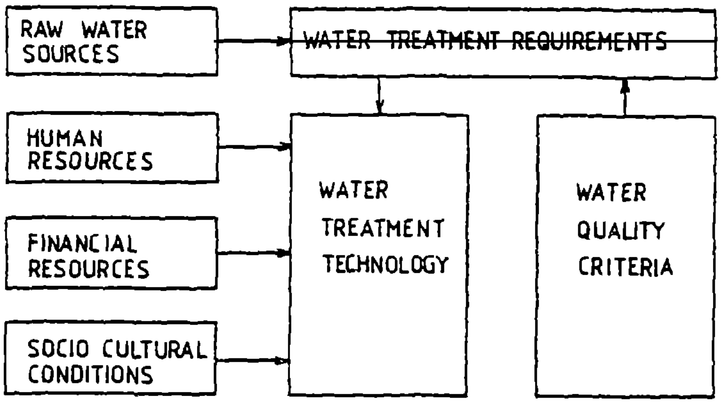


Figure 6.1 Basic relations in the design of water supply systems.

Considering the variety of technical solutions available (cf figure 3.1) and the diversity of the prevailing conditions in different regions, it is not surprising that several concepts and strategies have emerged. Term such as intermediate technology, low cost technology, on site solutions and appropriate technology are examples of such. The latter term has been described in many ways, of which two examples are given below.

Appropriate technology has been defined by WHO (McJunkin -79) as "technology that is not only scientifically sound, but that is acceptable to users, providers and decisionsmakers alike; that it fits within local cultures, that it is capable of being adapted, further developed and manufactured locally whereever possible at low cost; and that it is sufficiently simple in design and execution for local use". Further, "it means not just a device, but any association of techniques, methods and equipment which together can contribute toward solving a ..... problem".

Kalbematten et al (1980) have, in a World Bank report, given an operational definition: "A method or technique that provides a socially and environmentally acceptable level of service or quality of a project with full health benefits and at the least economic cost. " A more rigorous definition, however not operationally useful, would be; "the technology for which the net present value of the stream of health and environmental benefits, is maximized, subject to a constraint on social acceptability".

From these two descriptions of "appropriate technology" at least one point is clear: The concept expresses a value (similar to terms like good or beautiful) and as such, it is subjective and cannot be explicitly defined. What we can do is establish criteria for the appropriateness of technology applied under certain conditions.

Derrow and Pam (1981) state that appropriate technology is a term which represents a particular view of society and technology. To clarify some of the reasoning underlying the concept, ten criteria are given.

1) it permits local needs to be met more effectively because local people are involved in identifying and working to address these needs;

2) it means the development of tools which extend human labor and skills, rather than machines which replace human labor and eliminate human skills; there is no attempt to eliminate the human element, but to make it both more productive and more creative;

3) it represents a comprehensible and controllable scale of activities, organization and mistakes which people lacking sophisticated management training can work together and understand;

4) it allows a more economical operation through minimizing the transport of goods in an era of expensive energy, allowing greater interaction of local industry and permitting greater use of local resources-both human and material;

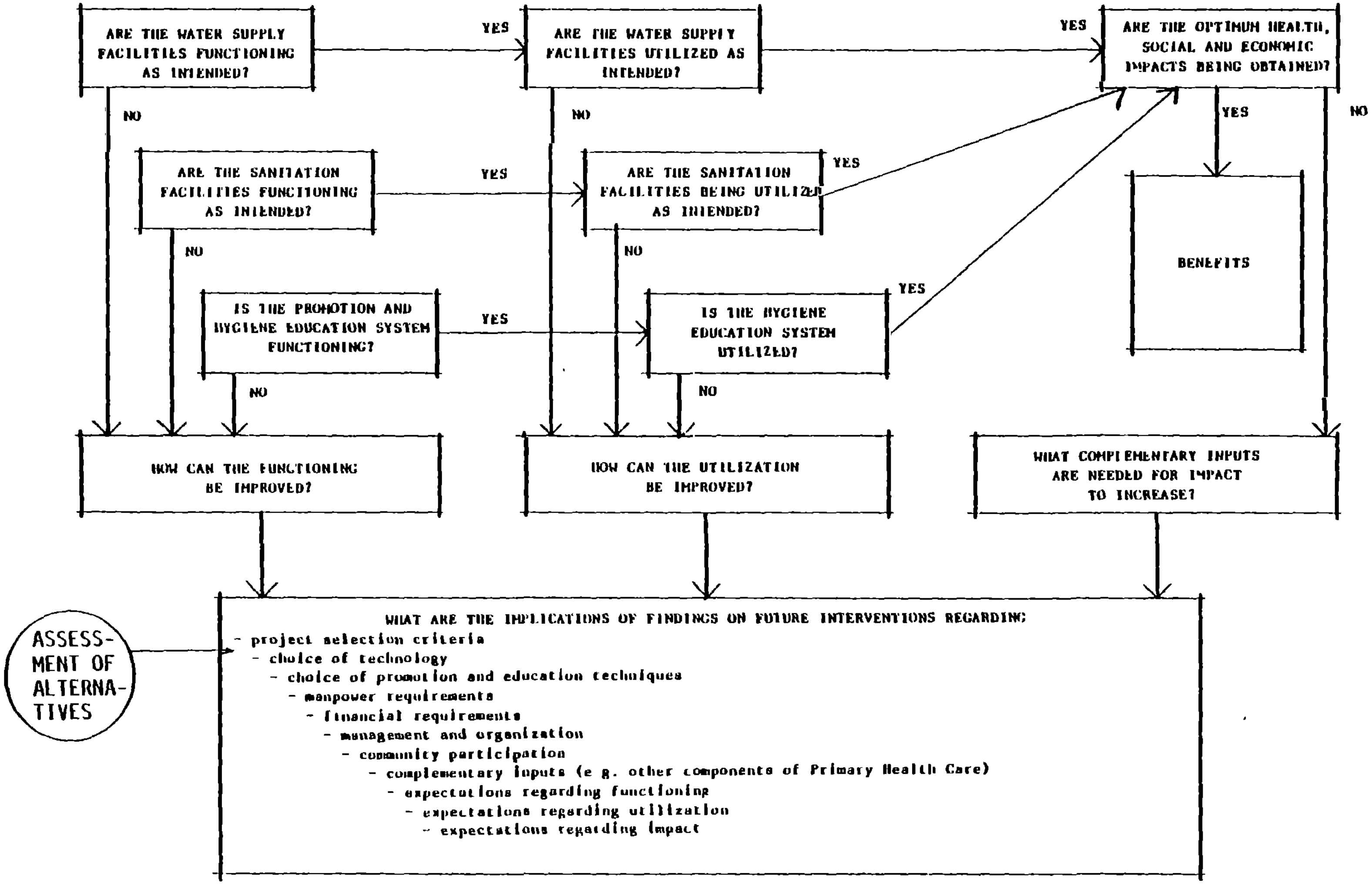
5) it eliminates many expensive or unavailable finance, transportation, education, advertising, management, and energy services; and avoids the loss of local control, which such outside services imply;

6) it helps to establish a self-sustaining and expanding reservoir of already existing skills within the community;

7) it tends towards decentralization of production, thus permitting the full benefits of work to remain within a community; this also allows control to remain within the community;

8) it provides a region with a cushion against the effects of outside economic changes (e.g., the collapse of the world sugar market or the sudden unavailability of fertilizer );

9) it helps to reduce economic, social, and political dependency between individuals, between regions, and between nations, by recognizing that people can and will do things for themselves if the obstacles are removed;



Note: YES = Yes, to a great extent.
NO = No, to a great extent

Figure 6.2 Questions to be answered in the evaluation of water supply programmes (WHO -83).

10) it is in harmony with the cultural traditions of the area; this does not mean that it is stagnant, but that it evolves along with the culture, and does not contradict values which the people believe to be important; the technology is adapted to fit the culture rather than the culture being forced to adapt to fit the technology.

The use of the term "appropriate technology" implies that two questions are already answered:

- Appropriate, for whom and in what sense?
- Technology, selected in which way and on what grounds?

This does not mean that it is completely wrong to call, for example, the India Mark II handpump a piece of appropriate technology. But in doing so, we have gone through a selection process based on passive and active (intentionally utilized) experience. The result, the choice, will be quite correct, at least in certain regions and under certain circumstances.

In order to more widely transfer technology to be used in different situations and to perform technology assessment, we require a systematic way of learning from experience,i.e. to evaluate.

The selection of proper technology for a project on a local/regional program scale requires a methodology for:
a/ Evaluation of projects in operation.
b/ Assessment of alternatives.

Procedures for the first type of evaluation have recently been very clearly presented (WHO -83). The publication includes an algoritm indicating questions to be answered in the evaluation process, see figure 6.2. This diagram, however, lacks the entrance of knowledge of alternative technology. Matters dealing with functioning, utilization and implications of findings for future interventions are only based on experience from existing projects and technique already applied. "Project selection criteria" and "choice of technology" also require complementary assessment, as indicated in figure 6.2.

Assessment of alternative technology must be done with respect to natural resources and conditions at hand. Cairncross and Feachem (ITDG -80) have presented an approach in this direction, see figure 6.3. It would, however, be more helpful to start at the opposite end, i.e. to see what can be done with the local water sources available.

As the concept of appropriate technolgy is not possible to explicitly define, evaluation is necessary in order to optimize the process of selection of a technique for a given purpose. The role of evaluation in planning is important. The WHO-publication Minimum Evaluation Procedure (MEP), cf figure 6.2 , will probably be a valuable instrument for future project evaluation studies.

In order to properly assess alternatives and techniques other than those already applied within the project, program or province, a set of procedures similar to those of MEP are needed. Together with such a procedure it is, however, essential that sufficient technical knowledge exist within the local or regional planning and engineering authority, so that the alternatives can be truly identified.

In many cases a technology like tubewells with handpumps is the best option, not when compared with other sources of water or other treatment techniques, but due to conditions such as lack of electricity, standard of the maintenance organization, etc. With no doubt, tubewells can be very costly compared to a simple dam construction or surface water utilization, if such alternatives are feasible. Thus, the technical knowledge and procedures for technical assessment are indispensible both in finding the most cost-effective solution in individual projects and in creating systems which efficiently utilize the available water sources in the long run.

Further research of criteria for appropriate technology and a more concrete set of practical, applicable indicators of the criteria are needed, as well as a methodology for the systematic use of such indicators.

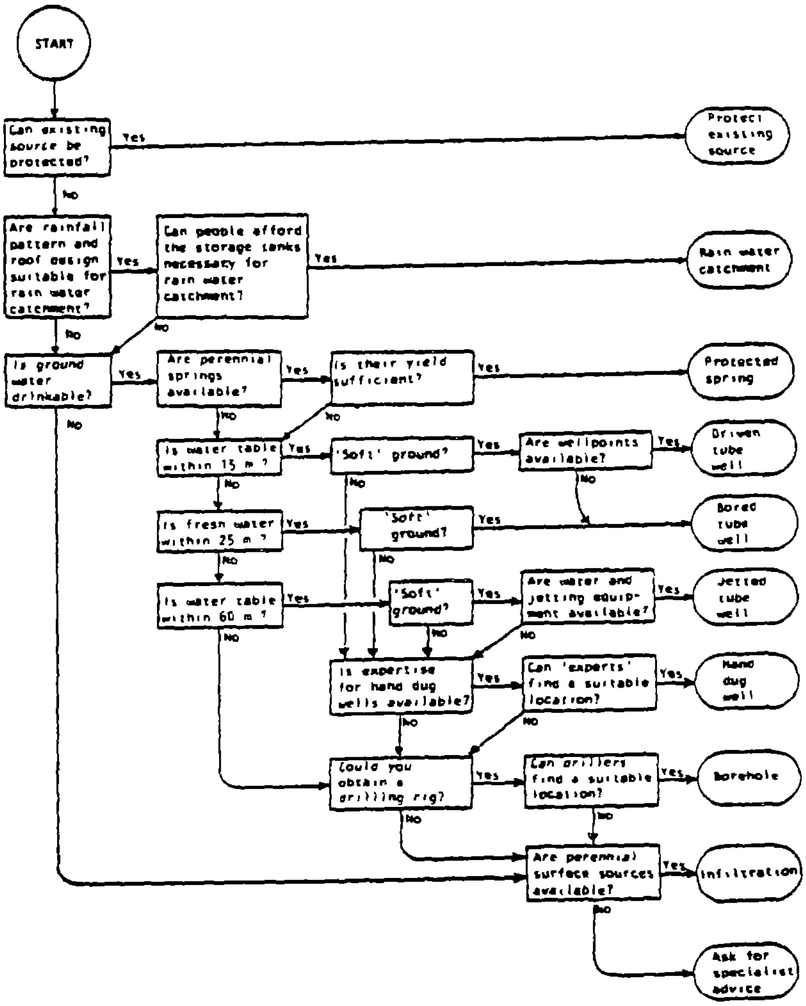


Figure 6.3 Choosing a source of water. Follow the arrow corresponding to the question in each box (ITDG -80).

## 7. SUMMARY AND CONCLUSIONS

The paper describes tubewell drilling and handpump installation in India and the problems related to handpump design.

The field study in India showed that about 25 % of the handpumps installed were out of order. In the villages with operating pumps, some people will often use a traditional source of water if available . This is a believed to be related to inconvenience of a long waiting time. The Indian standard of one pump per 250 people is not sufficient.

The laboratory study showed that many improvments in pump design can be made. It also points out the importance of using good quality and proper material in the pump components. Some conclusions regarding handpump design can be drawn:

- A polyester band has proven to be a good alternative to the chain used at present in the connection between handle and pump rod.

- Leather cup seals perform better than synthetic seals. The reason is believed to be the porous structure of the leather,which allows particles to be embedded.

- The quality of the hide and the tannage process are of the outmost importance for the life time of the cup seal.

- The new rod guide will protect the pump rod and the rising main from breakdowns.

- The new valve cone can replace the rubber ball used today. The cone will have higher reliability and better hydraulic properties.

- The new foot-valve can be produced by extrusion moulding at a rather low cost.

- Both the cone and the foot-valve should be made of POM and not of PVC plastics.

- The cup seals are likely to last longer if PEX plastics are used in the cylinder.

- An open type cylinder will be easier to maintain. A design suggestion based on the PEX material is given.

The laboratory results are only indicative. A good result in the laboratory has to be verified by field trials.

Further development is needed in order to reach the VLOM concept. Research should also be directed towards a methodology for assessment of alternative techniques for rural water supply.

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

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Date....................

Time....................

HOUSEHOLDSTRUCTURE

Name of head of household ......................................................

| Sex | | Age | | | | No of years of formal education | Status (caste) | Indices of wealth | Latrine | | Occupation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F | M | 0 - 1 | 2 - 12 | 13 - 60 | 60 + | | | | yes | no | |
| | | | | | | | | | | | |
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SOURCE OF WATER

1. Which watersource did the household use during the last week?
☐ traditional (open well, river, pond etc)
☐ new (tubewell)
☐ both

2. Why did the household use this (these) watersource (s) ? (The main reason)
☐ there is no other
☐ water from the tubewell is too ewpensive. We cannot afford to pay.
☐ we may not use the tubewell (because we belong to a low caste etc).
☐ it is situated closer to the household
☐ we prefer the water from this source (it is cleaner, has a better taste etc)
☐ social reasons (we meet our friends there)
☐ both, because the tubewell did not function all the time
☐ both, because of other reasons............................................
...................................................................

3. Distance to watersource?
....................m

4. How many times per day do you go for water?
.................... times

5. How much water do you usually take each time?
....................l

6. How much time do you spend each time you are going for water?
....................minutes

7. Who does normally collect water for the household
☐ man
☐ woman
☐ child
☐ old person

USE OF WATER

8. Do you use different pots for different purposes? (e.g. one for drinking water, one for the animals etc)
☐ yes
☐ no

9. Where do you wash your clothes?

☐ at home
☐ at the traditional watersource
☐ at the tubewell
☐ elsewhere.............................................................

10. Where do you wash yourselves?

| man | woman | children | |
|---|---|---|---|
| ☐ | ☐ | ☐ | at home |
| ☐ | ☐ | ☐ | at the traditional watersource |
| ☐ | ☐ | ☐ | at the tubewell |
| ☐ | ☐ | ☐ | elsewhere.................................. |

11. What happens with the water already used?

☐ we throw it anywhere
☐ we use it to irrigate our garden
☐ we throw it on a place which is common to all the village
☐ elsewhere.............................................................

HEALTH

(If there are children 0 - 1 year questions 12 - 16 should be answered)

12. Has the child (have the children) got breastmilk during last week?

| 1:st child | 2:nd child | |
|---|---|---|
| ☐ | ☐ | yes |
| ☐ | ☐ | no |

13. Has the child (have the children) got nothing else but breastmilk during last week?

| 1:st child | 2:nd child | | |
|---|---|---|---|
| ☐ | ☐ | yes | (if yes go to question 14) |
| ☐ | ☐ | no | (if no go to question 15) |

14. What has the child (have the children) got otherwise? (if yes on question 13)

| 1:st child | 2:nd child | |
|---|---|---|
| ☐ | ☐ | boiled water from a pot which is not only used for keeping boiled water |
| ☐ | ☐ | unboiled water taken from a pot which is not only used for keeping water |
| ☐ | ☐ | boiled water taken from a pot used only for this purpose. |
| ☐ | ☐ | unboiled water taken from a pot used only for this purpose |
| ☐ | ☐ | unprepared food(not boiled) |
| ☐ | ☐ | prepared food |

15. How many times since yesterday morning has the child (children) passed stools?

1:st child.......... 2:nd child

16. Were the faeces

| 1:st child | 2:nd child | |
|---|---|---|
| ☐ | ☐ | normal |
| ☐ | ☐ | in form of diarrhoea |

HEALTH EDUCATION/HEALTH SERVICES

17. Have you got any kind of education in hygiene and nutritional questions?

☐ yes, but we cannot afford to follow the advices
☐ yes, but we cannot follow the advices of social reasons
☐ yes, and we have the possibility to follow the advices but we don't believe in them
☐ yes, but we don't follow the advices because.................................

☐ no

18. Do you have the use of a dispensary in the village?

☐ yes, and we try to contact with it when we get ill because...................
...............................................................................
☐ yes, but we never try to contact with it because...........................
...............................................................................
☐ no

Appendix II

VILLAGE WATER SUPPLY SURVEY

Village________________Population_______________
(How estimated________________)

---

TUBEWELL

1. The well is located: ☐ in the center of the village
☐ outside the village
☐ ___________________________

Estimated mean distance from house to well __________m.

---

2. The location was based on:
- ☐ population /household density
- ☐ general opinion in the village
- ☐ opinion of influential person in the village
- ☐ sanitary / contamination aspects
- ☐ hydrogeological aspects
- ☐ existance of passable roads etc. for drilling equipment

---

3. ☐ The well is accessible to everyone
The accessibility is limited due to
a ☐ social rank
b ☐ caste
c ☐ other obstructions,_____________________

---

4. The water is:
☐ free of charge ☐ paid at one time_________
☐ subjected to a charge of__________________
paid to_____________________

---

5. The well, when pump is in order, is used by ________% the population.

---

6. Capacity according to pump test________________
Estimated water consumption________________$m^3$/day

---

7. If well, with working pump, is not fully utilized, this could be explained by:
- ☐ Inconvenient location
- ☐ The water is not accepted as suitable drinking water
- ☐ General disinterest
- ☐ Low yield
- ☐ ______________________________________________

---

8. Description of previous water source:___________________
______________________________________________

PLATFORM

9. ☐ No platform is constructed
☐ The well has a fair platform
☐ The well has i good and firm foundation

Special remarks------------------------------

---

10. Condition of platform drainage:
☐ Good drain provided, approx.____________m.
☐ Stagnant water
☐ No drainage constructed
Special remarks______________________________

---

~~HAND PUMP~~

11. Type: ☐ Mahasagar
☐ Jalvad
☐ Sholapur-Jalvad
☐ India Mark II

Installed_________ by _______________________

---

12. Condition of pump:
☐ Good
☐ Fair:_____________________________________
☐ Not working

---

13. If not working: Nature of breakdown:
☐ Pump head (above-ground mechanism)
☐ Below-ground mechanism
Special remarks________________________________

---

14. If not working: How long has the pump been out of order?

------------------------------------------------------

---

15. If not working for long time.
Reasons why the pump has not been repaired:
☐ Breakdown has not been reported, because
☐ villagers don't know whom to contact
☐ disinterest
☐ -----------------------------------------
☐ Breakdown reported, but nothing has happened
☐ Repairteam have tried and failed, due to
☐ lack of tools, spares
☐ poor training
☐ ----------------------------

---

16. Water sample nr______collected for laboratory analysis.