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Documento de Trabajo

WP 9/I/82

HAND/FOOT PUMPS
for Village Water Supply in Developing Countries - Technology and Maintenance

Analysis and review of the existing literature and reports of field

by H.P. Bänziger
on behalf of Helvetas

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1. PUMPING TECHNOLOGY

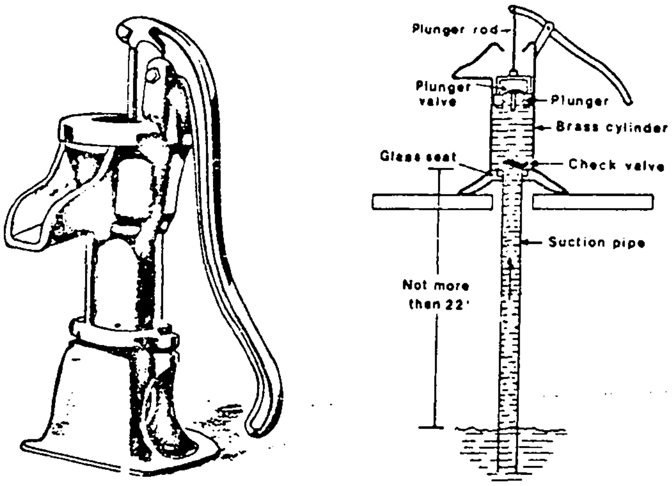
1.1. General

Pumping units can be divided into two types:

- shallow well pump
- deepwell pump

Shallow well pump

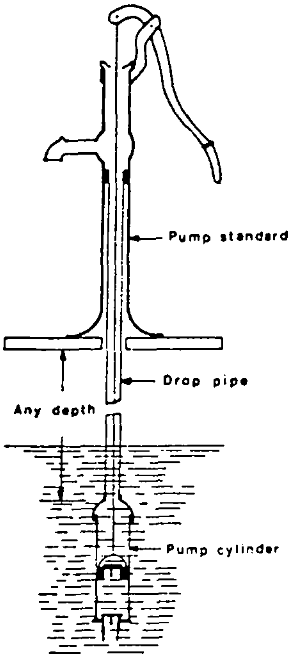
The plunger and its cylinder are located above the water level - usually within the pump stand itself. This pump relies on atmospheric pressure to lift the water to the cylinder; thus it is limited to water lifts of about 7 metres.



TYPICAL SHALLOW WELL LIFT PUMP

Deepwell pumps

In the deepwell pump the cylinder and plunger are located below the water level in the well. This pump can lift water from wells as deep as 180 metres. The forces and weal created by the hydraulic head increase with the depth to the water table. Also, the maintenance and repair problems associated with reaching the cylinders set deep in the well are much more difficult than in shallow well pumps. Thus the design and costs of pumps for deep well use are more critical than for shallow wells.



DEEP WELL LIFT PUMP

Hydraulics, Force and Energy

The hydraulic design of the pumps is concerned with the rate of discharge, the head to be overcome in lifting the water, the structural forces generated by the lift, the energy input required, and the length and frequency of the handle. These factors affect the design of the handle assembly, the pump stand, the bearings at handle pivot points, the pump rod connection to the handle and the plunger assembly, the cylinder, and the water seal ("cup" or "bucket") between the plunger and the cylinder wall. (See ANNEX A)

References

Hand Pumps, International Reference Centre for Community Water Supply, The Hague, Technical Paper No. 10, 1977.

1.2. Types of Hand/Foot Pumps

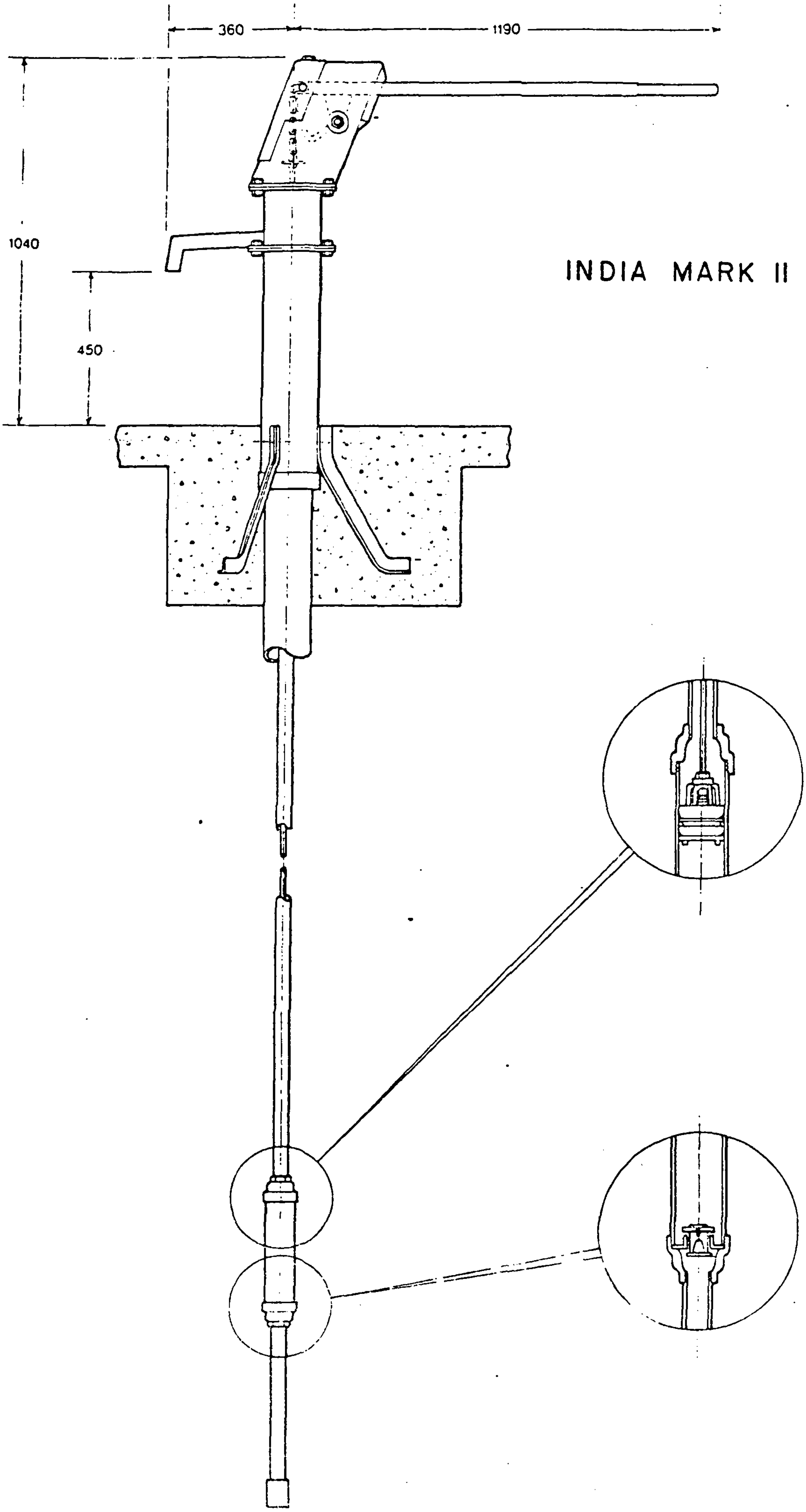
Reciprocating Pumps

Most manual pumping devices uses in community water supply are of the reciprocating type.

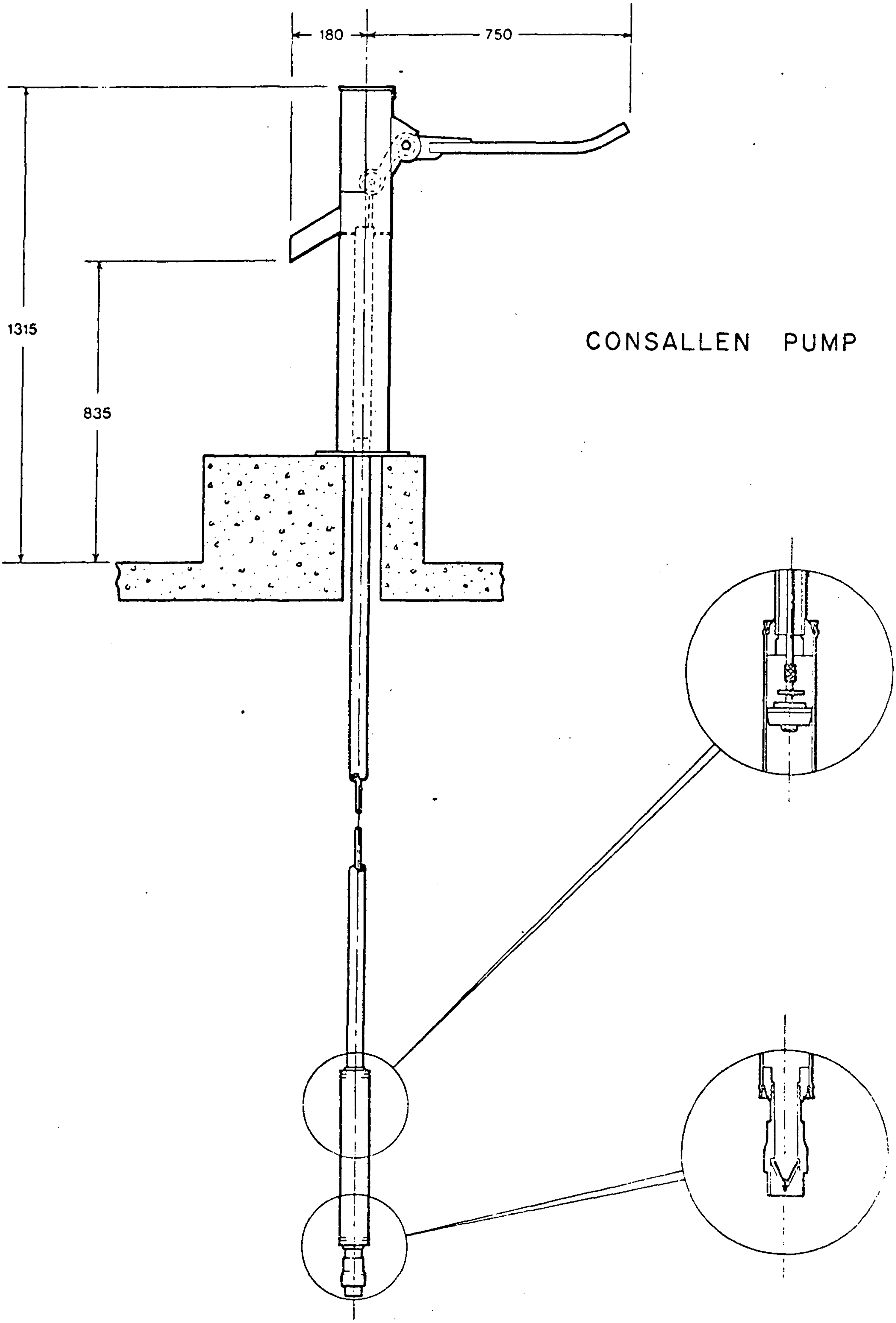
Features:

- Transfer of the work on the handle lever to the reciprocating plunger or piston requires a fulcrum pin (pivot) and one or two other pins. These are sources of friction, and these by wear, and require lubrication. Rotaray crank and wheel operated reciprocating hand pumps have similar requirements.
- The hand pump handle or crank is a lever which provides mechanical advantage in raising the plunger. The mechanical advantage is restrained by the strength and the anthropomorphic geometry of the human power source - man, woman, or child.
- As the plunger lifts the water to the pump spout there is a friction, and these by wear, of the cups or seals between the plunger perimeter and the cylinder casing.
- The discharge and suction check valves open and close, and thereby wear, during each pumping cycle.

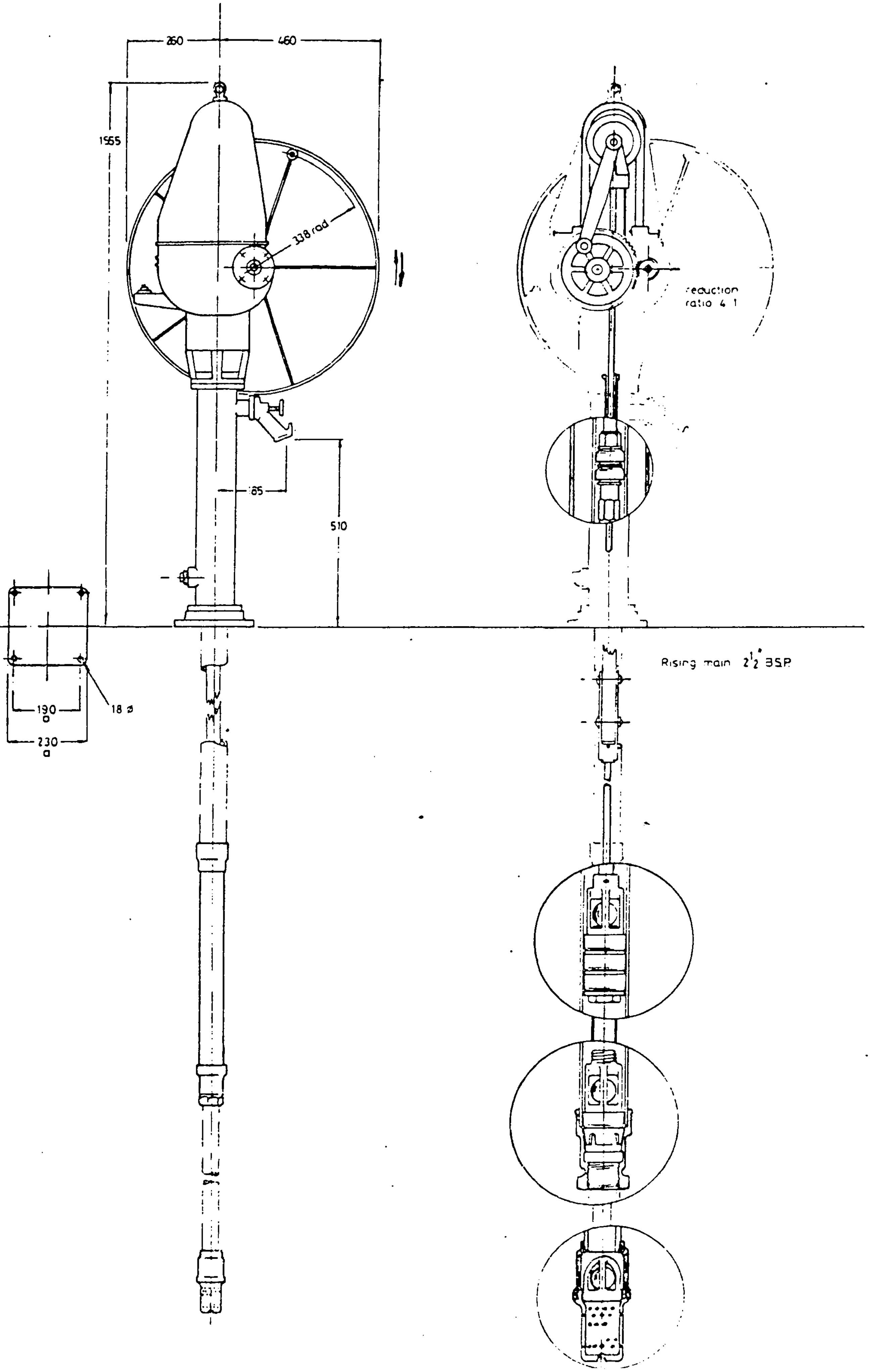
These inherent features of the reciprocating hand pump have been the focus of much research and development on hand pumps and explain many of the differences in currently manufactured hand pumps.



INDIA MARK II


180
750
1315
835
CONSALLEN PUMP

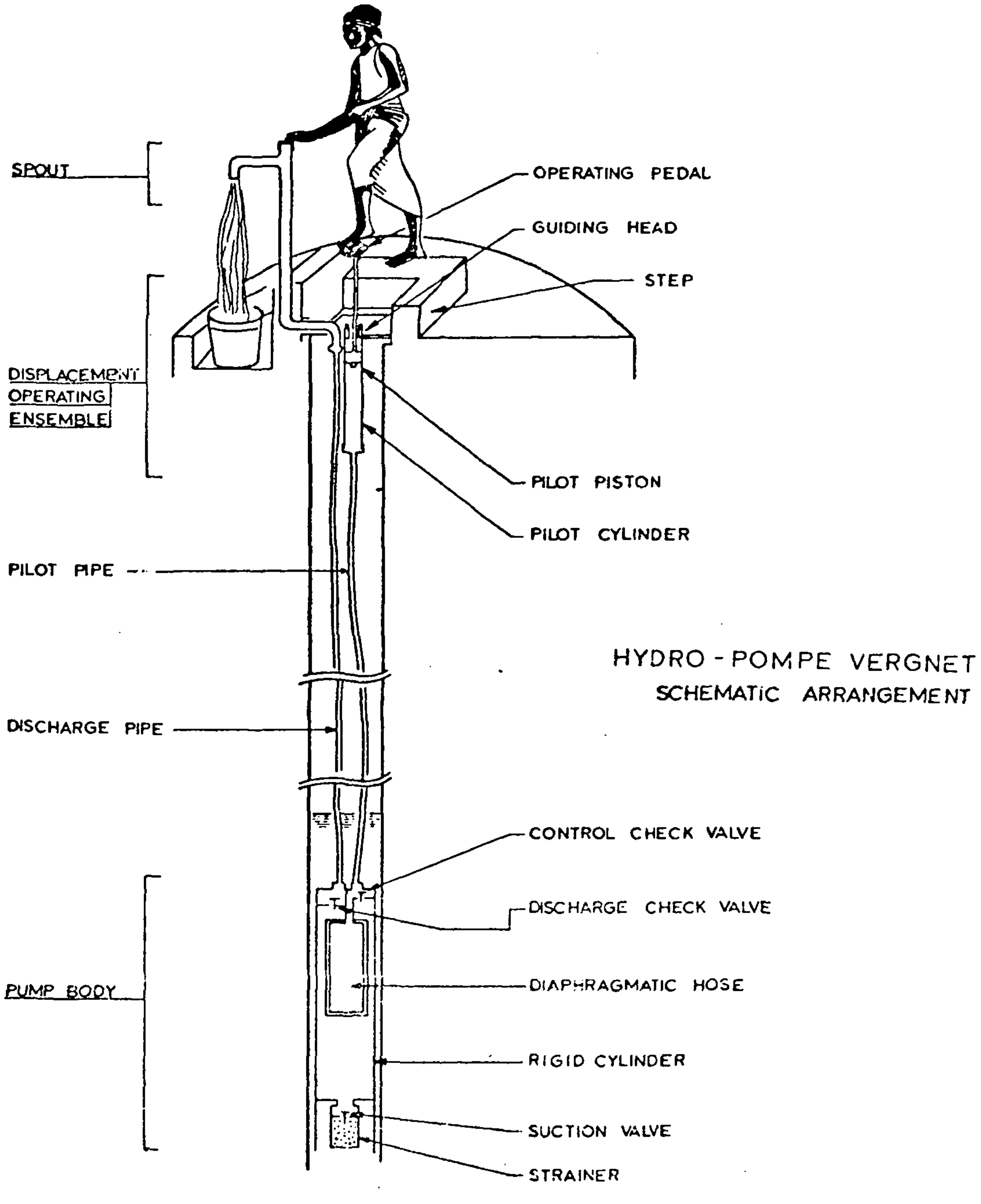
GODWIN WIH51 PUMP



Diaphragm Pump

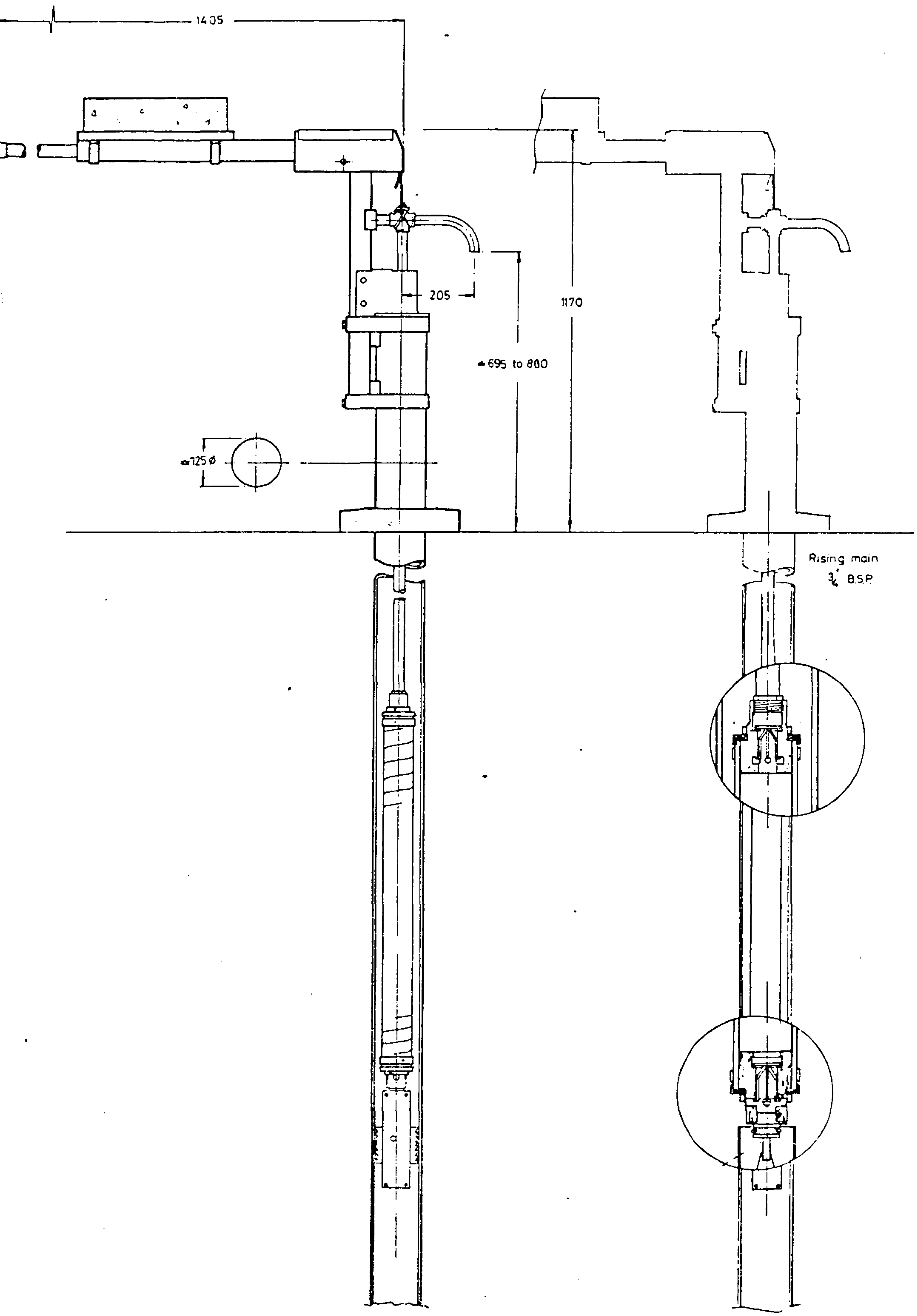
Another type of positive displacement pump is the diaphragm pump. These pump also uses inlet and outlet check valves. However, its cylinder is flexible, expanding to draw water in, contracting to force it out, much like a heartbeat. Its merit is, vis-à-vis reciprocating pumps, that it eliminates the necessity for moving the plunger and its sliding, wearing cup seals.

A Diaphragm handpump is the Swedish-made Petro-Pump and the French-made Hydropompe Vergnet.

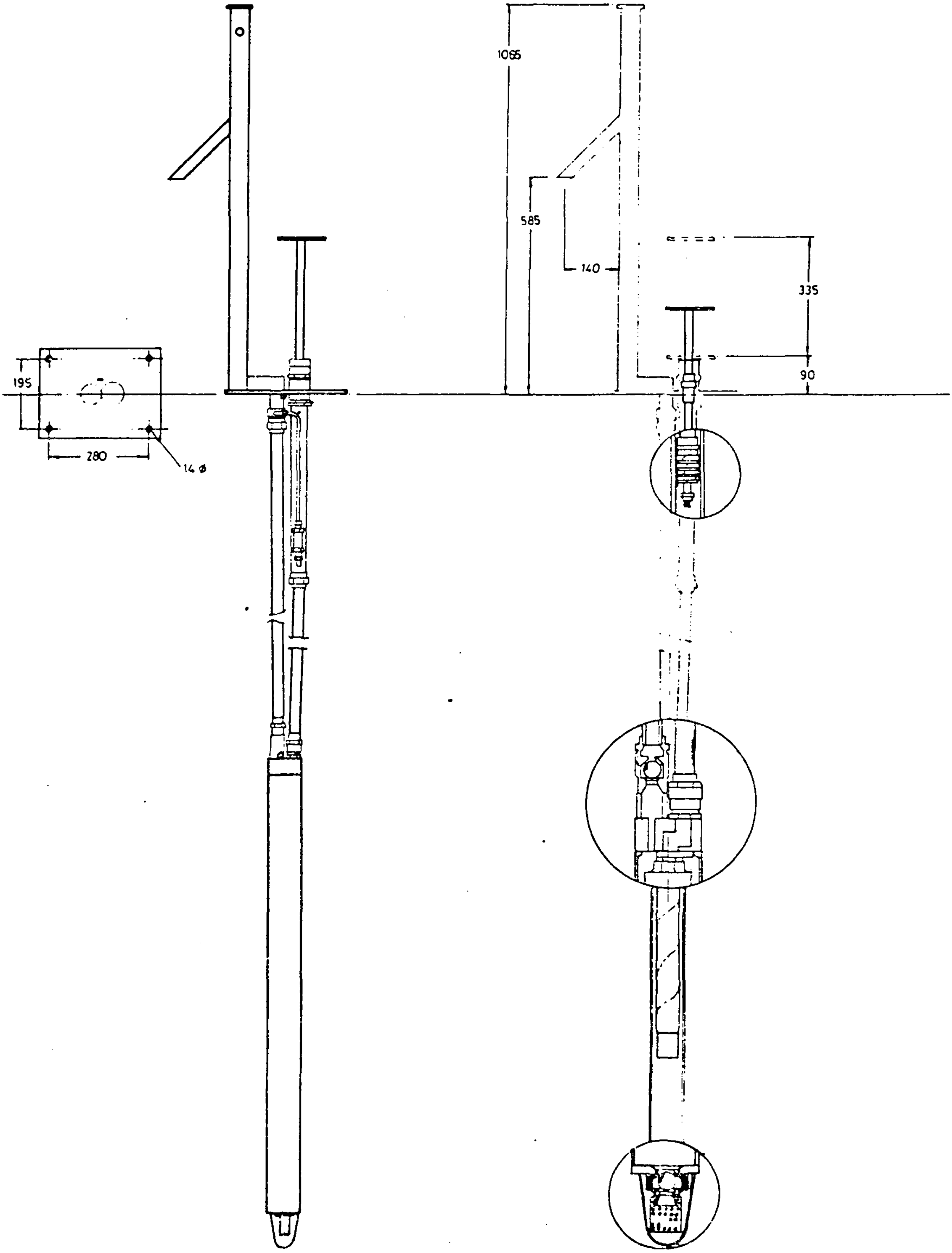


HYDRO-POMPE VERGNET
SCHEMATIC ARRANGEMENT

PETROPUMP

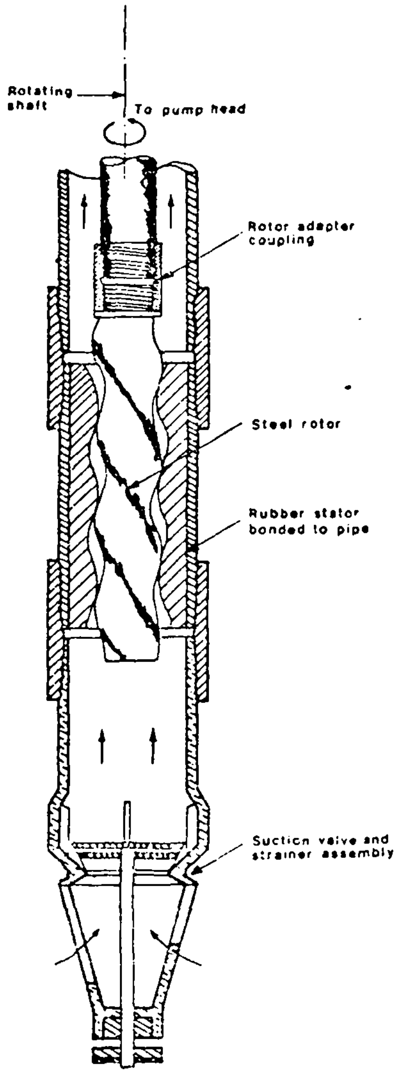


POMPE VERGNET

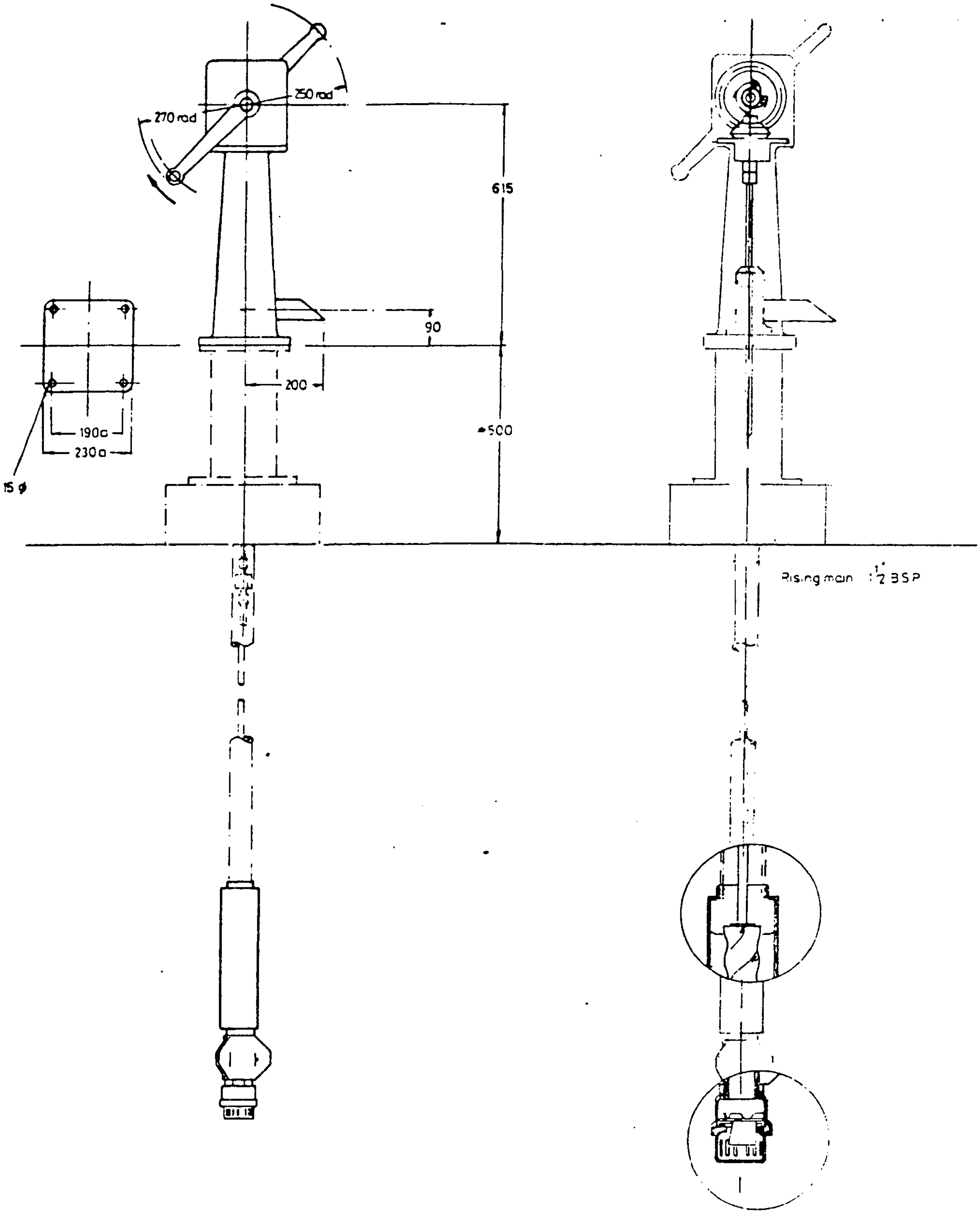


Rotary Pump

A rotary typ pump, the helical rotary or progressive cavity pump, consists of a single thread helical rotor turning within a double thread helical stator. The meshing helical surfaces push the water up the drop pipe (river) with a uniform movement similar to a slow moving piston in a cylinder of infinite length. This requires no values, no cup seals, and - in place of the reciprocating lever linkage of the pump head - it uses a rotary crank with a right-angle gearbox to turn the rotor. The rotary pump is known as the "Mono" pump after its Englisch manufacturer. Another developed pump of this type, known as the "Monyo" is available from Canada and the USA.



CROSS SECTION OF
HELICAL ROTOR PUMP



MONO ES 30 PUMP

Some Hand Pump Manufacturers

India

Charotar Iron Factory, opp. New Ramji Mandir, Anand, Gujarat.
(makers of a pump similar to the *Wasp*).
Coimbatore Water and Agricultural Development Project, 69 Venkatasami Road,
R. S. Puram, Coimbatore 641002.
(makes *Jalna* type pumps).
Dandekar Bros Ltd, Shivāji Nagar Factory Area, P.O. Sangli, Maharashtra.
(*Jal Javahar* pump, also similar to the *Wasp*).
Gujarat Small Industries Ltd, Nanavati Estate, near Chakudia Mahadeo, Rakhial,
Ahmedabad-23. (makers of the *Kirti* pump).
JPSR Company (Mittra Das Ghose & Co.), Howrah, near Calcutta, (makes low-lift
and deep well hand-pumps).
Kirloskar Bros Ltd, Kirloskarvadi, Dist. Sangli, Maharashtra.
(makers of the *Kareri* deep-well hand pump; many other products).
Kumar Industries, P.O. Edathara 678611, via Palghat, Kerala.
(several types of low-lift and deep-well hand pump).
Lifetime Products Corporation, Industrial Area, Jodhpur.
(makers of a pump similar to the *Wasp*, but with detailed differences).
*Marathwada Sheti Sahayya Mandal, Jalna, Dist. Aurangabad, Maharashtra.
(originator of the *Jalna* hand pump; non-commercial manufacture).
Maya Engineering Works, Calcutta.
(known for the *Maya No. 6* low-lift hand pump for shallow wells).
Mohinder & Co, Kurali, Dist. Ropar, Punjab.
(low-lift hand pumps).
*Senco Industries, A-12, Coimbatore Private Industrial Estate, Coimbatore-21.
(commercial manufacturers of *Jalna* type pumps, and other kinds).
*Sholapur Well Service, 560/59 South Sadar Bazaar, Civil Lines, Sholapur-3,
Maharashtra. (makers of a re-designed *Jalna* hand-pump – see figure 3).
*Vadala Hand Pump, Marathi Mission, Ahmednagar, Maharashtra.
(non-commercial maker of a *Jalna* type pump; the *Jalvad*).
*Water Supply Specialists Private Ltd, Post Box 684, Bombay-1.
(makers of the *Wasp* deep-well hand pump).

Other Indian pumps have included the *Patel*, the *Mahasagar*, and the *Economy*, all with conventional pump-head assemblies. The *India Mark II* hand-pump is manufactured by several of the above firms; for details, write to UNICEF-WES, 11 Jor Bagh, New Delhi 110003.

Africa

ABI Pumps, Abidjan Industries, B.P. 343, 45 Rue Pierre et Marie Curie, Abidjan,
Zone 4c, Ivory Coast.
(make *Pompe Alternative - ABI type M*; no details).
Comptoirs Sanitares de Madagascar, B.P. 1104, Tananarive, Malagasy Republic.
*Craelius Terratest Ltd, P.O. Box 40090, Nairobi, Kenya.
SAFICOCI, B.P. 1117, Abidjan, Ivory Coast.

Shallow Wells Project, Shinyanga, Tanzania.
(pump factory in operation from April 1976 making *Uganda* type pumps).
Siscoma, B.P. 3214, Dakar, Senegal.
(make various types of pump, some of French design).

Western Countries

Barnaby Climax Ltd, White Ladies Close, Little London, Worcester WR1 1PZ,
England.
(makers of *Climax* pumps).
Briau S.A., B.P. 43, 37009 Tours Cedex, France.
(makers of the *Africa*, *Classique* and *Royale* pumps).
Consallen Structures Ltd, 291 High Street, Epping, Essex CM16 4BY, England.
(makers of *Consallen* pumps).
*Dempster Industries Inc., P.O. Box 848, Beatrice, Nebraska 68310, U.S.A.
(deep-well hand-pump, *model 23F*; simple and inexpensive).
*Etablissements Mengin, Zone Industrielle d'Amilly, B.P. 163, 45203 Montargis-
France.
(makers of the *Vergnet* pedal-operated pump).
H.J. Godwin Ltd, Quenington, Cirencester, Gloucestershire GL7 5BX, England.
(fly-wheel drive, conventional and experimental hand-pumps).
GSW Limited, Hill Street, Fergus, Ontario, Canada.
(makers of Beatty pumps).
Lee Howl and Co. Ltd, Tipton, West Midlands, England.
(low-lift pitcher spout and other hand-pumps).
Monarch Industries Ltd, P.O. Box 429, Winnipeg, Canada.
(makers of *Beatty* pumps).
*Mono Pumps Engineering Ltd, 1 Sekforde Street, London EC1, England.
(makers of the unique, low-maintenance *Monolift* hand-pump).

(*denotes pumps used by, or on trial with UNICEF).

1.3 Appropriate Technology

Appropriate technology has been defined as technology that is not only scientifically sound but, that is acceptable to users, providers, and decisionmakers alike; that it fits, within local cultures, that is capable of being adapted, further developed, and manufactured locally whereever possible at low costs; and that it is sufficiently simple in design and execution for local use.

It is one of the great illusions, in the appropriate technology movement that seemingly technological problems, can be solved purely by attention to hardware.
In case of handpumps, the problem has at least five dimensions:

a) the communities using the wells and pumps;
b) the agencies administering well programmes;
c) the objectives for which the wells were provided;
d) the typ of pump used;
e) the environment-climate, hydrology and geology.

A description of these dimensions is given in Annex B.

1.4 Hand/Foot Pump, Design and Manufacture

1.4.1 Background

Present handpump designs are leading to very high expenditure on repair and maintenance, particularly transport costs, in most developing countries, as well as causing unacceptably high proportions of water wells to be out of use of any given time.
Many, perhaps the majority of the problems have their roots either in the sociological and cultural attidudes of the pump users or in the organisation (or lack of it) of the handpump installation and maintenance programme.

One major problem however, is the unreliability of many of the pumps which have been installed and the havoc wrought with the water supply consequent upon it. This unreability may result from several sources:

- the intensive use of a pump in a village water supply scheme which may require it to be in operation for perhaps 12 hours or more of the day, when it was designed for only occasional use;
- the use of cheap and unreliable pumps in an effort to provide water to the greatest number of people within the scope of a limited budget;
- the choise of a poor pump simply due to the lack of suitable, unbiased and reliable test data on the pumps available;
- lack of sufficient knowledge of pumps to foresee those peculiar features which could clash with the cultural behaviour of the pump users.

1.4.2 Discussion and Recommendations

Before discussing detals of pumps, consider simply some of the most important aspects of a pump , which must be taken into account when making a choise.

1. The pump should be as simple as possible and reasonably easy to repair when necessary.
2. Maintenance required should normally be as little as possible. In some cases, however, a cheaper pump requiring more maintenance may be preferable, if the maintenance can be carried out easily.
3. Manufacture, should not present any major quality control problems and, preferably, should be undertaken in the country where the pump is installed.
4. The pump must be reliable.
5. Pumps should be resistant to abuse pilferage of parts and vandalism. It is felt that this feature is the one

which accounts for many of the apparent differences in reliability which are reported for the same pump in different areas.

6. The pump should be acceptable to users and compatible with their cultural traditions, reasonably easy to use, (also by small people, including women and children) and produce water at an acceptable rate.
7. The pump should be compatible with the hydrological features where it is to be installed (i.e. well depth, annual variation in water table, quality of water, type of acquifer).
8. The price should be as low as possible, consistent with the other criteria being satisfied.

Now consider what these features could mean, in practical terms, on a pump and what should be looked for, taking them sequentially as before

1. Simplicity and ease of repair. To satisfy this requirement, a pump should not be excessively heavy. The operating mechanism should not be complicated and should also be designed to use readily available or easily manufactured components. Dismantling a pump should not require anything more than the simple tools normally available in the field and be straight forward.
2. The need for maintenance is often regarded as going hand-in-hand with price, but this is not necessarily so. Besides, maintenance costs will almost certainly be far higher than any price involved in reducing maintenance to a minimum. Elimination of bearing lubrication, (and often, increased reliability) can be obtained by using sealed ball races instead of pinned bearings. Ball races however are more susceptible to damage by impact loading, such as might occur by knocking a handle against its metal stops, and in many cases

a self-lubrication bush may be a better answer. Other parts which require continual lubrication or adjustment should also be eliminated, e.g. stuffing box nuts. Most other preventative maintenance required is usually due to wear of moving parts, and this can often be reduced by careful choice of materials (see 7 for example).

3. This needs no further comment.

4. Reliability, defined as the frequency with which a pump breaks down and requires repair, is a function of many variables. Components which wear rapidly, even if they do not cause failure themselves, may affect other components which do fail (e.g. a worn stuffing box nut can cause pump rod failure). Sometimes poor assembly of the pump can cause failure e.g. incorrectly locked nuts and bolts on the pumpstand, or even between pump rod connections. Sometimes, choice of incorrect materials results in corrosion and subsequent failure. All these possibilities, and more, must be considered when examining a pump. Some can be predicted by careful inspection, some can only be found by testing.

5. It is felt that the lack of resistance to abuse, vandalism and pilferage is a major downfall of many pumps. Pumps should be designed to resist abusive contamination by using a correctly designed spout and baseplate. External fixings and fasteners should be an absolute minimum. The ideal is to have only one external fastening which is very carefully protected, and difficult to remove without special tools, and through which access is gained to other fastenings. This is not always possible, nor indeed in some cases even necessary, but it is felt that a pump which approaches the ideal is likely to have a wider area of application. Pumps should also be resistant to impact, either accidental or deliberate. Cast iron handles, pump mechanisms easily knocked out of alignment, etc., should be avoided.

6. The overall user acceptability of the pump can obviously vary from one place to another depending on abstruse factors sometimes. Some features, such as ease of use, however, are less variable. Tests would indicate that in general, on conventional pumps it is best to use a handle of a mechanical advantage of at least 6:1, preferably 8:1, a long handle with a relatively smaller arc of movement and with a counterbalance weight. A larger cylinder, used with a large mechanical advantage handle and a longer stroke. The stroke should not become so small as to give a stroke length less than about 80 mm however.

7. Choosing the correct pump for the geological conditions is very important, e.g. the corrosion resistance of the pump must be dependent on the water quality. The size of cylinder used, and any counterbalance weights on the handle, should be determined from the well depths. If the well is likely to run dry, or the pump cylinder likely regularly to become dry, then a conventional cylinder with leathers should be avoided. The possibility of solid impurities in the water should be taken into account, and the effect of this on the pump wear assessed. Even such things as variation in water temperature may need to be considered.

Having considered some of the possibilities which must be looked at, it will hardly be surprising if it is said that none of the pumps tested will suit every situation; nor indeed is there a pump which comes as close to the ideal as is possible. Some pumps are so expensive that they would almost be ruled out on price grounds alone; some could not be made to give good service without modifying them out of all recognition. For the purposes of comparison, the three major sections of a pump will be looked at separately, i.e. cylinder, connecting assembly and pumpstand.

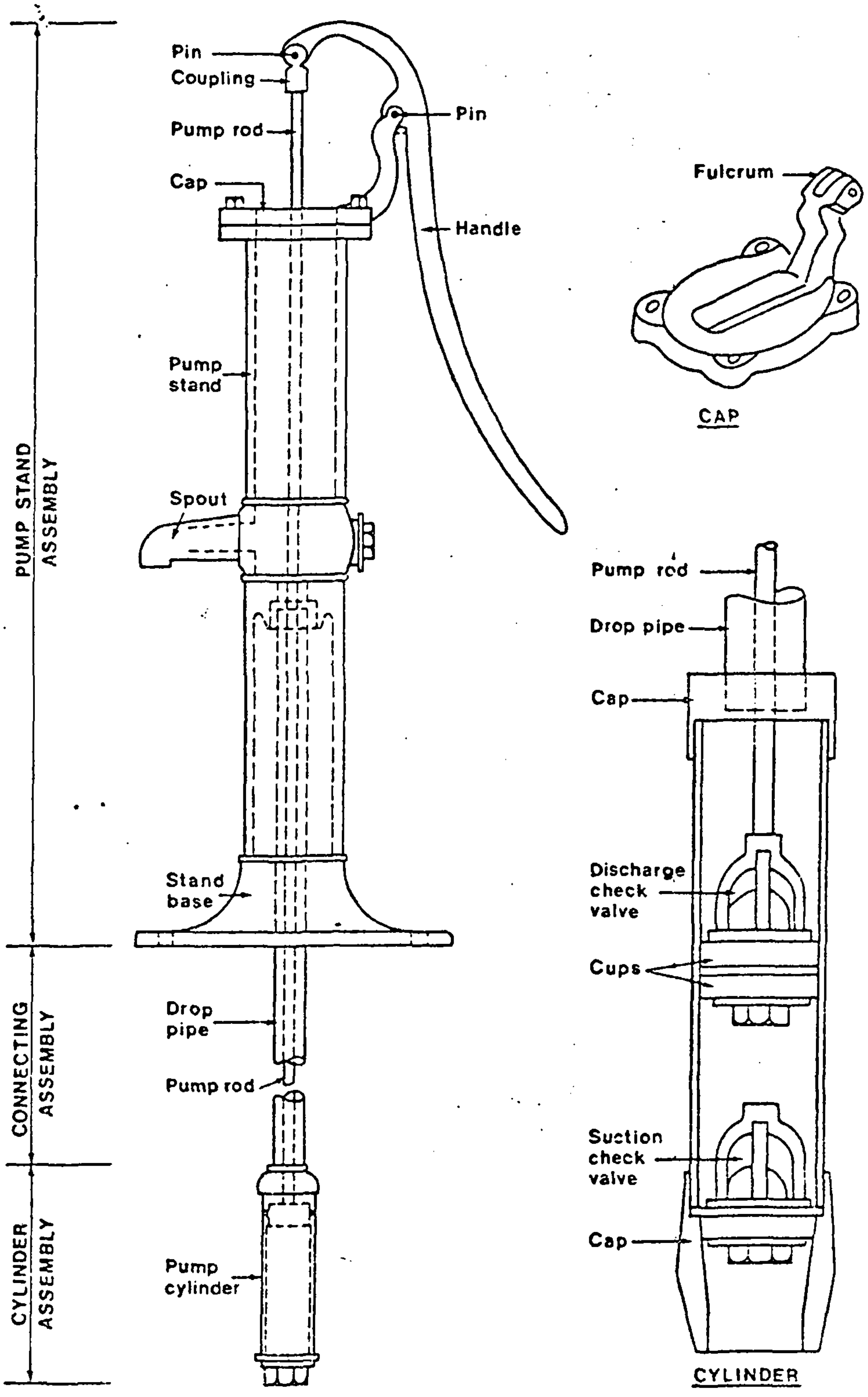


FIG. 1 HAND PUMP NOMENCLATURE

1.4.3. Research and Development

International efforts to develop pumps for water supplies in rural areas of developing countries have stimulated over the last years several major research and development projects. (See ANNEX C)

A panel of World Bank, UN and other experts is encouraging manufacturers of handpumps throughout the world to make fundamental changes to their existing designs, to suit the needs of the Water Decade.

The main change in current handpump designs sought by the expert panel is the development for the VLOM pump. VLOM (village level operation and maintenance) would combat the very high costs of routine maintenance or repairs. (See ANNEX D):

The panel's answer is to simplify the below-ground components of handpumps in such a way that replacement of worn or broken parts will be simple and cheap. To overcome the major difficulty of raising the pump cylinder to the top of the well hole, attention is being fucussed on maximum use of different kinds of plastic for as much as possible of the underground components, and finding a way to drain the column of water when pulling out the pump. In particular, substituting plastic for conventional galvanised steel in the drop-pipe, through which water is pumped to the surface, can cut the weight by a factor of ten or more.

As well as the weight reduction, which avoids the need for heavy lifting equipment, use of injection-moulded plastic for the replaceable parts of handpump mechanisms could have a signifacant impact on costs of spares. That in turn would mean that stocks of regularly needed parts could be held in villages, and routine maintenance of groups of pumps could be managed by a local caretaker equipped only with a set of tools - and f.e. a bicycle, if he serviced more than one village.

The incentive for direct beneficiaries to carry out their own repairs is strong, and the logistic and cost problems of longdistance mobile teams would be largely eliminated.

So dominant are repair and maintenance costs in rural water supply programmes, that the conventional design criteria of strength and durability, which have led to the predominance of heavy-duty equipment, are rapidly giving way to the new VLOM rules of making repairs easy and cheap.

The experts are convinced that, even if the working parts of a handpump have to be completely replaced more frequently, providing those parts are cheap, readily available, locally manufactured, and easily installed, cost savings and improved pump usage would be substantial compared with an expensive, robust, heavy installation, which might require fewer service calls during the same five years.

1.4.4. Laboratory Tests and Field Trials

Details of handpump tests performed and the methods of analysis of the results have been given in a paper entitled "Guidelines for Hand Pump Testing", presented by the International Reference Centre for Community Water Supply, The Hague, Holland.

A wide scale, fully comparative testing of handpumps under controlled laboratory conditions has been carried out by CA Testing & Research (CATR) at the UK Consumer's Association. Those tests, were initiated by the UK Overseas Development Administration about for years ago, when 12 handpumps chosen to represent as many design types as possible were put through rigourous trials, including a 4000 hours endurance test. The results, reported in October 1980, were made known to the individual manufactures, agencies and governments. (See ANNEX D and E)

CATR concluded that, of the 12 pumps tested, only four were worthy of consideration for general use in developing countries, and in two of those, significant modifications were needed to the pumps actually tested.

Pumps achieved an excellent rating in CATR's tests for overall design, frequency of maintenance and breakdown, corrosion resistance and safety, and high marks also for ease of manufacture, performance efficiency, resistance to abuse or neglect, and well-head sealing:

- Consallen (UK)
- Inolia Mark II
- Brithis Monolift with modifications
- French Vergnet footpump with modifications

The Swiss Association for Technical Assistance (SATA) has reported about field trials in Mali (Projet de Forages Hydrauliques, Zone Mali-Sud) (See ANNEX F)

Types of pumps described:

- Vergnet 4 C2
- ABI
- Bourga Simplex
- Bourga Super
- Deplèchin Tropic VII

Proceedings of a workshop on training for rural water supply in developing countries held in Malawi (Aug. 1980) include papers of the resulting discussions, descriptions of the field visits and research action plans about shallow wells and handpumps. (See ANNEX G)

Types of pumps described:

- Convallen (UK)
- British Monolift
- Boswell (Ethiopia)
- EWRA/IDRC Pumps (Ethiopia)
- Shinyanga (Tanzania)
- Kangaroo (Tanzania)
- Mark Series (Malawi)
- Ndowa Pump

Laboratory tests endurance and user reactions

The Consumers' Association is best known in the UK for its comparative trials of such products as motor cars, do-it-yourself tools, domestic appliances, etc. The association's consumer magazine *Which?* produces regular buying guides based on price and performance testing, including endurance tests.

A not dissimilar approach has been adopted in CATR's evaluation of handpump designs. Individual pumps are being ranked under a variety of headings from ease of use and frequency of breakdown, to user reactions and safety.

Pumps tested are bought anonymously and testing begins with a check on the condition of the pump and its packaging on delivery and the accompanying literature. Design judgements include assessments of quality and complexity and the pump's suitability for manufacture, repair and maintenance in developing countries, together with sociological and ergonomic evaluations.

CATR has devised a series of user tests, which involve volunteer pumpers, men, women and children of varying age and height. Each is asked to try out the pumps briefly and then to fill a standard bucket while an observer records standard data on time taken, number of strokes, etc. The users then complete questionnaires designed to measure the general acceptability of the design.

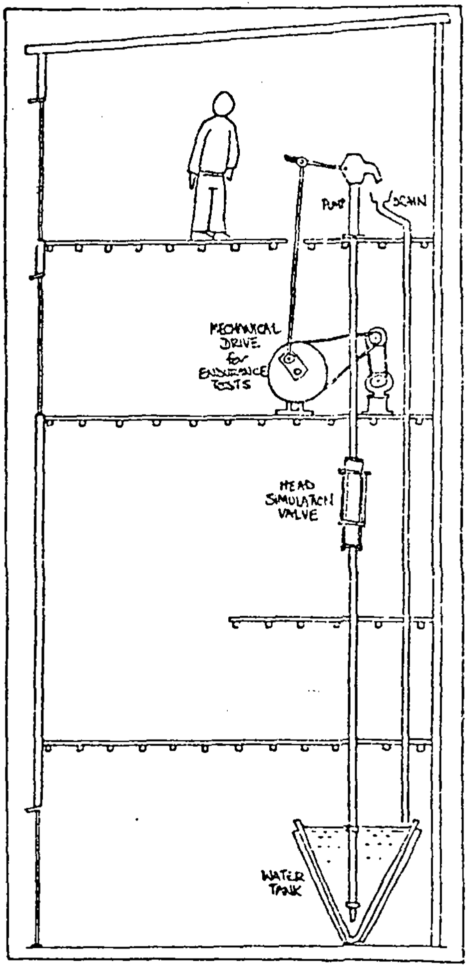
Performance tests include measurements of leakage, volume pumped per stroke against various heads, and forces necessary to operate the pump at different speeds and heads. Each pump then undergoes a 4000h endurance test involving over 10 million strokes, designed to simulate the effect of about three years use at 4h per day. A special mechanical drive arrangement and head-simulation devices standardise the tests, which include varying water quality, and a final 1,000h test in hard water containing fine sand. Repairs are carried out during the tests, but no preventative maintenance occurs.

Fault reports are fed back continuously to manufacturers, so that designs can be evolving while testing goes on.

CATR's first handpump tests for the UK Overseas Development Administration involved 12 pumps: Consallen LD5 (UK); India Mark II; Vergnet AC2 (France); Mono ES30 (UK); Petropump 95 (Sweden); Dempster 23F (USA); Climax (UK); Godwin W1H 51 (UK); ABI type M (Ivory Coast); GSW (Beatty) 1205 (Canada); Monarch P3 (Canada); and Kangaroo (Netherlands).

As described in the main article the Consallen came out as CATR's "best buy", with conditional acceptance given to the India Mark II, Vergnet and Mono. Of the others, the Swedish Petro, as a result of CATR's criticisms, has since been substantially modified, and will now be included in CATR's second series of tests. ABI is joining with Vergnet in a hybrid model, also due for re-test and the Kangaroo is being redesigned. CATR says it is not aware of any design changes in the others which would alter its conclusion that they were not suitable for general use in developing countries.

Under the UNDP/World Bank Global Project, CATR has now begun a second series of tests on an initial set of twelve, to be extended to fifteen and possibly more as funds become available. Those scheduled to be tested this time are: Korat 608 A1 (Thailand); Kawamoto Dragon No 2 (Japan); Jet-matic (Philippines); Moyno IV 2b (USA), Briau Nepta (France); Atlas Copco (Kenya); ABI-Vergnet (Ivory Coast); New No 6 (Bangladesh); Bandung Shallow Well (Indonesia) AID/Batelle Deep Well (USA/Indonesia); Nira AF-76 (Finland); VEW (Austria); Ethiopia; New Petro (Sweden); and Volanta (Netherlands).



An indication of the importance that manufacturers are attaching to the laboratory trials is the immediate response from Korat, Nira and Briau, who have already revised designs following preliminary comments from CATR, according to Test Manager, Ken Mills.

1.4.5. Manufacture of Hand/Foot Pumps

Manufacturers of handpumps are being encouraged to move fabrication of pumps into developing countries, by forming jointventures with local firms.

The desirability of local manufacture is based on possible opportunities for:

- lower capital costs of production
- transportation savings
- reduction in foreign exchange requirements
- stimulation of local initiative, industry and labor
- better availability and access to repair and replacement parts.

There are two types of local manufacture. The first is mass production in foundries, machine shops, and factories of cast iron or steel pumps similar to those in the international export market. Such manufacturing is pratical and practiced in many developing countries, notably India. The appropriatness of a particular technology will vary widely. For example foundries are widespread in Southeast Asia. They are rare in West Africa. Manufacturing facilities of the India Mark II Hand Pump (See ANNEX H).

Local manufacture does not guarantee "appropriateness". Many handpump manufactured in developing countries are not indigenous but are poor quality imitations of imported pumps. Further, lack of competition or competition solely on the basis of price are institutional shortcoming detrimental to evolution of appropriate technology.

2. HANDPUMP MAINTENANCE

The following chapter 2 represents a summary of the draft "Handpump Maintenance" to be published by the International Reference Centre for Community Water Supply and Sanitation (E.H. Hofkes, December, 1980)

2.1. Preface

Wise pump design or selction may prevent many difficulties, but regularity of maintenance is the key to reliable pump performance.

Lack of well-conceived maintenance schemes, and shortage of mechanics all add to the poor performance record of hand pumps.

There are no fixed rules to determine which balance of involvement of the government and the village communities is right for each country. An effective hand pump maintenance system is not simply a technological object but a conglomerate of technology, institutions and people.

The selection of a suitable handpump maintenance strategy and the establishment of an effective maintenance organization require careful consideration of many factors.

The psychological impact of inoperative hand pumps must be considered. In the rural areas where hand pumps are most important, the introduction of the well and pump often is a major event. To obtain maximum benefit, health educational activities should accompany the event. This would include information on health, benefits, correct use of well water for drinking, cooking and washing, and information on the basic care of the hand pump. If the pump becomes inoperative and is not repared, the chances of improving water use and hygienic habits would be lost.

A central principle in any handpump water supply project should be that the pump design keeps in view the maintenance requirements, and the needed tooling and spare parts. The maintenance of the pump should be cost-effective and suited to the conditions.

A handpump programme requires a longterm commitment to maintaining the equipment and providing the spare parts needed. Whether the funds for new construction come from national or external sources, the relationship between construction and maintenance exists, and should be considered from the start if the investment is not to be wasted.

2.2. Maintenance Strategies

The selection of a maintenance strategy involves:

- the type of pump(s) to be used
- the type of maintenance system
- the way maintenance will be financed

A maintenance system for handpump supplies can be operated in two differen ways:

Corrective Maintenance

This is the type of maintenance performed on a non-scheduled basis to bring handpumps back to satisfactory functioning by correcting a failure or poor performance. It includes repair and adjustment of pumps to keep them operating.

Preventive Maintenance

This is the type of maintenance performed to keep handpumps in satisfactory condition by providing regular inspection, detection and correction of minor failures before they occur or develop into major problems. Lubrication, adjustments and overhands are made at regular, pre-determined intervals.

Both corrective and preventive maintenance can be performed at serveral locations:

1. Repair pumps in place
2. Remove, repair, and re-install
3. Remove, install spare unit, and repair defective pump at central workshop

The choice of the appropriate strategy and the unit of replacement/repair is primarly one of economics, but in many situations implications of development policy and logistics umst also be considered.

To organise preventive maintenance of handpumps is not a simple project. It may take several years to bring into smooth functioning. Its initial impact can even be an increase in total cost, largely in materials. Properly organized and introduced, the ultimate results to be expected are a reduction in the unit cost of maintenance and an improvement in the pumps' reliability and performance.

One question of maintenance strategy is whether the provision of maintenance should be the responsibility of the government, or of the community, or a shared one between the government and the community. In most cases the responsibility for maintenance of the pump is shared by the water supply agency, the local government and the community using the pump. (See ANNEX I)

2.3. HANDPUMP MAINTENANCE SYSTEMS

2.3.1. GENERAL

Through the history of hand pump use there have been many approaches to the problem of keeping large numbers of pumps operating. Here, some of the ways used to maintain hand pumps are examined. The choice of pump, the organisation of maintenance, and the way it is financed are inter-related.

Most hand pump maintenance systems can be characterized as a one level or a two level system. The one level system is one where all maintenance is the responsibility of a central organization. In the two level system, maintenance is shared with the local communities.

In both systems the central agency usually installs the pump. It usually also handles the major repairs or replacement of pumps, and maintenains stores for stockkeeping of parts and lubricants. It provides transport, and training.

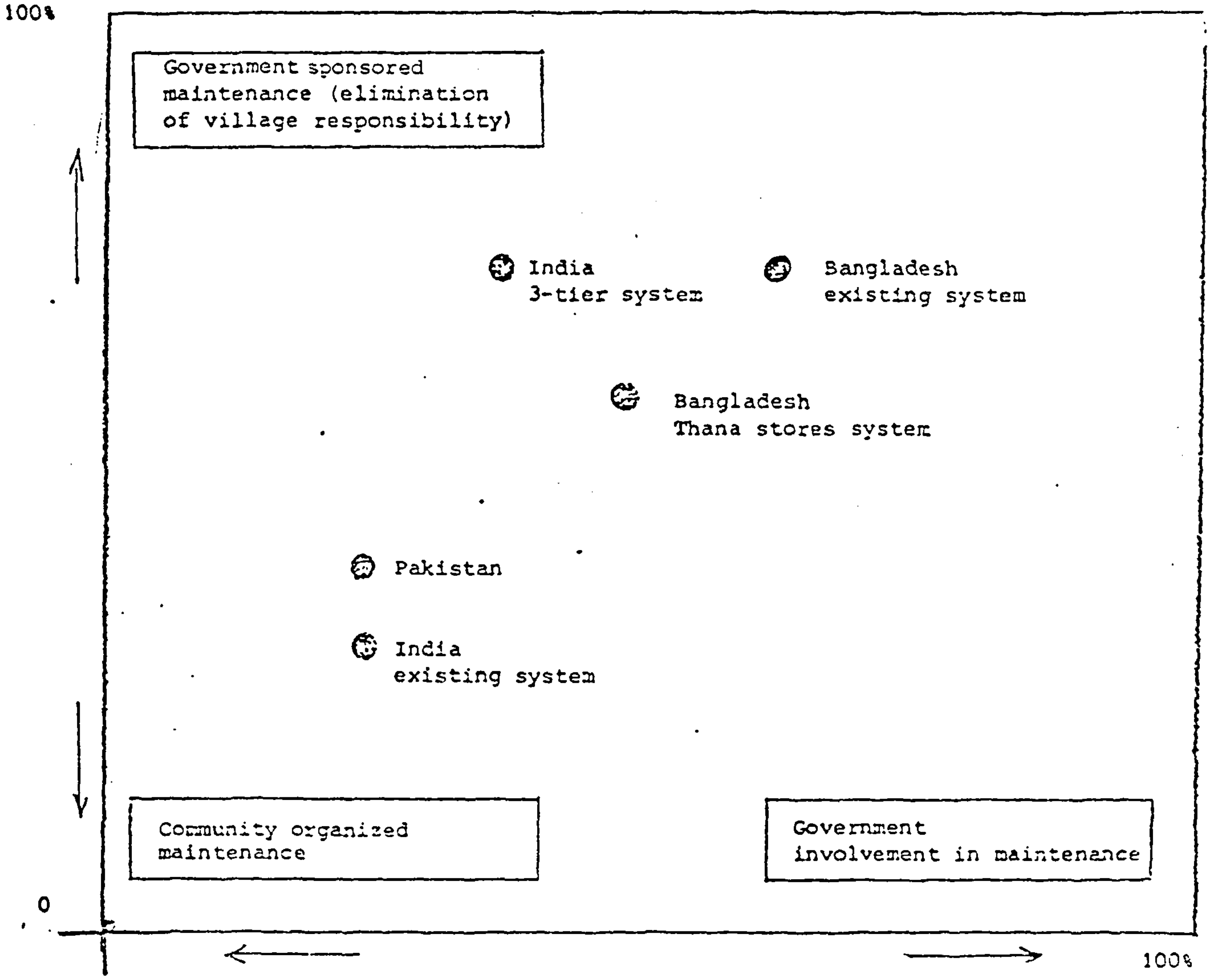
In the two-level system the local community, or a resident employed by the central agency, assumes responsibility for all lubrication, bolt tightening and minor repairs, and the replacement of the pump's cup seals ("leathers"). Where villagers only deal with the basic maintenance tasks, the back-up service will have to visit the pump at regular intervals (e.g. every three months) for a thorough servicing. This system is found in parts of India.

In some handpump installation programmes, selected villagers are given a training in pump maintenance. After that, virtually all responsibility is left in their hands. This approach has been tried in Kenya and in Tanzania. Each village is required to nominate a person before the well is constructed. He will go to the district office for two weeks to learn about pump maintenance. He will be responsible for maintaining the pump once it is installed, and he will keep a small stock of pump components and spare parts in his house. If a major breakdown occurs he will go back to the district office and either get the parts needed to do the repairs himself, or else get the district mechanics to do the job.

In Malawi where 90% of the country's population lives in the rural areas, a programme has been carried out for the drilling of tubewells - 120 to 150 feet deep - on which handpumps were fitted. About 5000 of such tubewells with handpumps are spread across the country. These are fairly well-maintained by 20 special teams who inspect them regularly and make urgent repairs on request. The system works well, but it has one major disadvantage. The annual maintenance cost is about $ 70 for each tubewell and pump. At this price, Malawi which has a per capita income of $ 140 simply cannot afford to provide tubewells for the entire population. Moreover, because of the complicated techniques used for well drilling and pump maintenance, it is difficult for the villagers to contribute any labour to bring costs down.

Generally, if handpumps water supplies are installed with a suitable degree of community involvement, a sense of pride and ownership can develop in the community, and a high level of maintenance can more readily be achieved.

Fig. 3.1. presents some actual cases illustrating varying degrees of government involvement and community responsibility in the maintenance of handpumps.



Note: Arrows indicate possible range of government involvement

Fig. 3.1. Government involvement in maintenance of hand pumps.

The different types of handpump maintenance system may be characterized as follows:

(a) Zero maintenance
(b) Governmental maintenance
(c) Community maintenance

2.3.2. ZERO MAINTENANCE SYSTEM

Zero maintenance refers to the attempt sometimes made to allow for very poor to non-existent maintenance in rural areas by using very robust handpumps which are not likely to need any servicing or repair for a long time. Such pumps are then often treated as if no maintenance at all is needed.

This is nearly always a mistake. All machines need some maintenance. The key argument in this document is that, at the design stage, one should make clear choices as to which maintenance tasks are to be left in the hands of the local community, and which will be the responsibility of the government water supply agency's technical staff. That is, the real choice does not include "zero maintenance" at all, but only the alternatives of "community" and "government" maintenance, with various combinations of these two.

In all cases, choices must be based on knowledge of the skills of the local people, the availability of tools and materials, and the extent of technical back-up that is possible. In some situations, government-provided maintenance will be excluded by shortages of skilled technicians or by the great distances they would need to travel to reach scattered rural communities. Government maintenance may also be excluded in these instances where water supply projects aim especially at local, low-cost maintenance. Even so, there will be many cases where government maintenance is possible, and a choice has to be made about the extent to which it will be used.

An example can serve to illustrate the shortcomings of treating even simple and robust equipment as if it needed no maintenance at all.

The ox-drawn farm implements used widely in Africa are often viewed as needing no maintenance at all. They are strongly made in steel and rarely break. But with use, the optimum shape of tines and plough-shares is gradually lost. Angles and edges are distorted by wear and sometimes by slight bending. The result is that more and more effort is needed by the oxen to draw the implements through the soil,. and they do a much less efficient job.

2.3.3. COMMUNITY-ORGANISED MAINTENANCE

Quite frequently, there is no formal government organization for the maintenance of hand pumps. Where the pumps are financed exclusively from private sources this may be acceptable. The owners of the wells and hand pumps are likely to have sufficient resources to purchase spare parts, and the commercial suppliers will ensure that spare parts are on sale. In addition, where hand pumps are privately owned, use will be less intensive and the direct involvement of the owner will result in greater care than is normal for handpumps used by a community. For community organised maintenance it is necessary that the community accepts the responsibility and makes arrangements for the necessary resources to be available locally. The chances of this approach meeting with succes are small in weak-organized communities; where the pumps also are of a complicated design there are likely to be severe maintenance problems.

In many projects using simple pumps, there is the intention from the outset that local people shall be entirely responsible for maintenance. In other cases, where maintenance planning has been neglected, it may just turn out that the community is left to look after the pump, with only occasional visits by a technically qualified person, if at all.

One advantage of a conscious policy of encouraging community-organized maintenance of pumps is that it can bring out local initiative and reduce the burden of maintenance costs on the government. Government resources can then be channeled to new well construction and handpump installation. This approach completely depends on the people's attitude towards the pump. Where the well and pump are seen as something the government has given without any request or consultation, the local people will normally expect the government to maintain the hand pump. However, if the local people see the hand pump as something that was achieved after considerable local action, they feel it is theirs. Knowing that the government policy is to leave the maintenance to the local people, the community is lead to organise and carry out the maintenance satisfactorily.

Yet, too often too much is left to chance. By introducing the term "community-organized maintenance", we hope to stimulate clearer thinking as to what are the precise responsibilities and possibilities for the local people. Proper planning of community-organized maintenance would take account of the following:

(1) The attitudes of the people. Have they been able to influence the planning of the handpump water supply, and have they participated in its installation, so that they regard the pump as truly theirs? Or do they regard the pump as belonging to some outside, alien agency, who logically should provide for its maintenance?

(2) The division of responsibility for the regular care of the pump, for the purchase of materials needed in repairs, and for actually carrying out repairs.

(3) The means the community will have for obtaining assistance when special maintenance skills are required.

(4) The tools and equipment available to the local people, and the availability of the spare parts needed for repairs.

For handpumps fitted on shallow wells (up to 5 metres deep), a community-organized maintenance system rooted entirely in local resources and totally independent of government help would be possible, but in practice the pump is very likely to be abandoned soon. The villagers would revert to the use of buckets for drawing water. This conclusion is supported by a project in Ghana where the use of pumps at shallow wells was deliberately rejected because it was felt that in practice the pumps would not be maintained. In such cases, the health hazards of using buckets can be partly offset by permanently attaching them to the well, so that people cannot take them home, nor will use their own dirtier buckets. Even so, the practice is not satisfactory. The best approach may be to enlarge the technical capabilities of the local people urging them to replace the buckets by a pump as soon as they judge for themselves that they can cope with the maintenance requirements.

What will happen in practice with a handpump that, from the government agency point of view, is regarded as too small an item for a technician to be sent many miles just for routine servicing. The pump will be used by the people for as long as it works, but when the inevitable happens and the pump breaks down, the cover of the well is opened and buckets are let down to draw water. This negates the very purpose for which the pump was installed, that of sealing the well against contamination from the surface.

A policy of community-organized maintenance of handpumps delegates the full responsibility for maintenance to the communities. Where successful, it is an excellent system. But in many developing countries it is not yet reasonable to expect small communities to maintain their hand pump. Frequently, this system will result in an unacceptably large number of handpumps out of operation, and the resources the government has used in well construction and hand pump installation will be wasted. Moreover, in the early stages when people are not yet accustomed to using well water, and in fact may prefer the taste of their old water source, the first breakdown of the pump provides a convenient excuse to return to the old water source.

The overall cost of community-organised maintenance will be no less and probably even higher than under other systems. But the cost to the government is greatly reduced. A community-organized maintenance system does require that private suppliers organise the import or local manufacture of spare parts, their transportation, storage and administration. It is thus quite possible that the foreign exchange costs of a community maintenance system are high. Only where a very simple locally produced pump is used, costs can be reduced to a level lower than would apply to a government-provided maintenance system.

2.3.4. GOVERNMENTAL MAINTENANCE

At the opposite extreme to community-organized maintenance is the system whereby the government takes all responsibility, and bears all the costs for the maintenance and repair of hand pumps. There are many ways the government can organise these duties. A special government agency may be established which would be responsible for the maintenance of all hand pumps installed by the government. It may have offices at the lowest level at which the government can maintain offices. Another option is that the government establishes a technical organization for water pumps, roads, power and any other services which may conveniently be grouped together. Where functions not connected with hand pump maintenance are grouped under a government regional or district office, there is the disadvantage that the other demands may result in neglect of the hand pump maintenance. The road construction programme for example, would easily take precedence over handpump maintenance.

One advantage of the government taking all responsibility for handpump maintenance is that there is no doubt where the responsibility rests. This is particularly relevant, if more than one organization is involved in installation and maintenance of the pumps. Especially where there is one central organization for handpump installation and maintenance, the value of proper installation will be recognized in terms of reduced maintenance costs.

Where the government assumes all responsibility for maintenance it will have to arrange for the procurement of spare parts, provide staff and transportation, carry out the major hand pump repairs, and where feasible, renovate wells. If the government has a substantial hand pump installation programme, it would be preferable to manufacture spare parts locally, and then there are possibilities for standardisation, and economies of scale through the purchase of raw materials and spare parts in quantity.

It is always advisable to plan the government maintenance system before the hand pump programme is embarked on. The geographical distribution of pump installations in the rural areas may need to be related to a route which the service mechanic or maintenance vehicle can follow. In some areas, installation of the pumps may need to be linked to the road building programme.

The maintenance schedule would typically ensure that pumps are serviced, say, every two months. The maintenance mechanics would carry tools and spare parts in their vehicle, and also have some hoisting gear for these cases where pump rods and cylinders have to be lifted from the well. To cater for the risk of breakdowns occurring between the servicing visits the pumpcaretaker in each community will be supplied with tools for interim repairs or the means to summon help when necessary.

2.4. HANDPUMP MAINTENANCE ORGANIZATION

2.4.1. MAINTENANCE REQUIREMENTS

The maintenance requirements of a handpump may be listed as follows:

- Keeping the pump and the surrounding area clean;
- Lubrication and bolt tightening;
- Inspection by a trained mechanic to determine whether any parts need to be replaced;
- Equipment for major overhauls and repairs;
- Procurement of the necessary spare parts, and the store keeping of adequate stocks;
- Administrating the flow of spare parts.

Figures 4.1., 4.2. and 4.3. illustrate handpump maintenance requirements. They are summarized in table 4.1.

In practice problems will occur, such as:

- cracked concrete slabs and covers
- loosened anchor bolts
- broken pump rods
- broken or split handles
- hinge points worn out
- bolts and nuts stolen
- wooden pump handle and support stand stolen and used as fuel for cooking
- contamination of well and surroundings.

Parts which frequently give rise to defects should be modified on grounds of the experience of the maintenance groups. For the pump head this means that no wooden parts should be used and the number of hinge points, bolts and nuts kept to a minimum.

Table 4.1. Schedule for maintenance of simple hand pumps

daily	1.	lock and unlock the pump at hours agreed by the village.
	2.	clean the well-head.
weekly	1.	thorough clean-up of pump, well-head and surroundings.
	2.	oil or grease all hinge pins, bearings, and sliding parts, after checking that no rust has developed on them.
	3.	record any comments from users about irregularities in working (tightness of parts, leaks from stuffing box, fall-off in water raised). Correct these when possible.
monthly	1.	if necessary, adjust the stuffing box or gland. Usually this is done by tightening the packing nut. This should not be too tight - there should be a slight leak when the adjustment is correct.
	2.	check that all nuts and bolts are tight, and check that there is no evidence of loose connections on the pump rods.
	3.	check for symptoms of wear at the leathers, noting any comments from users about any falling off in the water raised. If the pump fails to raise water when worked slowly (e.g., at 10 strokes per minute), replace the leathers.
	4.	carry out all weekly maintenance tasks.
anually	1.	paint all exposed parts to prevent development of rust.
	2.	repair any cracked concrete in the well-head and surrounds.
	3.	check wear at handle bearings and replace parts as necessary.
	4.	check plunger valve and foot valve; replace if found leaking.
	5.	check the pump rod and replace any defective lengths or connectors.
	6.	replace packing at the stuffing box or gland.
	7.	carry out all monthly maintenance tasks.

After Pacey (1976)

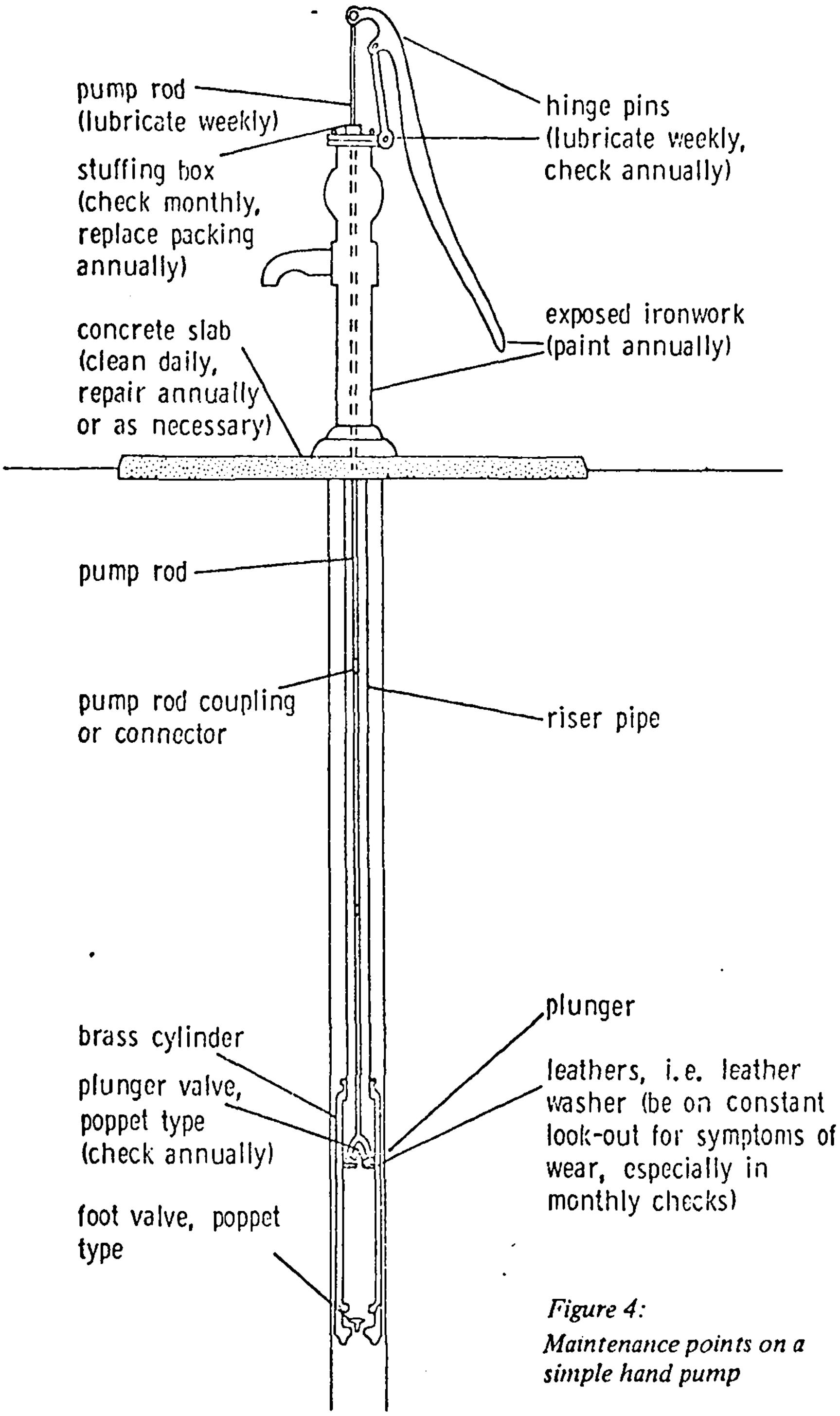


Figure 4:
Maintenance points on a simple hand pump

Fig. 4.1. Maintenance needs of hand pump components
(after Pacey, 1976)

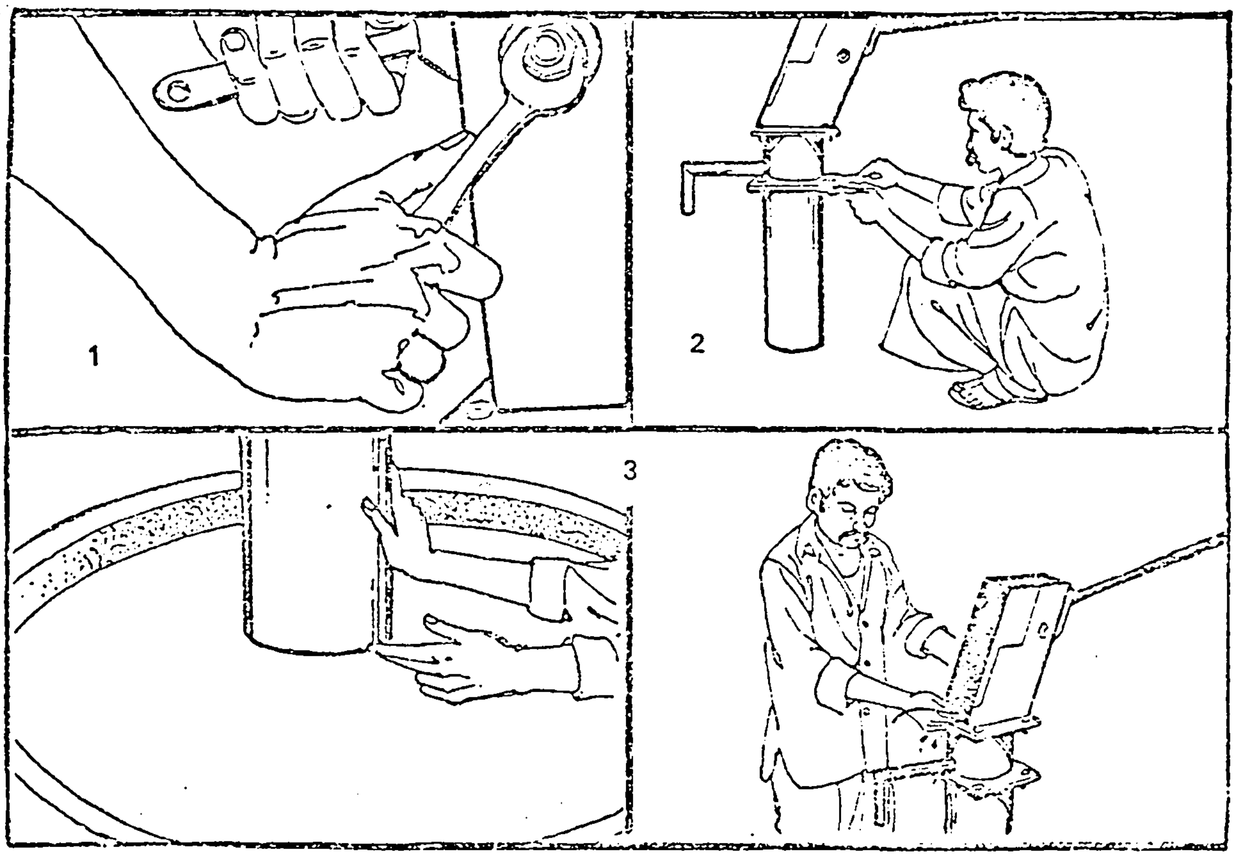
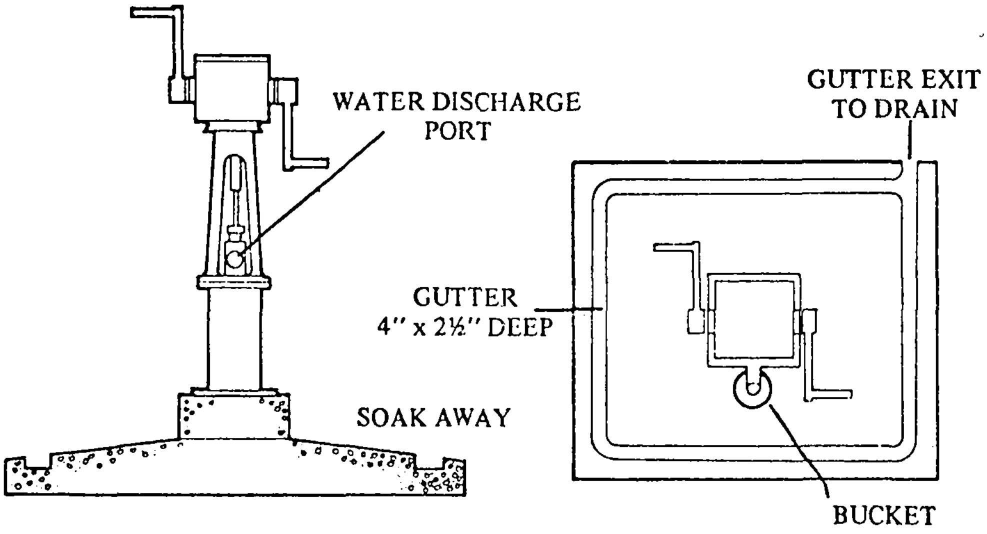


Fig. 4.2. Information Pamphlet prepared for Tamil Nadu Water and Drainage Board, Madras, India.

RIVERS STATE
RURAL WATER SUPPLY SCHEME



SIDE ELEVATION PLAN

Figure 2: Mono-lift pump in Nigeria – detail of top end, (by permission of MONO PUMPS ENG. LTD).

Below: Instructions aimed at users

IMPORTANT

1. IT IS THE DUTY OF THE VILLAGE/TOWN PLANNING COMMITTEE TO ENSURE THAT ALL PEOPLE KNOW HOW TO USE THE PUMP CORRECTLY.
2. DO NOT TRY TO FORCE OR JERK THE HANDLES ROUND OR APPLY ANY MECHANICAL MEANS IF STIFFNESS IS ENCOUNTERED REMEMBER THIS IS A HAND OPERATED PUMP.
3. A SLOW EASY ROTARY MOVEMENT IS REQUIRED TO OPERATE THE PUMP – CONSTANT USE WILL RELIEVE ANY STIFFNESS.
4. DO NOT LET CHILDREN PLAY WITH THE PUMP – IT IS NOT A TOY.
5. REMEMBER THIS PUMP IS YOUR GATEWAY TO A BETTER HEALTHIER LIFE: IT'S WORKING LIFE WILL BE DETERMINED BY THE WAY YOU LOOK AFTER IT.

Fig. 4.3. Information Pamphlet prepared by Rivers State of Nigeria Water Supply Authority

2.4.2. ORGANISING HAND PUMP MAINTENANCE

When organising a maintenance system for hand pump installations, an important factor is the rate of expansion of the handpump installation programme. There is always a danger of trying to expand too quickly. It takes years to train staff, to arrange for procurement of pumps and spare parts and to establish a spare parts distribution system. Most difficult of all, to educate and train the people for their role in the maintenance system. Working continuously and starting from a zero base it could take as long as ten years before a country otherwise suitable for hand pump water supply sytems is able to absorb a massive hand pump programme aimed at reaching a major portion of the rural population. During this period the choice of hand pump, organization type, and method of financing would be established. The spare part distribution and a local manufacturing capacity would be built up. Staff would be trained, equipment purchased and its maintenance organized. In this way, the overall maintenance system would develop gradually and sufficiently to absorb later massive expansion. However, the general situation is such that few countries can delay their planned hand pump installation programmes for such a length of time.

It would be advantageous to test two or three alternative systems of handpump maintenance on a pilot scale for a period of two or more years, prior to the final selection of the maintenance system to be used nationally. Even this may not be possible under the pressure for rapid expansion of the pump installation programme to meet the urgent water needs.

In creating a government organisation for handpump maintenance it is possible to either create an entirely new organization, or to expand the duties of an existing organization. Generally establishing a new department within an existing organization is the easier solution in most situations.

It should be recalled at this point that the unit costs of maintenance, particularly with a centralized government — controlled system, are related to the number of hand pumps and the density of their sites. When planning a maintenance system it is important to appreciate that as the system expands, economies of scale become more significant. When the first hand pumps are installed costs will be much higher because the unit costs of providing hand pumps and constructing wells at dispersed sites is initially high. But as the number of pumps increases, unit costs will be reduced. More important from the maintenance view-point is that as the pump installations increase in number, the distance between them generally is reduced and spare parts can be stockpiled more nearby for servicing economically a number of wells. The importance of the density of handpumps should not be overlooked when planning the organization for their maintenance. At some stage it may be possible to change from distant stockpiling and maintenance dependent on motorized maintenance teams, to local stockpiling and less capital intensive servicing.

Using the above guidelines, it should be possible to specify a suitable maintenance system including an appropriate pump model, organisation type and financing method. Then the specifications may be further detailed to cover the personnel, facilities and equipment required.

The requirements briefly are:

1. A caretaker close to the well to carry out cleansing and minor repairs.
2. A mechanic equipped to replace worn parts.
3. A maintenance team for major maintenance and repair.
4. A spare part purchasing and distribution unit with storage facilities.
5. A manufacturing facility for spare parts.
6. Raw materials procurement for the spare parts production.
7. Inspection procedures for quality control of spare parts production.
8. Financial resources to operate the system.

A key factor is how the maintenance system is organized to fit into the overall structure of government of a particular country. Commonly designated levels are: national, provincial (district) and local.

(1) National Organization

With a national organization it is possible to control all components of the maintenance system for any pump or financing scheme completely from top to bottom. Some aspects can be handled by the national organization, some should be left for lower level government or local initiative. With a national organization, considerable leverage exists with regard to procurement of spares, the cost for which can be included under the general taxation, or spare part rates can be charged for separately. With a national organization the structure must be designed to cope with any differences between the individual areas of the country.

(2) Provincial (state) organization

A provincial organization will have fewer different situations to deal with than a national organization. But it may be dependent on outside sources for indigenous or imported pumps. A pump manufactured within the area would be most appropriate. In some countries (e.g. India) a state organization may serve a larger area or larger population than most national organizations in other countries. But it is often ill-placed to manage its affairs because it does not have the independence of a national organization nor is it close enough the people to easily obtain full and adequate local involvement. Therefore, all aspects of provincial organizations need careful thought, and coordination with the national authority is most important.

(3) Local organization

These will be most effective where a simple pump is in use and where the maintenance is user-financed. The success of local organizations will depend on the full benefit of community participation.

In this system, the pump will either be locally produced or brought in from another area. The production and inspection aspects are therefore simplified, although in the case of pumps manufactured outside the area the provision of spare parts becomes more difficult and may require considerable local stock-piling of spare parts. Smaller trucks and other transport will be possible but transportation requirements will not be eliminated.

The method of paying for maintenance and spare parts has an impact on organizational structure dependent on whether (1) the government pays all costs; (2) the (local) government subsidizes the cost or (3) the community using the pump pays all the costs.

(1) Government pays:

Where the government pays for maintenance and spare parts the maintenance organization must extend down to the village level. It is quite practical for a villager to be employed as the pump caretaker. With the government paying all costs extension of the handpump system may be hampered through financed limitations. This may lead the more wealthy private citizens to establish their own well and handpump system. Competition for available spare parts between parallel government and private systems is likely to be a feature of this system.

(2) Government subsidises cost:

Most frequently this is achieved through the government providing a maintenance and spare part delivery organization with the people paying all or part of the cost of the spare parts. They may also pay a service charge for having government personnel maintain their handpumps. Alternatively, the local people may themselves organise and carry out the most simple maintenance tasks, while the government carries out and finances the major repairs. The government organization in this system must be able to collect charges and recycle these funds for the purchase of spare parts. Quite often in developing countries handling such a flow of funds can be a major administrative and accounting problem, and it may not be possible to directly link revenue and expenditure when any surplus has to be paid into general government account.

3. The community using the pump pays all costs ;
In this case the people may either pay a charge for a service provided by the government maintenance organization, or by hiring local maintenance and repair people, take direct responsibility for the maintenance of the pump.

From the above it will be seen that every decision on a component of a handpump maintenance system (e.g. pump type, organization type, financing method) affects all the other components, and so influences the overall maintenance system. In practice, they must be selected step-by-step, as an effective handpump maintenance system cannot be developed overnight.

2.4.3. MAINTENANCE INPUTS

Staff and Personnel

Where the government arranges handpump maintenance the number of people directly employed on maintenance activities will depend on the extent to which responsibility for maintenance is shared with the local communities. Another important factor is the total number and density of pumps in an area. No firm conclusions on staff needs are possible but the ratios found in India, Bangladesh and Tanzania provide some insight.

Table 4.2. Typical Ratios of Staff Employed for Handpump Maintenance

	Labour, Technical and Management Employees per 10.000 hand pumps(4)		
Staff level	Tanzania(4)	Bangladesh(1)	India(2)
Executive level and above	30(3)	1	1
Middle level	60	10	20
Lower level	240	50	160
	330	61	181

Note:

1. Existing system - not "Thana stores" system
2. Tamil Nadu (3 Tier system), not existing system
3. Large proportion of executive staff probably due to relatively small size of existing hand pump system
4. Tanzania does not have 10,000 hand-pumpinstallations; figures are pro-rated.

Table 4.2. indicates that for maintenance alone between 6 and 33 employees are required for every 1000 hand pumps maintained. This number is in addition to the pump caretakers at the local level (one per hand pump). Clerical and administrative posts in the maintenance organization are required but not shown in Table 4.2. and in addition other government units will have to be strengthened to cope with the additional manpower and activity of the maintenance programme. It is estimated that the effect of these would be to raise the ratio of staff

employed to between 10 and 50 persons employed on maintenance per 1000 wells. This may be conveniently expressed as between 1 and 5 persons per 100 hand pumps. The lower end of the range would be more appropriate for a high-density extensive handpump programme such as in Bangladesh, the higher end for newly developed systems and systems with widely separated handpumps and wells such as in Tanzania.

Finance

As further detailed in section 4.4., costs of hand pump maintenance may range from $ 5 per hand pump to $ 125 per year per handpump. Higher pump density would normally bring costs in the $ 10 to $ 30 per year range, and for a lower density it would be somewhat higher but usually not more than $ 100 per hand pump. Based on 100 persons served by well, per capita maintenance costs are thus in the range of $ 0,1 to $ 1 per year. These may not seem large amounts but as hand pumps are most frequently used in (very) poor areas, it will be difficult to raise such sums locally. According to a publication of the World Bank, any charges for water should not exceed a maximum of 5 percent of family income. However, even when considerably less than this amount is required for pump maintenance the mechanism to collect the money does not normally exist except for funds raised through the general taxation process. There may be a case for government taxation to cover all or part of the cost of handpump maintenance. It is also not unreasonable to expect the village community to pay for spare parts, with the government paying the distribution of spare parts and major repair costs. In addition to the maintenance costs there is the cost of the eventual replacement of the well to consider. The well generally costs several times as much as the pump, and replacement of the well is therefore almost always a matter that has to be handled by the government. The technical skills and capital needed will be much greater that village community can normally provide. In most cases well replacement is therefore to be financed by the government from general revenue with preferably some partial contribution by the village. Attempts to get the village to repay the full cost of the well over a number of years are likely to fail because once the government has installed the well, any threatening that it will be removed or closed is unreasonable.

Transport

The number and types of vehicles required by a government maintenance organization will largely depend on the topography of the country and on the railway and road systems. For example, use of railways may be feasible in one country whereas in another, most transports will be by road. For transport of hand pumps and spare parts trucks would be required. For general supervision, the senior staff of the maintenance organization would require vans or cars and/or possibly four wheeled drive vehicles. Dependent on the type of maintenance conducted and the weight of the equipment moved, fourwheeled drive pickups or trucks may be required. In remote and difficult terrain such as parts of Nepal, where roads do not exist in many areas, the maintenance organization may require animal transportation. The size of transport vehicles should be as small as possible, and motorcycles and bicycles should have preference to vehicles. It has to be noted that all these transport units themselves require maintenance and therefore the government system if it is to operate efficiently, must also make provisions for the supply of spare parts for trucks, vehicles, vans, cars, motorcycles, bicycles, etc. The necessary skilled maintenance people must be available and repair facilities to keep the transport fleet in operating condition. The costs of maintaining this fleet and vehicle depreciation probably form an important part of the overall maintenance costs.

Equipment

The maintenance organization will require equipment to carry out routine maintenance on the wells and to make any repairs necessary. The kind of equipment required would be wrenches, lifting gear, screwdrivers, hammers, backsaws and whatever other tools and equipment is required for the kind of hand pump in use. In addition, it might be advisable, dependent on the type of handpump installed, to provide the handpump caretaker with a very basic set of tools to carry out the simplest kinds of maintenance, such as bolt-tightening and (in the case of shallow well pumps) the replacement of the piston cups. In a more developed system the pump caretaker would be provided with grease for regular lubrication of the moving parts. However, this would depend largely on socio-cultural factors since in some instances, such general issue of material would not be recommended. Provision of tools and material and replacement costs obviously form part of the overall maintenance costs.

Housing

In a government-controlled maintenance system, government staff frequently require living accomodation and, dependent on local custom, it may be necessary to construct housing for these people. This is mentioned because when estimating the capital investment for a government maintenance system it may be necessary to allow for construction of housing. For the lowest level of staff who will be in the largest numbers, housing would probably not be considered the government's duty, but if they are expected to carry out their tasks conscientiously they must either be given sufficient income to purchase or to rent their own accomodation or else they must be provided with living quarters. Many countries find the provision of staff quarters the most appropriate option.

Offices, Stores, and Workshops

An essential part of any government-controlle maintenance organization is a system of offices, stores, and workshops. At these locations the government staff will have their base ~~store~~. Maintenance materials will be stored and any repair on pumps, vehicles and equipment carried out. Generally these offices and workshops will reflect the organizational set-up, with a head office, regional and district offices. Lower down the chain of operation, as work concentrates more on the pure maintenance function, offices and stores will usually be combined. The planning of a spare parts distribution system will be dependent on the sources of supply and areas of demand. In planning the stores organization, considerable scope exists for obtaining maximum efficiency, or the reverse. In places where spare parts are issued, it is often economical to also collect the replaced items. These can be sold as scrap or possibly they can be reconditioned.

2.4.4. MAINTENANCE COSTS

Regardless of the hand pump selected, some maintenance costs will be involved in keeping the pump in satisfactory operating condition. Each pump has wearing components which periodically must be replaced. Vandalism and accidents result in the need to replace damaged units from time to time. The objective of course is to select a pump which has the promise of requiring only an acceptable amount of maintenance.

The difficulty is to establish the level of long term maintenance required for a particular pump. The extent of maintenance required is related to such factors as the useful life of the various component parts of each pump, the relative number of pump parts involved, the frequency of service calls required for routine maintenance and parts replacement, and the type of equipment needed to service the pumps. The analysis and evaluation of maintenance costs is complex. It involves many value judgments.

Because of the value judgments involved, the approach being used is to establish the range of maintenance costs which the pump under consideration is likely to require. For instance, for the most optimistic circumstances the lowest possible maintenance cost is estimated. Similarly, the highest maintenance costs are estimated from a pessimistic viewpoint as far as future maintenance is concerned. Between these two extremes, a "most likely" cost of maintenance is arrived at for the various pumps under consideration. In this way, an assessment can be made of the effect the various value judgments might have on the overall estimate of total maintenance cost.

Life Span of Pumps

The common supplier's claim that his hand pump will last for 15-20 years under "normal operating conditions" is a far too simplistic approach to be of much value in the selection of the best pump. Each hand pump has a number of components. Several of these components will probably last many years with little or no maintenance. Others have a more limited life span because of wear or vulnerability to breakage. As with any mechanical device, a hand pump has wearing parts which have to be replaced periodically more or less in relation to the number of operating cycles. So when we speak of the life span of a pump, we are not referring only to the most rugged and longest lasting component, we are really assessing the unit's set of components as a whole, and its overall usefulness.

Theoretically the usefulness of a hand pump could be extended over a very long period of time by simply replacing worn out or damaged parts one by one as required. It could be said that when every part has been replaced at least once, the life span of the original pump had come to an end. Such an approach has little merit in evaluating the life span of different pumps unless the cumulative cost of parts is taken into account. What is required is a separate evaluation of the probable useful life of each component part over a span of 15 to 20 years. Within a 20-year time frame, an estimate is required of the number of times each component part would have to be replaced under the operating conditions. Some parts would economically be replaced only once, whereas it could be logical to replace others several times within a 20-year period. The cumulative cost of such replacements for each pump compared with others, provides a reasonable way to establishing the economic life span of alternative pumps.

Other factors which are an integral part of establising the life span of the pump as a whole are the number of component parts and particularly the number of parts which are vulnerable to wear and damage. The cost of spare parts to replace the worn out components also play an important role in the overall evaluation of the pump. Some of the most significant factors do not pertain to the pump itself, but to the maintenance costs associated with the trucks, motorcycles, and manpower required to inspect, service and repair defective units.

In order to determine the probable range of spare part requirements and overall maintenance costs of pumps three estimates should be made of the probable life span of each component part. In other words, an estimate is made of the shortest useful life a component part might have. At the same time another estimate is made of the longest possible life span of this same part. Using these two as extremes, a "most likely" life span is selected.

Long-term Total Costs of Pumps

In selecting the most economical hand pump to suit the prevailing conditions, it is the long term total cost involved which is of concern. A low cost pump with a high maintenance, or a high cost pump with low maintenance, may not be as economical as a median cost pump with average maintenance. It is the combination of initial pump cost with the projected maintenance which has to be compared for a number of pumps which are likely to be capable of providing the desired level of performance.

The total cost includes initial price, and annual maintenance costs including spare parts and replacements. Associated workshop and administrative charges are also part of the total costs of the pumps. It has often been assumed that the purchase of high priced pumps will automatically reduce maintenance costs. Whereas a high quality pump is no doubt desirable, the most costly units are not necessarily the most economical.

One aspect which is frequently overlooked is that regardless of the type of hand pump selected, some basic form of maintenance organization is always required. Therefore a high-priced pump does not totally eliminate the need for maintenance. Another aspect is that high-priced units usually have high priced spare parts. Even costly hand pumps require some replacement spare parts, and although they may not have to be replaced often, the cost is high when it does happen. Therefore over a 20 year span the parts for such a pump may be considerably more costly than for other pumps, even though fewer are required.

Some exceptionally high-priced pumps that are commercially available, are also very bulky and heavy. This could necessitate special equipment for installation and maintenance purposes, which in turn increases the maintenance costs. Also, some high-priced pumps have not shown a marked improvement in performance over lower priced units.

The initial cost is only one of the factors involved in making a pump selection. If a more expensive pump results in lower maintenance or substantially improved performance and reliability, the additional cost can usually be justified. However, it is generally desirable to select the lowest-cost pump which will satisfactorily do the job. Any additional price paid for a pump must be justified through lower maintenance costs and higher performance. These do not automatically come with pumps which are higher priced.

Comparative data of handpump maintenance costs are presented in table 4.3. A sample breakdown of maintenance costs (as in the Shinyanga Shallow Wells Project, Tanzania) is given in Table 4.4.

Table 4.3.Comparative data of Hand Pump Maintenance costs

Country	Typical Cost ($) Well + Pump	Persons Served	Percapita ($) Annual Maintenance Cost	Maintenance Responsibility	Percent Wells In Operation %	Comments
Bangladesh	$ 200	100	0.05	Government	80	Shallow well pumps. Bicycle service men.
Burma	200	150	0.05	Government	?	Serviced by mobile units.
Ghana (Upper Region)	300-2000	200	0.35 ±(1)	Project	90 ±	Test project for maintenance costs.
India (1)	800	500	0.04	Most Government Part Local	85 ±	Three tier system.
India (2)	700	500	Local choice	Local	20	Old system.
Indonesia	200-400	100	?	Not defined	?	Price range for shallow/deep pumps
Nepal	200-500	100	0.07	Local	?	Higher capital for artesian wells.
Tanzania	1500 ±	200	0.6(1)	Project	90 ±	Project at present-future split government and people.
Thailand	$ 900	150	?	Local/Government	?	Responsibility split various (6) government agencies plus local people. people.

Note (1) The very much higher maintenance costs for the two African examples (Tanzania and Ghana) are notable. This may be due to : (a) More accurate consideration of overhead costs in these two projects, (b) Greater transportation due to low well density, (c) Inflated effect of expatriate involvement on salaries, and (d) Inifficient system of maintenance (too much transport from a distance not local stores with local labour).

Table 4.4. Sample Breakdown of Handpump Maintenance Costs (as in Shinyanga Shallow Wells Project, Tanzania)

Costs of 60 pump and well inspections per month (carried out by one inspection team)

I. Group A

Salaries + nights-out	laboratory technician	Shs. 540/-	
	plumber	" 500/-	
	driver	" 480/-	
			Shs. 1,520/-
Material costs	tools	Shs. 100/-	
	spare parts handpump	" 500/-	
	5 bags of cement	" 200/-	
	grease	" 50/-	
	paint	" 100/-	
	40 water quality analyses	" 1,400/-	
			Shs. 2,350/-
Transport costs	on average about 1,600 km per month at Shs. 2/- per km (Landrover)		Shs. 3,200/-
	total group A		Shs. 14,140/-

II. Group B

Salaries + nights out	foreman	Shs. 500/-	
	4 labourers	" 1,850/-	
	driver	" 480/-	
			Shs. 2,830/-
Material costs	tools	Shs. 100/-	
	100 bags of cement	" 4,000/-	
	12 loads of gravel	" 1,200/-	
	12 loads of sand	-	
	1 motor pump (fuel)	" 300/-	
	chlorine solution 5%	" 120/-	
	HACH chlorine-tester	" 100/-	
			Shs. 5,820/-

Transport costs :	on average about 2,400 km per month at Shs. 3/- per km (truck)	Shs. 7,200/-
	total group B	Shs. 15,850/-

III. Supervision

Salary costs supervisor	: Shs. 800/-	
salary costs driver	: " 380/-	
transport costs (1,000 km)	: " 2,000/-	
total supervision		Shs. 3,180/-

Thus total costs per month are:

Shs. 14,140/- + Shs. 15,850/- + Shs. 3,180/- = Shs. 33,170/-

Average maintenance costs for checking 60 pumps and wells per month (i.e. 2 wells per day) will be:

$$\frac{\text{Shs. } 33{,}170/-}{60} = \text{about Shs. } 553/- \text{ per check}$$

Maintenance costs, with two checks per year, Shs. 1,100/pump and well.

2.5. ASSESSING HANDPUMP MAINTENANCE SYSTEMS

2.5.1. GENERAL

It is not easy to separate the efficiency of a handpump maintenance system from the abilities of the staff and personnel operating it. A system may not be working well but it is possible that with a different staff or organisational changes better results would be obtained. Table 5.1. provides an assessment of maintenance systems by results.

Table 5.1. Assessing Maintenance Systems by Results

Handpumps in operation percent	Apparent maintenance adequacy
More than 90	Excellent, effort may be made to maintain performance but to reduce cost
70 to 90	Satisfactory, but some improvement possible
50 to 70	Indication of flaws in some part of the organization of handpump maintenance
Less than 50	Indication that maintenance is inadequately managed and/or insufficient resources are channelled to handpump maintenance.

A reasonably effective handpump maintenance system should succeed in keeping at least 70% of the pumps in operation. But is this system efficient and are the costs of maintaining the wells reasonable? There are cases where 'demonstration projects' or externally-financed projects through very large expenditures, maintain hand pumps in good condition although maintenance is not really organized in a manner suited to the requirements of the country. For example, a group of agricultural extension workers discovered that some 80 per cent of the hand pumps in their area were out of order. They proposed to take responsibility for pump maintenance in this area and as an experiment, the government agreed. Under the existing system the maintenance men were employed by the government and they could obtain spare parts from a government store and ride by bicycle visiting a group of hand pumps for maintenance and necessary repairs. The maintenance men complained they were supplied with insufficient spare parts to do their job. But it is possible that they sold part of their stock to private hand pump owners. The extension workers recruited new maintenance men who received training from the government. The project supervisor provided a card for each hand pump. On this card was space to fill out lines of information for each visit to the hand pump. Data included on the card were the location of the hand pump, the date of visit, any spare parts fitted, and the signature of the caretaker of the hand pump. The supervisor agreed with each maintenance men a routine for visiting the wells under his care, once per month. During the month, while on other duties, the supervisor checked the condition of three or four hand pumps chosen at random. If more than one hand pump was found not operating properly, it was taken as evidence that the maintenance man was failing in his duty. The mechanic was aware that his job could be terminated for cause. The information on each hand pump visited, was returned each day to a card index system in the office of the supervisor. After six months, over 90 per cent of the hand pumps in the area were in operating condition. Having overcome the backlog of work and bringing the hand pumps up to an acceptable condition it was found possible to reduce the frequency of the visits to once every two months and service a greater number of wells. It should be mentioned that by reason of his strong personality the supervisor was able to ensure that he always had a stock of spare parts from the central stores. It also required a literate maintenance man, not always the case with such staff. The experiment, while showing that the maintenance system could be made to work, does not prove that it is necessarily suitable for use on a countrywide basis with the available quality of staff.

2.5.2. CASE STUDIES

Bangladesh

Previously, in Bangladesh a government-controlled handpump maintenance system existed that operated as follows. The government purchased spare parts in bulk and collected them into central stores. Spares were then distributed according to need and allocation, to stores at the district and subdivisional level. At the next lower level, the thana, maintenance men were employed, normally four in number, each having responsibility for maintaining about 200 hand pumps. They collected spare parts from the subdivisional stores and bicycled out to the villages to maintain or repair hand pumps. In this system there was no payment by the people for the spare parts.

The maintenance mechanics were, in theory, responsible for routine preventive maintenance. However, their role frequently reverted to that of repair men, traveling to a broken hand pump when informed by the local people. The hand pump used was one that required frequent maintenance, the maintenance costs were paid by the government and there was one great maintenance organization for the whole country. Involvement of the people was minimal, except in the initial selection of the well site and the appointment of a caretaker who was nominally responsible for the well.

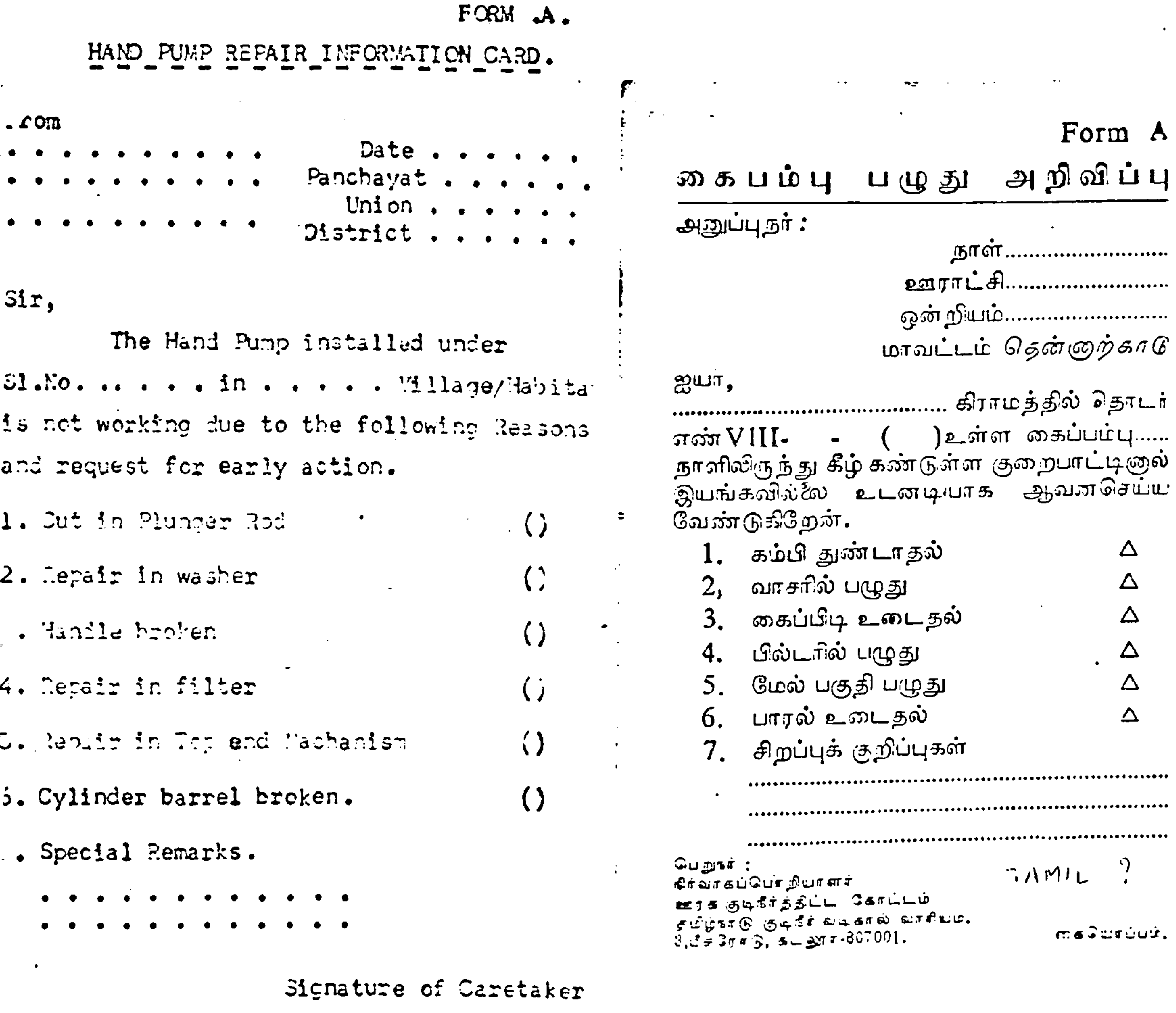
Bangladesh's record for hand pump maintenance is not worse than for many other countries. However, 25% of pumps out of order at any one time must be considered too high a failure rate and the government was required.to pay for the entire cost of hand pump maintenance. With 400,000 hand pumps in operation and an annual maintenance cost per hand pump of US$ 5 (US$ 3 in spare parts, and US$ 2 in operating costs), the total annual expenditure on hand pump maintenance would be US$ 2 million. To pay only US$ 2 million for hand pumps serving almost 40 million people may not look excessive. But in a country with a gross national product of only US$ 2,000 mln. (1978) it is difficult to make US$ 2 million available and the maintenance financing would increase further as more pumps are installed. It is therefore necessary to transfer at least part of the cost of maintenance from the government to the people.

The following modifications were proposed to make it possible to charge the people for the cost of hand pump maintenance. The government would continue to purchase from local sources (and, where necessary, to import) all spare parts. These would be stored centrally by the public health engineering department. From the central stores, spare parts would be distributed to government stores at the subdivisional level. The government would further establish small new stores at the thana level, an additional 350 stores, throughout the country. For each store at the thana level there would be a government sub-assistant engineer supervising a group of government-employed maintenance men. At the next lower level, the union level, each union would appoint a union-employed maintenance man who would be paid a small salary by the union and would have the duty of maintaining all hand pumps in the union area. The cost of the spare parts required in the union, would be paid from the union budget. The necessary funds could be raised by local taxation or by directly charging for the spare parts.

The system operates as follows. The government obtains new supplies of spare parts and sends them to the thana stores. The union maintenance man will service the hand pumps in the union, installing any necessary spare parts. He purchases spare parts from the thana stores. Each hand pump is placed under the direct charge of a pump caretaker. The caretaker is generally a responsible person living close to the well. He will receive some training from the government with regard to proper care of the hand pump and some health education training. Part of his duties would be to keep the area around the hand pump clean and carry out the minor routine maintenance. He is also expected to keep a record of the visits of the union maintenance man, and in the event of pump break down, he has to inform the union mechanic. The government employed-maintenance men at thana level are expected to carry out the major repairs. For example, in the event that the well itself becomes clogged with sand, they are expected to cleanse out the well and so prolong the life of the entire installation.

This new system has been tested on a pilot scale and is being introduced with some modifications for the entire country during a period of several years. The system is not perfect and has added to the overall cost of hand pump maintenance. But, it does offer the first possibility in Bangladesh of transferring a part of the cost of pump maintenance from the government to the people and so increases the local involvement.

The thana stores maintenance system does not raise capital for the eventual replacement of the well. It is not exactly known what the life of the new wells based on PVC pipes and PVC well screens will be, but a useful life of between 10 and 20 years may be expected. It is therefore necessary to reserve in the order of US$ 10 per year to provide for the eventual replacement of the well and pump. By pricing the cost of spare parts supplied by the thana maintenance system above cost price, it would be possible to obtain funds for the eventual replacement of a well and pump. However, there is an upper limit to how much can be charged for hand pump spare parts. This is set by the prices of spare parts on the private market. Some other mechanism will therefore be necessary to generate funds for the replacement of wells and pumps.



FORM A.

HAND PUMP REPAIR INFORMATION CARD.

.rom

. . . . Date . . . . . .
. . . . Panchayat . . . . . .
Union . . . . . .
. . . . District . . . . . .

Sir,

The Hand Pump installed under Sl.No. . . . . . . in . . . . . Village/Habita is not working due to the following Reasons and request for early action.

1. Cut in Plunger Rod ()
2. Repair in washer ()
. Handle broken ()
4. Repair in filter ()
. Repair in Top end Mechanism ()
. Cylinder barrel broken. ()
. Special Remarks.

. . . .
. . . .

Signature of Caretaker

Form A

கைபம்பு பழுது அறிவிப்பு

அனுப்புநர் :

நாள்..........................
ஊராட்சி..........................
ஒன்றியம்..........................
மாவட்டம் தென்னாற்காடு

ஐயா,

.... கிராமத்தில் தொடர் எண் VIII- - ( )உள்ள கைப்பம்பு...... நாளிலிருந்து கீழ் கண்டுள்ள குறைபாட்டினால் இயங்கவில்லை உடனடியாக ஆவனசெய்ய வேண்டுகிறேன்.

1. கம்பி துண்டாதல் △
2, வாசரில் பழுது △
3. கைப்பிடி உடைதல் △
4. பில்டரில் பழுது △
5. மேல் பகுதி பழுது △
6. பாரல் உடைதல் △
7. சிறப்புக் குறிப்புகள்

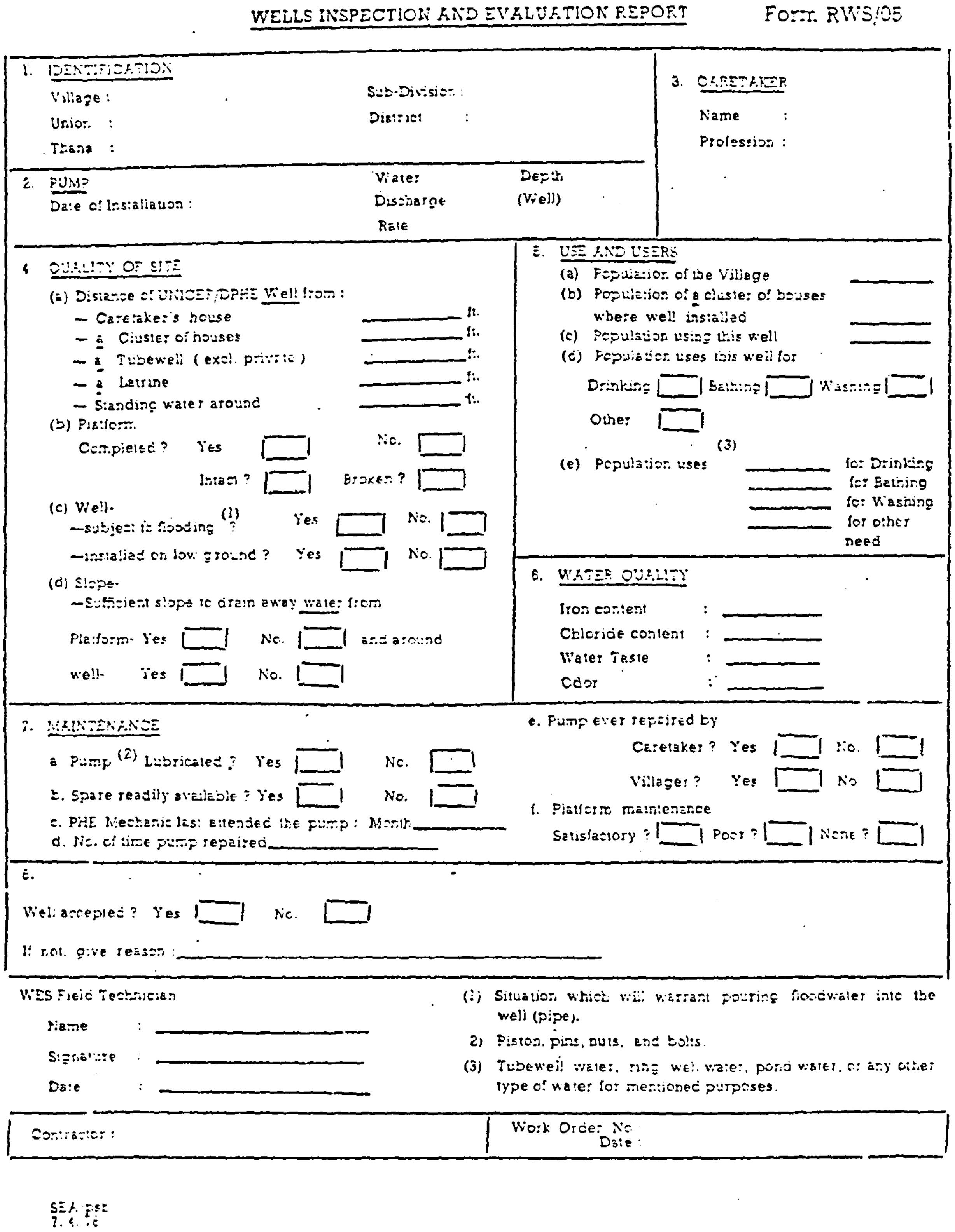
....
....
....

பெறுநர் :
நிர்வாகப்பொறியாளர்
ஊரக குடிநீர்த்திட்ட கோட்டம்
தமிழ்நாடு குடிநீர் வடிகால் வாரியம்.
3,பீச்ரோடு, கடலூர்-607001.

TAMIL ?

கையொப்பம்.

Fig. 5.1. Handpump Maintenance Card used in Bangladesh



WELLS INSPECTION AND EVALUATION REPORT

Form. RWS/05

1. IDENTIFICATION

Village :
Sub-Division :
Union :
District :
Thana :

2. PUMP

Date of Installation :
Water Discharge Rate
Depth (Well)

3. CARETAKER

Name :
Profession :

4 QUALITY OF SITE

(a) Distance of UNICEF/DPHE Well from :

- Caretaker's house ______ ft.
- a Cluster of houses ______ ft.
- a Tubewell (excl. private) ______ ft.
- a Latrine ______ ft.
- Standing water around ______ ft.

(b) Platform.

Completed ? Yes ☐ No. ☐

Intact ? ☐ Broken ? ☐

(c) Well-

—subject to flooding (1) ? Yes ☐ No. ☐

—installed on low ground ? Yes ☐ No. ☐

(d) Slope-

—Sufficient slope to drain away water from

Platform- Yes ☐ No. ☐ and around

well- Yes ☐ No. ☐

5. USE AND USERS

(a) Population of the Village ______
(b) Population of a cluster of houses where well installed ______
(c) Population using this well ______
(d) Population uses this well for

Drinking ☐ Bathing ☐ Washing ☐

Other ☐

(e) Population uses (3)

______ for Drinking
______ for Bathing
______ for Washing
______ for other need

6. WATER QUALITY

Iron content : ______
Chloride content : ______
Water Taste : ______
Odor : ______

7. MAINTENANCE

a Pump (2) Lubricated ? Yes ☐ No. ☐

b. Spare readily available ? Yes ☐ No. ☐

c. PHE Mechanic last attended the pump : Month______

d. No. of time pump repaired______

e. Pump ever repaired by

Caretaker ? Yes ☐ No. ☐

Villager ? Yes ☐ No ☐

f. Platform maintenance

Satisfactory ? ☐ Poor ? ☐ None ? ☐

8.

Well accepted ? Yes ☐ No. ☐

If not, give reason :______

WES Field Technician

Name : ______
Signature : ______
Date : ______

(1) Situation which will warrant pouring floodwater into the well (pipe).

2) Piston, pins, nuts, and bolts.

(3) Tubewell water, ring well water, pond water, or any other type of water for mentioned purposes.

Contractor :

Work Order No :
Date :

SEA pst
7. 4. 76

Fig. 5.2. Wells Inspection and Evaluation Report used in Bangladesh

India

Previously, in India the government used to construct wells and install handpumps, without any special arrangements for maintenance and repair of the pumps. The advantage of this approach is that the government can standardise equipment and ensure a satisfactory well construction and the use of suitable handpumps. The great disadvantage was that the government did not develop an organization to carry out the routine maintenance, and therefore, did not have the opportunity to promote health education through an established pump maintenance network. This maintenance system generally gave poor results. Where pump maintenance was completely left to the local communities, as many as 80% of the pumps were inoperative within two years after installation.

Considerable efforts have been made to produce a better handpump (the India Mark II deepwell pump), and to provide for its proper functioning through improved maintenance. A new maintenance system was developed (the "Three-tier system), and first used in the State of Tamil Nadu. This system has been successful in reducing the number of inoperative handpumps. The Three-tier Maintenance System provides for staff at village, block and district level to look after all handpumps.

At Village level: In the village there is a handpump caretaker appointed by the community. He ensures that the handpump is working properly, that there is proper drainage of excess water, that there is some sort of control over the use of the handpump to ensure that it is not abused, and that the villagers are aware of the importance, for health reasons, of taking drinking water from the protected well. If a handpump breaks down it is the caretaker's duty to report it to the district maintenance team.

At Block level: There is one inspector-mechanic whose duty it is to regularly visit and check approximately 100 handpumps. He reports breakdowns that he cannot repair to the District Maintenance Team. He is equipped to repair minor faults in the pumphead mechanism.

At District level: Each district has one or more Mobile Maintenance Teams which can quickly reach and repair any hand pump that breaks down. These teams consist of three men under an Assistant Engineer, equipped with a vehicle. They carry the tools and spare parts needed to do any type of handpump repair job. They also install new conversion heads on old hand pump installations.

The first tier of the new maintenance system - the village pump caretaker - is crucial to the success of the whole system. Unless the maintenance staff at the Block and District level is informed promptly when a handpump breaks down, repairs will be delayed and the maintenance system will not function as intended.

The pump selected for use with the three-tier maintenance system is the Indian Mark II deep well hand pump. This pump was carefully tested and has proven to be a robust machine requiring only infrequent major servicing. The village pump caretaker is a volunteer and receives no payment from the government but his position usually carries some prestige and he may receive some fee from the local community. Maintenance is shared between the caretaker in the village, the inspector-mechanic at block level, and by the mobile maintenance team at district level, for the major repairs. The cost of maintenance is mainly born by the government but through the pump caretaker the community is involved in the care of its pump. As part of his training, the hand pump caretaker is informed of the importance of good hygiene and of providing a safe water supply. It is intended that he will become a health education promotor in his village. The mobile team will use a service exchange system for pump servicing. This means that instead of carrying out repairs at the well site, they will fit a new or reconditioned pump and take the old pump to the workshop for servicing and repair. This process speeds up the work of the mobile team, ensures that they leave the hand pump in good condition and allows repair work to be conducted in the workshop.

The cost of three-tier maintenance system have been roughly estimated for service to 500 wells and hand pumps as follows:

	Annual cost, US$
vehicle depreciation	1.052
mobile team salaries	1.176
fuel, etc.	1.200
local staff (excl. caretakers)	1.400
spares and contingencies	5.172
	US$ 10.000

On average for the 500 wells the maintenance cost thus is US$ 20 per well per year. This does not include any allowance for the caretaker's expenses. However, the contingencies included are sufficiently large to cover this item if necessary.

It is too early to judge whether the three-tier system will have all the beneficial effects desired. But the system appears to have a good chance of success. UNICEF project staff have concluded as follows, "Untill the local bodies at block level are upgraded to cope with maintenance, or we can design a deep well pump that they can maintain ...... then there's no doubt in our minds that only a governmental structure at this point in time can successfully effect viable maintenance".

Tanzania

In Tanzania, under the Shinyanga Shallow Wells Project (a rural water supply project for the construction of 800 shallow wells, assisted by the Netherlands), a maintenance system for the installed handpumps has been established, and is being further developed.

Two alternative systems are considered:

- centralized maintenance, with 2 complete check-ups per well and per year, as practised during the initial stage of the Shinyanga Shallow Wells Project.
- decentralized maintenance with responsibilities delegated to the villagers, and decentralized repair groups.

Under the initial, centralized system the pump maintenance organization did consist of 3 sections, under a supervisor:

These were:

an inspection section, divided in a number of maintenance teams, each operating in a specific area; a laboratory section, having a central laboratory with the necessary staff; and a repair section, consisting of 3 to 5 workers and a foreman.

The work of each inspection team would include:

- inspection of the parts of the pump above ground, and carrying out any necessary repairs.
- dismantling the lower parts of the pump if these are not operating effectively. If the pump cylinder is out of order, it is replaced by a spare one and the defective unit is sent to the central workshop for repair.

The work of the laboratory section would comprise the determinaton of all relevant constituents in the water samples taken by the inspection groups, and during the survey.

The work of the repair section would be the repair of the concrete platform and the surroundings of pumps.

Every six months, each hand pump was taken apart, and the following maintenance work carried out:

- unfasten the pump stand, rising main, pump rod and remove the pump unit.
- pump the well dry with a motorpump and remove all dirt, insects and garbage.
- disinfect the well with an amount of 50 grams of bleaching powder. As soon as the well is filled up again with about half a metre of water, pump this water around and spray the highly concentrated liquid over the entire ring and cover.
- check and/or repair the pump cylinder, all pipe connections, hinge points, bolts and nuts, the cover and the concrete.slope.
- after these activities the water is pumped out again and the cylinder and pumphead are installed.
- information is given to the village authorities about the condition of the well.

Later, the system for the maintenance of the pumps was decentralised. The objective was to attain a considerable reduction of the costs, although at a lower standard of maintenance, by placing the first responsibility for pump maintenance with the

The District Maintenance Officer's task is to check the village maintenance, to help with the larger repairs and to ensure the provision of spare parts. He will keep records on all wells in his district. He is responsible to the central organization where he also can obtain the spares required and can request help for major repairs. In Shinyanga, the District Maintenance Officers each have a motorcycle on which a large box can be mounted for tools and spare parts. Experience in Shinyanga Region shows that one inspection group can complete 300 well checks per year. A frequency of 2 checks per well and per year has proved to be optimal. The number of wells that can be controlled by one group, is thus fixed at 150. The distance between the wells plays an important role, and for wells in less sparsely populated areas than Shinyanga Region the capacity per group may be considerably higher.

In the centralized maintenance system the annual maintenance costs per pump and well in a situation comparable with Shinyanga Region (about 700 wells spread over an area of 50.000 square kilometers) ranged from Shs 1,000 to 1,500* per year.

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* Shs 7,50 = US$ 1,00 (1978)

In the decentralized maintenance system the costs were considerably reduced to about Shs 700/per well and pump, per year:

transport costs	Shs 125,--
materials	Shs 150,--
salaries, etc.	Shs 25,--
sundries	Shs 50,--
Total per well check:	Shs 350,--, or: Shs 700,-- per well per year

Costs may be further reduced by introducing a system whereby the villages are charged, for the maintenance of their pump and well. The pump and well would become the property of the villages, which would have to buy any spare parts needed from the District Maintenance Officer. The costs of spare parts may be estimated at Shs 300,-- per pump and well per year. For an average 300 villagers using a pump, the direct maintenance cost would thus amount to Shs 1,-- per person per year.

Periodical Check-up

Date of check/	Controlled/ repaired by	Well dry?	General impression of: well cover	well surrounds	pump	Pump repaired	Water sample	Remarks/ action taken
30.2.76	maintenance	no	ok	mess	ok	-	yes	drain cleared out

Fig. 5.6. Maintenance Report Sheet used in Shinyanga Shallow Well Project (Tanzania)

2.5.3. DUTIES OF THE VILLAGE PUMP CARETAKER

The duties of the village pump caretaker include:

1. See that the villagers operate the handpump properly so that it will have a long life.
2. Service the handpump once a week.
3. See that excess water is channelled into a garden or soakage pit.
4. Keep the area around the handpump clean and free of refuse.
5. If the handpump breaks down, report it to the proper authority.
6. Maintain the handpump log book.
7. Explain to villagers that water from a handpump is better for their health than water from a pond, river, or over well.

Preventive Maintenance

Once a week the Caretaker should do the following:

1. Check axle-bolt. Make sure lock-nut is tight.
2. Check flange bolts fastening water chamber to pedestal and make sure they are tight.
3. Make sure handpump is firm on its base.
4. Clean out trash from drain hole below inspection cover.

Care and Operation of the Handpump

Proper care and operation of the handpump will lengthen its life and reduce the chances of breakdown. Proper use of the handpump is important. While pumping:

1. Stand directly behind the handpump.
2. Use long strokes, not short ones.
3. When finished, let handle return slowly to resting position.
4. Don't let excess water collect around the handpump. See that it runs into a garden or a soakage pit.
5. Keep the area around hand pump clean and free of refuse.

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ANNEX A

TECHNOLOGY OF MANUAL WATER PUMPING

Excerpt of the FAO-Paper

"Manual Pumping of Water for Community
Water Supply and Small-Scale Irrigation"

by E.H.A. Hofkes, IRC, The Hague
(S. 4 - 14)

2. TECHNOLOGY OF MANUAL WATER PUMPING

2.1 HISTORY

Although many manual pumping devices exist, the type used most frequently for community water supply and small-scale irrigation is the reciprocating (positive displacement) plunger pump.

This type of pump has an ancient history. A study of literature (Eubanks, 1971) reveals that a certain Ctesibius invented, around 275 B.C., a reciprocating pump. His pump was a twin cylinder lift type, with external valves and without any packing between the plunger and the cylinder wall. It was used for fire fighting. Hero (2nd Century B.C.) and Vitruvius (1st Century B.C.) were familiar with this pump. Archeological remnants of reciprocating pumps from later Roman times are occasionally found. They were in wide-spread use in medieval Europe.

Ewbank (1972) states that a reciprocating pump of wood was used as a ship's pump in the early Greek and Roman navies. The construction of these pumps is uncertain, but they may have been similar to those described in old books.

Agricola (1950) clearly shows that the design used in Saxony in the sixteenth century. At this time, in addition to the conical leather plunger or bucket, plungers in the form of perforated wood or iron disc were commonly used, the perforations being covered by a disc of leather which acted as a valve.

The foot valve typically was a hinged metal flap and was attached to a metal seating. The pump was usually made in three sections,the middle being the working barrel, while the short bottom section contained the suction valve. These early wooden pumps were of the lifting type, but when made in metal, in order to economise material and cost of manufacture, the working barrel was usually placed at the top. and a narrow suction pipe used. The suction valve was placed at the bottom of the barrel.

In 17th-century England, reciprocating pumps made of wood or lead and with the plunger packed with leather were in common use. It was not until about the middle of the nineteenth century that improved transport and communication made it economical to manufacture cast, machined, metal handpumps for distribution over a wide area.

In the late 19th and early 20th centuries, a tremendous number of different pump models were produced. Perhaps 3000 manufacturers produced handpumps in the U.S. alone. They were primarily used on farms by single families and their livestock. Windmills were increasingly used to drive pumps.

All these pumps were designed on the basis of the same operating principles, and they differed little from the traditional models. In the period since Ctesibius (some 2250 years) little was done to improve the manually operated reciprocating pump. In the industrial countries, interest in this type of pump virtually disappeared, when they found less and less use. Over the last few years, it has been recognized that manual pumping units have an important role to play in providing adequate supplies of water for domestic use and small-scale irrigation in rural areas of developing countries. Water supply authorities in these countries and the international organizations and bilateral agencies providing development assistance, are now pursuing the improved technology of manual water pumping with vigour.

2.2. FUNDAMENTAL HYDRAULICS

The theoretical discharge capacity of a reciprocating handpump (single acting) is a function of the cylinder volume swept by the plunger during its upward, pumping stroke, and the number of strokes per unit of time. This is illustrated in Figure 1.

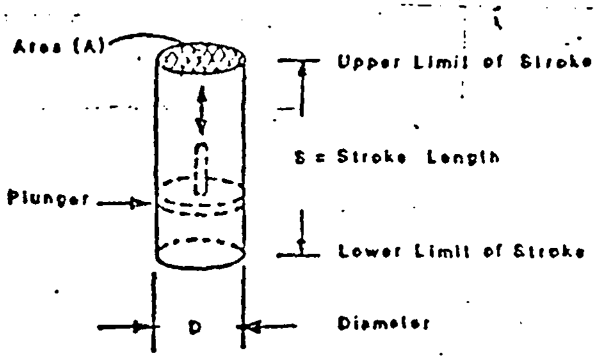


FIGURE 1 SWEPT CYLINDER VOLUME

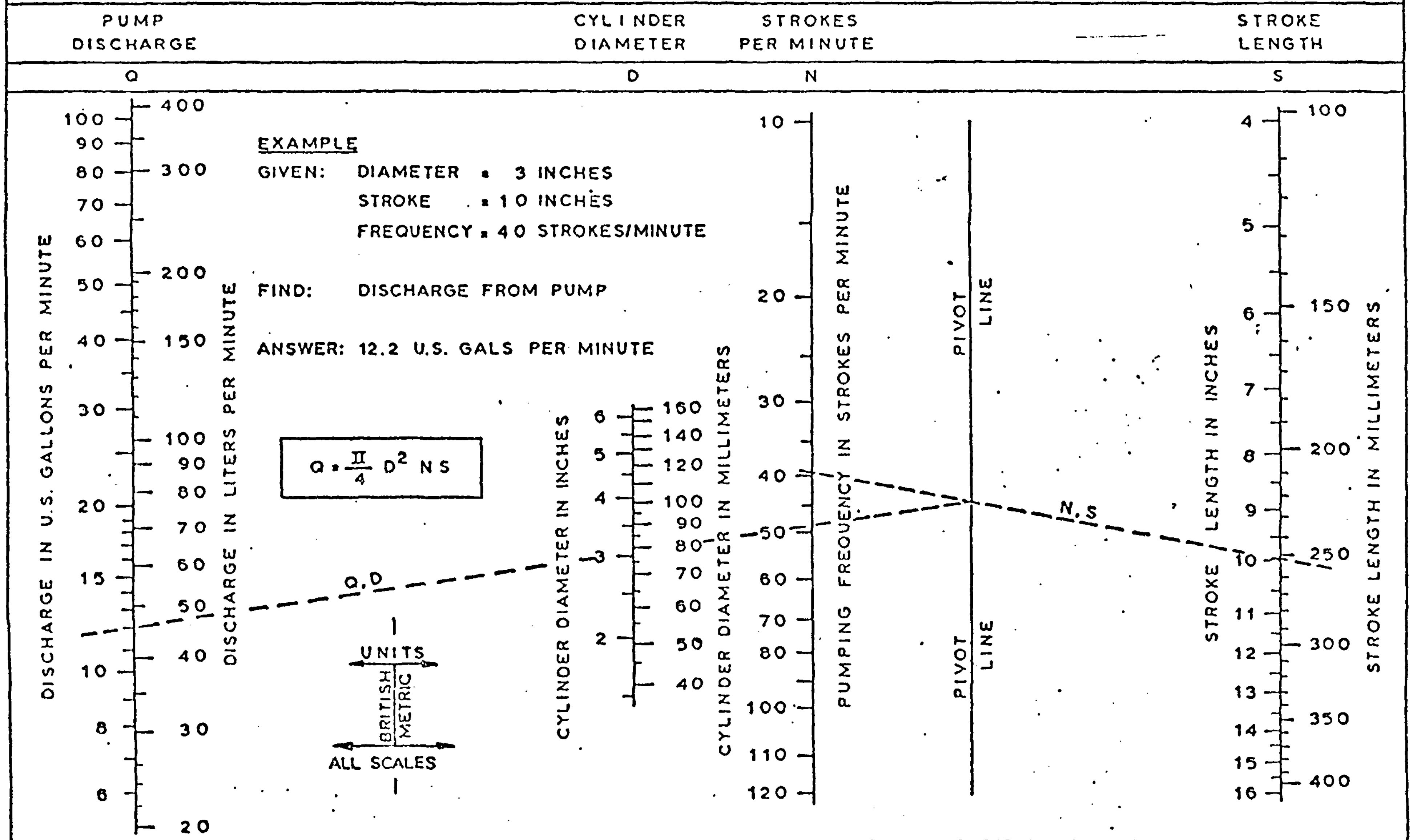
The swept cylinder volume (V) is the product of the (horizontal) cross sectional area (A) and the length of the plunger stroke (S). The cross sectional area (A) can be written in terms of the cylinder diameter (D):

$$A = \frac{\pi}{4} D^2$$

The discharge capacity (Q) for a given number of pumping strokes per unit of time (N) may be calculated with the equation:

$$Q = \frac{\pi}{4} D^2 . S.N.$$

FIGURE 2. NOMOGRAPH FOR HAND PUMP DISCHARGE



EXAMPLE

GIVEN: DIAMETER = 3 INCHES
STROKE = 10 INCHES
FREQUENCY = 40 STROKES/MINUTE

FIND: DISCHARGE FROM PUMP

ANSWER: 12.2 U.S. GALS PER MINUTE

$$Q = \frac{\pi}{4} D^2 N S$$

NOTE: NOMOGRAPH BASED ON 100 PERCENT GEOMETRIC CYLINDER DISPLACEMENT FOR SINGLE ACTION, RECIPROCATING HAND PUMPS (ZERO SLIP)

The nomograph shown in Figure 2 can be used to determine the theoretical discharge capacity of a particular pump in terms of litres per minute or U.S. gallons per minute.

The actual rate of discharge normally varies slightly from the theoretical discharge due to failure of the valves to close instantly when the plunger changes direction and to leakage between the plunger and the cylinder wall during pumping. This difference is known as slip and is defined as the difference between theoretical discharge (Q_t) and actual discharge (Q_a) as a percentage of the theoretical discharge, that is:

$$\text{Slip} = \frac{Q_t - Q_a}{Q_t} (100)$$

Slip should not exceed 15 percent, preferably 5 percent, in a well designed and maintained pump. Under certain conditions, (e.g. a long suction pipe of small diameter, below the cylinder) the flow velocity may be sufficiently high to keep the plunger discharge valve open during part of its upward movement. In such cases the actual discharge may exceed the theoretical discharge capacity; this phenomenon is called 'negative slip'. Although beneficial in terms of the hydraulic efficiency of the pump, it may lead to excessive 'pounding' and even cavitation.

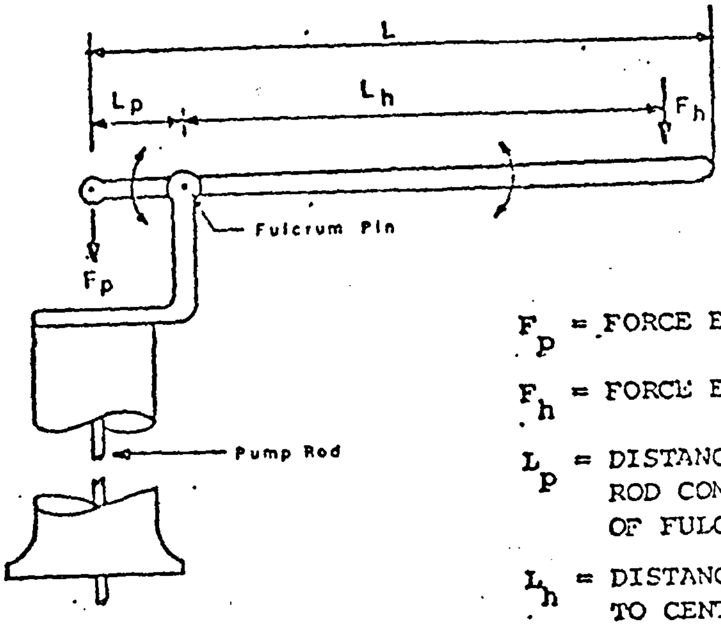
Hydraulic efficiency in terms of swept cylinder volume should not be confused with mechanical efficiency which can never exceed 100 percent.

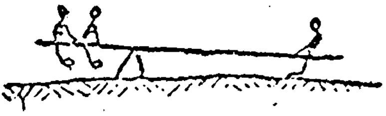
2.3. FORCE AND ENERGY REQUIREMENTS

2.3.1 *MECHANICAL ADVANTAGE*

The force exerted on a pump rod and, through the rod to the pump handle may be as high as 50 kgf (110 lb). However, the muscular force available for continuous pumping by an individual person is generally limited to 10 - 18 kgf (20-40 lb). Through the pinciple of mechanical advantage, muscle power can be multiplied to successfuly operate handpumps in wells up to even 180 meters (60 feet) in depth.

The principle of mechanical advantage is illustrated in Figure 3.





F_p = FORCE EXERTED BY PUMP ROD

F_h = FORCE EXERTED BY HAND

L_p = DISTANCE FROM CENTRE OF PUMP ROD CONNECTION PIN TO CENTRE OF FULCRUM PIN

L_h = DISTANCE FROM "CENTRE" OF HAND TO CENTRE OF FULCRUM PIN

FIGURE 3: MECHANICAL ADVANTAGE OF PUMP HANDLE AS LEVER

Consider the lever-type pump handle shown in Figure 3. It pivots about the fulcrum pin. At one end, L_p distant from the fulcrum, the handle is connected by a pin to the pump rod. Through this pin the force exerted by the pump rod, F_p, pulls on the handle. At the other end of the handle, L_h distant from the fulcrum, the hand pushes down the handle with a force, F_h.

If the distances L_p and L_h were equal and the forces F_p and F_h were equal, the handle would be in balance or 'equilibrium' and would not move. If the distance L_h were twice the distance L_p but the force F_h only half the force F_p, then the handle would continue to be balanced. Indeed any combination in which the product (or 'moment' as it is termed in mechanics) of the distance and force on one side of the fulcrum is equal to the product of distance and force on the other side of the fulcrum would be stable. That is, at equilibrium, $F_h L_h = F_p L_p$. The ratio of the handle distance L_h to the pump rod distance L_p is known as the mechanical advantage.

$$\text{Mechanical Advantage} = \text{MA} = \frac{L_h}{L_p}$$

By similar analysis, the mechanical advantage MA for a rotating crankshaft with crankhandle or wheel can be shown to be:

$$\text{MA} = \frac{\text{Radius of Handle Rotation}}{\text{Radius of Crankshaft Rotation}}$$

EXAMPLE

Given a pump rod force of 88 kgf (190 lb). What handle force is needed if the mechanical advantage of the pump handle is 4 to 1.

$$F_h = \frac{F_p}{\text{MA}} = \frac{88 \text{ kgf}}{4} = 22 \text{ kgf } (48.5 \text{ lb})$$

A typical mechanical advantage for a shallow well pump is about 4 to 1. This means that a pump rod force can be balanced by a handle force about one quarter as large. For deep wells a greater mechanical advantage may be chosen, even 10 to 1 (McJunkin, 1977).

The mechanical advantage cannot be increased without limit. As distance L_h from the fulcrum to the hand is increased, the arc swept by the end of the handle increases. Too large an arc makes for difficult operation. Decreasing the pump rod to fulcrum distance L_p increases the mechanical advantage but it simultaneously decreases the stroke length S of the pump rod and its attached plunger.

2.3.2 *FORCES: CONVENIENCE AND EASE OF USE*

Where the required force on the handle for operating the pump is too high, especially for handpumps operated by women and children, improvement may be obtained by extending the handle for greater mechanical advantage or reducing the pump rod force by using a smaller diameter pump cylinder.

If R represents the allowable (average over pumping cycle) force required to operate the pump conveniently and easily and MA the mechanical advantage of the handle assembly, then the actual pump rod force (F_a) must not exceed the product of R and MA:

$$F_a \leqslant R \times MA$$

For an allowable average handle force of 18 kgf (40 lb), a conventional mechanical advante of 4 to 1, and a steel pump rod of normal diameter, the relationship between pumping head and cylinder diameter for comfortable operation of deepwell handpumps may be tentatively calculated as tablulated in Table 1.

TABLE 1: MAXIMUM HEAD FOR COMFORTABLE OPERATION OF DEEP WELL HAND PUMP

CYLINDER DIAMETER		HEAD (LIFT)	
Inches	mm	Feet	Meters
2	51	Up to 75	Up to 25
2½	63	Up to 60	Up to 20
3	76	Up to 45	Up to 15
4	102	Up to 30	Up to 10

2.3.4. *ENERGY REQUIREMENTS*

In handpumps, the energy requirement (or rate of work), is an important parameter.

$$\text{Energy requirement} = \frac{Q.H}{\eta} \quad \text{(watt)}$$

Q = rate of discharge (l/sec)
H = pumping head (m)
η = mechanical efficiency of pump (%)
g = gravitational constant (m/sec^2)

The above equation shows that the energy requirements for operating a pump have an inverse relationship with the pump's mechanical efficiency; the lower the mechanical efficiency, the higher the energy input required.

The appropriate SI unit of energy (watt) should preferably be used. However, energy is frequently expressed as horsepower (h.p.) 1000 watts = 1 kilowatt = 1.34 hp.

By definition man (or woman or child) is the motive force that drives the handpump. Most pumps used for domestic water supply are operated by many users, ecah pumping only a few minutes at a time. Usually many of the users are women and children.

The power available from the human muscle depends on the individual, the ambient environment, the efficiency of conversion and the duration of the task.

Very few measured data of human energy output for work such as water pumping have been obtained under field conditions. The power available for long term useful work, for example 8 hours per day, 48 hours per week, by healthly young men is often estimated at 60 to 75 watts (0.8 to 0.10 horsepower). This value must be reduced for individuals in poor health, malnourished, of slight stature, or aged. It must also be reduced for high temperature of high humidity of the work environments. Where the man and his work are poorly matched - for example pumping from a stooped position - much of the energy input is wasted.

The power available during short work periods is much greater. There are examples of well-trained athletes generating up to 2 horsepower for efforts of 5 to 10 seconds. Table 2 summarizes data obtained from Krenkel (1967).

TABLE 2: MAN GENERATED POWER

AGE OF MAN	USEFUL POWER BY DURATION OF EFFORT (in H.P.)					
Years	5 min	10 min	15 min	30 min	60 min	480 min
20	0.29	0.28	0.27	0.24	0.21	0.12
35	0.28	0.27	0.24	0.21	0.18	0.10
60	0.24	0.21	0.20	0.17	0.15	0.08

Modified from Krenkel (1967).

Using an assumed effective energy output of 75 watt (0.10 HP) for operating a pump, a tentative measure of the pump's mechanical efficiency can be obtained from the equation:

Mechanical Efficiency $\eta = 13.3\ QH$ (in percent)
Q = rate if discharge (l/sec)
H = pumping head (m).

2.3.4. *ANIMAL POWER*

Draft animals are a common and viatal source of power in many developing countries. Animal power is poorly suited to direct drive or reciprocating pump devices. In Africa and Asia, they are widely used for pumping irrigation water from large diameter, open, shallow wells. The most efficient use of animals is at fixed sites to pull rotating circular sweeps or by pushing treadmills. Both methods require gears and slow moving, large displacement pumps. A horse of 700 to 800 kg (1500 to 1900 lb) can work up to 10 hours per day at a rate of 1 horsepower (about 750 watts). For short bursts of 5 to 30 minutes a horse can work at about 4 horsepower (3 kilo watt) (McJunkin, 1977).

2.3.5. *WINDPOWER*

Direct drive of a pumping device by a windmill requires matching the characteristics of:

(1) the local wind regime
(2) the windmill
(3) the pump.

By far the commonest type of wind pump is the slow-running wind wheel driving a piston pump. The pump generally is equipped with a pump rod extending through a pump stand assembly and upper guide with a hole for connection with the drive axis of the windmill. Provision may be made for pumping by hand during calm periods without wind.

ANNEX B

APPROACHES TO THE PROBLEM

Excerpt of the Intermediate
Technology Publication:

"Hand Pump Maintenance in the
context of community well projects"

An Oxfam document compiled by
Arnold Pacey

(S. 10 - 14)

wells more highly than in some other countries is indicated by the large number of private individuals who have invested in a private pump for their own household. This contrasts with the situation 20 years ago when people did not want wells near their homes "so as not to be troubled by any mess which might occur". Long-term experience of well water has apparently changed attitudes quite markedly, so that now, vigorous complaint is made if the public well is out of action.

Also, the government has organised an effective maintenance service, and UNICEF has provided this service with a free supply of spare parts. Another factor is that maintenance of the shallow well pumps used in Bangladesh presents fewer problems than does maintenance of deep well pumps, because the parts requiring attention are more accessible. Because the most intractable problems occur with *deep well pumps, it is with these that this paper is principally concerned* – though much of what is said will be applicable to shallow well pumps also. (Deep wells are designated as wells in which the water table is more than 8m below the surface).

2. Approaches to the problem

The conventional way of looking at this problem is to assume that what we need is a new design of hand-pump, which will be more robust and reliable than the ones which break down on such a spectacular scale. Several organisations have therefore put a lot of effort into the redesign of conventional pumps, notably UNICEF, WHO, the AFARM agencies in Maharashtra (MAH 4, MAH 31) and the Battelle Columbus Laboratory (commissioned by USAID and later by UNICEF). The aim of most of this work has been to produce a pump which will work with minimum maintenance in the harsh conditions of Africa and India, where heat, dust, poor lubrication and poor materials inevitably add to the problem.

There have undoubtedly been benefits from this work, but one must beg leave to doubt whether the key problems have yet been faced or tackled. It is one of the great illusions in the appropriate technology movement that seemingly technological problems can be solved purely by attention to hardware. In this instance, the problem has at least five dimensions:

a) the communities using the wells and pumps
b) the agencies administering well programmes
c) the objectives for which the wells were provided
d) the type of pump used
e) the environment – climate, hydrology and geology

3. The communities using the wells

One comes across some very depressing statements about the communities using wells. We are told that there is often "a lack of community spirit towards water supplies, even to the extent of vandalism". Some villages are said to show "little concern for putting the pumps in order – they will not even oil the moving parts". And it is observed that privately-owned pumps which are used only by the owner's family are usually well maintained, even in villages where the public pump is neglected. So it is very obvious that the problem of getting communities to work together and take collective responsibility for their wells in not being effectively tackled.

In some villages, when the pump breaks down, the people may remove it from the well. In Tanzania, this happens because the people can then let buckets down into the wide, hand-dug wells. In India, where a pump has broken at a borehole, it has been known for people to hand-dig a new well alongside it, so that they can get at the water without being dependent on the pump.

On the other hand, some villages do take great pains to look after their pumps. This is true in much of Bangladesh, and in one south Indian village a wire cable transmission system on the pump was a constant source of trouble, so villagers very ingeniously replaced it with a length of bicycle chain.

If one village can do this, why not others? The answers seem to fall into two categories:

I. *People may not have come to appreciate the benefits of using well water;* their experience of it may be short, and there may have been no effective health education on its value. There may also be real disadvantages, as when the well is too far from people's homes; when it is on Hindu upper caste land in India when intended for Harijan people; when the water is insufficient in quantity (i.e. there is excessive draw-down in the well); and when the water is brackish to taste. These subjects are often not investigated sufficiently before a pump is installed, and the views of villagers are often not sought.

II. *The people may not feel that the pump is theirs,* because of their lack of involvement in its installation, and because no specific responsibilities for its maintenance have been defined. The *New Internationalist* (February 1975) commented: "The villager often does not know how the drilling rig and pump work, where they have come from, why they have come to this particular village, what advantages they offer. He has not contributed anything in the planning, money, labour or time". Therefore he feels that the well and its pump do not belong to the village; he does not feel responsible for them, and he is perhaps uncertain whether he should try and tinker with the pump if it goes wrong. This may be unfair to most projects, but it contains an element of truth about many.

4. The agencies administering well projects

One reason why agencies have been slow to recognise the difficulties mentioned in the previous paragraph has been that *construction* and *maintenance* of wells have been thought of as quite separate operations, to be carried out by different agencies. Construction is often in the hands of a specialised well-drilling team, employed by a government, or sometimes a voluntary agency. But completed wells are usually handed over to a local authority for maintenance (e.g. in India, to a Panchyat Union). This division of responsibility means that well drillers can remain blissfully unaware of the ways in which the construction phase of the work can permanently influence villagers' attitudes to the completed well with its pump.

The situation arises because the agencies which drill wells have had to put great effort into running sophisticated drilling machines in difficult conditions, and this has often had to be done as part of a crash programme during drought conditions. It is very understandable, then, that community development, follow-up, and maintenance planning have all been neglected.

The local authorities which take over responsibility for pump maintenance are sometimes conscientious, but more often fall down on the job. It often takes three months before an effort is made to repair a broken pump. Private technicians sometimes take advantage of the delay to repair pumps for exorbitant charges. The particular ways in which local authorities are most deficient in their organisation of pump maintenance are apparently as follows:

a) The idea of maintenance as a means of *preventing* breakdowns is lacking. Administrators confuse "maintenance" with "repair".

b) Records of how often each pump is visited by a technician and what is done to it each time are rarely kept, so there is little chance that maintenance will be regular or that faulty pumps which need replacing will be identified.

c) Pumps are not standardised and it is difficult to keep adequate stocks of spare parts for all the types used.

d) Skilled manpower is short and transport costs for technicians visiting pumps are high. The available budget is often too small.

5. The objectives of well projects

It is evident that the use of drilling rigs has been a factor in limiting the participation of local people in well projects, and in distracting agencies away from longer term problems. But of course, drilling rigs offer vital advantages in terms of speed of working and the depth to which wells can be sunk – and they can, if the effort is made, be fitted into community development programmes.

If, to keep people alive in a drought situation, it is necessary for a water supply to be created as rapidly as possible, then one is justified in taking short cuts which neglect long-term considerations. But one must be clear that such wells are a form of humanitarian or emergency relief – they are to be classified as "welfare" and not "development", and one must not be surprised if few long-term benefits emerge.

6. The type of pump used

The choice of a pump for a well or borehole itself depends on whether the objective of the project is welfare or development, as will be shown below. However, an even more basic consideration is to avoid pumps which are obviously defective in design and construction. Many of the problems which have arisen with well projects in south Asian countries are due to the very poor quality of some of the pumps

manufactured there. In India especially, reputable manufacturers do exist whose products can be relied on, notably the more prominent of those listed in the appendix. But many pumps in south Asia suffer from some or all of the following defects:

(a) poor quality cast iron (very widespread, often due to high phosphorus content).
(b) roughly finished cylinders; cylinder bore uneven.
(c) use of cast iron for cylinders instead of brass (brass is more expensive, but can be given a much better finish; to use cast iron is a false economy).
(d) no protection from rust; parts often badly corroded before the pumps are even installed.
(e) excessive wear on leather washers because of (b), (c) and (d).
(f) poor screw threads; nuts and bolts will not stay together.
(g) roughly drilled pivot holes.
(h) no provision for lubrication.

On top of all these difficulties, the size of pump components is not standardised to a sufficient degree of accuracy, so when a pump needs a spare part, there is no guarantee that the new part will fit – indeed, nuts and bolts sometimes arrive with incompatible threads.

Obviously, one form of appropriate technology development which is urgently needed is a programme which would upgrade the quality of work done by small, manufacturers of pumps. There is an obvious need for better foundry practice, and also for training in better machine shop practice, including the use of jigs and fixtures which will make it possible to produce interchangeable parts.

7. Hydrogeological considerations

The hand-pump problem has become widespread and notorious partly because so many rural drinking water schemes depend on wells or boreholes, even when alternative forms of water supply are possible. Again one needs to be clear on the welfare/development issue. Where long-term development is intended, the solution of water supply problems will often require the conservation and use of surface water resources – in all areas, even in semi-desert without permanent streams, there is some surface water at some seasons of the year. But to create a good drinking water supply from such sources is often a more time-consuming and difficult matter than the routine sinking of a well, so the latter course may be best for an emergency or welfare project – even when over-exploitation of groundwater and lack of conservation measures give the well a predictably short life.

On the more immediately practical level, a well and its pump are sometimes neglected because they are sited in a very inconvenient place. In areas where geological surveys are incomplete, hydrogeologists are so often wrong that their views should not be given undue importance. Unless it seems quite wrong from a geological point of view, the first attempt to make a well and find water should be at a point where villagers want it. In India, wells for Harijan people should always be on Harijan land.

A final point related to hydrogeology is that people will inevitably and quite logically neglect pumps if the wells they draw from are unsatisfactory, either because the water tastes bad, or because there is not enough water. Bores which seem unpromising from either point of view should be capped, with no pump installed.

In particular, the sufficiency of supply should be checked by means of a pumping test. A hand-pump, not a motorised pump, should be used for this, because if sufficient water is available, but only with large draw-down, hand-pump performance may fall off so much that villagers give up using it. Tests with a motorised pump could disguise this entirely. Part of the pumping test should be a check on hand-pump performance at various draw-down levels. This should help in deciding the best depth for the pump cylinder in the final installation – it should usually be located below the draw-down water level. If the pumping test is done during the rainy season when the water table is high, allowance must be made for the reduced water level to be expected in the dry season.

Part Two: Strategies

8. Three Packages

"An effective pump system is not simply a technological object but a conglomerate of technology, institutions and people – individuals who must plan, design, manufacture, finance, purchase, install, operate, maintain, oversee and use the pump. This often neglected concept is an important reason why as many as 40 to 80 percent of hand-pumps are inoperative within 3 years of their installation."

This comment by F. E. McJunkin in WHO's draft guideline on hand pumps puts in a nutshell the principle on which any strategy for tackling the pump problem must be based. But it is the weakness of most Western experts that their outlook on technology is one which isolates 'hardware' from this conglomerate of other activities. Thus the stock response to a technical problem such as persistent pump breakdowns is to look for solutions which have to do only with such items of hardware as the pump's structure and mechanism. The result is that there has been a great deal of emphasis on the redesign of pumps. Because so many very bad pumps are in use, quite a lot has been achieved by improved design and better construction, and this has strengthened the illusion that a total solution can be found by concentrating on the hardware.

But the redesign of pumps can only go part of the way towards a solution, because, as we have seen, so much else in the human and social dimension contributes to the failure of hand-pumps. One way of understanding this wide range of factors is by studying them as a "systems problem," in which the pump hardware is seen as only one component in the total system. "A hand pump is a small technological instrument in a large social system", the WHO guideline comments. Other components are the organisations which construct and maintain wells, the people who use wells, and the communities to which they belong. It is, of course, true that all applications of technology involve people, and therefore involve systems which have social components, and it is common experience in Oxfam projects to find that the *social components of technological systems* are more significant, or more difficult to cope with, than the hardware components.

Because the hand pump problem was seen as not just a matter of the pump, but also of the system to which the pump belongs, the problem was discussed with the System Department of Lancaster University, two members of which visited Oxfam House during the summer of 1975. Systems theory has not often been explicitly applied in the field of rural development, but rural development workers do have in their own jargon a number of words which betray the influence of systems concepts. One of these is the word "package", and it may be more acceptable in the present context to use that. So instead of saying that we wish to investigate *systems* which will achieve the satisfactory functioning of village wells and pumps, we can equally and alternatively say that we wish to look at various *packages* of measures which will improve the performance of well/pump projects.

The remainder of this report will examine three possible "systems" or "packages" which offer different solutions to the problem of chronic pump breakdowns. The three packages are distinguished from one another mainly by different degrees of involvement of local people and communities, and are as follows.

a) Total village self-reliance in the manufacture and maintenance of pumps.

b) Partial self-reliance, with factory-made pumps, but with villagers at least partly responsible for maintenance. Typical pumps suitable for use in this package are shown in figure 1.

c) Elimination of all village responsibility, the pump being provided and maintained without participation by the villagers who use it. Pumps designed for this package are shown in figures 2 and 3.

9. Package for total village self-reliance

Some people have argued that if a pump could be designed capable of being made by a village craftsman using simple tools and local materials, then the maker of the pump would always be on hand to repair it when necessary and the village would be entirely self-sufficient in its pump requirements.

This argument has considerable validity for low-lift pumps, and particularly for irrigation pumps, because in many parts of India, China and south-east Asia, there are traditional designs for such pumps which have been built by village craftsmen from time immemorial. Persian wheels in India and the dragon-spine pumps in countless Chinese rice-fields are obvious examples. Many people have attempted to

ANNEX C

RESEARCH AND DEVELOPMENT PROJECTS

Excerpt of the FAO-Paper

"Manual Pumping of Water for Community Water Supply and Small-Scale Irrigation"

by E.H.A. Hofkes, IRC, The Hague
(S. 26 - 28)

RESEARCH AND DEVELOPMENT

International efforts to develop pumps for water supplies in rural areas of developing countries have stimulated over the last 10 years several major research and development projects. These include (McJunkin, 1977):

(1) The AID/Battelle Pump. A comprehensive programme to develop a sturdy, dependable pump for shallow and deep wells for universal application in developing countries. While never placed in mass production, its research findings have stimulated and influenced most other handpump development programmes.

Field testing of the AID/Battelle handpump is proceeding in Costa Rica and Nicaragua under an agreement involving the governments of those countries, the Central American Research Institute for Industry (ICAITI), and the Georgia Institute of Technology (U.S.). The AID Battelle pumps under test were manufactured in Costa Rica and Nicaragua. Thirty AID/Battelle pumps deepwell and shallow well handpumps are being evaluated in the field. For comparative purposes, four other, imported pumps are also being tested.

(2) New No. 6 Pump. A shallow well pump developed in Bangladesh with UNICEF assistance, this pump is now in mass production. It incorporates many Battelle features. Plastic (PVC) seals have replaced the leather seals used previously. Considerable experimentation and prototype testing was done. The pump improvement work evolved over several years through many design modifications based on field experience.

(3) India Mark II Deepwell Pump. This pump has been developed by the Government of India with major assistance from UNICEF and WHO. The "Sholapur" pump design was adopted as the basis for the development. Design improvement first concentrated on the handle mechanism, failure of this component being the pricipal factor in breakdown of pumps. The original cast iron pedestal mounting to the well casing pipe was re-designed into a pedastal to be grouted into the pump platform, completely independent of the well casing.

(4) Hydro Pompe Vergnet. A newly developed pump using a novel operating mechanism. The pump is foot-operated; a hydraulic piston drives a diaphragm pump immersed in the tubewell. With WHO and UNICEF assistance, prototypes of the Vergnet pump were field testing in Upper Volta. The pump can be used as a lift pump or force pump, not as a suction pump. Further development for depths over 15 to 20 meters seems to be required.

(5) Petro Pump. An interesting new variation of diaphragm pump, suitable for use in deep wells. The pumping element of "cylinder" consists of an elastic rubber hose, reinforced by two layers of spirally wound piano wire, and equipped with a ball-type check valve at each end - fixed by a metal bracket. The lower end of the hose is fixed within the well by expander jaws wedged against the casing; the upper end of the hose is attached to a string of ½- inch (19 mm) pipe which serves as both the pump connecting rod and the drop pipe.

(6) Shinyanga Pump. This pump has a wooden pumping head which closely resembles the Kenya Pump manufactured in Nairobi and widely used in East Africa. However, whereas the Uganda pump uses a brass cylinder, the Shinyanga pump has a polyvinyl chloride (PVC) plastic cylinder. A rubber double ring cupseal with an internal shape retaining stainless steel ring is used. The cup must be imported and is relatively expensive (about $10 each). However, it is expected to last perhaps as long as 10 years.

(7) Kangaroo Pump. This a foot-operated pump. The pump head consists of two pipes sliding over each other, with a spring fitted in between. The outside sliding pipe is connected to the pump rod, and operates the piston in the pump cylidner. The downward stroke serves to compress the spring, which is then left to produce the water discharge upward stroke.

(8) The International Development Research Centre (Canada) has a pump development project underway which concentrates on use of new materials, particularly plastics; improvement of valves and seals, and wooden bearings.

(9) A comparative testing project for handpumps is being carried out by the Harpenden Rise Laboratory (U.K.) funded by the Overseas Development Ministry (U.K.). Some 12 different pump models are tested under a scientific protocol, probably the most complete used sofar. The pumps

under test include most of the pumps earlier mentioned, several with wheel-type drive, a helical rotary type, the DPHE/UNICEF "New No. 6", developed in Bangladesh, the AID/Battelle, and four of the novel pumps on the market.

(10) The extensive comparative field tests of handpumps undertaken in northern Ghana by the Ghana Water and Sewerage Corporation, assisted by the Canadian International Development Agency and Wardrop Associates, Consulting Engineers, are completed and a final report has been prepared.

The results of pump research and development should be used with caution. Pump improvements that seem obvious in the office or laboratory do not often work in the field. A corollary is that successful performance in the laboratory does not guarantee success in the field.

ANNEX D

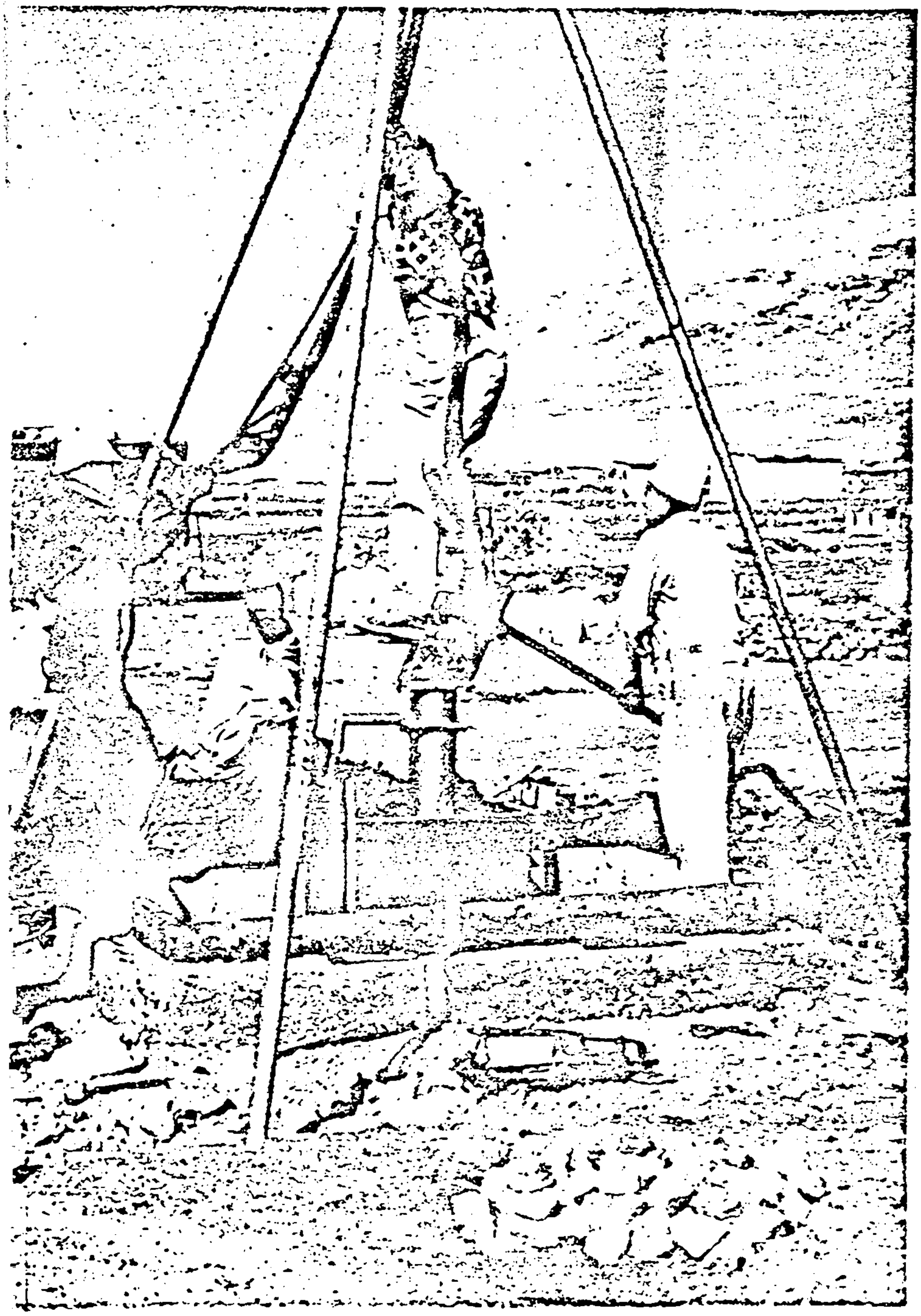
LOW-MAINTENANCE HANDPUMPS FOR VAST WORLD MARKET

Exerpt of the journal
WORLD WATER, December 1981

1981-1990

WANTED:
Low-maintenance handpumps for vast world market

The prize for successful development of a VLOM (village level operation and maintenance) handpump design could be a market of as many as 20 million such pumps by the end of the century. UN experts want manufacturers to concentrate on designs that do not require expensive mobile teams for routine repairs.



ledding in the leather cupwashers on the India Mark II can call for unconventional ways of ncouraging the downstroke, as in this installation in Lesotho.

icture by courtesy of Chris Evans, CATR

A panel of World Bank, UN and other experts is encouraging manufacturers of handpumps throughout the world to make fundamental changes to their existing designs, to suit the needs of the Water Decade. If they do, there could be a call for as many as 20 million pumps by the end of the century on schemes to supply safe water to present and future rural populations.

Present handpump designs are leading to very high expenditure on repair and maintenance, particularly transport costs, in most developing countries, as well as causing unacceptably high proportions of water wells to be out of use at any given time. As a result, past investment in rural water supply projects has not been producing the scale of benefits which ought to be possible. And sums of money to be spent on mobile maintenance teams mean that future national plans aimed at meeting the Water Decade target of clean water for all by 1990 are being put at risk.

These conclusions are emerging from a global project, funded by UNDP and executed by the World Bank, in which existing and new handpump designs are being tested in the laboratory and in the field. Data is also being collected from existing rural water supply projects in Africa and Asia, the Middle East and Latin America.

"Technological development" has now been added to the scope of the project, with the idea that the results may be evaluated to produce a series of approved designs which would be available to any manufacturer without patent protection.

The main change in current handpump designs sought by the expert panel is the development of the VLOM pump. VLOM (village level operation and maintenance) would combat the very high costs of routine maintenance or repairs. In some instances, maintenance costs account for 85% of the amortised costs of rural water supply installations.

With rare exceptions, servicing of the high-wear elements at the bottom of a typical 20/30m-deep well calls for lifting equipment and a team of specialists including expensive spares which can only be stored on a regional basis. Service calls can therefore not untypically involve a 200km round-trip for a team of three or four trained mechanics, who may well be unable to cope with more than one or two pumps a day as a result. Trucks, fuel, spares and equipment costs combine with shortages of skilled manpower to inhibit proper maintenance and lead to a high percentage of inoperative installations.

In an East African country, where the government has won high praise for its commitment to rural water supplies, and supervision of projects is better than in many other countries, it has been calculated that average maintenance costs amount to $400 per pump per year.

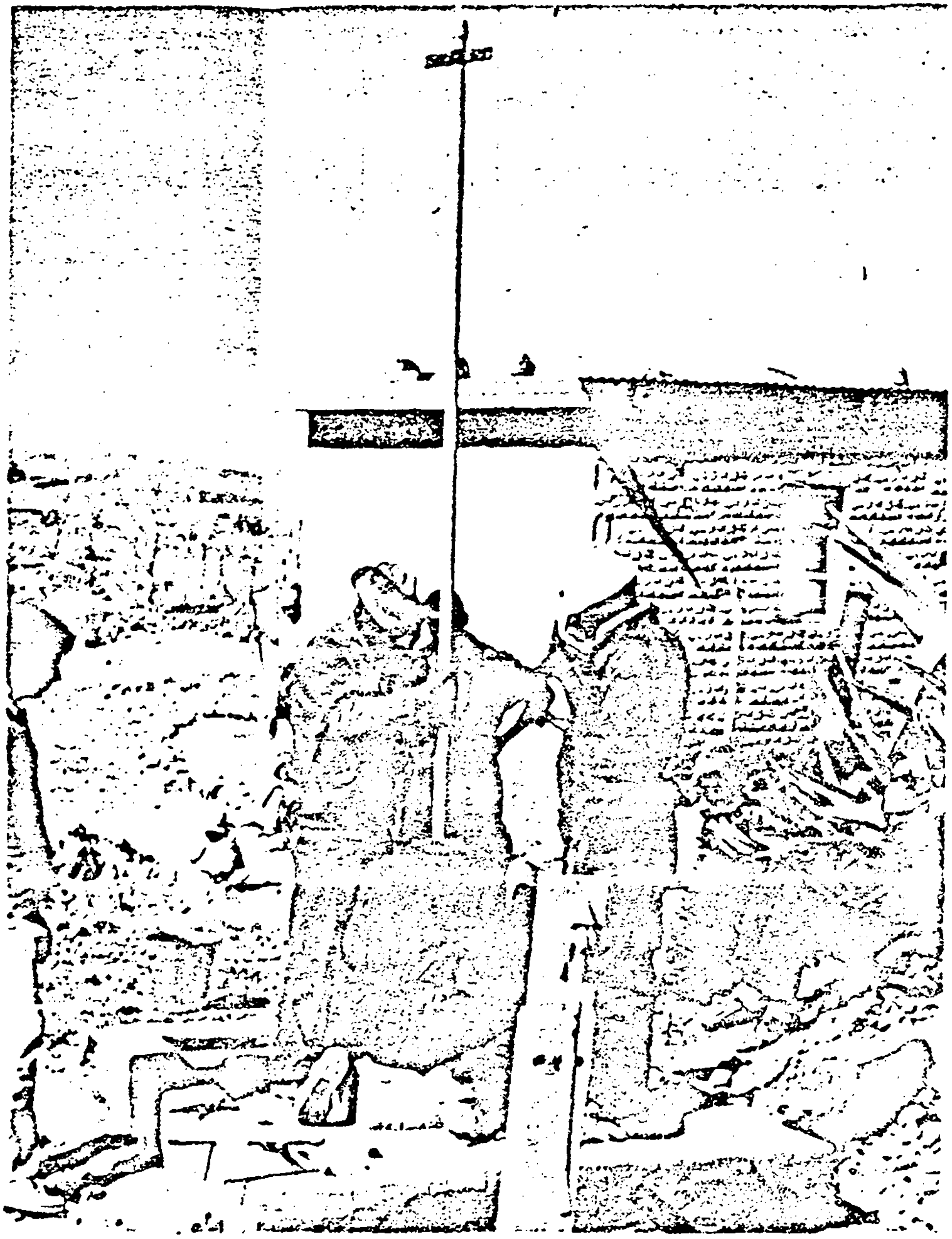
The panel's answer is to simplify the below-ground components of handpumps in such a way that replacement of worn or broken parts will be simple and cheap. To overcome the major difficulty of raising the pump cylinder to the top of the hole, attention is being focussed on maximum use of different kinds of plastic for as much as possible of the underground components, and finding a way to drain the column of water when pulling out the pump.

In particular, substituting plastic for the conventional galvanised steel in the drop-pipe, through which water is pumped to the surface, can cut the weight by a factor of ten or more, and mean that the combined weight of pump-rod, drop-pipe and cylinder for a 20m-deep installation could come down from about 200kg to a much more manageable 25-35kg.

As well as the weight reduction, which avoids the need for heavy lifting equipment and therefore for trucks to carry it, use of injection-moulded plastic for the replaceable parts of handpump mechanisms could have a significant impact on costs of spares. That in turn would mean that stocks of regularly needed parts could be held in villages, and routine maintenance of groups of pumps could be managed by a local caretaker equipped only with a set of tools — and a bicycle, if he serviced more than one village.

A number of development projects are being carried out in Africa and Asia and if the target could be achieved — and the World Bank's regional project officers are confident that it can — the high cost of maintaining every pump would come down to about $20-30/pump/year. The local repair capability would also cut pump downtime significantly, and prevent the need to use the old polluted sources. The incentive for direct beneficiaries to carry out their own repairs is strong, and the logistic and cost problems of long-distance mobile teams would be largely eliminated.

So dominant are repair and maintenance costs in rural water supply programmes, that the conventional design



The Consallen's plastic drop-pipe makes installation and removal of the underground equipment a simple operation (above). The completed installation (below) is the closest currently available to the UN panel's VLOM pump ideal.

criteria of strength and durability, which have led to the predominance of heavy-duty equipment, are rapidly giving way to the new VLOM rules of making repairs easy and cheap.

The experts are convinced that, even if the working parts of a handpump have to be completely replaced more frequently, providing those parts are cheap, readily available, locally manufactured, and easily installed, cost savings and improved pump usage would be substantial compared with an expensive, robust, heavy installation, which might require fewer service calls during the same five years.

So the call is going out to handpump manufacturers that the UNDP/World Bank global project attaches top priority to development of a VLOM pump, and project manager Saul Arlosoroff of the World Bank is hoping that as many as ten designs may be ready for field tests in a year's time.

Manufacturers are also being encouraged to move fabrication of pumps into developing countries, by forming joint-ventures with local firms. The panel sees local manufacture both as a way of overcoming foreign exchange problems for spares, and as an incentive through employment for governments to assure ready availability of replacement parts.

Meanwhile, testing and evaluation of existing handpump designs goes on, and the World Bank/UN team is wrestling with the problem of what recommendations to make to prospective purchasers or donor agencies seeking its advice on suitable pumps for particular countries.

As well as reports from field officers and some studies of rural water supply projects after a few years of implementation, the panel also has at its disposal the results of laboratory tests carried out by CA Testing & Research (CATR) at the UK Consumers' Association. Those tests, were initiated by the UK Overseas Development Administration about four years ago, when 12 handpumps chosen to represent as many design types as possible were put through rigorous trials, including a 4,000 hours endurance test.

The results, reported in October 1980, were made known to the individual manufacturers, agencies and governments. Though the 280-page report has not been made freely available, its conclusions are beginning to spread around the developing countries, and some manufacturers are already producing modified designs as a result.

CATR concluded that, of the 12 pumps tested, only four were worthy of consideration for general use in developing countries, and, in two of these, significant modifications were needed to the pumps actually tested. Closest to CATR's concept of the optimum handpump, even before the VLOM concept became an established part of the experts' thinking, was the Consallen pump.

The Consallen achieved an excellent rating in CATR's tests for overall design, frequency of maintenance and breakdown, corrosion resistance and safety, and high marks also for ease of manufacture, performance efficiency, resistance to abuse or neglect, and well-head sealing. It also had the advantage, now becoming the overwhelming parameter, of employing a plastic (ABS) drop-pipe, which makes repair and maintenance operations cheap and simple.

Also coming out well from the CATR tests was the India Mark II, a pump specifically designed by UNICEF for heavy-duty applications on rural water-supply schemes in India, where water may have to be drawn from great depths (up to 80m) and the pump may be required to operate for up to 16 hours a day continuously.

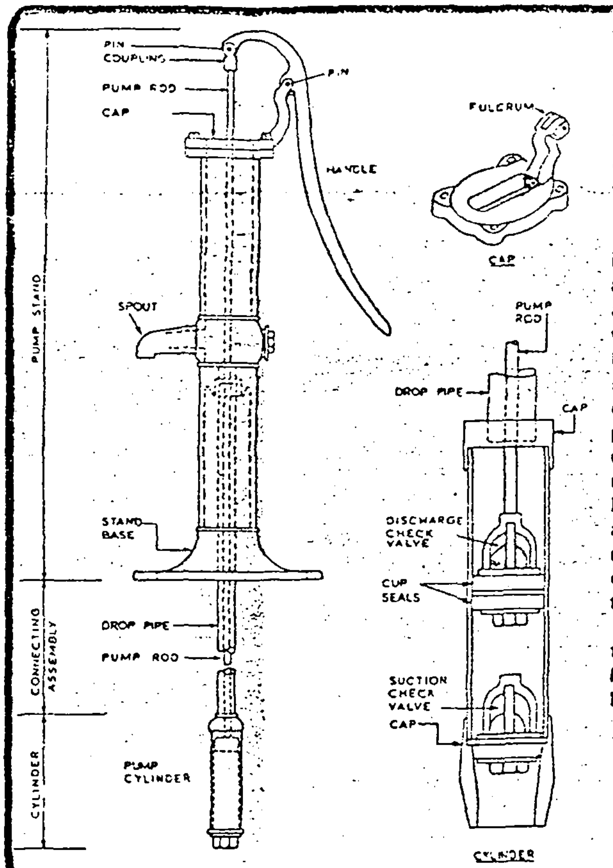
The resulting design has been extremely popular both in the Indian sub-continent and more recently in parts of Africa, though one of its designers, Ken McLeod, the World Bank's regional project officer for East Africa does not believe that in its present form the Mark II is right for the lighter duties generally applying in African countries. McLeod would prefer to see the design modified to take in the new VLOM approach, and a few Indian manufacturers including INALSA, are understood to be working on changes, including plastic below-ground components.

One of the main problems if the pump is used on shallower wells (especially below about 20m) arises from the use of a chain and quadrant system to link the pump handle to the pump-rod. The system therefore depends on the weight of the pump-rod to return the plunger on the downstroke. With some leather washers, the resistance can be too much and there is no way to force the plunger down.

With the standard galvanised steel drop-pipe weighing 3.2kg/m, the pump-rod another 0.93kg/m, and the cylinder itself 8.8kg, the India Mark II will always need an A-frame and hoist arrangement to remove the cylinder for service. The aim of its design was to limit service requirements, and the pump is said to be capable of operating for at least 12 months continuous use even when lifting from depths of 60m.

The two pumps which CATR thought could be suitable with modifications were the British Monolift and the French Vergnet footpump. Manufacturer Sofretes/Mengin has since simplified construction of the foot-operated version of the Vergnet which CATR said made it difficult to make in developing countries.

The company is also concentrating efforts on the ABI/Vergnet hybrid handpump in collaboration with Abidjan Industries in the Ivory Coast. The new hybrid is one of 15 pumps currently undergoing trials in CATR's new series of tests funded as part of the global testing programme. The ABI/Vergnet is in principle a VLOM pump, although there are some reservations about its complexity



This diagram of the internal parts of a typical handpump design is taken from a draft handpump catalogue under preparation by the Netherlands-based International Reference Centre for Community Water Supply & Sanitation (IRC).

Publication of the catalogue is scheduled for March 1982, and IRC is keen to hear from any handpump manufacturer who wishes to be included. Information on individual pump models includes a general description, basic specification and performance ratings, and details of the pump head, connecting assembly and cylinder. IRC points out that inclusion of a pump in the catalogue must not be taken as an endorsement or recommendation of the particular pump.

Information should be sent to: IRC, PO Box 5500, 2280 HM *Rijswijk (The Hague), The* Netherlands.

The Monolift came out badly in CATR's early tests because of high leakage between the rotor and stator, which made it difficult to achieve any flow once the head exceeded about 20m. Manufacturer Mono identified the problem as differential expansion between the rubber stator and metal rotor, and corrected it by supplying cylinders designed for specific water temperature ranges.

As a result, Mono claimed and CATR accepted (but did not have the opportunity to verify) that pumping performance was very much improved. Otherwise CATR found the Monolift to be reliable, robust and requiring relatively little maintenance, and saw the design as particularly suitable for applications where the water was likely to contain sand.

Field trials

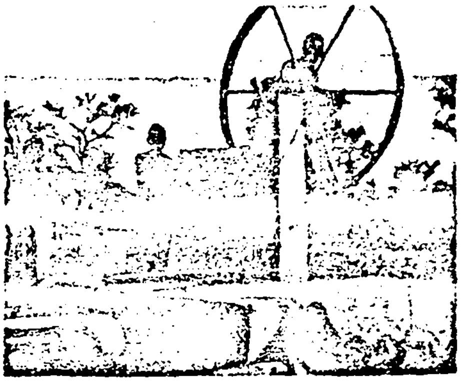
While CATR continues its tests of existing handpump designs — and Saul Arlosoroff is hoping that experimental designs can also be included before long — the global project is moving into the next important phase, that of performing comparative tests of different designs in similar field conditions.

A plea is going out to donor agencies involved in rural water supply projects, and to non-governmental organisations active in the water sector, for opportunities to be created for samples of *alternative pump designs to be included alongside the project pumps. The hope is* that comparative testing can be carried out in up to 20 countries, with groups of 30-50 trial pumps replacing the models chosen for the rest of the project in each case.

A monitoring protocol has been developed specially for the Global Project, and standard monitoring forms are now being finalised by Arlosoroff's group. The idea is that a UN volunteer will be attached to each field trial and will help to monitor installation, operation and maintenance, and socio-cultural aspects of different types of handpump in a way which allows direct comparisons to be made between individual designs.

West Germany and the Nordic countries have already committed support to the project and are suggesting to countries receiving aid that funds should *be allocated to handpump trials.*

After recent cuts, UNDP funds will not stretch to hardware; the budget request of $3.7M is only enough to fund the manpower requirements, consultants and software needed for the field trials. So participating donors are being asked to find the money for buying and installing the pumps, and for the vehicles, workshops, etc (which would probably be necessary anyway irrespective of the comparative trials). Some extra contribution may be necessary for additional monitoring or training staff, and for fuel *for vehicles.*



Some manufacturers have already begun to respond to the UN challenge to produce a VLOM pump. This Volanta pump from Insto of the Netherlands uses a cable to drive the cylinder instead of screwed rods. As a result, the manufacturer says, installation or dismantling is quick, simple operation for one man with no special tools. Flywheel operation can be handled by a five-year old child, and the pump is said to be suitable for depths of 4-100m.

World Water *understands that Danish manufacturer Grundfos is also working on a VLOM pump design, but the company says it has no news for publication yet.*

The incentive to agencies to participate is strong: if the project succeeds in promoting the development of a number of VLOM pump designs, unprotected by patent, local manufacture and dramatically reduced maintenance costs will bring down the costs of individual aid projects enormously and mean that many more pumps can be installed for the same investment.

Arlosoroff is hoping that this argument may eventually win round other major donors whose traditional attitudes to aid present difficulties on this kind of project. Such donors tie assistance to use of their own country's technology, forcing unacceptable restrictions on the global project administrators' plans for comparative tests of pumps selected on the basis of performance and design characteristics, rather than country of origin.

It is hoped that ways may soon be found to involve USAID in some Latin American and Asian projects, the French in three West African countries, and the UK, without inhibiting the objectivity of the trials.

Among the developing countries, Arlosoroff reports a generally enthusiastic response to the suggestion of comparative trials. Top priority is being given to 16 countries (Malawi, Kenya, Zambia, Tanzania, Ivory Coast, Upper Volta, Togo, Niger, Ghana, India, China, Sir Lanka, Thailand, two Latin American countries and Bangladesh). In Bangladesh, trials may be incorporated in UNICEF's massive shallow tubewell programme for rural water supplies (*World Water*, December 1979), and in the research and testing element incorporated in a $20M World Bank project to install 180,000 handpumps for irrigation.

Bangladesh has a need for 1½ million handpumps by 1990 for potable water supply alone, and 300,000 of them will

How many pumps are needed?

Estimates of the total number of handpumps that will be required during the UN Water Decade, and beyond it to the end of the century, vary enormously, depending on assumptions made about the degree of service to be provided, and the design life of the handpump used.

Statistics collected during preparations for the Water Decade revealed that, by 1990, some 1,833 million people in the developing world excluding China would need to be reached with new clean water supplies. Almost 1,400 million of those are in rural areas, where handpumps are the predominant form of supply.

Recent figures from China suggest that at least 400 million people in rural China must be provided with handpump supplies over the same period. By the end of the century, population growth will have added at least another 800 million people throughout the developing world.

At the same time, existing pumps will need to be replaced and, by the end of the century, even those installed during the Decade will mostly have been renewed. If the UNDP/World Bank Global Project is successful in promoting development of a VLOM pump, renewal, though very much cheaper that at present, will also be more frequent. One estimate is that all the main parts of a VLOM pump may need to be replaced over a period five years.

The other key parameter in assessing demand for handpumps is the number of people to be served by each installation. In global terms, the World Bank is working on a figure of 200 people per pump, though in one very important country, Bangladesh, the target by the end of the century is 75 people per pump, for an estimated rural population of 90 million.

***World Water's* estimate that some 20 million or more handpumps may be needed by the year 2000, breaks down as follows:**

- **New handpumps to serve 75% of the rural population outside China by 1990 (1,000 million) plus 400 million people in China at 200 people per pump, means seven million new pumps;**
- **Replacement pumps over the same period will be needed for at least 500 million people, giving another 2½ million pumps;**
- **Serving 75% of the population growth by the year 2000 (600 million) will require another three million handpumps;**
- **Renewal of virtually all of the pumps in use before 1990 by the end of the century will call for at least another 10 million pumps.**

That means a total of at least 22½ million handpumps, even if replacement is only considered to be necessary after ten years or more.

need to lift water from deeper than the 7m limit of UNICEF's Bangladesh No 6 pump. Research adviser Tim Journey, working with UNICEF's programme officer Ken Gibbs, has the task of identifying the right pump(s) for both drinking water and irrigation, with one possible outcome seen as a new design for a multi-purpose, multi-drive pump.

In Africa, tests will be under way this month in Malawi, where Ken McLeod is expecting to implement comparative trials on at least two projects, possibly with UNICEF and Christian Services finance.

Kenya is also very keen and a 100km² site near Mombasa has been earmarked for 200 handpumps, 50 in newly drilled boreholes and 150 in existing open wells. Swedish (SIDA) funds are expected for the project, and, as well as handpump comparisons, efforts will be made to provide health data linked to improved water supplies, as the region suffers annually from enteric disease outbreaks.

The German bilateral agency GTZ has offered to support trials on projects for which finance has already been committed in Tanzania, Niger and elsewhere, and Saul Arlosoroff is very hopeful that funds can be found to support at least one project in the Ivory Coast, which he describes as "one of the best case studies in the world to illustrate the Water Decade handpump concept".

Arlosoroff is enthusiastic about the way that the Ivory Coast Water Authority has tackled rural water supplies following difficulties with some locally manufactured handpumps (a problem which CATR says was predicted by its own studies). Initially, villagers are being asked to pay for regular maintenance of new pumps, while local people are trained to undertake their own servicing. As the villagers take over, so their payments are reduced, and at the same time, failures are expected to decrease as VLOM pumps are introduced.

Studies to be undertaken will include monitoring of the new ABI-Vergnet hybrid pump alongside other designs. Arlosoroff contrasts the Ivory Coast situation with that in another West African country, where the country has been divided into several regions because bilaterals each wanted to supply a different pump.

Each area needs its own mobile crews and spares, which, Arlosoroff maintains will be impossible to keep going when the bilaterals move out. "If local manufacturers had been producing reliable pumps, most of the donors say that they would have chosen to use them, but the lack of available technology meant that they had to import both pumps and technology".

While the field trials are getting under way in the top priority countries, efforts are also being made to identify worthwhile projects in Asia and Latin America. Interest has already been shown in India, China, and others, and preliminary inquiries have started to select appropriate sites.

UN Volunteers are now being recruited to monitor the field trials, and Arlosoroff thinks that six or seven trials should be under way by Spring 1982. The intended schedule is for trials in the 20 countries to spread over three years, during which time experimental designs will be gradually introduced alongside existing ones. Depending on future funding, it may be that tests of new versions will have to be spread over a longer period, running into 1986, but the aim remains to develop VLOM pumps for trial before the end of 1982 or mid 1983.

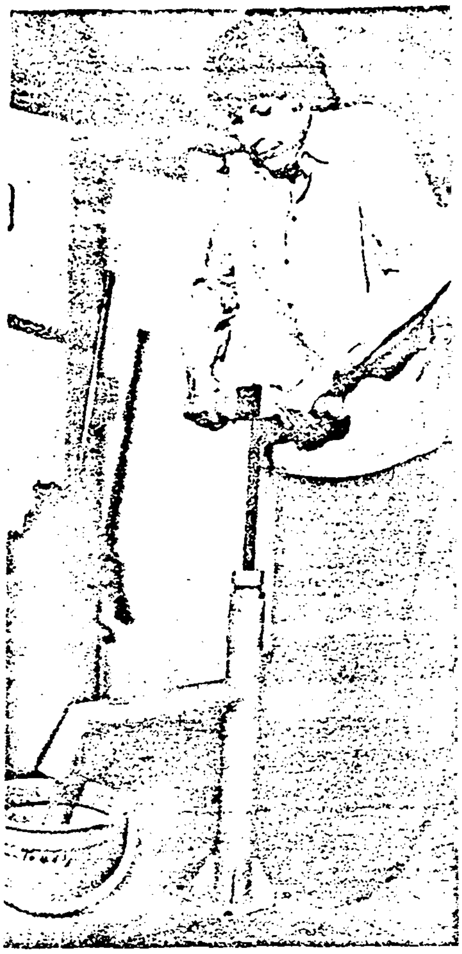
Initially, pumps to be included in the field trials will be selected on the basis of encouraging performance in the CATR tests, or on the recommendation of members of the global project monitoring panel. Any faults or recommended design modifications will be fed back to the manufacturers regularly, in the hope that better pump designs can evolve continuously.

If funds can be found, experimental designs will be added to the 15 pumps already undergoing tests in the CATR laboratory, and promising ones will immediately be introduced into the field trials. Patent protection will be discouraged, as the aim is to produce designs suitable for manufacture in any developing country.

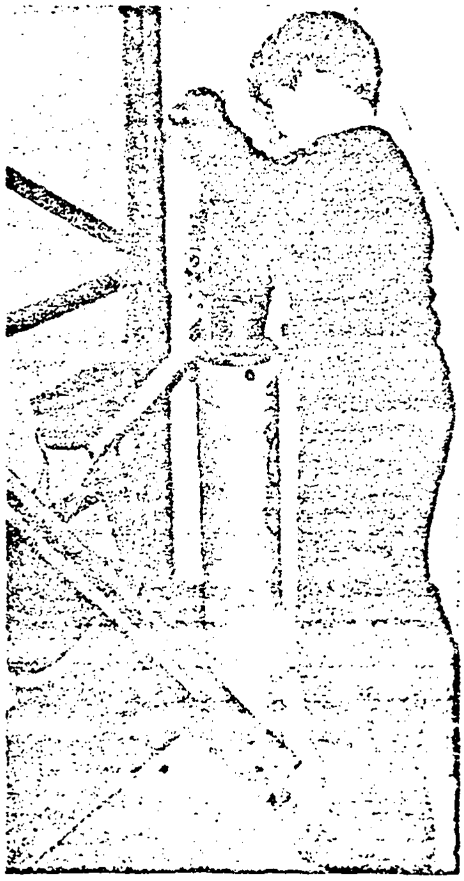
During the field trials, the monitoring team will operate district servicing crews, and regular inspections will be made of all pumps to evaluate performance and maintenance requirements. The standard monitoring forms have been designed to enable valid comparisons to be made of installation, operating performance, resistance to accidental damage or vandalism, breakdown rates, ease of maintenance, costs of operation and maintenance, and general acceptability of the pump in the community.

Danish socioanthropologist Kirsten Jørgensen is acting as consultant to the project, and has devised a special form to monitor socio-cultural aspects of handpump use. She will also help to analyse the results during the development of new designs, with the aim of making any VLOM design appropriate for the user groups concerned.

As well as their use on the UNDP/World Bank global project, the monitoring forms are to be made freely available to donor agencies or government authorities willing to use them on any rural water supply project. Results will be analysed by CATR to produce direct comparisons between new and existing designs, and hopefully, some form of recommendation on the suitability of different designs for different circumstances.



Users of varying size put pumps through comparative tests in CATR's laboratory, and each pump undergoes an endurance test lasting 4,000 hours in a purpose-built testing tower (far right).



ANNEX E

HAND/FOOT OPERATED WATER PUMPS FOR USE IN DEVELOPING COUNTRIES

Excerpt of the final summary report
from CA Testing & Research (CATR)
at the UK Consumer's Association

TABLE 2

OVERALL SUMMARY

PROPERTY	Petro	Vergnet	Dempster	Mono	Climax	Godwin	Abi	Beatty	Monarch	Kangaroo	India Mark II	Consallen
	A	B	C	D	E	F	G	H	J	K	L	M
Ease of manufacture	4	2	3	2	1	1	3	2	3	4	4	4
Ease of installation	3	5	3	3	1	1	3	3	3	3	3	3
Frequency of maintenance	4	3	1	5	5	5	4	2	3	4	4	5
Performance **	3	3	5	1	5	4	4	4	4	1	4	4
Ease of use	3	4	4	3	5	3	5	4	3	1	5+	3
Frequency of breakdown	3	4	1	5	4	5	3	4	3	1	5	5
Resistance to abuse and neglect	2	4	1	4	3	3	2	1	2	5	4	4
Overall design.	2	4	2	4	4	4	2	2	2	2	4	5
User acceptability	3	4	4	1*	5	2	4	3	3	1	4	3
Adequacy of well head seal	3	4	4	4	3	3	1	4	4	3	5	4
Corrosion resistance	4	5	2	2	2	2	2	2	2	3	2	5
Safety	5	5	5	5	2	5	5	2	5	4	5	5
Approximate price (£) excluding pipe	220	330	60	340	500	630	360	165	250	165	65	170

+ In deeper wells. Cannot easily be used in wells shallower than about 20 m.

* If performance was acceptable would be 3 - 4.

** Performance ratings are based on mechanical and volumetric efficiency measurements only.

Ratings are on a 1 - 5 scale :

5 - very good

1 - poor

DISCUSSION AND RECOMMENDATIONS (Cont)

A larger cylinder, used with a large mechanical advantage handle, is better than a small cylinder, used with a small mechanical advantage handle and a longer stroke. The stroke should not become so small as to give a stroke length less than about 80 mm however.

7. Choosing the correct pump for the geological conditions is very important, e.g. the corrosion resistance of the pump must be dependent on the water quality. The size of cylinder used, and any counterbalance weights on the handle, should be determined from the well depths. If the well is likely to run dry, or the pump cylinder likely regularly to become dry, then a conventional cylinder with leathers should be avoided. The possibility of solid impurities in the water should be taken into account, and the effect of this on the pump wear assessed. Even such things as variation in water temperature may need to be considered (see summary of Code D).

Having considered some of the possibilities which must be looked at, it will hardly be surprising if it is said that none of the pumps tested will suit every situation; nor indeed is there a pump which comes as close to the ideal as is possible. Some pumps are so expensive that they would almost be ruled out on price grounds alone; some could not be made to give good service without modifying them out of all recognition. For the purposes of comparison, the three major sections of a pump will be looked at separately, i.e. cylinder, connecting assembly and pumpstand.

Perhaps one surprising result of the tests is that no major problems were encountered with any of the conventional brass cylinders during endurance tests. No leathers were replaced on any cylinder. It would seem that, provided leathers are made correctly, they are capable of giving a very long life with perhaps two provisions: firstly, that the leathers are kept wet; secondly that the cylinder bore is smooth. If leathers are continually drying out, and becoming wet again, (e.g. on shallow well pumps and deepwell pumps where the cylinder is not immersed), rapid deterioration is bound to occur. If the conditions where drying out occurs cannot be avoided, then some other seal material must be considered.

Leathers, however, are very variable and can markedly affect the ease of use of a pump. The forces required to operate a pump immediately after its installation can be very different from those measured three days later, due to swelling of the leathers. It would seem that manufacture of good leathers is critical. Some that were seen during the course of the tests described here were too thick and jammed in the cylinder; some were too hard and did not flex sufficiently, and some were badly made and curved inwards. Those supplied with Code C were thought to be consistently good.

As a general purpose cylinder for a conventional pump, therefore, any of those on Codes C, E, F, H, J, L could be used, though some have slight disadvantages. Codes E and F are used with 2½" diameter pipe, but are extractable. The remainder have 1½" or 1¼" pipe connections and are non-extractable. Code G cannot be recommended because of the doubts cast over its quality of manufacture. Codes C and L alone have brass liners and C particularly, could be more affected by corrosion.

DISCUSSION AND RECOMMENDATIONS (Cont)

Code L is also short and, thus, very careful plunger alignment is required during installation. Codes H and J are rather thin and more easily dented during the manhandling associated with installation. The cylinder on Code K cannot be recommended due to the poor valves; Code M has a stainless steel cylinder which does not use leathers and also has a stainless steel pump rod. It can be reliable but is difficult to dismantle for repairs, (see summary).

Very little can be said about the connecting assemblies. Most use galvanized drop pipe and rod and, provided the water is not excessively corrosive and connections are properly made and locked, problems should be rare. (The exception may be due to high momentary stresses caused by knocking of a pumpstand handle against its stops). The use of plastic (ABS or PVC) pipe may be necessary in some cases to avoid failure through corrosion. The use of PVC is best limited to fairly shallow wells where the pipe can be solvent-welded together and removed from the well in one length. Threaded connections may cause problems because PVC is not resistant to cyclic stressing. ABS is acceptable with both threaded and solvent-welded connections, though, on Code M, minor instances of thread damage occurred during the frequent screwing and unscrewing of connections during testing. Our main worry is that, particularly on deeper wells, the rigidity of the pipe may not be sufficient to prevent considerable "snaking" of the pipe on the lifting stroke. The long term effects of this have yet to be shown. The larger diameter pipe is obviously better.

Considering the pumpstands and pumps as a whole, where the below ground components are unique to the pump, there are four pumps which we would select as being generally worthy of consideration, with suitable modifications where necessary.

Code B was robust and resistant to abuse, and of adequate performance. It could pump from a wide range of well depths. Maintenance and installation were easy and maintenance only required at infrequent intervals (1000 - 1500 hours of use). The problem with regard to the loss of prime and consequent fall in the maximum pedal height would need to be resolved however. The design is also fairly complex and requires a wide range of manufacturing processes. It is probably not suitable (in most developing countries) if local manufacture is envisaged.

Code D - If (and only if) the performance problems of the pump have been overcome, it could well be worth serious consideration, particularly if the water is likely to have sand in it. A few simple modifications are suggested in the summary. The pump is reliable, robust and requires very little maintenance.

Code M is a very promising design and, with a few slight modifications to the pumpstand, could come very close to what we consider the ideal. The design is biased towards corrosion resistance, however, and in some cases the use of more conventional materials for the below ground components could prove equally suitable, and possibly make maintenance and repair simpler.

DISCUSSION AND RECOMMENDATIONS (Cont)

Code L is also a very good pump and very cheap, but with a few modifications, we feel it could be made still better and more cheaply. Its main downfall at present is its limitation to fairly deep wells. Its only other potential problem is that the number of external fastenings, though these are good, is greater than is desirable. The pump is easy to use, very reliable and requires little maintenance.

In conclusion we think that a suitably designed conventional pump could easily fulfil the majority of the needs for drinking water wells in developing countries. None of the pumps tested fully met all the requirements we think necessary, but Codes L and M came nearest. Such a pump should possess a modular design so that the correct pumping cylinder, connecting assembly and pumpstand could be selected depending on the conditions prevailing in the area of installation.

For example:

The cylinder could be a standard brass or stainless steel one but with the options of different seals depending on the water quality and water table variations likely to be encountered.

The connecting assembly could be plain steel rod and galvanized pipe or, perhaps, ABS pipe and stainless steel rod as an option for very corrosive waters.

The pumpstand would be of fairly standard design but with options for the types of bearing and the base design (i.e. whether the pump is concreted in, or fixed to, the well apron with anchor bolts).

We recommend that such a design should be drawn up and field-tested as soon as possible.

There will still be the requirement for additional pumps for use in more unusual situations, such as very deep wells, pumping sandy water etc; designs similar to Codes B and D could play a useful role here.

ANNEX F

HELVETAS

Excerpt of the SATA-REPORT

"Les pompes a motricité humaine
au niveau du projet
Inventaire - Comparaison -
Types de pannes"

Projet de Forages Hydrauliques
Zone Mali-Sud

by A. Mathys, Hydrogéologue, [illegible]

1. INTRODUCTION

Au 31 Décembre 1981 la zone Mali-Sud (Cercles de Bougouni, Kolondièba et Yanfolila) était équipée de 170 pompes à motricité humaine, posées et entretenues par notre projet, toutes en état de fonctionnement.

Parmi ces 170 pompes il y a :

- 156 pompes Vergnet 4 C2
- 10 pompes ABI
- 2 pompes Bourga Simplex
- 1 pompe Bourga Super
- 1 pompe Deplèchin Tropic VII

2. LA POMPE VERGNET 4C2

2.1. INTRODUCTION

Cette pompe fonctionne selon le principe suivant :

- Refoulement de l'eau par dilatation d'un enceinte déformable (baudruche en caoutchouc) avec commande à pied en surface.

L'avantage de ce système est que les pièces susceptibles de s'user (celles du mécanisme de commande) sont accessibles en surface, sans devoir démonter toute la pompe et peuvent être changées rapidement par un des usagers ayant un minimum de formation.

Le corps de pompe immergé, relié à la surface par 2 tuyaux en PVC souples peut être ramené à la surface par 2 personnes, sans instruments de levage. Pour peu qu'ils disposent d'une formation technique minimale et qu'ils puissent se procurer les pièces de rechange, cette pompe peut-être prise en charge totalement par ses usagers.

La pompe Vergnet comporte cependant certains désavantages :

- Faible débit (env. 700 l/h) *
- Pannes trop nombreuses (voir ci-dessous)
- Prix des pièces de rechanges trop élevé par rapport au pouvoir d'achat des villageois.

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* Les débits des pompes mentionnés dans ce rapport sont des débits réels, obtenus par un pompage normal.

2.2. INVENTAIRE DES POMPES ET DES PANNES

La pompe Vergnet est encore à l'état de prototype. Ses fabricants proposent toujours de nouvelles modifications. Pour faire un inventaire significatif, il a été nécessaire de faire 2 groupes de pompes :

- Les pompes "nouveau type", avec cylindre inox et nouveau système de réamorçage, comme elles sont installées depuis environ une année au projet. L'inventaire des pannes s'étend de la date de la pose au 31 Décembre 1981.
- Les pompes "ancien type", avec cylindre généralement en laiton chromé et ancien système de réamorçage.

  Ces pompes ayant toutes une ou plusieurs années de service, l'inventaire des pannes porte sur la période du 1er Janvier au 31 Décembre 1981 et donne par là une idée de l'entretien annuel que nécessite la pompe Vergnet.

2.2.1. Pompe Vergnet, équipement "nouveau type"

2.2.1.1. Tableau 1 : Inventaire des pompes et des pannes

Dans cet inventaire il est noté :

- Le lieu d'implantation et le Cercle (B = Bougouni, K = Kolendièba, Y = Yanfolila).
- La profondeur de la crépine (en m)
- Le nombre de jours de service

Nous avons distingué :

- Les interventions sur la partie supérieure de la pompe (pièces d'usure accessible au niveau de la pédale).
- Les interventions sur la partie inférieure, nécessitant l'enlèvement de la fontaine et la sortie du corps de pompe.

Les pièces n'ayant pas nécessité de changement et reconnues comme fiables ne sont pas mentionnées dans le tableau. Ce sont :

- Le cylindre de commande inox qui, malgré un contrôle regulier de son diamètre intérieur, n'a jamais marqué d'usure notable.
- Le boitier supérieur du corps de pompe, qui n'a marqué aucun défaut depuis qu'il est en inox.
- La pédale.
- La baudruche qui, sur l'ensemble des pompes et depuis le début du programme n'a connu qu'un déchirement.

2.2.2.2. Récapitulation des pannes et commentaires au tableau

Sur 73 pompes, non-neuve au départ et en service pendant une année il a été relevé :

- 61 interventions sur la partie supérieure
- 32 interventions sur la partie inférieure.

soit un total de 93 interventions, soit plus d'une panne (1,3) par pompe.

Détail des pannes et leur fréquence par rapport au nombre total de pompes.
Interventions parties supérieures :

33	joints de piston	45 %
28	Pistons	38 %
25	Segments racleurs	34 %
18 X 4	Segments	25 %
15	Bagues de guidage	21 %
4 X 2	Butées basses	5 %
2	Ecrous de guidage	3 %

Interventions parties inférieures :

26	Changements de clapets	36 %
dont : 12	clapets réamorçage	16 %
11	clapets d'aspiration	15 %
4	clapets de réfoulem.	5 %
5	Manchons	7 %
1	Changement de cylindre	
1	Changement boitier supérieur du corps de pompe.	

Remarque : La somme des fréquences des pannes est supérieure à 100 % car une intervention comprend souvent le changement de plusieurs pièces.

On retrouve les mêmes types de pannes que sous 2.2.1. mais avec une fréquence beaucoup plus élevée. Pour les interventions sur la partie inférieure, notons le changement de 5 manchons dû à l'usure du filetage. Or ces manchons ne sont pas interchangeables, il est nécessaire de les dessouder puis de ressouder un nouveau manchon, ou de changer toute la fontaine, ce qui est onéreux.

Le nombre d'interventions sur les clapets montre bien leur faiblesse. Le clapet de réamorçage a été modifié par la suite mais pas le clapet d'aspiration (11 pannes). Le clapet de réfoulement présente un taux de panne acceptable.

2.3. APPRECIATION GENERALE DE LA VERGNET 4 C2

En fonction des données ci-dessus on peut calculer le coût moyen des pièces de rechange par pompe et une année de fonctionnement.

Nous n'avons pas inclus dans notre calcul les clapets de réamorçage puisque les anciens ne sont plus montés et que les nouveaux ont fait jusqu'à présent la preuve de leur fiabilité.

La base de calcul est le prix des pièces départ usine majoré de 10 %.

Les pièces de la liste sous 2.2.2.2. représentent une valeur totale de 831'725.-FM soit environ 11'400.-FM par pompe.

Pour que la Vergnet soit une pompe fiable le constructeur doit :

- Améliorer le clapet d'aspiration
- Prévoir le manchon interchangeable
- Donner au piston une plus grande résistance à l'usure.

D'autre part, et ce qui n'apparait pas sur les tableaux, la qualité de la finition laisse beaucoup à désirer :

- Aucun des cylindres inox reçus ne sont polis à l'intérieur. Cela signifie que la pompe, tel qu'elle est livrée par le constructeur n'est pas utilisable à cause des frottements trop importants entre le piston et le cylindre, ce qui nécessite un polissage du cylindre par nos soins avant la pose

- Un nombre important des clapets reçus ne sont pas étanches.

Lorsqu'un débit important n'est pas nécessaire, cette pompe pourrait être la solution idéale dans le sens où elle peut être prise en charge par ses utilisateurs, et à condition que le fabricant fasse preuve de plus d'exigence sur la finition et le contrôle des pièces.

3.- LES POMPES A TRINGLES

3.1. INTRODUCTION

Le mécanisme est celui d'une classique pompe à piston. L'eau est refoulée par le mouvement de va et vient d'un piston immergé mis par une tringlerie de commande placée à l'intérieur de la colonne de refoulement (tubes galvanisés).

Cette tringlerie est commandée en surface soit par un levier soit par un volant.

Le corps de pompe étant toujours immergé, l'ensemble piston-segment et le cylindre s'use peu. Elle est par conséquent plus fiable, mais nécessite pour son installation comme pour toute intervention sur la partie immergée un système de levage (trépied + palan) lourd et encombrant et ne peut par conséquent être réparée, en principe, que par un service technique compétant.

Le principe du volant parait meilleur car le mouvement communiqué au piston est règulier alors qu'un levier sera manoeuvré différement par les usagers (petits coups pour les enfants, grands coups pour les adultes) et il en résulte une usure différentielle du piston.

3.2. LA POMPE ABI

La pompe ABI, fabriquée en Côte d'Ivoire est une pompe à tringle reliée directement au bras par une entretoise. 10 pompes sont actuellement en service au projet où elles donnent satisfaction.

Inventaire des pompes

Village		Profondeur crépine	Jours de service
1 Banzana (Marché)	B	25,0	368
2 Banzana (Marigot)	B	21,0	367
3 Bougouni (Faraba)	B	18,0	395
4 Dani	B	18,0	306
5 Goualala	Y	18,0	202
6 Koumantou (Marigot)	B	24,0	386
7 Tonfa (Route)	B	13,0	385
8 Tonfa (Nord)	B	14,0	384
9 Torola	B	30,0	365
10 Wogona	B	12,0	365

Ces 10 pompes ont une moyenne de 352 joursde service.

1 intervention a été nécessaire à Goualala (changement des thordons) sur la partie supérieure de la pompe.

Aucune intervention n'a été faite sur la partie inférieure, nécessitant un démontage complet de la pompe.

Cette pompe a un débit de 1 m^3/h. Elle est appréciée des usagers par sa facilité de maniement. Elle a l'avantage d'être fabriquée en Côte d'Ivoire.

3.3. LA POMPE BOURGA

La pompe Bourga, fabriquée a Sevaré (MALI) est une pompe à tringle mue par un double volant.

Il existe plusieurs types de pompes Bourga. Nous avons au projet :

3.3.1. La Bourga Simplex

La Bourga simplex débite 2 m /h avec un piston Ø 100 mm (crépine à 21 m) et 1,6 m^3/h avec un piston Ø 90 mm (crépine à 27 m).

Elle peut être maniée par un adulte ou deux enfants.

Nous avons deux pompes en service :

Bassa (B) crépine à	21 m	215 jours de service
Bougouni (Lycée) crépine à	24,5 m	30 " "

Une intervention a eu lieu sur la pompe de Bassa à la suite d'une rupture du manchon de la bielle, qui a dû être ressoudé.

14 pompes Simplex vont être prochainement installées par nos soins.

3.3.2. Bourga Super

Construite sur le même modèle que la Simplex elle offre un débit de 4 m^3/h, mais doit être maniée par deux adultes ou quatre enfants.

1 pompe est installée à :

Folona (B) crépine à 21 m 318 jours de service où elle n'a jamais nécessité d'intervention.

Les pompes Bourga ont l'avantage d'être montées au MALI. Elles offrent un débit intéressant.

Du fait de son inertie, le volant demande un effort pour être mis en mouvement et est de ce fait un peu plus pénible a manoeuvré pour les jeunes enfants et les vieilles personnes que la pompe à bras.

Le contrepoids à levier est peu pratique et peut se révéler dangereux.

3.4. LA POMPE INDIA MARCK II

La pompe India, fabriquée aux Indes est une pompe à tringles, mues par un bras. La liaison entre le bras et la tringlerie se fait par l'intermédiaire d'une chaine (style chaine à moto).

Une pompe India a fonctionné pendant 125 jours à Bougouni sans problème. Au bout de cette période la partie supérieure du corps de pompe s'est dévissée, et lors de l'intervention du mécanicien le corps de pompe et la tringlerie sont partis au fond du forage.

Elle a un débit comparable à la pompe ABI, mais son coût est moitié mais élevé.

4 pompes India vont être mises en service prochainement au projet.

3.5. LA POMPE DEPLECHIN TROPIC VII

Pompe a volant, elle est comparable à la Bourga Simplex mais présente l'avantage d'avoir le contrepoids inclu au volant.

D'autre part se système piston - clapets peut être sorti sans avoir à démonter la colonne de refoulement (tubage), mais un palan est tout de même nécessaire pour soulever le bâti de la pompe.

Une pompe Depléchin est en service au projet depuis 26 jours.

4.- NOUVELLES POMPES PREVUES

Au cours de l'année 1982 le projet va tester 3 nouveaux types de pompes :

La pompe Briau Nepta mixte 2 personnes	(10 pompes)
La pompe Briau Nepta mixte 1 personne	(4 pompes)
La pompe ABI-Vergnet "	(2 pompes)

La pompe Briau Nepta est une pompe à tringles mue par un bras. La liaison entre la tringlerie est le bras se fait par l'intermédiaire d'un cable en polyester.

La pompe ABI-Vergnet fonctionne selon le même principe de la Vergnet 4 C2, soit refoulement par déformation d'une membrane élastique, mais elle est manoeuvrée par un bras.

5.- CONCLUSIONS

Comme l'expérience l'a prouvé en Côte d'Ivoire, les usagers doivent être le plus possible indépendant d'un service d'entretien public. C'est pourquoi il est indispensable d'assurer une formation technique à des responsables villageois afin qu'ils soient capable de réparer leur pompes.

Dans ce contexte la pompe Vergnet 4 C2 représente la seule alternative, malgré son faible débit et son nombre important de pannes, du moins dans un premier stade.

Dans un second stade on peut envisager la formation de réparateurs régionaux sur pompes à tringles, qui seraient équipés du matériel de levage nécessaire.

Un service centralisé à Bougouni reste indispensable pour l'approvisionnement en pièces détachées pour le dépannage éventuel de cas difficiles et pour la formation technique.

Bougouni, le 31 Décembre 1981

A. Mathys

Hydrogéologue

ANNEX G

RURAL WATER SUPPLY IN DEVELOPING COUNTRIES

Excerpt of Proceedings of a workshop on
training held in Zomba, Malawi,
5 - 12 August, 1980

Shallow Wells and Hand Pumps

Aseged Mammo[1]

At present, there is a general lack of potable water in rural parts of Ethiopia. There are a number of ways of supplying such water: engine-driven pumps, from boreholes, shallow wells, springs, rivers, lakes, etc.

Of the many alternatives, springs are widely regarded as the cheapest source of clean water, if they are available. Rivers and lakes are few, and streams last only during or just after the rainy season, after which time they are too turbid to be used as a source of potable water.

Another source of potable water is hand-dug wells. In rural Ethiopia, one of the local craftsmen is always the well digger. At present, however, most hand-dug wells are improperly constructed and use primitive water-lifting devices such as buckets and inner tubes that are unhealthy and time consuming. The use of hand pumps would facilitate the withdrawal of water from these wells.

In a country like Ethiopia, where there is a tremendous demand for hand pumps and a shortage of funds for importing foreign goods, a plausible hand pump has to be inexpensive and reliable to be imported.

This report, apart from a short section on wells, is essentially a comparison of some hand pumps that are in use in Ethiopia, both imported and locally designed and manufactured.

The project is financially and technically supported by the International Development Research Centre (IDRC) and the United Nations Development Programme/United Nations Industrial Development Organization (UNDP/UNIDO), and implemented through the Ethiopian Water Resources Authority (EWRA).

The designing and manufacturing were carried out in the Mechanical Engineering Department, Faculty of Technology, Addis Ababa University. This research is essentially a continuation of research on hand pumps and windmills that took place at Addis Ababa University during the "Development through Cooperation Campaign," which spanned the years 1974-1976.

Wells

Selection of Well Sites

According to the EWRA Central Region, and presumably in general, almost all water points are established at the request of the local population. When the request arrives, a team is sent to determine what type of water-point design will satisfy the local demand, as well as be most economical to implement.

The team first considers the possibility of springs in the vicinity. If none are available, it must then consider shallow or deep hand-dug wells or perhaps boreholes with engine-driven pumps. Wind-powered water points are not, as yet, available.

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[1] Research and Development Engineer, Mechanical Engineering Department, Addis Ababa University, Addis Ababa, Ethiopia.

Construction

When the most economical water-point design is a hand-dug well, a work crew is sent to camp near the site. Presently, a major problem exists with the supplying of construction and other support equipment to the work crews. As much as 50 percent of the crew's productive time can be lost trying to purchase and ship materials and handling per diem requisitions.

Technical difficulties are less of a problem. For example, if the soil is too loose, it will cave in before the casing is lowered. A temporary wooden frame, therefore, must be made as digging proceeds. Another problem with loose soil is that it keeps falling into the water, making frequent cleaning of the well necessary. In one location in Awara Melka, 200 km southeast of Addis Ababa, the aquifer material contained a lot of pumice which is much less dense than water. These rock particles were suspended in the water and were sucked into the hand pump that had been installed. After a month of operation the piston and foot valve were both stuck.

There is now a standard well design developed by the Central Region for use by the EWRA. The United Nations Children's Fund (UNICEF) and the Evangelical Church Mekane Yesus (ECMY) are two of the well "suppliers" to this project with their own standard designs. These designs are affected by the pump type to be used, the terrain, and the degree of cleanliness required of the water (e.g., UNICEF well covers have no manhole).

This particular project doesn't deal with well digging or construction directly, but requests wells to: (1) have studs cast in the concrete to match the holes in the pump stands being used and (2) be easily accessible from the main road and within a 200 km radius of Addis Ababa. In areas beyond this boundary, maintenance and follow-up are carried out by local residents. Eventually, all manufacturing (except for pistons and foot valves), installation, and maintenance of pumps will be carried out by the regions themselves. Currently, there are no hand pumps installed in boreholes in the Central Region and very few elsewhere.

Hand Pumps

In the EWRA Central Region (where more than two-thirds of the pumps are installed to date) there are three categories of hand pumps being used. The following list gives the category and the types of pumps used within each: (1) imported: (a) Consallen, (b) mono (myno); (2) semi-local: (a) Boswell; and (3) local (EWRA/IDRC): (a) BP, (b) BPL, (c) type C, (d) type D. This list doesn't include all hand pumps that are in use in the Central Region, but is a collection of those hand pumps which are closely connected to the EWRA and, hence, this project.

Consallen

These hand pumps were installed when the United Kingdom was giving aid to the EWRA Central Region. They are installed mainly in the Maki area about 130 km south of Addis Ababa, and have a 2, 2.5, or 3 in. (5.1, 6.4, or 7.6 cm) piston and cylinder (depending upon the depth of the well); a 1.25 in. (3.2 cm) riser PVC pipe; steel pump rod; and steel pump stand with lever. The piston has rings and is running in a stainless steel cylinder. The foot valve consists of a rubber sealer against a slotted or perforated steel body. Unless foreign particles are introduced, the sealer is quite effective. The riser pipe is connected with a PVC flange to the pump stand.

When operated, because of the tight fit between the piston and cylinder, the pump feels heavy, even at low pumping heads. Also, the riser pipe snakes, particularly at faster pumping speeds. Consequently, the PVC flange at the pump stand breaks and repeated failures of the 1.25 in. (3.2 cm) riser pipe at the threaded connection were experienced. Foot valve leakage was not acceptable in many cases, after some time of operation. Except for the flange connection in the stand, the part of the pump above ground stands up to a lot of mishandling.

Mono

This is a rotary positive-displacement pump. The piston is a solid steel helix running in a matching rubber cylinder. There may or may not be a foot valve because the fit of the piston and cylinder is very tight. The transmission shaft is steel and is guided by rubber bearings in the riser pipe. Pumping is accomplished by rotating the arms that are on opposite sides of the pump stand. A bevel-gear pair transmits the torque to the pump rod (transmission shaft), which has the piston attached to its other end.

This pump is normally regarded as the best type as far as reliability and ease of pumping are concerned. The only maintenance problem is oil loss at the seal of the gearbox bearings. The United Nations Children's Fund, which is importing and installing this type of pump, leaves a quantity of oil with a person living nearby to fill up the gearbox once a month or as required. The newer version of the mono pump, the myno pump, will have double O-rings at these points in the gearbox to reduce oil leakage. If, however, there is a considerable loss in the height of the static water level (drought), parts which rely on water for lubrication, such as the starter in the mono pump, could suffer heavy wear and tear. The greatest problem with this type of pump is its cost, which is presently about U.S.$1200.

Boswell

In the past, this pump was imported in its entirety. Now, the only imported parts are the pump rod, piston, and cylinder. The Boswell pump is basically a piston pump with a distinctive, above-ground structure. The piston and foot valve both possess leather cup seals to minimize leakage. The cylinder is brass-lined, galvanized steel pipe. The foot valve can be withdrawn without taking up the 2 in. (5 cm) galvanized steel riser pipe by screwing the lower end of the piston into the foot valve. The pump rod is galvanized steel.

There are many varieties of this pump, but generally the pump stand is always offset from the riser pipe. The lower arm is very long (about 2 m, with a relatively small mechanical advantage of 3.3) and the pump stand is relatively high.

Installation of this pump is difficult because the stand and riser pipe are offset. As a result, alignment of the pump rod end of the lever with the "stuffing box" (the above-ground portion of the riser pipe) is never perfect. The pump rod upper end normally scrapes the wall of the riser pipe. The stops which limit the up and down strokes of the handle are frequently worn away. The piston cup seals expand when immersed in water and pumping is very heavy, even at low heads, just after installation. By the time pumping is no longer heavy, the cup seals have worn down and are almost ready for replacement. Unscrewing of the piston from the pump rod has been experienced.

The pump stand, piston, and cylinder are the major problem areas of this pump. In agreement with UNICEF and EWRA staff, it was decided that an attempt be made to modify the Boswell pump in this project. The tentative plan was to (1) have the stand screwed directly onto the riser main by using the type BPL pump stand designed by this project for this purpose (with a mechanical advantage of 4 and a maximum stroke of 20 cm); (2) redesign the leather cup seal to reduce piston-cylinder friction, but keep volumetric efficiency reasonably high; and (3) have pins drilled through parts of the piston to prevent it from working itself loose.

The pump stand is being manufactured at the Society of International Missionaries (SIM) workshops at the rate of 120 per year. It is planned to manufacture 160 per year by extending the SIM and/or the Oxfam workshop at the EWRA.

The pump rod, piston, cylinder, and foot valve are still being imported at a cost of U.S.$100 per pump. The pump stand is being made locally for Br370 (U.S.$178) and the 2 in. (5 cm) galvanized steel riser pipe is locally purchased.

Local EWRA/IDRC Pumps

This project is working on three types of hand pumps: types B, C, and D. Type B pumps are further subdivided into types BP and BPL. They consist of a piston, cylinder, and foot valve submersed in water. Type BP

(Fig. 1) uses plastic (PVC) riser pipe and a direct-acting handle operating in a bicycle-pump fashion. It is designed for shallow-well pumping (up to 20 m depth). Type BPL (Fig. 2) is the same as type BP below the well apron, but employs above-ground leverage and is designed for use in deeper hand-dug wells (depths up to 35–40 m). Type C (Fig. 3) is an inertia pump in which the water column and riser pipe are suspended on a spring and oscillate at the natural frequency of vibration of the system. Type D is also an inertia pump in which only the water column is oscillating.

Type C (Fig. 3)

These pumps have pipes that are suspended on a spring on the well apron. The foot valve is at the other end and pumping is accomplished by oscillating both pipe and water in the pump. The pump is self-priming, has very few parts, and has

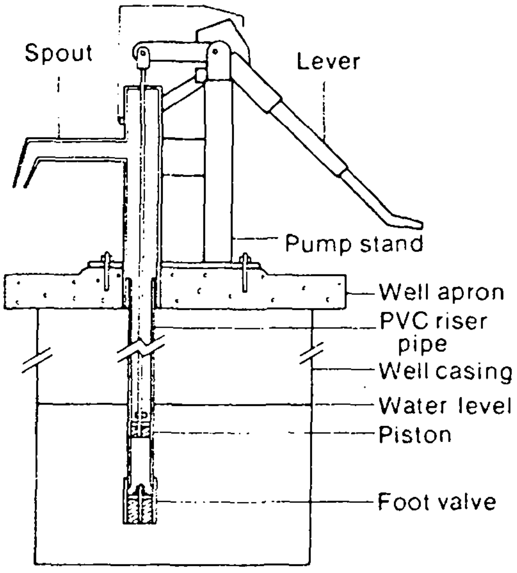

Fig. 2. Type BPL pump assembly.

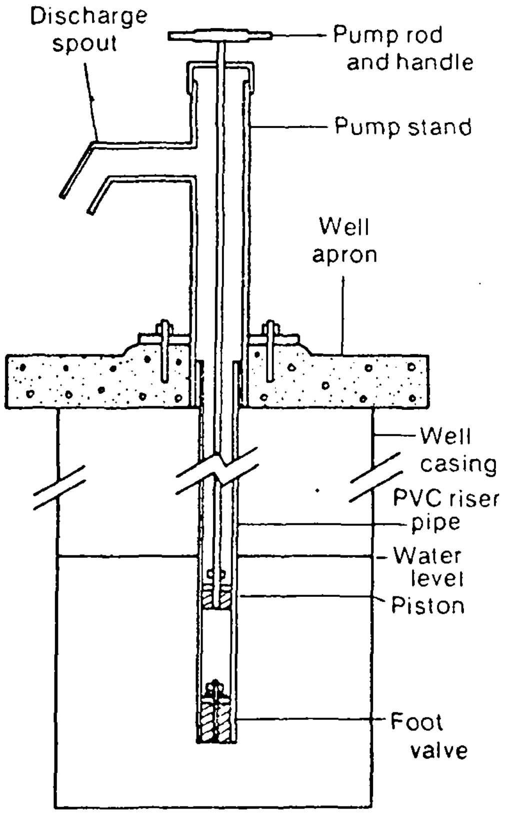

Fig. 1. Type BP pump assembly.

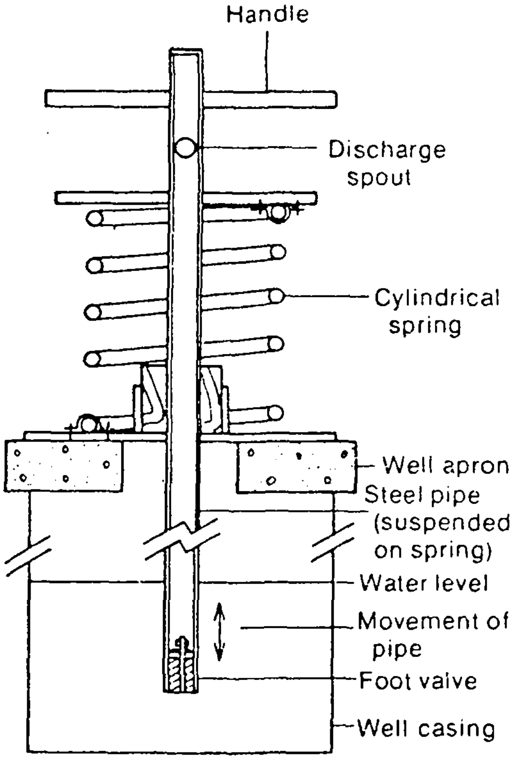

Fig. 3. Type C pump assembly.

high efficiency. It can, theoretically, be used with very high heads, and is relatively easy to pump. Collection of water is accomplished via a flexible hose attached to the discharge spout. Development of this pump has been slow due to the emphasis placed on other pump types. The main problem with this pump is that the required spring characteristics are demanding. The operating speed, i.e., the natural frequency of vibration of the system, must be 1.5-2 Hz. On wells with heads of up to 14 m, induced stress in the spring wires is 3000-5000 kg/cm². Because the springs are not readily available locally, facilities for the manufacturing of the springs will be necessary if the pump is to be used. Another problem which must be solved involves obtaining the steel needed to make the springs, because it is not available locally. It will be necessary to overcome these difficulties if the type C pump is to be successful.

Type D

This pump has a stationary pipe in which the water oscillates at its natural frequency. Excitation is accomplished by a piston and cylinder arrangement on the top. At the other end of the pipe is a foot valve.

Because the pipe is stationary, induced stresses are relatively low. The fact that the pump head (cylinder and actuating piston) could be arranged offset from the well makes this pump attractive as a sludge pump (dewatering pump). This pump is not self-priming, however.

Experiments on this pump were temporarily stopped due to a foot valve problem (it would not tolerate muddy water). When the foot valve problem was finally solved, priority was then given to type C pump development and later, based on a consulting report from the University of Waterloo, toward the type BP pump. The BP pump has since been used as a sludge pump as well, which led to further delay in the development of the type D pump. More information on the type D pump will become available in the future when efforts will be geared away from the type BP pump, which is now in a relatively advanced stage of development.

Type B

This pump consists of a pipe at the end of which is a foot valve. The lower end of the pipe serves as a cylinder. The piston is submerged in the water at the end of a pump rod. The piston has a valve incorporated in it. A type A pump, which was the same as the type B pump, except that it had no valve in the piston, was discarded early in the project in favour of the type B pump.

Experiments on the type B pump were first started using galvanized steel pipe for the riser pipe and cylinder. It was found, however, that the surface of these pipes was too rough, resulting in an inefficient system and considerable wear on the piston. It was then decided to line the bottom metre of pipe (the cylinder) with thin PVC pipe.

The type BP pump (Fig. 1) as it stands now, has a pump stand made of galvanized steel pipes that are welded and painted. The riser pipe is PVC (1.5 or 2 in. (3.8 or 5.1 cm)) and screws directly onto the stand. The joints between the pipes are made using steel couplings and at the end is a foot valve. The pump rod consists of pipes cement welded by bell ends, and at the lower end is the piston. This type of pump is designed for pumping from depths up to 10 m with the 2 in. (5.1 cm) (BP50; Fig. 4) riser pipe and from depths up to 20 m with the 1.5 in. (3.8 cm) (BP40) riser pipe. Lower heads (1-4 m) could be handled with 3 in. (7.6 cm) or 2.5 in. (6.4 cm) pipe, but these sizes are not produced locally. The handle is made of wood and is clamped onto the 0.5 in. (1.3 cm) PVC pipe pump rod. There is no mechanical advantage on the BP50 and BP40 versions, which decreases pump stresses and cost while making pumping more difficult.

Installation of both the BP and BPL pumps is not time consuming; 3 h are sufficient for two technicians and a helper to completely install a BP40 or BP50 pump. In one instance, installation was completed in 1.5 h. The BPL pump would take about 5 h to install because the pump rod has to be measured exactly, and the steel rod and 0.75 in. (1.9 cm) PVC pipe pump rod joined on-site. The following are some the problems experienced with this pump that have now been solved.

Fig. 4. BP50 pump supplying 20-25 m^3/day from a depth of 3 m to the town of Assossa (pump installed in August 1979).

Pump stand. The most frequent problem with the pump stand involved the pump-rod guide, which was also serving as a crude stuffing box. The wood which was used had to be boiled in oil to make it a more durable bearing surface. When fastened with screws and/or when it was in contact with the handle during pumping, the guide would break and the pieces would go down into the riser pipe. To avoid the screws that initiated most of the cracks, the "cap" idea was started. The impact of the handle was still breaking the wood, however, so it has now been replaced with polyethylene, which has to be imported.

Another problem involved children putting material in the spout opening, which caused heavy piston and cylinder wear and eventual sticking. To eliminate the problem the spout, which was straight originally, was designed to face downward to make it more difficult for children to put material into the opening.

In one instance, the base plate cracked and the pump stand and riser fell down. To remedy this problem, ribs were welded onto the base plate to reinforce it.

Pump rod. Within 1 week of the installation of the first pump, the pump rod was broken about 30 cm below the handle. Although thin-walled steel tubing was added to reinforce the pump rod, this too was breaking, just below the lower bolt that attaches the pump rod to the handle. As a result, present pumps have at least 1 m of pump rod reinforced with a solid steel bar. To avoid drilling holes in the pump rod it is now clamped to the handle by friction only. A better solution to this problem, however, would be to use a solid nylon bar which is strong enough, but is lighter and can be welded to the PVC pipe. Nylon of this nature will be manufactured locally some time in the future. The pump rod stop (which prevents the rod from being pulled out all the way) was frequently becoming detached. Now, a bell-end joint on the pump rod about 50 cm below the handle also serves as a stop.

Riser pipe/cylinder. This is the major problem at present. Because the 2 in. and 1.5 in. (5.1 cm and 3.8 cm) pipes received from the local factory were not consistent in their dimensions, had wavy internal surfaces, a high out of roundness rate, and an uneven wall thickness, longitudinal cracks in the pipe developed after a few weeks of operation. After being approached on the matter, the management of the factory that had been providing the pipes pledged to supply pipes of better quality.

In a couple of instances, the riser pipe failed at the root of the thread coupling it to the pump stand. Currently, a design change is under way that avoids threaded connections (stress concentration). Because plastic couplings are not locally available, standard steel pipe couplings are used for the other connection.

Because the largest high pressure pipe produced by the factory is 2 in. (5.1 cm) in diameter, it is used in the lower head pumps

(1-4 m) (2.5 or 3 in. (6.4 or 7.6 cm) pipes would give higher discharges).

Cylinder. The last metre or so of riser pipe also serves as the cylinder. Field tests have shown that loss of volumetric efficiency has been mainly due to wear on the PVC cylinder rather than on the polyethylene piston. Thus, it is now envisaged to have the last metre of the riser pipe consist of a detachable unit, which can be replaced when it wears down (every 6-12 months, depending on the amount of usage and type of pump). It is more critical on the BPL type pump with its short (20 cm) stroke.

Piston. The piston also becomes a serious problem on the BPL type pump. Longer pistons (two coupled together) were unsuccessful in decreasing the rapid loss of volumetric efficiency. A design change to a piston with rings, after the preliminary IDRC (University of Waterloo) design, and which can easily be installed and withdrawn in the riser/cylinder, is under way. No changes in design are immediately planned on the pistons of the BP50 and BP40 pumps. However, there may be slight changes when the units go into mass production.

Foot valves. The centrally-pinned type design was abandoned early in the project in favour of the present design, in which the sealing rubber flapper is free to move up and down on a central stem (brass bushing). Because the steel washers adjacent to the brass have shown a tendency to corrode, the bushing is made of steel. The 1.5 in. (3.8 cm) foot valve was troublesome because it had little sealing area. Now, all foot valves are of the 2 in. (5.1 cm) type, with an adaptor/coupling for use on 1.5 in. (3.8 cm) pipes. This foot valve is now very effective in sealing and highly tolerant to foreign particles. There have been no further foot valve problems since the last modification, except once, when excessive amounts of floating pumice were sucked into the pump.

Cost Comparisons

Prices quoted in Table 1 are from the people who import the pumps. In the case of the local pump (type BP), the figures are taken from Aseged and Jensen (1979).

Conclusions

With respect to costs, spare parts, and backup, the best pump is the type BP pump for heads of up to about 20 m. However, the robust pump-stand design of the Consallen and overall reliability of the mono pump are desirable. In these respects, the type BPL pump requires further development.

Table 1. Price breakdown of various pump types.

Pump type	Price (Br) (1 Br = U.S.$0.48)	Approximate amount of foreign currency in price (%)	Remarks
Consallen	900[1]	100	
Mono (myno)	2480[1]	100	Myno with double oil seal will be slightly more expensive than mono
Boswell	860[2]	40	25 m head
BP50	185[3]	20	8 m head
BP40	220	20	16 m head
BPL	450	20	25 m head, with similar piston as in BP50

[1] *Consallen and mono pump prices are for the pump stand, piston cylinder assembly, and pump rod only.*

[2] Stand, BR370; riser (5.1 cm × 25 m), Br300; piston, foot valve, and pump rod, Br207.

[3] Labour cost for type BP pumps assumed at Br5/h.

It has also been shown from field tests, however, that no hand pump is maintenance free. Routine inspection and maintenance cannot be done by the EWRA because it does not have the manpower, organization, or sufficient funds.

Therefore, in order for any hand-pump program to be successful, the participation of the community is imperative! Maintenance should be carried out at the village level, with only marginal involvement from a central government body.

Aseged, M. and Jensen, K. 1979. Research and development in water pumping technology in rural areas. Interim Technical Report. Polyethylene PVC Hand Pump. Addis Ababa, Ethiopian Water Resources Authority.

Shallow Wells Project, Shinyanga Region

Y.N. Kashoro[1]

Shinyanga Region is one of the 20 regions in Tanzania south of Lake Victoria. It has an area of about 50 000 km^2 and is divided into four districts (Shinyanga, Maswa, Bariadi, Kahama) and one subdistrict (Meatu). It has a population of 1 325 000, who are settled in 684 villages.

The region has a semi-arid tropical climate, with an average annual rainfall of 700-1000 mm. The rains start in mid-October and end in early May. The elevation in the region varies between 1500 m above sea level (asl) in the Bariadi District and 1100 m asl in some parts of the Kahama District. The majority of the region has an undulating landscape. The temperature is fairly constant throughout the region, with highs ranging from 28°C in March to June to 32°C in October and lows varying from 15°C in June and July to 19°C in October to December.

Shinyanga Shallow Wells Project

The Shinyanga shallow wells project started in October 1974 in response to recommendations of the Shinyanga water master plan survey, which was carried out in 1973. In the survey report it was recommended that 2000 shallow wells be constructed in the Shinyanga Region as a quick and inexpensive method of serving most of the population in the region. This was followed by a bilateral agreement between the United Republic of Tanzania and the Kingdom of the Netherlands, whereby it was agreed to set up a construction unit to construct 700 shallow wells and in the course of construction to train Tanzanians to man the project. This task was accomplished in June 1978 and the project was turned over to the Tanzanians. Table 1 shows the present distribution of shallow wells throughout the region.

Selection of Well Sites

Requests and applications for well construction come from the villages to the districts and, finally, to the region. At the district level, the applications are compiled in order of priority, the most needy villages being first. These lists of villages are then sent to the regional development committee with a copy going to the regional water engineer. The regional development committee decides which district or part of the region should be started first, bearing in mind that concentration in one particular area could be cheaper and construction could progress more rapidly.

Table 1. Shallow-well distribution throughout the Shinyanga Region.

District	No. of wells	No. of villages	Population served
Shinyanga	365	115	109500
Maswa/Meatu	262	80	78600
Bariadi	222	52	66600
Kahama	145	50	43800

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[1] Project Manager (Shallow Wells), Ministry of Water, Energy and Minerals, Shinyanga, Tanzania.

Knowing the villages and their priorities, a hydrogeologist studies aerial photos, maps, and all available data to locate possible seepage areas, riverbeds, old riverbeds, possible valleys, vegetation, etc. This is followed by a visit to the village, at which time he contacts the village chairman and others from whom he can seek information such as where the village is currently obtaining its water supply during the dry season and where, within the area, water might be found. A reconnaissance survey is then made of the village to locate potential sites for shallow wells based on accessibility, soil suitability, and population within the village. A study of the geology of the area is important for locating recharge areas and possible aquifer locations. Rainfall and evaporation data are also useful for determining potential water supplies in an area. Based on all of this information a survey plan is then made.

Surveying of Well Sites

After a thorough investigation, potential well sites are marked and a survey is carried out to determine if water is present and, if so, its quality and quantity. Two methods of drilling are used in the surveys depending on the material being penetrated: hand drilling methods are used in soft material and in hard material a mechanical drill is employed. Hand drilling can easily go down to a depth of 10 m in sand, loam, and other loose materials, whereas mechanical drilling is capable of penetrating hard weathered and cemented materials and normally continues until the water table is reached. If, during drilling, the soil tends to cave in or collapse, a casing is used. When the aquifer is reached, its thickness is measured and a pump test is carried out to determine the yield of the well. Water samples are also taken at this time to determine water quality. In the Shinyanga Region, high fluoride and salt contents are the main hazards to the potability of groundwater, particularly in East and Central Shinyanga District and Maswa. These factors influence the health of consumers. Efforts are made during site selection, however, to avoid such pollution problems.

Well Construction

In Shinyanga there are three methods used for constructing wells: hand-dug wells, hand-drilled wells, and mechanically-drilled or dug wells.

Hand-Dug Wells

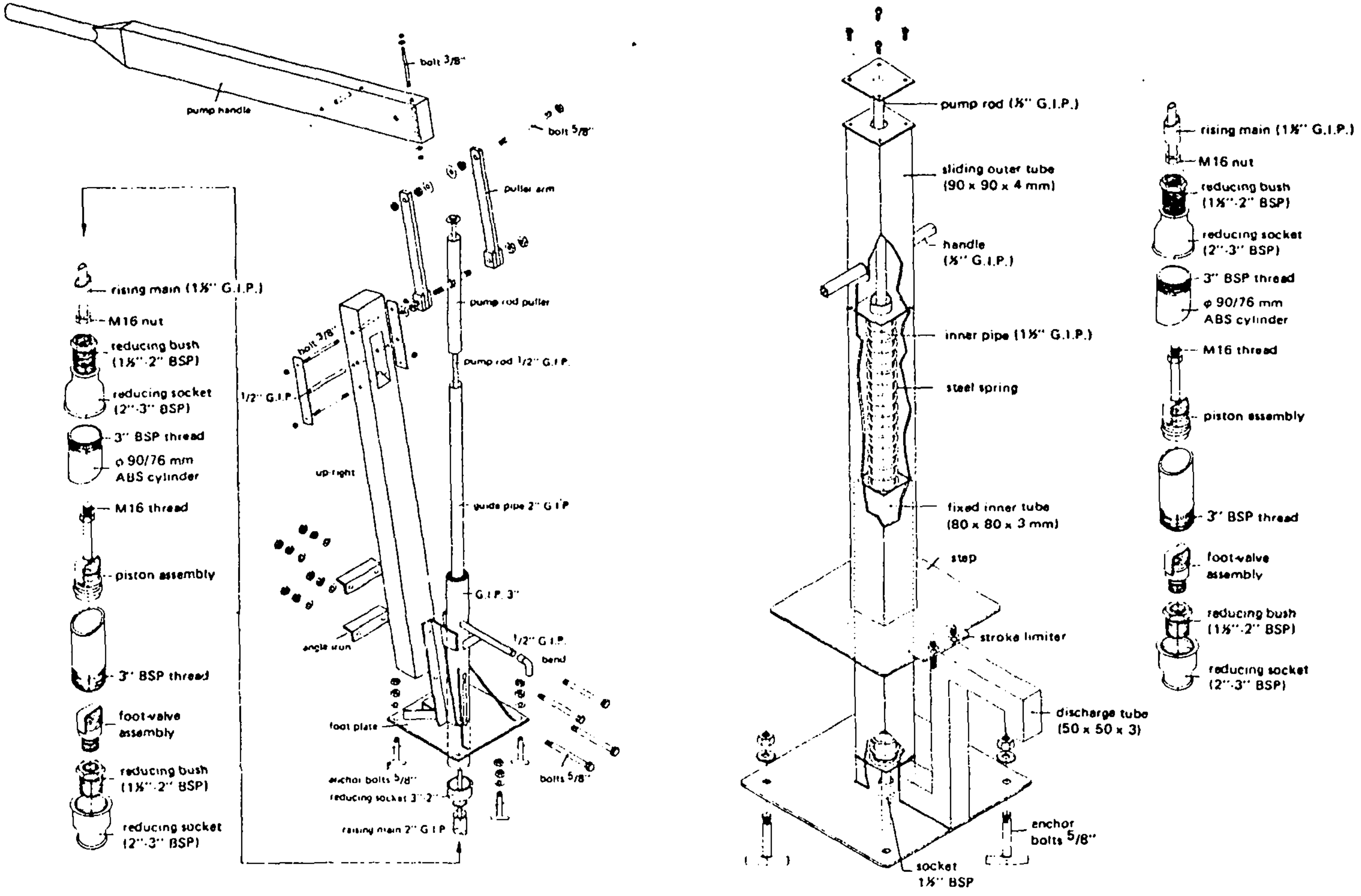
This type of well is constructed using traditional methods of digging a hole with a hoe or pickaxe. After reaching the aquifer, the hole is lined with concrete rings and covered with a concrete cover. Hand-dug wells become very expensive if the depth goes beyond 10 m. This is mainly a result of the need to use dewatering pumps during their construction and the cost of lifting soil from the well, which is time consuming and very laborious if hard layers are encountered. Using this method, one well sinker with four self-help labourers can dig two 7 m deep wells per month. This method of producing wells is appropriate in cases where it is felt that it is important to leave some knowledge of construction techniques at the village level.

Hand-Drilled Wells

Hand-drilled wells are drilled by using a 25 cm auger turned by two self-help labourers. When the hole has reached the required depth, it is lined with slotted 15 cm diameter PVC pipe casing and gravel-filter packing is applied around the outside of the pipe. This method is the cheapest method for drilling wells for hand pumps, but is only applicable in sand and soft materials where it is not difficult to drill with such an auger. One foreman and eight self-help labourers can drill two wells per week using this method.

Mechanically Drilled Wells

Where the aquifer is deeper or the material is harder and cannot be penetrated by hand drills, a percussion rig is used. The borehole is cased with slotted 15 cm diameter PVC pipe with gravel-filter packing around the outside of the pipe. This method, with some modification, could be used as a quick method of constructing inexpensive shallow wells. One foreman, four rig-crew members, and three labourers can produce one well per week. This method is the only



(a) (b)

Fig. 1. (a) Shinyanga pump; (b) Kangaroo pump (reproduced from Shallow Wells, 2nd ed., 1979, pp.126, 130, DHV Consulting Engineers, P.O. Box 85, Amersfoort, The Netherlands).

Table 2. Well-inspection report, June 1979-May 1980.

District	No. of wells	Total inspected	No. of repairs	Low recharge wells	Dry wells, November 1979	Wells polluted/ disinfected
Shinyanga	365	400	120	80	15	30
Bariadi	212	300	50	10	3	4
Maswa	152	200	30	5	10	7
Meatu	110	95	20	3	5	5
Kahama	145	310	46	6	3	24
Total	984	1305	266	104	36	70

one practical in cases where many wells must be produced in a short period of time. Its main disadvantage, however, is that it does not involve the community nor leave any drilling expertise in the community.

The Shinyanga Pump

The Shinyanga pump (Fig. 1a), which is an improvement of the United Nations Children's Fund (UNICEF) and Uganda pumps consists of four main parts: pump stand, wooden upright and handle, rising main and pump rod, and pump cylinder and piston. After taking the necessary measurements, the pump is installed and the rising main and pump rods are cut, threaded, and screwed together with the pump cylinder. The pump is then lowered into the well and the wooden uprights and handle are bolted together on the pump stand.

With the exception of the cylinder and piston, the rest of the pump is fabricated in a Shinyanga workshop. The workshop has the capacity to manufacture 35 pumps per month. Since June 1978 about 200 pumps have been sold to other regions in Tanzania.

The Kangaroo Pump

This pump (Fig. 1b) was designed to try to minimize maintenance by avoiding the use of hinge points requiring periodic lubrication. The head of the pump incorporates a spring which is compressed by pushing on a foot plate. As the spring recoils it produces the energy for the pumping stroke. Water can be pumped from a depth of 6 m with a 4 in. (10.2 cm) cylinder, 10 m with a 3 in. (7.6 cm) cylinder, and 20 m with a 2 in. (5.1 cm) cylinder. Because there are no hinges and wear on the pipes is minimal, a maintenance-free period of 10 years has been estimated for this design.

Maintenance of Shinyanga Shallow Wells

When construction is completed, the well is turned over to the village chairman, together with a certificate of well ownership. Two people are then selected and trained to maintain the well. If repairs to the well are required, a form is filled out and sent to the district maintenance officer, who is housed in the office of the district water engineer. Most of the villages now understand this system. However, due to a lack of transportation and an increasing number of breakdowns, the district maintenance officer cannot always cope with all of the requests for repairs which are received. By employing a maintenance officer at the divisional level, as the number of well repairs increases, this problem may be reduced. Apart from this, regular inspections are carried out at wells to determine their condition. Water level checks are also carried out. Pollution and chemical fluctuations are monitored as well (Table 2). In Shinyanga, unless improperly installed, the Shinyanga pump normally has a 2 year maintenance-free period. Women and children, being the most common users, look after their pumps well, because they know that a breakdown means walking a long distance to obtain unclean water. As a result, nobody tampers with the pump.

Mark Series Well Pumps

K. Jellema[1]

The hand pump is probably the most important contribution made by the government to the community in support of the wells program. Often, it is the pump that makes people enthusiastic about the program and, consequently, willing to dig a well on a self-help basis. When the people see how a pump on an existing well facilitates the drawing of water and improves water quality, it speaks for itself, encouraging the spreading of the program.

Mark Series Pumps

Pump design in its early stages was governed mainly by criteria such as investment costs, ease of installation, and local availability of parts. Later, the emphasis shifted toward factors related to maintenance and pollution control. It is now felt that the skills and resources required to make repairs, as well as the cost of worn-out parts, are of more importance than the initial investment costs.

There is another factor which influenced pump design. Being a program oriented toward assisting village communities, the response of the rural people was often so encouraging that pump production could not keep up with demand. Shortage of imported materials sometimes prompted the designer to follow solutions which might not be the best but would, at least, allow pump production to continue.

Design Modifications

The pump used in shallow wells was developed completely as a result of field research; no laboratory testing was carried out at all. This resulted in a considerable number of modifications, both to the pumpstand assembly and the "in-well" parts. Four pump stands have been in use since 1975, all of which operate on the "bicycle pump" principle (Fig. 1). Because pumping heads are usually less than 5 m, there is no need for lever-type pump stands and the accompanying "hinge" problems. A bicycle-type pump has the additional advantage of high plungers without seals (cup leathers or piston rings). Badly worn plungers still function satisfactorily when operated at high pumping rates. The advantages of a PVC pump pipe were realized soon after the first Mark I pumps were installed. No corrosion, lower investment costs, and a smoother surface are the obvious benefits of a PVC pump pipe.

Design modifications to the plunger and foot valve (in-well pumping mechanism) were more extensive than those to the pumpstand assembly (Tables 2, 3). Further modifications were introduced as a result of an International Development Research Centre (IDRC) sponsored international pump-research project. For example, the plunger was changed from a perspex disc to a PVC disc with a polyethylene sleeve because there is little friction between PVC and polyethylene. Thus, nearly all of the resulting wear occurs on the polyethylene part, which is cheap and easily replaced.

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[1] Wells Engineer, Department of Lands, Valuation and Water, Lilongwe, Malawi.

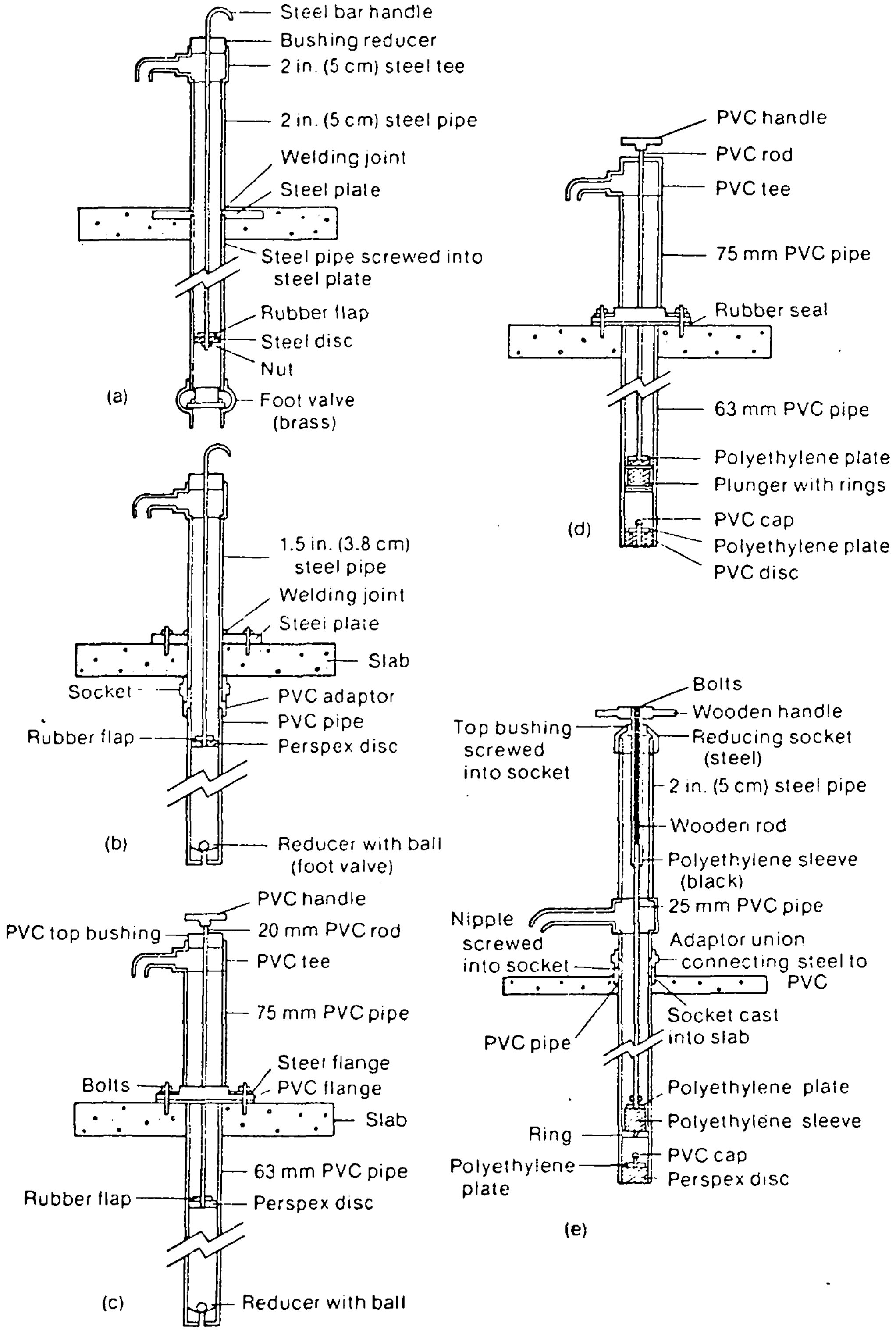

Fig. 1. Mark series well pumps. (a) Mark I; (b) Mark II; (c) Mark III; (d) Mark IV, and (e) Mark V.

Table 1. Modifications incorporated into the Mark V pump.

Pump type	Problem	Solution used in Mark V pump
Mark I-IV	Splashing water at the top bushing	Lowering the outlet tee and extending the outlet pipe away from the well head creates storage above the outlet, resulting in decreased leakage
	The pump had to be removed for measuring water levels in the well or when adding chlorine	A small socket (1 in. (2.5 cm)) is cast in the slab and closed with a plug that can be unscrewed for inspection
	Wastewater and dirt enter the well through small gaps between the flange and slab	The pump stand is screwed into a 3 in. (7.6 cm) socket that is cast into the slab. The resulting seal stops dirty water from entering
Mark II	The steel pipe of the pump stand is connected to the PVC pump pipe by means of a PVC adaptor with internal threads. Rust and frequent dismantling spoil the PVC threads	A special fitting, called an adaptor union, connects the pump pipe to the stand. This union has no PVC threads, only a PVC collar that holds the pump pipe
	Plunger inspection and checking for foot-valve leakage requires lifting of the entire pump	The PVC pump stand features a retractable plunger. In the case of the Mark V pump, the plunger can be withdrawn after the pump stand is unscrewed from the adaptor union
Mark II-III	Bouching as a result of foot valve closure	The plate-valve stroke of the foot valve should be as small as possible. At present, a valve stroke of 5 mm is used. A further decrease, however, might be feasible
Mark III-IV	The top part of the 20 mm PVC rod wears out in 1-2 years. When replacing the rod, a new handle is also required	The stronger 25 mm class 16 PVC pipe is protected against wear by a 1 in. (2.5 cm) polyethylene pipe that can be replaced by taking the bolts out of the handle
	Replacing the top bushing results in the cutting of the PVC pump rod	After removing the wooden handle, the top bushing can be screwed into the socket
	The PVC flange on this PVC pump head cracked due to excessive forces and/or aging of the PVC as a result of exposure to ultraviolet light. Repairs included a complete new pump-stand assembly	A pump stand made of galvanized pipe and fittings is very strong and all parts can be replaced if necessary

Table 2. Pump-stand assembly.

Mark series	Standpipe	Handle	Rod	Fixture	Top bushing
I	2 in. (5.1 cm) steel	Steel bar		Loosely to slab	Reducer
II	1.5 in. (3.8 cm) steel	Steel bar		Flange and bolts	Reducer
III/IV	75 mm PVC	PVC tee	20 mm PVC	Flange and bolts	PVC plate
V	2 in. (5.1 cm) steel	Hardwood	25 mm PVC	Screwed into 3 in. (7.6 cm) socket	Polypropylene

Table 3. In-well pumping mechanism.

Mark series	Pump pipe	Plunger body	Plunger valve	Foot valve
I	2 in. (5.1 cm) steel	Steel disc	Rubber flap	Brass
II	63 mm PVC	Perspex disc	Rubber flap	Reducer with ball
III	63 mm PVC	Perspex disc	Rubber flap	Reducer with ball
IV	63 mm PVC	PVC disc with polyethylene rings	Polyethylene plate	PVC disc
V	63 mm PVC	PVC disc with polyethylene sleeve	Polyethylene plate	PVC disc

Table 1 lists the problems experienced and the resulting solutions that were incorporated into the Mark V pump. Field testing of the Mark V pump only started in June 1980, so it is too early for an evaluation of its field performance. However, the following problems are anticipated: (1) The 25 mm PVC rod is reinforced with a hardwood rod 1 m long. Consequently, the rod is less flexible than that of the Mark III/IV pump. As the rod becomes bent, due to extensive pumping, it will touch the inside of the steel pump stand. The resulting wear of the 1 in. (2.5 cm) polyethylene pipe might be unacceptable. (2) Installation of the pump requires a 24 in. (61 cm) pipe wrench. Wrenches of this size are difficult for field assistants to carry on a bicycle. Fortunately, once the nut of the adaptor, which is welded to a 3 in. (7.6 cm) pipe end, is screwed into the socket, there is no need to unscrew it because the pump pipe can be lifted through the nut. (3) Replacing the polyethylene sleeve on the plunger requires the use of solvent cement. This means it can only be done by a field assistant, not by the pump attendant. Further experimentation will be carried out to overcome this problem.

ANNEX H

MANUFACTURING FACILITIES OF THE INOLIA MARK II HAND PUMP

TELEPHONE PLAZA 4-1234

CABLE ADDRESS UNICEF

UNICEF

UNITED NATIONS CHILDREN'S FUND · FONDS DES NATIONS UNIES POUR L'ENFANCE

UNITED NATIONS, NEW YORK

WS/81/225
18 March 1981

File: Hand Pump (India Mark II)

INDIA MARK II HAND PUMP

Report on visit to INALSA */ by
Paul J. Biron (Sunday, 8 March 1981)

1. Background

1.1. The India Mark II hand pump, developed over the recent years to meet initially the requirements of the Rural Water Supply in India, has proved to be, when properly installed and cared for, one of the few existing units suitable for community usage; its score has been unequalled during a recent comparative evaluation involving some 12 hand pumps of various design and origin.

1.2. The India Mark II pump has been developed through a close co-operation between the Indian authorities and UNICEF New Delhi; as a result, its design is not patented and its manufacture anywhere it could be justified and feasible would not be subject to a licensing/franchising agreement. Several manufacturing plants are producing the pump concurrently in India; however, only few are officially recognised as qualified possible suppliers to UNICEF and for the Government (Richardson and Cruddas, Madras, owned by the Government; INALSA, private company, New Delhi and Rajpur).

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*/ Industrial and Allied Sales Private, Ltd., Surya Kiran, 19 Kasturba Gandhi Marg, New Delhi-110001. Phone 352317. Telex 31 3536 INAL IN. Telegram - INALSA.

UNICEF

UNITED NATIONS CHILDREN'S FUND
FONDS DES NATIONS UNIES POUR L'ENFANCE

INTEROFFICE MEMORANDUM

TO: UNICEF Offices
(*/ as listed below)

FROM: Paul J. Biron
Senior Programme Officer

DATE: 24 April 1981

FILE NO.: WS/308/81

SUBJECT: India Mark II Hand Pump

During a recent stop over in New Delhi, some time was allocated to visit one of the manufacturing facilities of the India Mark II Hand Pump.

..... The attached report is an attempt to convey some detailed information on the manufacturing steps (and production requirements) of the unit.

For a quick preliminary assessment of whether local production can be entertained, some relevant factors have been quantified, so that the incidence of local costs, specific of each situation can be appraised, e.g: 110 kg of mild steel products per pump, 5000 kwh of electricity, 15 skilled workers, mostly welders, lathe and milling machine operators (1 each at least), 35 unskilled labourers, 10 clerical staff, 3 engineers, in order to achieve a production of 600 pumps per month.

On three levels - the factory is located in a comparatively old building - floor space occupied is of the order of 5000 square meters. Two reciprocating mechanical saws, one lathe, one milling machine and one drilling machine would be required, as well as 6 to 10 arc welding sets, 2 to 3 spray painting cabins, various hot baths for cleaning, degreasing sub-assemblies.

Some thought may be given also to a local assembly only of pump parts imported from one of the several Indian production units, (particularly the pressed/stamped out parts) to cut down on the shipping cost. This however implies that a complete set of jigs/templates be imported and used (value US$ 10 - 12000). It also implies that dip galvanizing facilities be available to corrosion proof sub-assemblies after welding.

1.3. Some 40,000 pumps India Mark II are produced annually in India, of which UNICEF purchase about 10 per cent, mostly for UNICEF-supported rural water projects in India. However, over the past 3 or 4 years, a limited but increasing number of pumps has been purchased and shipped out of India for eventual use in similar rural projects, particularly in West and East Africa, where hand pumps customarily used so far may cost 3 or 4 times as much.

In some instances, particularly with the ambitious goals of the International Drinking Water Supply and Sanitation Decade, a fairly large demand for India Mark II pumps may be envisaged, and may conflict with the requirements of the Indian programme.

This explains the interest in analysing the conditions of manufacture as a preliminary step to any feasibility study required in each specific case.

2. Acknowledgement

2.1. The visit was kindly arranged by Dr. John Skoda, following up on the writer's intention expressed end 1980, and made possible by his unexpected brief stopover in New Delhi early March 1981.

Mr. K.S. Kalra, Vice President of INALSA, was not available, but Mr. K.B. Erry, Deputy General Manager (Marketing), kindly provided transport to and from the plant and conducted the visit. Both

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Mr. R.P. Bhandari, Plant Superintendant, and Mr. V.K. Agarwal, Quality Control Engineer, participated in the visit and the discussion. All three were extremely co-operative.

2.2. Mr. Erry recently visited West Africa (in particular Ivory Coast, Benin, Togo and Ghana), when he met with Marcello Bevacqua, UNICEF Abidjan. INALSA has been contemplating going into a partnership with local investors in Ghana, but the scheme has not yet materialized. (INALSA appears to be willing to study any such possible venture, with private individuals/groups or governments.)

Either Mr. Kalna, or Mr. Erry, is planning to visit shortly Indonesia, in support of a recent enquiry from the Government to quote for the supply of a number of India Mark II pumps.

3. <u>Summary</u>

3.1. The India Mark II hand pump is entirely fabricated from standard mild steel plates, tubing and profiled sections, with the exception of the cast iron cylinder, and its reducing couplings, its seamless brass liner, bronze plunger with leather cup, bronze foot valve with rubber seal, and a short length of Simplex chain.

3.2. Each pump requires some 110 kg. of mild steel. The INALSA plant, with a work force of 15 skilled and 35 unskilled workers (plus 10 clerical staff), produces on a single shift (6 days of 8 hours per week) 600 pump units per month, and uses monthly 5,000 kwh of electricity (power installed is 120 HP). To ensure uniformity throughout the

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production, INALSA uses a comprehensive set of jigs for sub-assemblies and final assembly (reported cost of the set Rs. 80,000). Similar jigs are used by other pump manufacturers, so that all pump parts are interchangeable, irrespective of their origin.

3.3. Management and supervision are carried out by three engineers. Many of the components are prepared by sub-contractors (2 to 3 for each article to reduce production delays, effects of possible strikes, possible disputes over contract renewals, etc). Similarly, some contractors are used to carry out important steps in the manufacturing process: cutting, punching, electro-plating, heat treatment of spindle, hot dip galvanizing of water tank, etc. As a result the plant uses only few machine tools: lathe, drilling machine, milling machine, screw presses. Spot control is carried out by inspectors from the Crown Agent. (It is envisaged to give a complete rust proofing to all parts of this pump.) A set of specially designed tools can be used for mounting, dismantling and maintenance on the well site, together with fitters tools.

4. Description of the pump

The pump consists of:

- A tubular pedestal fitted with a tripod of laminated angle legs, which is lowered over the well casing, the legs being embedded in a concrete plinth.

- A water tank with discharge spout.

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ANNEX I

GOVERNMENT AND COMMUNITY INVOLVEMENT IN MAINTENANCE

Excerpt of the draft "Handpump Maintenance"

by E.H.A. Hofkes (December, 1980)

GOVERNMENT AND COMMUNITY INVOLVEMENT IN MAINTENANCE

One question of maintenance strategy is whether the provision of maintenance should be the responsibility of the government, or of the community, or a shared one between the government and the community. The extreme options of either complete government responsibility or all responsibility exclusively with the community, are unusual. In most cases the responsibility for maintenance of the pump is shared by the water supply agency, the local government and the community using the pump. There are maintenance duties such as cleansing the pump platform and surrounds that are always best handled by the community. In selecting the mix between government and local involvement there will be areas in which the central government can act most efficiently, areas where the local government will have the greatest impact and areas where community involvement is essential.

There are advantages to be gained from community participation, provided that the community accepts the responsibility, and that selected members of the community receive training in the duties which they are expected to perform.

The choice of maintenance strategy involves the overall combination of the pumps, maintenance organisation and funds. Factors of concern include the failure rate of pumps, cost of spares, transportation costs, vehicles and tools required, and any test equipment.

No general recommendations can be made concerning which strategy forms the best approach, since each situation must be examined individually by relating cost implications, policy aspects and logistics.

For instance, different combinations of maintenance response time and maintenance cost represent a typical trade-off situation (Fig. 2.1.).

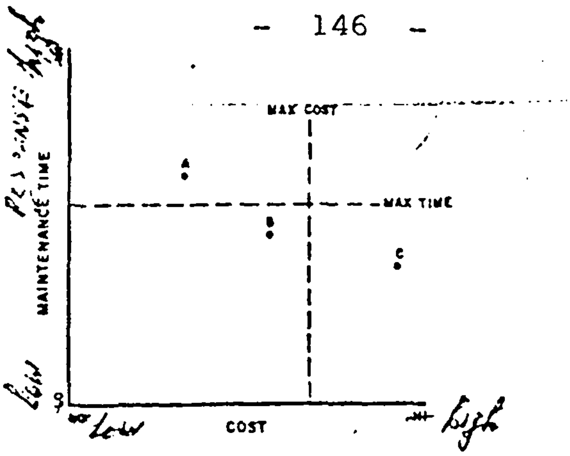

Fig. 2.1. Trade-off of Maintenance Response Time and Cost

Here three alternate strategies, A, B, and C are analysed with respect to cost and maintenance response time. It is assumed that two constraints are imposed on the choice of strategy. These are: (1) a maximum response time acceptable to the users; and (2) a maximum cost. From the plots made it will be observed that only strategy B meets both conditions.

Another factor bearing heavily on the maintenance strategy choice, is the density of handpump installations in a particular country or area. If the density is great, the strategy should probably be directed towards a short maintenance response time, frequent servicing of the pump, and a dispersed type of maintenance organization. For a sparse pump density, long intervals between pump servicing, a unified , centralised maintenance organisation, and government financing of the costs are likely to be the most suitable maintenance strategy.

Greater community involvement in the maintenance of a handpump often not only results in better care and upkeep of the pump, but also helps stimulate related activities such as health education and the use of water for hygiene.

Therefore, although a government-controlled maintenance system may seem to be the best strategy under the existing conditions, increased community involvement may still be preferred in order to obtain long-term maintenance benefits and greater health educational impact.

Table 2.1. is provided as a schematisation of the maintenance strategy selection.

Table 2.1. Maintenance Strategy Selection

Category	Strategy Selection Factors		
	Maintenance period	Organization type	Financing
complex deep well pump	long	unified	government
simple shallow well pump	short	dispersed	user
intensive usage of pump	short	dispersed	user
non-intensive usage of pump	long	unified	government
central government	long	unified	government
local government	short	dispersed	user
poor community	short	unified	government
wealthy community	long	dispersed	user
complicated pump		dispersed	
simple pump		unified	
existing maintenance system	can be helpful or not helpful		

The existing maintenance system, if any, is here presented as a final factor after other factors have been considered.

The above considerations are summarized in Table 2.2.

Table 2.2. Maintenance Strategy Selection

Maintenance Period	Organisation Type	Maintenance Funding	Maintenance Strategy
short	dispersed	government	5
long	dispersed	government	5
short	unified	government	2
long	unified	government	3
short	dispersed	user	4
long	dispersed	user	1
short	unified	user	3
long	unified	user	5

Description:

1. Strategy for more wealthy areas
2. Strategy for less wealthy areas
3. Strategy for sparsely populated and/or areas requiring deep well pumps and/or where the government power is very centralized
4. Strategy for densely populated areas and/or areas requiring shallow well pumps, and/or where government power is delegated to local authorities
5. Strategy not generally approproate.

This analysis can now be completed by considering the circumstances of use for the pump.

Table 2.3. Circumstances of use of pumps

Hand pump type	Intensity of use	Type of structure Government	Economic circumstances
deep well	high	centralized	poor
deep well	high	centralized	wealthy
shallow well	high	centralized	poor
shallow well	high	centralized	wealthy
deep well	high	local	poor
deep well	high	local	wealthy
shallow well	high	local	poor
shallow well	high	local	wealthy
deep well	low	centralized	poor
deep well	low	centralized	poor
shallow well	low	centralized	poor
shallow well	low	centralized	wealthy
deep well	low	local	poor
deep well	low	local	wealthy
shallow well	low	local	poor
shallow well	low	local	wealthy

By comparing the maintenance strategy indicated in table 2.2. with the circumstances of use of the pumps listed in table 2.3., a basis for the maintenance strategy choice is provided.

Although one or two maintenance strategies can be identified as feasible in most cases, it is usually possible to firmly determine which strategy would be preferable (Table 2.4.).

Table 2.4. Maintenance Strategy Selection

Hand pump type	Intensity of use	Type of Government structure	Economic circumstances	Feasible maintenance strategies
deep well	high	centralized	poor	2 or 3
deep well	hig	centralized	wealthy	1 or 3
shallow well	high	centralized	poor	2 or 4
shallow well	high	centralized	wealthy	1 or 4
deep well	high	local	poor	4
deep well	high	local	wealthy	4
shallow well	high	local	poor	3
shallow well	high	local	wealthy	3
deep well	low	centralized	poor	2 or 3
deep well	low	centralized	wealthy	1 or 3
shallow well	low	centralized	poor	2 or 3
shallow well	low	centralized	wealthy	1 or 3
deep well	low	local	poor	2 or 3
deep well	low	local	wealthy	1 or 3
shallow well	low	local	poor	2 or 4
shallow well	low	local	wealthy	1 or 4

A final consideration is the effect of any existing maintenance system on the most appropriate maintenance strategy. Abrupt changes are unlikely to be successful. For example if the government presently finances all the costs of the maintenance system, a sudden change to a user-financed system would be very difficult. However, if all the other factors described above indicate that user financing would be advantageous, then a gradual change in this direction would generally be desirable. If there is an existing situation where users are financing the maintenance costs then the existing system should be continued.