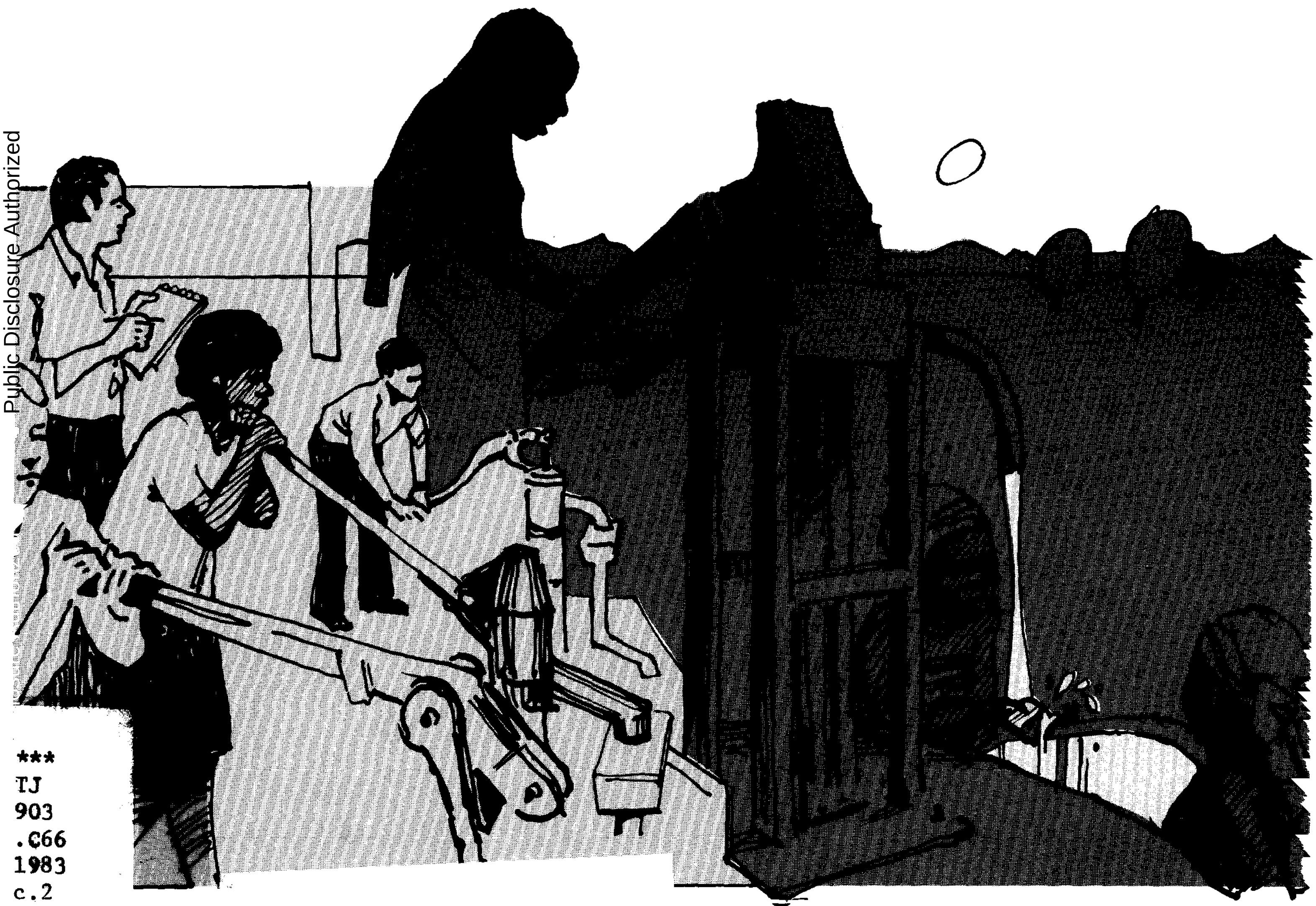
WORLD BANK TECHNICAL PAPER NUMBER 6

Rural Water Supply Handpumps Project

Laboratory Evaluation of Hand-Operated Water Pumps for Use in Developing Countries

Consumers' Association Testing and Research Laboratory

UNDP Project Management Report Number 2



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UNDP Project Management Report Number 2

The World Bank
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RURAL WATER SUPPLY HANDPUMPS

Final Summary Report
(Batches One and Two)

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PREFACE

Among the 1500 million people in developing countries who do not have access to adequate water supply and sanitation facilities, there are 1200 million who lack these basic services in rural areas.

The importance of providing safe water has been repeatedly stressed by national governments and international agencies. Recognizing the urgent need for improved water and waste management, the United Nations has declared the 1980's to be the International Drinking Water Supply and Sanitation Decade (IWSSD), establishing an ambitious goal to provide adequate water to the total rural population of the developing countries.

Handpumps installed in wells where groundwater is easily available provide one of the simplest and least costly methods of supplying the rural population with water. However, despite all efforts in the past, a number of serious technological and management problems remain to be solved.

Among the activities of the Decade is the United Nations Development Programme (UNDP) Division for Global and Interregional Projects "laboratory testing, field trials and technological development of handpumps project." The World Bank, with responsibility assigned to the Office of the Senior Advisor for Water and Wastes, was selected to be the executing agency to undertake the handpumps programme.

Within the first phase of the project, laboratory testing of a number of typical handpumps has started, contracted to the Consumers' Association Testing and Research Laboratories, of Harpenden, U.K., and the first interim report was issued in March 1982. Other reports on results of laboratory and field tests will published from time to time, in addition to other data on technological developments.

The aim is to examine and assist in the selection of a wide range of handpumps for further field trials and to provide information to all interested manufacturers to assist them in the production of more efficient and more reliable pumps. Laboratory tests are conducted on two randomly selected samples of pumps, to provide information on basic features rather than on the quality of total production.

The long-range objective of the programme is to promote the improved designs of handpumps locally manufactured in developing countries, pumps that can be maintained by trained village operators (VLOM pumps - Village Level Operated and Maintained).

One of the major outputs of the project will also be a financial analysis based on forecasted annual costs for maintenance and operation of a wide variety of handpumps. For this purpose we would be grateful to receive any information on the frequency of breakdown and maintenance costs obtained from any field operations or tests organized by a developing country government, aid agency, non-governmental organization, or others.

Any comments on this report would be most welcome.

Saul Arlosoroff
Project Manager/World Bank

ACKNOWLEDGEMENTS

This project, financed by UNDP projects GLO/79/010 and INT/81/026 has benefited from the comments received from many sources following publication in 1980 of the report "Hand and Foot-operated Water Pumps for Use in Developing Countries" by J.A. Kingham. This was the result of two and a half years work funded by the Overseas Development Administration of the United Kingdom Government and laid the foundations of the test protocol for this current project.

C A Testing and Research staff contributing to this project included Frank Jones, John Kingham, Timothy Lister and Clive Wade - testing division; Robert Brown, Michael Clarke, James Horn, Geoffrey Hughes, John Keen and Malcolm Osborne - engineering division; Cate Andrews, Margery Feeney and Edda Wyatt - administrative division. Tony Reynolds did the pump illustrations.

The efforts of these people were invaluable in the successful conclusion of this project.

SUMMARY

This is the final summary report on laboratory tests and assessments of 12 brands of hand-operated water pumps, carried out at a special installation of the Consumers' Association Testing and Research Laboratory, Gosfield. Two of the pumps were shallow-well suction pumps, one was a shallow-well force pump and the remainder were deep-well force pumps. Additional testing of another group of 12 pumps has recently begun.

The test programme was extensive, and took about 20 months to complete. It included detailed inspection of the pumps as received, including their packaging, engineering assessments with suggestions for design improvements, and user trials. Tests carried out included endurance, performance before and after endurance, impact and handle shock where applicable. Assessments of ease of installation, maintenance and repair were also made. The pumps are dealt with individually and brief details are given of all test results, summarized finally in a verdict.

In the Summary of Results, many general observations are reported, highlighting features which have become apparent as the testing progressed. Certain recommendations have been made to aid pump selection and improve designs.

Technical details of the tests were given in an interim report, and will be included in the final full technical report of the pumps assessed in batches 1 and 2, to be published in spring 1983.

The material is intended to assist handpump manufacturers in improving the quality of their products and to assist the authorities of developing countries in their decision-making process on the local manufacturing or import of handpumps.

TRANSPORTATION & WATER DEPARTMENT

Senior Advisor for Water and Wastes

This series of reports, produced on behalf of the Transportation and Water Department of the World Bank, Office of the Senior Advisor of Water and Wastes, provides information on a UNDP Global/Interregional Project, executed by the World Bank, dealing with the laboratory evaluation of rural water supply handpumps. In time, reports on field trials in developing countries and technological development of handpumps will be produced which will show how improvements in design and manufacturing quality of handpumps are materially helping towards reaching the goals of the International Drinking Water Supply and Sanitation Decade.

By 1985 a full report will be published dealing with all the technological, economic and socio-cultural aspects of this activity.

1. INTRODUCTION TO LABORATORY TESTING

1.1 Background

After a series of meetings during which experts recognized the importance of handpumps in the survival and economy of developing countries, the Overseas Development Administration of the U.K. Government decided in 1977 to test 12 different deep-well pump designs in the Consumers' Association Testing and Research Laboratory in an attempt to identify the reasons for early field failures and to obtain better value for the money spent in overseas aid. The ODA required all the laboratory information, including details of a long endurance test, to be submitted to the manufacturers to assist them in improving the quality and reliability of their products. The pumps tested were the Petropump 95, Vergnet, Dempster, Mono, Climax, Godwin, Abi, GSW (Beatty), Monarch, Kangaroo, India Mk II and Consallen. Their performance is briefly summarized in the Annex. A summary of the ODA report can be obtained from the Manager, UNDP Handpumps Project, TWD, The World Bank.

UNDP and The World Bank recognized that if the International Decade of Drinking Water Supply and Sanitation was to have any chance of success, this work had to be continued and, more importantly, coupled with extensive field trials and technological development to lead towards local manufacturing in the developing countries of appropriate designs.

Testing of the first two batches, numbering six pumps each, has now been completed, and is the subject of this summary report. Further batches of pumps, some of which are approaching the concept of Village Level Operation and Maintenance (VLOM), are being tested, and consist of two versions of the Volanta (Netherlands and Upper Volta), the Maldev (Malawi), modified Petro (Sweden), Abi-Vergnet-hybrid (Ivory Coast), Funymaq (Honduras), Sarvodaya (Sri Lanka), Rower Irrigation Pump (Bangladesh), two versions of the Preussag (Germany), two versions of Mono (U.K.), the RIHA (Australia) and others.

1.2 Laboratory Test Procedures for Handpumps

1. **Obtaining Pumps**
   - 1.1 Manufacturer or Agency
   - 1.2 Pump model and type
   - 1.3 Cost
   - 1.4 Delivery time

2. **Inspection**
   - 2.1 Packaging
   - 2.2 Condition of pumps
   - 2.3 Literature

3. **Weights and Measures**
   - 3.1 Weights of principal components
   - 3.2 Principal dimensions
   - 3.3 Cylinder bores
   - 3.4 Ergonomic measurements

4. **Engineering Assessment**
   - 4.1 Materials, manufacturing methods, fitness for purpose
   - 4.2 Suitability for manufacture in Developing Countries
   - 4.3 Ease of installation, maintenance and repair
   - 4.4 Resistance to contamination and abuse
   - 4.5 Potential safety hazards
   - 4.6 Suggested design improvements

5. **Pump Performance**
   - 5.1 Volume flow, work input and efficiency
   - 5.2 Leakage

6. **User Trial**
   - 6.1 Observation of users
   - 6.2 Users' responses

7. **Endurance Test**

   Four stages of 1000 hours each, using four different and increasingly severe qualities of water.

   - 7.1 Stage 1 - clean, hard water, approx. 7.2 pH.
   - 7.2 Stage 2 - clean, soft water, approx. 5.5 pH - the pH value will be maintained by adding hydrochloric acid, but the chloride concentration must not exceed 1 g/litre.
   - 7.3 Stage 3 - hard water to which Kieselguhr, with a particle size of 7.5 μm, has been added in the concentration 1 g per litre of water.
   - 7.4 Stage 4 - hard water with 1 g per litre of fine, sharp quartz sand of particle size between 75 and 500 μm.

   For stages 3 and 4, the water must be agitated.
   Dismantling, inspection and volume flow measurement after each 1000 hour stage.
   Full performance test after 4000 hours.

8. Abuse Tests

8.1 Side Impacts on pumpstand, up to 500 Joules
8.2 Side Impacts on handle, up to 200 Joules
8.3 Handle shock load test where applicable: 96,000 impacts for force pumps, 72,000 impacts for suction pumps at the endurance stroke rate.

9. Review

9.1 Ease of pump installation
9.2 Ease of maintenance and repair
9.3 Verdict

10. Reporting

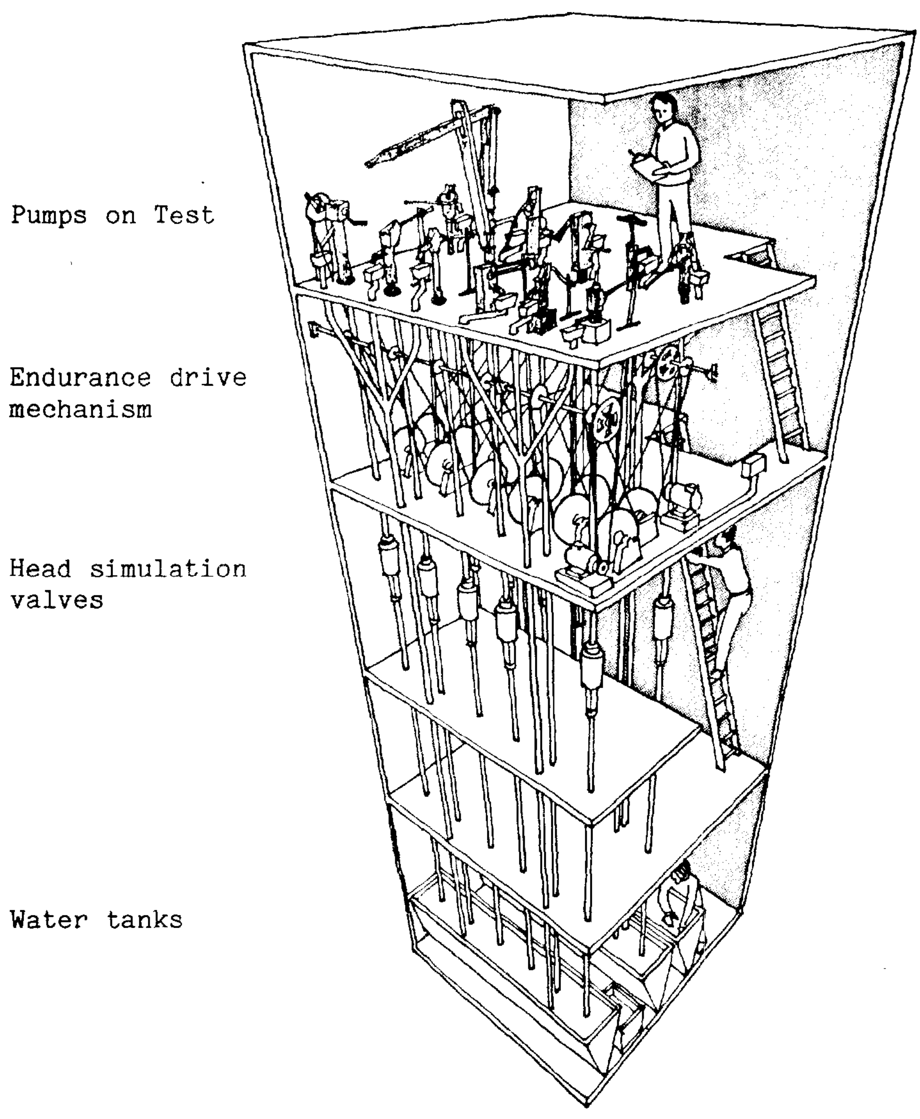
10.1 Interim report after items 1 to 6, with Data Checking Sheets sent to manufacturers
10.2 Further interim report(s) on problems encountered in endurance testing, if necessary
10.3 Final summary report
10.4 Final technical report, with full details of pumps, test methods and results, and including installation drawings and photographs.

1.3 Installation for Testing

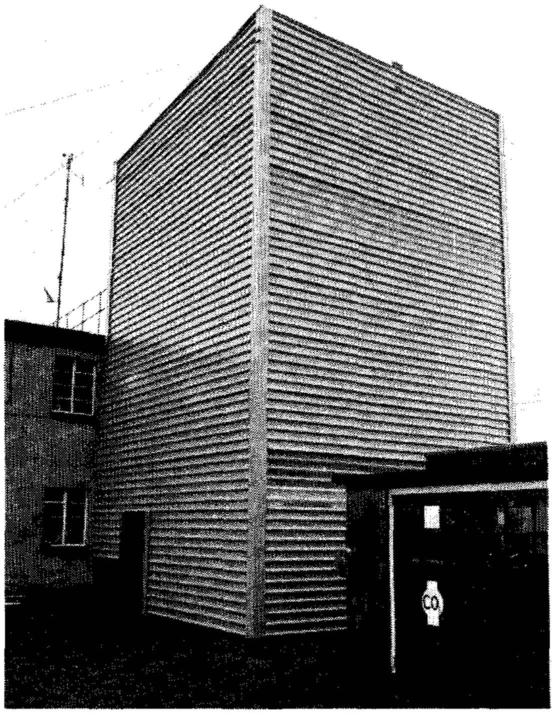
The pumps are installed on the top floor of a purpose-built 10 metre tower. They are arranged in batches of six, with a motor and tank for each batch.

The floor beneath the pumps houses the mechanical drives for the endurance tests. Beneath that, each deep-well pump is fitted with a head simulation valve which is designed to simulate well depths down to 45 metres.

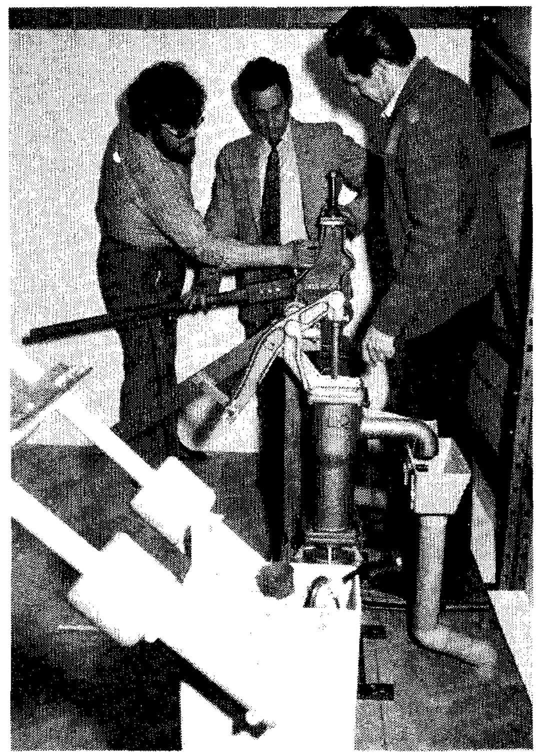
The level of water in the tank on the ground floor is maintained by a pump and constant level device.



Handpump Testing Tower

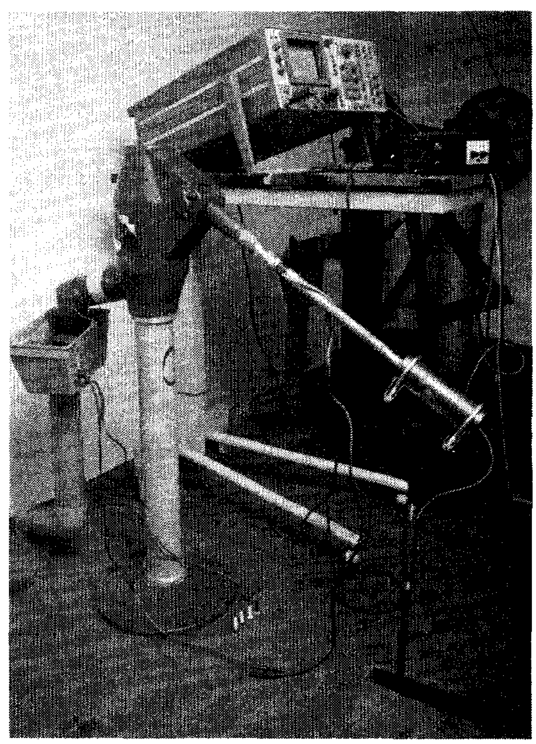


The exterior of the tower



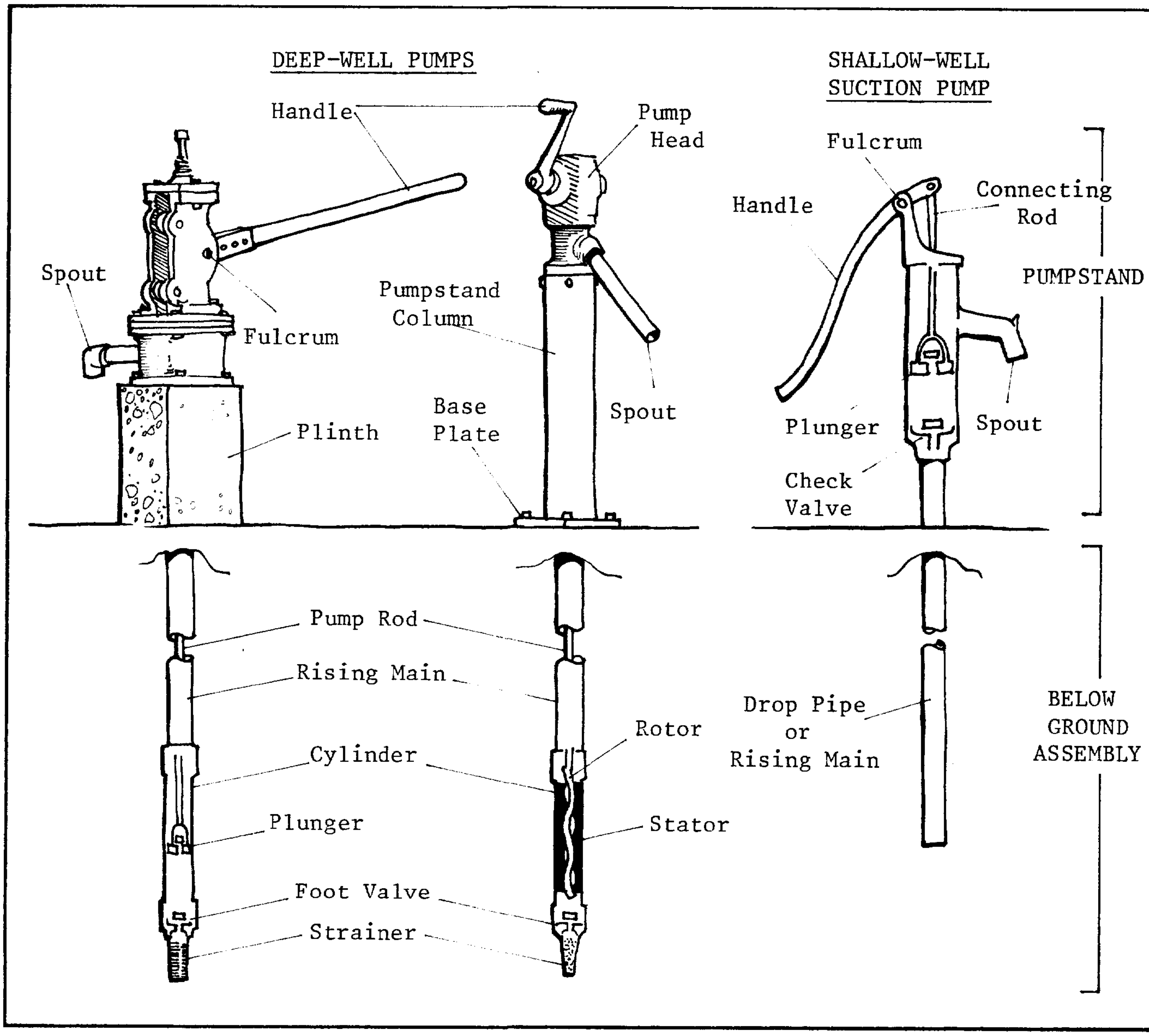
Some of the installed pumps
on the top floor

The endurance drive mechanisms



Handle shock test

1.4 Basic Pump Nomenclature



In response to comments received on Report No. 1, the following definitions will be used throughout.

A shallow-well suction pump is one where the plunger is in the body of the pump, above ground. For practical purposes, the maximum operating depth of this type of pump is 7 metres.

A shallow or deep-well force pump is one where the plunger is below static water level, at the bottom of the rising main. Such pumps are self-priming. The maximum operating depth is limited only by the strength of the pump and its operator.

Table 1: BRAND LIST of PUMPS TESTED

Code^	Name/Model	Manufacturer/Supplier	Deep or Shallow Well	Price (US$)* Approx	Country of Origin
A	Korat 608 A-1	Saha Kolkarn	Deep	295[a]	Thailand
B	Dragon No. 2 (D)	Kawamoto	Deep[+]	362[b]	Japan
C	Moyno 1V 2.6	Robbins & Myers	Deep	550[c] 739[d]	USA
D	Nepta	Briua	Deep	650[d]	France
E	Kenya	Atlas Copco	Deep	(669)	Kenya
F	New No. 6	Engineers Wood Steel Industries	Shallow Suction	(33)	Bangladesh
G	Nira AF76	Vammalan Konepaja oy	Deep	203[e]	Finland
H	Ethiopia Type BP50	E.W.W.C.A.	Shallow force●	(75)	Ethiopia
J	VEW A18	Vereinigte Edelstahlwerke (VEW)	Deep	1583[a]	Austria
K	Jetmatic	Sea Commercial Co.	Deep	32[f]	Philippines
L	Bandung	C.V. Malabar	Shallow Suction	(54)	Indonesia
M	Sumber Banyu ("SB")	P.T. Celco	Deep	(85)	Indonesia

^ For the tests, a code was assigned to each pump. The codes are shown in this report for easy reference to technical information contained in Report No. 1.

+ Was supplied as shallow-well pump with additional components for conversion to deep-well use

● 12 metres nominal maximum depth

* Cost if 50 purchased in one order. Figures in () are 1981 prices.

a Supplied complete for 20 m depth
b Supplied complete for deep-well use
c Pump only
d With 20 m below-ground assembly
e Pump and cylinder
f Without connecting rod and rising main

2. SUMMARY OF RESULTS

2.1 General Observations

Literature

All pumps should be supplied with instructions for installation, maintenance and use. Plenty of clear illustrations are of particular value in overcoming language and literacy problems.

Skills required

All the pumps require basic mechanical skills for installation and maintenance; some need considerable expertise.

Installation

Many pumps require lifting tackle for installation and maintenance because galvanised iron rising main is used. If uPVC or other plastic pipe could be used, the below-ground assembly could be installed or removed without lifting tackle.

Baseplate sealing

With some pumps, extra care is needed during the preparation of the base and subsequent installation to ensure an adequate sanitary seal.

Mounting Height

Many manufacturers give no indication of the correct height to which the pumps should be installed. The best pump designs are those which do not require a special pedestal built up on a wellhead. Pumps should have an in-built design feature which ensures that they are mounted at the correct height.

Spares

All the pumps may in time need manufacturer's spares, some of which can be costly. However, the cost per unit of a stock of spares will decrease as the number of pumps installed in the field increases. Emphasis should be placed on development of the VLOM concept with regionally produced spare parts if possible.

Two-person Operated Pumps

Rotary pumps operated by two people may have certain advantages. It may be necessary to investigate local cultural/sociological factors to assess the likely problems of this in practice.

Safety

Some manufacturers do not pay sufficient attention to avoiding safety hazards, even where this involves only a simple design change, i.e. long bolts with ragged ends, finger traps, tails of split pins.

Design Features

Handle: Based upon observations of users operating reciprocating pumps, a potential cause of wear in the handle pivot could be eliminated by adding a "T" at the end of the handle where applicable. Cast iron is prone to breakage and difficult to repair. Handles should be of resilient material, steel bar or tube, or wood where available.

Valves: Some manufacturers give insufficient attention to the amount of valve lift. It is often excessive, therefore lowering efficiency and introducing a risk of valves jamming open.

Pump rod Constraint: The test results suggest that where the design attempts to constrain the motion of the pump rod into a straight line, bending forces are generated which cause failure at the pump rod joints. (It would be helpful to obtain information from the field on this point).

Glands: These are not an ideal method of sealing the pump rod where it passes through the pumpstand, particularly if also used as rod guides. Wear is inevitable and the subsequent leakage apart from the loss of sanitary seal, could produce difficulties if tank filling is needed.

Faecal Contamination: Manufacturers should, where necessary, look at the designs of the outlet spout to ensure that users cannot seal off the outlet with their left hand after defecating, while pumping with their right hand.

Fasteners: Few manufacturers have considered rationalising the variety of fasteners used on the pump. These could often be all of one size or type, therefore requiring only one tool.

Discharge Valve: In view of the few applications where a tank filling facility is needed, the complication introduced in the pumpstand design is unnecessary and often creates points of weakness. See also Glands.

Quality Control

All designs require a measure of quality control but some of the more complicated pumps need very strict quality control in manufacture, particularly in developing countries. Use of simple jigs and fixtures can greatly help the quality control situation and ensure both correct original construction and interchangeable replacement spares.

VLOM (Village Level Operation and Maintenance)

Although some of the pumps come close to satisfying the requirements for VLOM, none do so completely. Attention to the above points would go a long way towards meeting the VLOM concept.

2.2 Recommendations from the 12 Pumps Tested

None of the pumps tested was satisfactory in every respect. All the designs represent some compromise between reliability, performance, ease of installation and maintenance, user convenience and so on.

The selection of the most appropriate pumps for community use depends on the local conditions. In different applications, particular parameters will be of greater or lesser significance. It is therefore very important to define these conditions before deciding which pumps to use.

However, for most applications, out of the 12 pumps tested we would expect the choice to be made from the following 6 pumps (given in alphabetical order):

Deep-Wells

Korat 608 A-1: Reliable below-ground, potentially suitable for manufacture in developing coutries with foundry skills, needs a small design change to eliminate the safety hazard.

Moyno 1V 2.6: Very robust and reliable, awkward to operate, output low. Unsuitable for manufacture in developing countries.

Briau Nepta: Easy for children to operate, very efficient, should be redesigned below-ground to eliminate the spring.

Nira AF76: Robust for wells down to 20 metres, as a result of many improvements incorporated by the manufacturer. Reasonably good compromise design.

Shallow-Wells

Ethiopia BP50: Force pump, close to VLOM. Self-priming, not a suction pump thus very suitable for drinking water supply. Awkward for children to operate, easy to install and maintain. Not very robust.

New No. 6: Suction pump, suitable for manufacture in developing countries with foundry skills, high output, but needs priming with consequent danger of contamination. Needs attention to corrosion protection of the plunger and foot valve.

2.3 Attribute Ratings

Table 2: Attibute Ratings

ATTRIBUTE	DEEP									SHALLOW		
	Korat 608 A-1	Dragon No. 2(D)	Moyno 1V 2.6	Briau Nepta	Kenya	Nira AF76	VEW A18	Jetmatic	Sumber Banyu ("SB")	New No. 6	Ethiopia BP50	Bandung
Ease of manufacture	4	3	1	3	4	2	1	3	4	5	5	4
Ease of installation	3	3	3	2	2	3	2	4	3	5	4	5
Frequency of maintenance	3	3	5	4	2	4	4	3	2	4	4	3
Ease of maintenance	2	2	2	2	3	2	2	3	2	4	3	4
Pump performance [a]	4	3	2	5	4	4	3	3	4	3	2	4
Ease of use	3	3	1	4	2	2	2	3	4	5	2	5
Reliability	4	2	4	3	3	3	3	2	1	2	4	2
Resistance to abuse	3	2	5	4	3	3	5	2	2	3	3	2
Overall design	3	2	4	4	2	4	3	2	2	4	4	3
User acceptability	3	3	1	4	3	3	2	3	4	5	2	5
Adequacy of wellhead seal	4	4	5	4	4	5	5	4	3	1	3	1
Corrosion resistance	3	3	5	4	2	4	5	3	4	1	5	3
Safety	2	3	5	3	2	5	2	3	3	3	4	3

[a] Based on measurements of pump efficiency only
Ratings are on a 1 - 5 scale: 5 = very good 1 = very poor
A number of these ratings would be higher if the suggested design improvements noted in the text were incorporated.

IMPORTANT NOTES on TABLE 2

1. Table 2 permits comparison of the various pumps for each attribute but is not intended to be used to compare the pumps overall. It is misleading to total the columns of ratings for each pump. Such totals do not form a valid basis of comparison between the pumps. Before comparisons can be made, a weighting must be applied to each attribute to reflect the available manufacturing techniques and local conditions of use in any specific country. A method of comparative analysis using a "weighting tree" will be fully described in the final technical report.

3. INDIVIDUAL PUMP EVALUATION

3.1 Introduction

For each pump, the illustration and description are followed by summaries of the test results under the following headings:

- Packaging
- Condition as Received
- Installation and Maintenance Information
- Manufacturing
- Safety
- Suggested Design Improvements
- Users
- Endurance
- Performance when New
- Performance after 4000 hours Endurance
- Abuse Tests
- Installation
- Pumpstand Maintenance and Repair
- Below-ground Maintenance and Repair
- Verdict

Details of all tests will be provided in the full final technical report.

Pump Lubrication

When the pumps were installed all moving parts were correctly lubricated. During the course of the endurance test no further lubrication was provided since it cannot be assumed that regular lubrication will occur in the field. If any components failed in the endurance test requiring the pumps to be dismantled, then correct lubrication was given on re-assembly.

Head Simulation Valve Setting

This valve was set either to operate at 45 metres or the greatest depth recommended by the manufacturer for the operation of his pump, whichever was the lower figure.

Endurance and Performance Stroke Speeds

For force pumps the endurance stroke speed was selected at 40 per minute, as being the highest rate sustainable by a person to fill a 20 litre container. In the performance test the pump rates included 50 strokes per minute since this is humanly possible for a short duration.

For suction pumps a maximum speed of 30 strokes per minute was selected for the endurance test, as operating above this speed produced cavitation under the plunger. Accepting cavitation, the suction pumps functioned at 40 strokes per minute, and this speed was therefore included in the performance test.

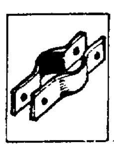
In all cases the arc of handle movement was selected to be just within the limit of the stops to avoid the risk of uncontrolled banging of the handle, which was the subject of a separate abuse test.

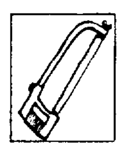
Abuse Tests - Handle Shock Load Test

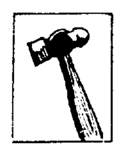
This test was carried out at the specified endurance stroke speed for 40 hours. Controlled shocks were provided on the handle stops with a force determined from a user test where the handle was allowed to travel with the normal level of effort on to the stops. Force pumps received 96,000 shocks and suction pumps 72,000 shocks.

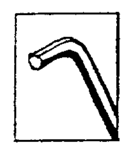
Requirements for maintenance and repair

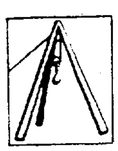
The equipment, level of skill and personnel required for installation, maintenance and repair are illustrated by the following symbols:

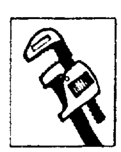

Clamp


Hacksaw

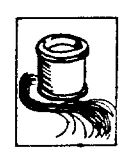

Hand Tools

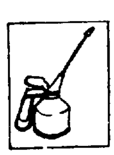

Hexagon Key(s)

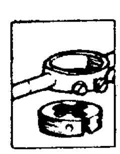

Lifting tackle

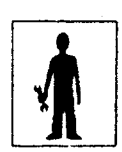

Pipe Wrench(es)

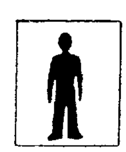

Flat Spanners


Jointing Materials

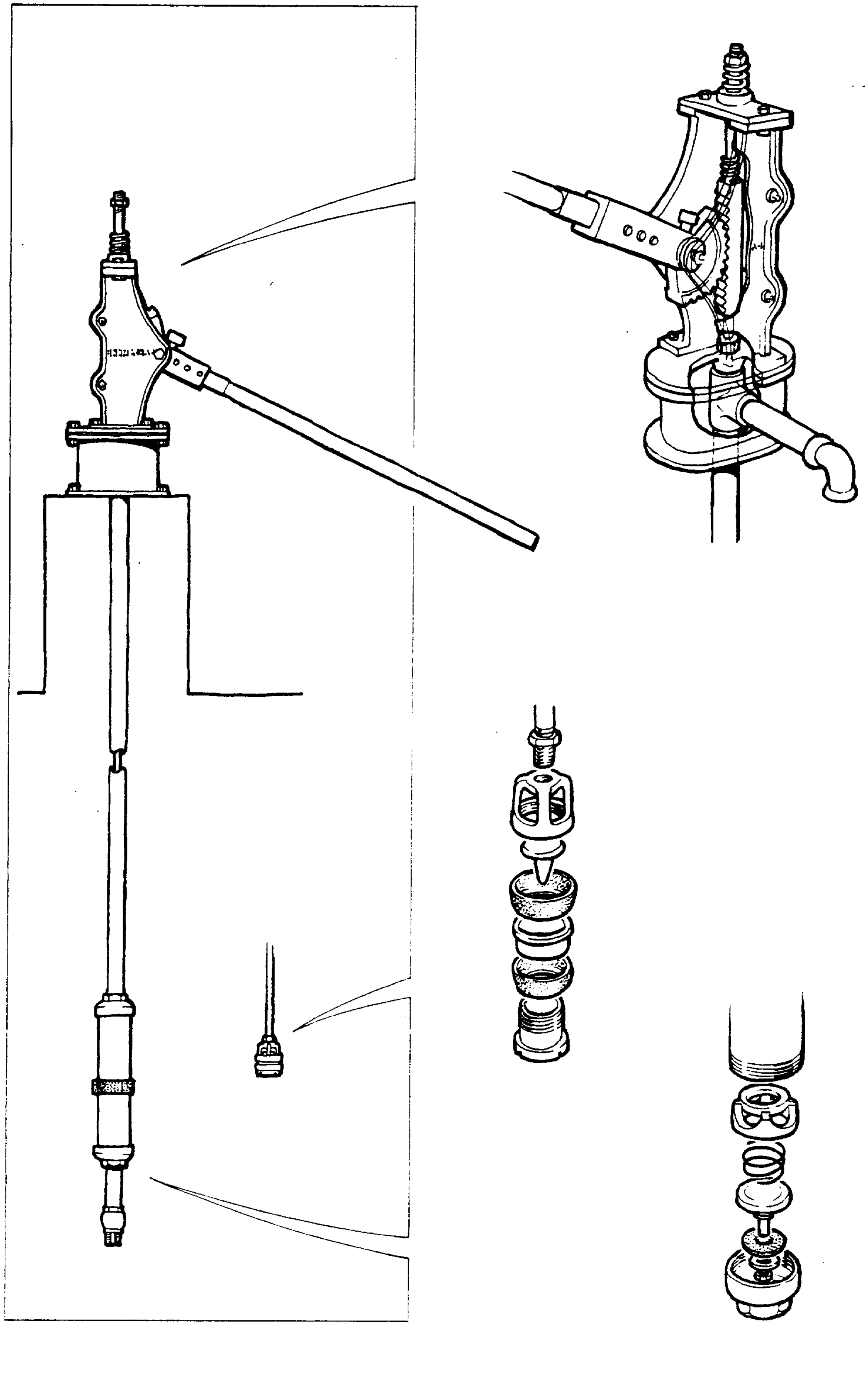

Lubricant (oil and/or grease)


Threading Die(s) and Die Stock


Skilled Person


Labourer

Korat Pump



3.2 Code A KORAT 608 A-1

The Korat 608 A-1 is a deep-well force pump, made in Thailand. The pumpstand is mainly cast iron with a rack and quadrant mechanism and a wooden handle. It must be mounted on a plinth at least as tall as the largest container to be used. The cylinder is seamless brass tube, and the plunger has two conventional leather cup seals. There are two foot valves, one in the base of the cylinder, the other at the end of a short dip tube below.

The pumpstand weighs 47 kg, the cylinder assembly 5.5 kg, and the pump has 0.5 inch diameter steel rods and 1.5 inch nominal bore galvanised iron rising main. The maximum outside diameter of the below-ground assembly is 90 mm.

Packaging

The pumps were delivered in two wooden packing cases, one containing the pumpstands, the other the handles, pipes and pump rods.

The case containing the pumpstands had been damaged and the grease cups on the handle castings of both pumps were broken.

Condition as Received

Both samples were in working order as received in spite of minor defects. In addition to the broken grease cup lubricators, a rack guide roller was seized on one sample and one foot valve had been incorrectly assembled. Such defects would be likely to cause premature failure of the pump if not remedied before installation. Seven of the eight cylinder end caps were porous castings.

Installation and Maintenance Information

None supplied with the pump.

Manufacturing

Where adequate skills in foundry work and simple machining are available, the Korat is well suited for manufacture in a developing country.

Safety

The quadrant and rack present a very dangerous potential finger trap, particularly in view of the large mechanical advantage of the handle.

The bolts used to assemble the pumpstand have sharp, raw ends.

Suggested Design Improvements

The plunger valve lift should be reduced, ideally to one quarter of its effective diameter, and its lateral location improved.

The grease cup lubricators are a good idea in principle, but more robust components are needed.

The quadrant and rack present a safety hazard and should be shrouded. This may be achieved by modifying the casting patterns for the pumpstand side plates.

In response, the manufacturer has modified the pumpstand by adding a cover plate shielding the quadrant from above, and by reducing the lift of the piston valve. The cover plate provides a good deal of protection but can easily be removed and left off. The suggested change to the casting is therefore preferable.

Users

Many users complained that the handle of the pump was too high, but this was not the only problem. The handle is long but the stroke is relatively short, with a predominantly vertical movement. Users found it difficult to bring several muscle groups into play since most of the effort had to be supplied by arms and shoulders only.

Endurance

The pumps was tested at 40 strokes per minute at a simulated head of 45 metres. 4000 hours of endurance testing completely wore out the quadrant. The rack teeth were also worn, but could be reversed top to bottom and used for a while longer with a new quadrant.

Both rack guide rollers seized towards the end of the endurance test programme. In the short term this would increase the friction in the pumphead and make the pump slightly harder to operate. In the long term it would generate localised wear on the rollers which would accelerate the wear on the rack and quadrant teeth.

The cylinder was generally in good condition after 4000 hours, with no significant wear. The leather cup seals and valves showed signs of wear, but still worked satisfactorily.

Performance when New

Volume flow varied somewhat with depth and speed, but all results were between 0.34 and 0.40 litre per stroke.

The work input requirement varied from a minimum of 50 Joules per stroke at 7 metres depth to a maximum of 218 Joules per stroke at 45 metres. Even at 45 metres the operating effort never exceeded 30 kgf.

Efficiency varied from a minimum of 46% at 7 metres to a maximum of 80% at 45 metres.

Performance after 4000 hours Endurance

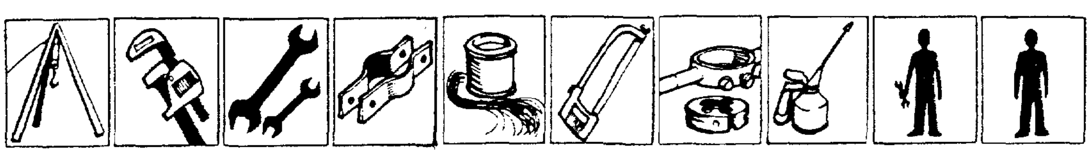
Volume flow remained relatively unchanged, indicating little wear of the plunger and cylinder, but work input had increased slightly and efficiency was therefore slightly reduced possibly due to a worn quadrant and lack of lubrication.

Peak operating efforts had increased slightly, possibly due to the worn quadrant, but remained below 35 kgf.

Abuse Tests

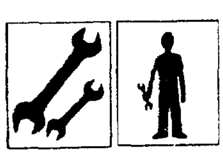
The Korat was undamaged in the side impact tests on both body and handle. In the handle shock test, the pump completed its allotted 96,000 cycles without failure.

Installation



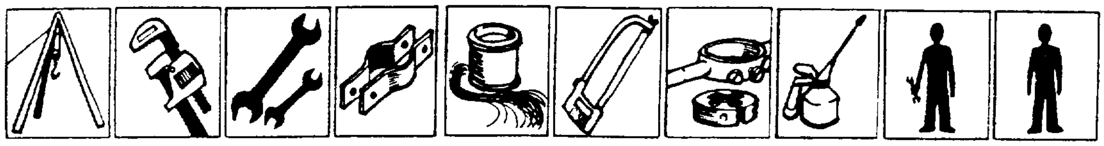
The pump requires a plinth at least as high as the largest water container to be used. The manufacturer supplied a multi-size spanner with the sample pumps.

Pumpstand Maintenance and Repair



Regular lubrication is required. The most frequent repairs are likely to be to the quadrant and rack; the handle bearings are likely to outlive the gear teeth. The pumpstand is easy to dismantle, and removal from the wellhead is not required. A broken handle could be replaced using indigenous materials, otherwise manufacturer's spares will be required.

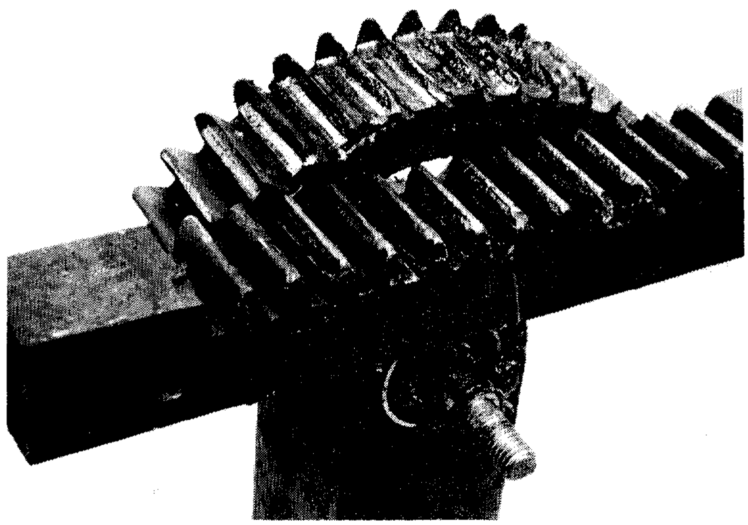
Below-Ground Maintenance and Repairs



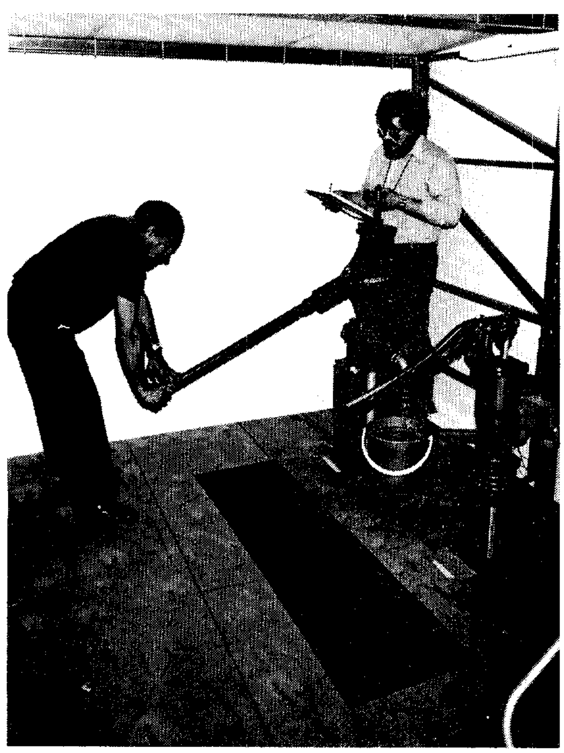
Repairs require removal of the entire below-ground assembly.

Verdict

A robust pump potentially suitable for community water supply. The rack and quadrant will wear in time but they can be easily replaced. Potentially dangerous moving parts should be permanently shrouded. Moderately priced.

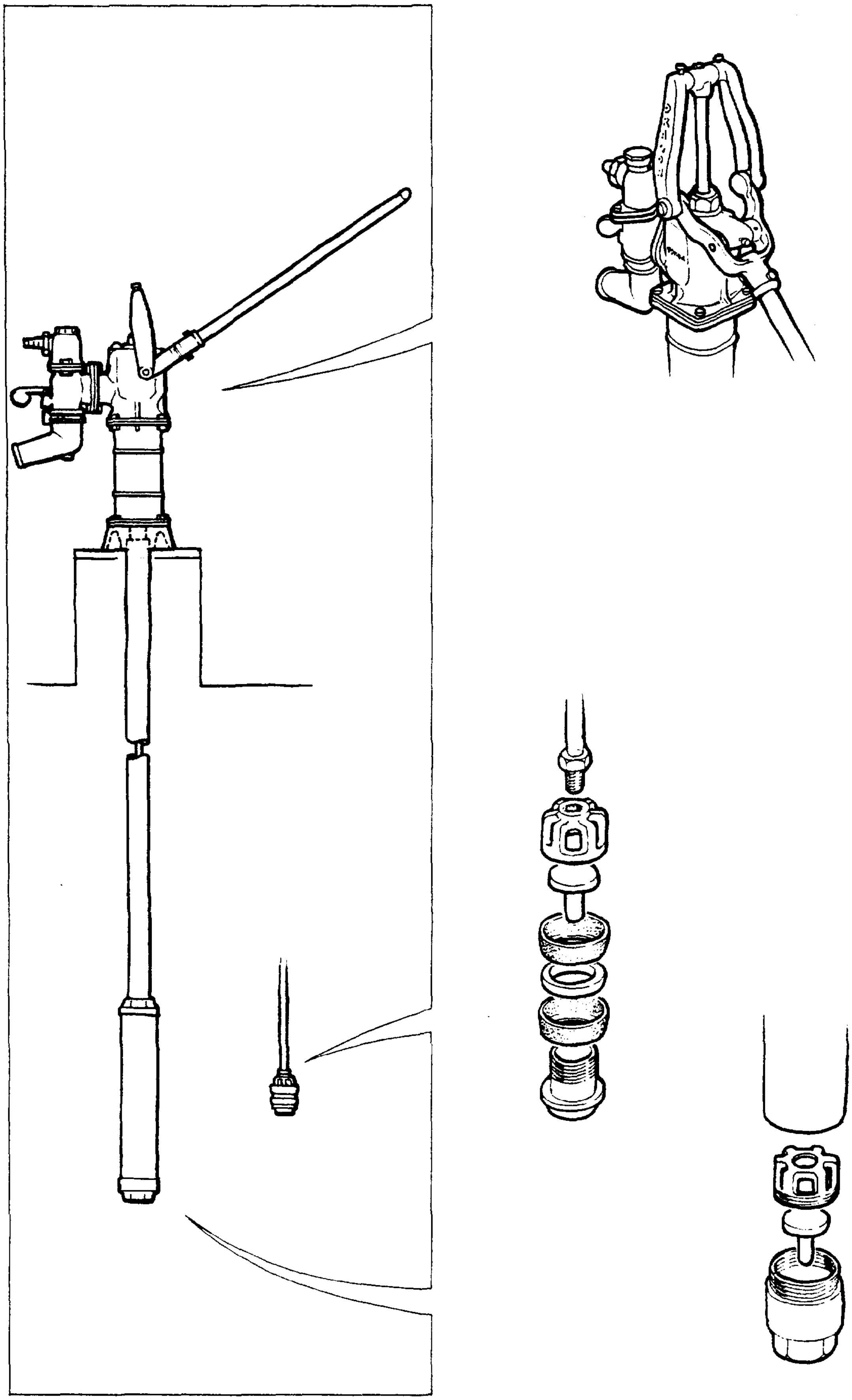


This shows the badly worn teeth of the quadrant after a 4000-hour endurance test. The rack is still in a usable condition.



A user operating the Korat pump, filling a 10 litre bucket during the user test.

Dragon Pump



3.3 Code B KAWAMOTO DRAGON No.2

The Dragon pump, made in Japan, can be supplied either as a shallow-well suction pump or as a deep-well force pump. We tested the pump in its deep-well configuration. The pumpstand is principally cast iron, with a discharge valve in the spout allowing either free discharge or delivery under pressure through a hose or pipe. The tubular steel handle moves through an unusually wide arc of 178^{o}.

In the deep-well configuration, the shallow-well cylinder body, with its enamelled steel liner, is retained as a pedestal. In addition, the pump requires a mounting plinth at least 325 mm high, to provide a minimum of 500 mm clearance under the spout. The deep-well cylinder is conventional, seamless brass tube of 63 mm bore with cast iron end caps. The plunger has two leathers cup seals, and the foot valve has a rubber seat.

The pumpstand weighs 19 kg in its deep-well configuration, the cylinder assembly 5 kg; the pump has 0.5 inch diameter pump rods, (not supplied) and standard 1.25 inch nominal bore galvanised iron rising main. The maximum outside diameter of the below-ground assembly is 70 mm.

Packaging

The pumps were delivered neatly and securely packed in two corrugated cardboard cartons.

One carton contained the pumpstands with all the components required for shallow-well use. The carton was fully lined with moulded packing for the pump head units.

The second carton contained the additional components needed for deep-well use, packed in expanded polystyrene beads.

Both cartons were unusually easy to handle.

Condition as Received

The pumps were received in excellent condition.

Installation and Maintenance Information

None supplied with the pump.

Setting up was difficult because the cylinder stroke length was virtually the same as the distance through which the pump rod connection moves in the pumphead. This could possibly lead to installation problems in the field if no instructions are provided.

Manufacturing

The Dragon pump requires a moderate level of foundry skill and the ability to carry out simple machining. The handle linkage demands careful manufacturing quality control to ensure easy assembly and satisfactory operation. It may be suitable for manufacture in some developing countries, but is not ideal.

Safety

The tubular steel handle is threaded at the outboard end to accept the moulded plastic cap. The cap is easy to remove and could be lost. This exposes the end of the handle, which is sharp because the burrs were not removed after cutting.

The handle fulcrum pinch bolt forms a potential finger trap.

Suggested Design Improvements

The free end of the handle should not be threaded but simply belled out and smoothed, omitting the plastic end cap.

The wishbone link may be simpler to manufacture in a developing country as two joggled steel strips.

The handle fulcrum pinch bolt should be moved 90° to the underside, or replaced by two circlips on the shaft, similar to those on the wishbone link pivots.

The height of the top housing should be reduced to:

(a) eliminate the counterbore in the gland nut,
(b) eliminate unnecessary machining of the pivot casting,
(c) increase the length of thread attaching the connecting rod to the pivot casting.

The discharge valve should be removed as a cost-saving measure and only supplied if needed. We understand that the manufacturer will now supply pumps with a simple discharge spout, if required.

All pump body flanges should be flat or increased in thickness as they are unsupported and can be broken by over-tightening the fixing bolts.

The base casting should be strengthened.

Users

Many users found it difficult to decide on the best method of operation for this pump because the angular movement of the handle is particularly large. In spite of this, some users chose a full stroke but found the exaggerated body movements uncomfortable.

Endurance

This pump was tested at 40 strokes per minute at a simulated head of 45 metres.

The pump failed at 2890 and 3207 hours when the pump rod broke within the thread at the top. Components of the handle mechanism including the gland nut had to be replaced after 2500 hours because of wear. The handle fulcrum had broken when wear allowed it contact the retaining bolt. At each intermediate inspection, the spout discharge valve was found to be seized through lack of use and was freed off.

In the final inspection, the foot valve guide was almost completely worn away, and there was substantial wear of the valve stem. The leather cup seals and cylinder bore were in good condition, with few signs of wear. The gland nut was again very badly worn.

The cast iron cylinder end caps and the piston rod were corroded, but not sufficiently to interfere to any great extent with maintenance or performance.

Performance when New

Volume flow was virtually unaffected by operating speed or depth and was between 0.52 and 0.55 litre per stroke, for a full stroke of the handle.

The work input requirement varied from a minimum of 120 Joules per stroke at 7 metres depth to a maximum of 366 Joules per stroke at 45 metres. The maximum operating effort was less than 10 kgf at 7 metres, rising to around 25 kgf at 45 metres.

Efficiency varied from a minimum of 29% at 7 metres to a maximum of 67% at 45 metres. From observation of water delivery over the full stroke, the top and bottom parts of the handle arc appeared to be less effective. An arc of approximately 90° at the centre of the stroke was used as a partial stroke and a modest improvement to a minimum of 33% at 7 metres was achieved.

Performance after 4000 hours Endurance

Volume flow was only marginally reduced after endurance testing, remaining over 0.5 litre per stroke. But the work input requirement was reduced, at most 327 Joules per stroke at 45 metres. Efficiency was therefore improved, ranging from a minimum of 33% at 7 metres to a maximum 77% at 45 metres.

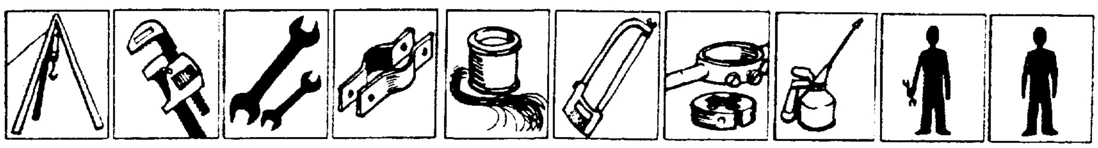
Maximum operating efforts were unchanged.

Abuse Tests

The Dragon failed the side impact test on the handle. Even at the lowest impact energy, 50 Joules, the handle began to bend. At 200 Joules, the base casting on the pumpstand broke. Therefore, the impact test on the body of the pumpstand could not be carried out.

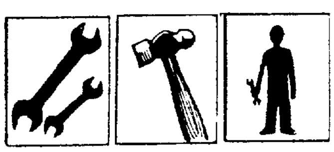
In the handle shock test, the handle was bumped against its upper limit stop only. At its lower limit the handle was close to the ground. It was considered that users would be unlikely to bump the handle on the lower stop. The pump completed its allotted 96,000 cycles without failure.

Installation



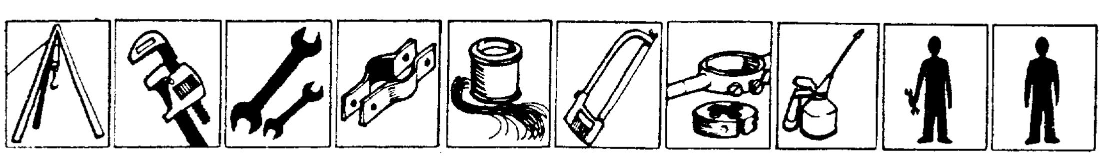
The pump requires a plinth of 325 mm high to provide a minimum of 500 mm clearance under the spout.

Pumpstand Maintenance and Repair



The pumpstand would benefit from regular lubrication. The repairs most likely to be required are to the handle fulcrum components, the connecting rod and the gland nut. In all these cases, manufacturer's spares would be required. The pumpstand is easy to dismantle, and need not be removed from the wellhead.

Below-Ground Maintenance and Repair

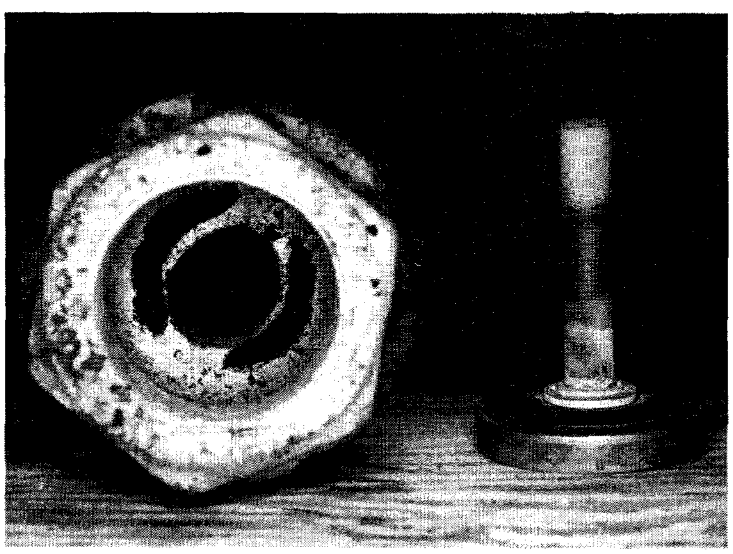


Repairs require removal of the complete below-ground assembly.

Verdict

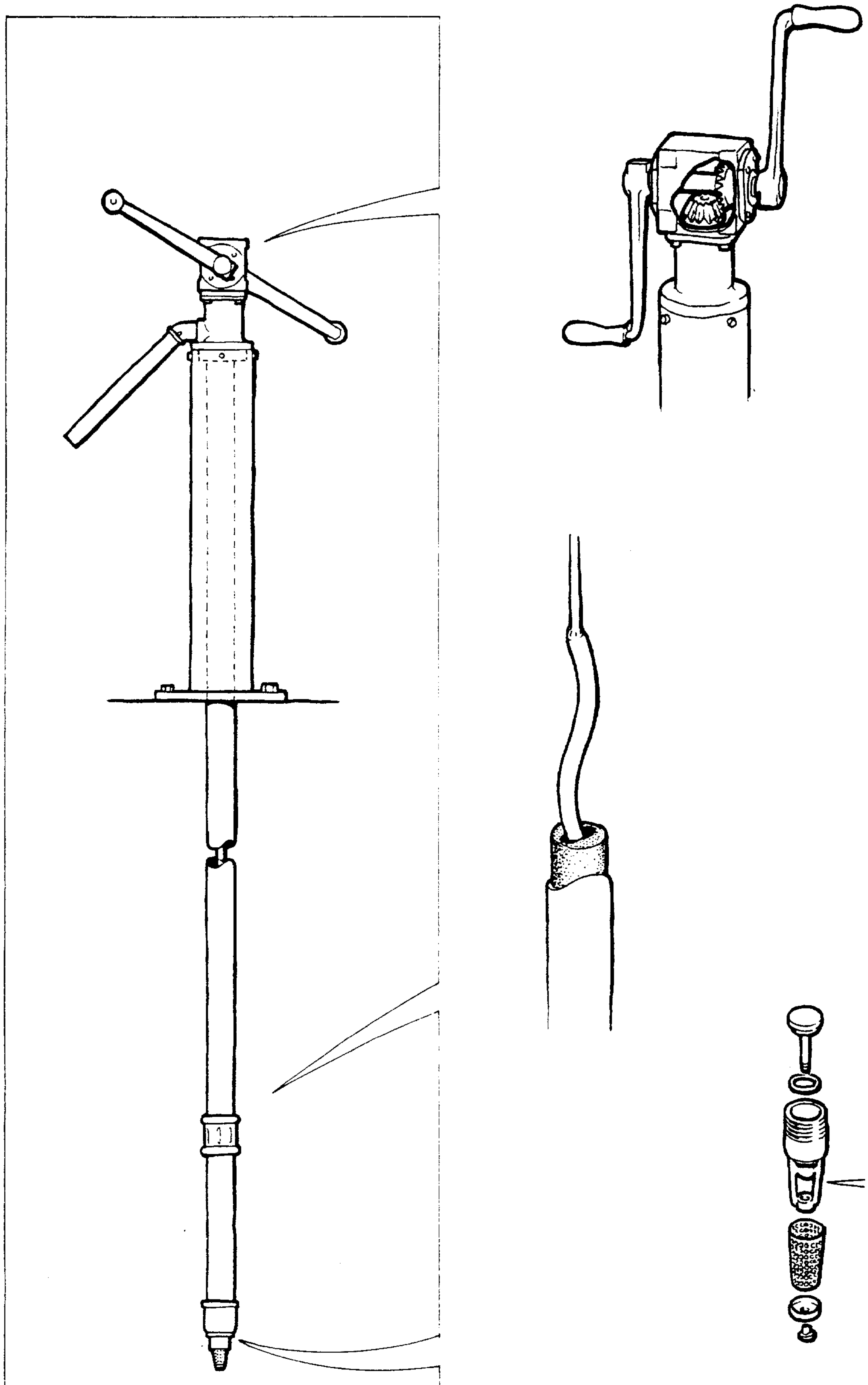
This pump appears to be designed for family use, possibly serving up to 15 people, and is unlikely to be sufficiently robust for community water supply. Intensive use will produce rapid wear in the moving parts of the pumpstand. Inexpensive.

Wear on the handle fork resulted in breakage of the iron casting.



This shows substantial wear of the foot valve poppet stem and its guide after 4000 hours.

Moyno Pump



3.4 Code C MOYNO 1V 2.6

The Moyno, made by Robbins and Myers in the USA, is a positive displacement pump, which has a plated helical steel rotor within a double-helical elastomeric stator. The pump rods rotate instead of reciprocating up and down. The pump is operated by a pair of rotary crank handles, driving a gearbox and one-way clutch. The pumpstand is very robust, of all-steel construction. The twin handles make the pump suitable for operation either by one or two people.

The pumpstand weighs 48 kg, the cylinder 16 kg and the pump uses 0.5 inch diameter steel rods and 1.25 inch nominal bore galvanised iron pipe. The maximum outside diameter of the below-ground assembly is 75 mm.

Packaging

The pumps were packed in two cartons made from heavy-duty corrugated cardboard (approx. 12 mm thick). The carton containing the pumpstands was supported on a wooden pallet. The other carton, containing the pipes and pump rods, had wooden ends and wooden internal reinforcements.

The cartons were strongly made and should absorb bumps and shocks well. However, if stored or transported in wet conditions they could deteriorate.

Condition as Received

The pumps were received in good condition. The only minor defect was a bent foot valve strainer, which was easily straightened.

Installation and Maintenance Information

None supplied with the pump.

Manufacturing

The Moyno requires a number of complex and some highly specialised manufacturing processes, in particular to make the rotor and stator in the cylinder and the bevel gears in the pumpstand. It is not suitable for manufacture in a developing country.

Safety

The spout is a length of galvanised iron pipe - the sawn end is sharp and potentially dangerous.

Suggested Design Improvements

The hand grips are an integral part of the roughcast steel handles and are uncomfortable to grasp and turn. They should be polished or replaced by rotating hand grips.

The sawn end of the spout should be smoothed.

In response to these suggestions, the manufacturer has modified the hand grips - the same casting is used but the hand grips are polished. The sharp edge on the spout is now removed.

Users

This pump was consistently disliked, especially by smaller users. Most of the effort must be supplied by the arms and shoulders only; there is little opportunity to bring other muscle groups into play. The efforts were high and the rate of delivery slow. Smaller users with limited reach, particularly children, could not maintain a smooth circular motion of the handles. This problem was more acute than for a conventional reciprocating pump because the users could not choose to operate the pump at less than full stroke. Several users tried to operate the pump with one handle only, but all except one reverted to two-handle operation. The rough, non-rotating hand grips were consistently criticised.

Endurance

The pump was tested at 40 revolutions per minute at a simulated head of 45 metres.

The Moyno failed once in the 4000 hour test programme, after 3178 hours. A rubber block is fitted in the bottom of the cylinder to prevent the rotor striking the base of the cylinder during installation. Although when first installed there was a clearance of 30 mm or so between the bottom of the rotor and the block, the block had worked its way up the cylinder bore and fouled the rotor, making the pump very difficult to turn. It was replaced in the correct position and the problem did not recur.

Some grease leaked out of the gearbox through one of the handle bearing seals, but the final inspection revealed that plenty of grease remained in the gearbox.

At the end of the test, the pump was generally in very good condition, with little corrosion. Wear was confined to the elastomeric stator which had been scored in several places by sand, but this was insignificant.

Performance when New

The volume flow decreased with increasing depth, from 0.23 litre per stroke at 7 metres to 0.15 litre per stroke at 45 metres.

The work input requirement was generally high, from a minimum of 130 Joules per stroke at 7 metres to a maximum of 209 Joules per stroke at 45 metres. The maximum effort was less than 15 kgf. Although this seems moderate in comparison with other pumps, the method of operation makes this force difficult to sustain throughout the complete turn of the handle. All the effort must be supplied by the arms and shoulders, whereas with a reciprocating pump, body weight can be used on the delivery stroke.

Pump efficiencies were low, from a minimum of 10% at 7 metres to a maximum of 36% at 45 metres.

Performance after 4000 hours Endurance

Volume flow was unchanged at 7 metres depth and slightly improved at 45 metres, at around 0.18 litre per stroke.

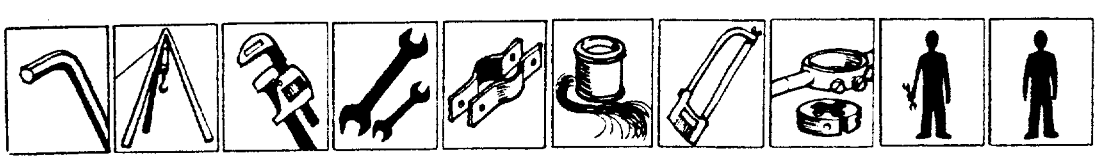
The work input requirement was considerably reduced at all depths, ranging from a minimum of 68 Joules per stroke at 7 metres to a maximum of 147 Joules per stroke at 45 metres. However, the rate of delivery remained low.

Efficiency was therefore much improved, varying from a minimum of 20% at 7 metres to a maximum of 58% at 45 metres.

Abuse Tests

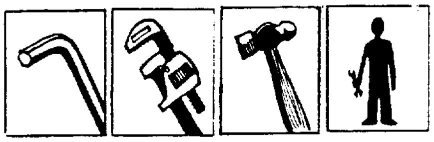
The Moyno was undamaged in the side impact tests.

Installation



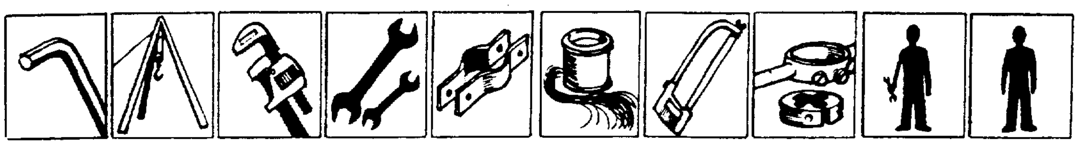
A die and diestock for threading the pumprod, together with clamps and hexagon keys were supplied with the test samples.

Pumpstand Maintenance and Repair



Frequent attention to the pumpstand is unlikely to be required. A broken handle could be replaced in the field, but internal repairs to the gearbox assembly may demand workshop facilities.

Below-Ground Maintenance and Repair

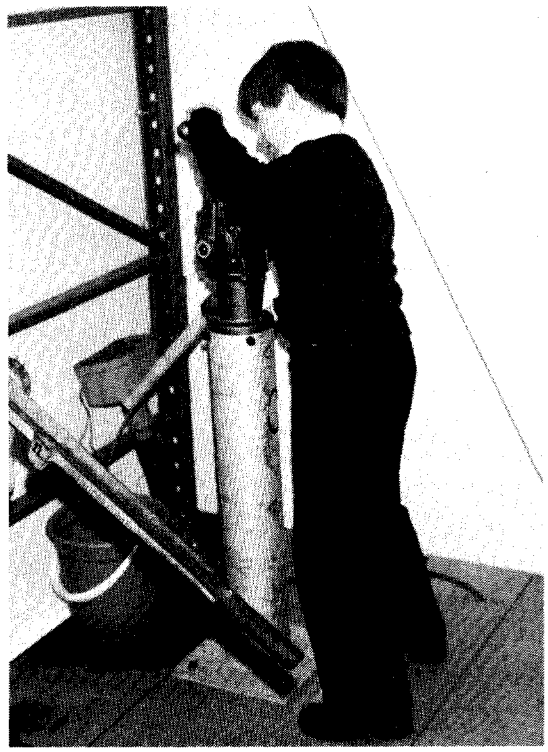


Frequent attention to the below-ground assembly is unlikely to be required. However, any repair requires removal of the complete below-ground assembly, and if the pumping element is faulty it must be replaced as a unit. In general, this pump requires an exchange rather than a maintenance routine.

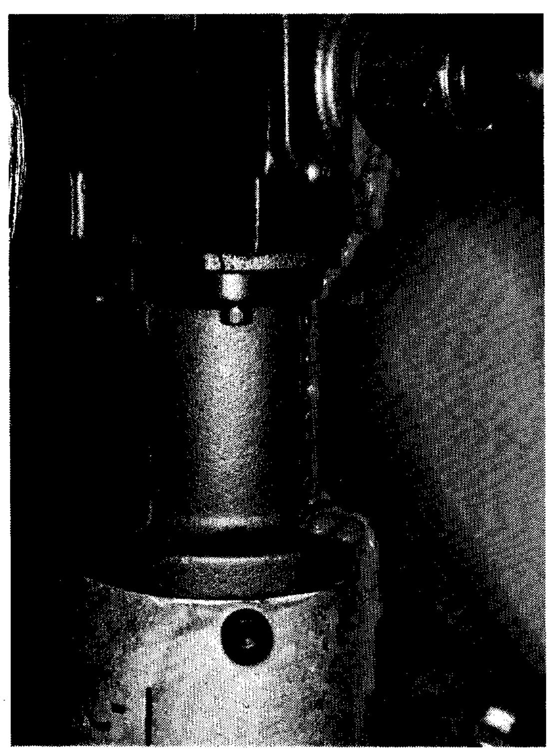
Verdict

A very robust pump, in good condition after 4000 hours of endurance testing. The rate of delivery was low, and the pump was hard work to operate at first, though it became easier with further use. Likely to be reliable, but may not be ideal for community water supply because of the difficulties of operation. Expensive to buy.

Moyno Pump



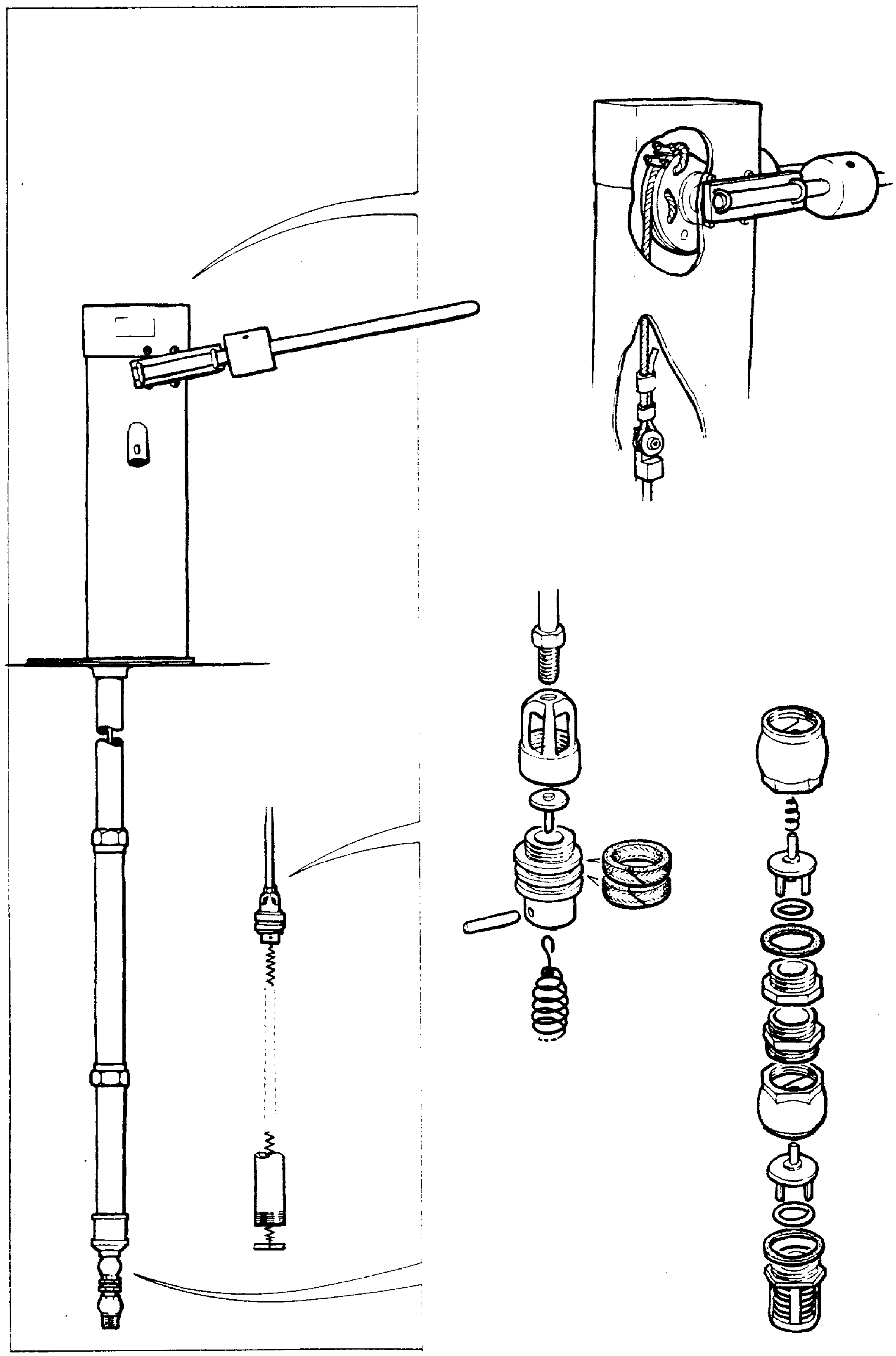
An 11-year-old boy working hard for his 10 litres of water.



Grease leaked for a while through the handle bearing seal but there was plenty of grease remaining in the gear-box after 4000 hours.

Moyno Pump

Nepta Pump



3.5 Code D BRIAU NEPTA

The Nepta is a deep-well force pump made in France. The pumpstand body is fabricated from sheet steel, the handle mechanism machined and fabricated from steel sections. The body is protected by a coating of nylon, the handle is galvanised. The pump rods are stainless steel attached at the top to approximately one metre of polyester cord, which wraps around a machined sector rotated by the handle.

The cylinder is seamless brass tube. The machined plunger uses two sealing rings of square-section textile cord in place of conventional cup seals. Tension in the pump rod and polyester cord is provided by a stainless steel spring attached to the bottom of the piston. Two foot valves are fitted, of similar design, each using a rubber O-ring seal.

The pumpstand weighs 41.5 kg, the cylinder assembly 15.5 kg and the pump uses 10 mm stainless steel rods within 1.25 inch nominal bore galvanised iron rising main. The maximum outside diameter of the below-ground assembly is 76 mm.

Packaging

These pumps were very well packaged. All the components except the drop pipe were contained in wooden packing cases.

The pumps were not entirely free from damage, however. The spout of one pump stand had rubbed on the packing case, damaging the plastic coating.

The pipes were bound together in groups of four. The threaded ends of the pipes were protected by plastic caps, surrounded by wood shavings and wrapped in small plastic sacks.

Condition as Received

Both samples appeared to be in working order as received, in spite of minor defects. The plungers in both samples were not assembled tight, and one piston-to-pump rod joint was not tight enough. Although not of immediate significance, these defects might cause premature failure if not remedied before installation. The nylon coating on the spout of one pumpstand had been damaged in transit.

Once installed, however, a more significant defect came to light. The pump would work at shallow depths, but was unsatisfactory at 25 metres and very poor at 45 metres. The reason was found to be leakage past the plunger seals, caused by wrongly-sized sealing cords. The cords appeared to have been cut to length to suit the machined grooves in the plunger, and with butt joints - as a result they were a poor fit in the cylinder in both samples. Spare cord had been supplied with the pumps, and new sealing rings were cut to suit the cylinder bore, and with angled, scarf joints. This markedly improved the pump efficiency, from 37% to 71% at 25 metres depth, for example.

Installation and Maintenance Information

A booklet was supplied with pumps, giving helpful instructions for installation. The instructions were in French only, but were well illustrated and useful.

Manufacturing

The only specialised process is nylon coating but this could be substituted by galvanising. However, the Nepta is not very suitable for manufacture in a developing country. Considerable skill in steel fabrication and relatively complex machining is essential.

Safety

The handle on the pump is particularly heavy and would be dangerous if the polyester cord were to break in use.

There are a number of potential finger traps between the handle and the pumpstand - increased clearances would help considerably.

Suggested Design Improvements

The plunger sealing rings should be cut to length to suit the cylinder bore rather than the machined grooves in the plunger body, and the joints should be cut at an angle. The manufacturer has adopted this suggestion.

The efficiency of the plunger valve may be improved by providing a rubber or leather valve seat.

The tension spring below the plunger should be omitted. In deep-well applications, the weight of the pump rods should be sufficient to maintain tension in the polyester cord. In shallower applications, thicker, heavier rods or additional weight added to the piston may be needed.

The baseplate should be strengthened to avoid distortion.

Either the setting instruction for the plunger position should be improved or the cylinder length should be increased.

Users

Many users complained that the handle was too low. The handle moves through a wide arc, 104° for a full stroke. The users were keen to try for a full stroke because of the pump's relatively slow rate of delivery but they found the exaggerated body movements uncomfortable.

Endurance

The pump was tested at 40 strokes per minute at a simulated head of 45 metres.

The only failures in the 4000 hour endurance test were of the tension spring. The spring broke and was replaced during the first 1000 hour period. 289 hours later the replacement spring broke and was replaced. It was not replaced when it broke for the third time since the pump seemed to work satisfactorily without the spring. The pump completed the last 1000 hours of the test without a spring.

In the final inspection, all the valves were found to be in good condition, though there were signs of wear. The upper sealing ring on the plunger was noticeably worn, but the lower ring was in good condition and working well. The cylinder bore was in very good condition, with no signs of wear. There was some play in the handle bearings, but they were still serviceable.

Performance when New

Having corrected the plunger seals, volume flow was substantially constant at around 0.39 litre per stroke.

The work input requirement varied from a minimum of 43 Joules per stroke at 7 metres depth to a maximum of 216 Joules per stroke at 45 metres. Maximum operating forces were generally low, less than 15 kgf at 45 metres.

Efficiency varied from a minimum of 52% at 7 metres to a maximum of 94% at 45 metres.

Performance after 4000 hours Endurance

Volume flow increased after endurance testing, to typically 0.46 litre per stroke at 7 metres and 0.42 litre per stroke at 45 metres. The work input requirement increased also, particularly at greater depths, to between 320 and 351 Joules per stroke at 45 metres. Peak operating forces were largely unchanged at 7 metres, but at 45 metres had increased to around 20 kgf.

Efficiency was slightly reduced at 7 metres, and considerably reduced at 45 metres for which 57% was the best result obtained.

Abuse Tests

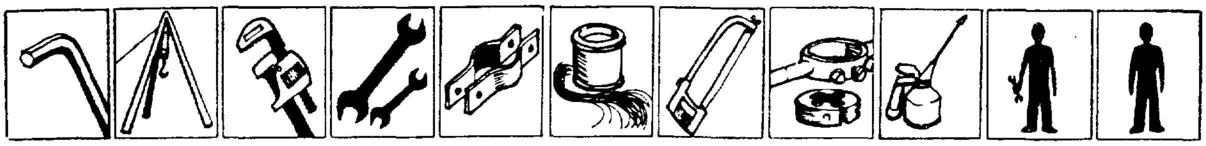
The baseplate tended to distort at 200 Joules impact on the handle and 400 Joules and above on the centre of the pumpstand.

In the handle shock test, after 26358 cycles the bump rubbers began to break up, and the back of the pumpstand body was becoming distorted.

The test was then terminated because the excessive movement of the handle eventually jammed the piston in the top of the cylinder.

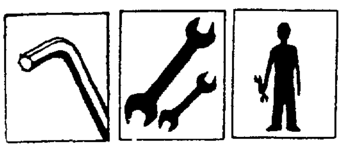
Nepta Pump

Installation



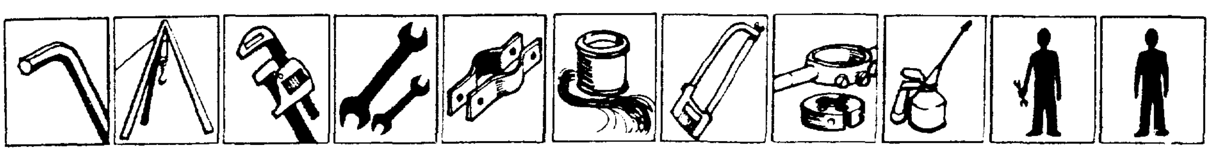
Clamps and hexagon keys were supplied with the test samples. This pump needs attention to the final adjustments of the polyester cord and the handle counterweights. Care is needed to ensure a sanitary seal at the wellhead.

Pumpstand Maintenance and Repair



This pumpstand is unlikely to require frequent maintenance, and need not be removed from the wellhead. The bearings may be replaced when necessary; a hexagon key is needed, but this was supplied by the manufacturer.

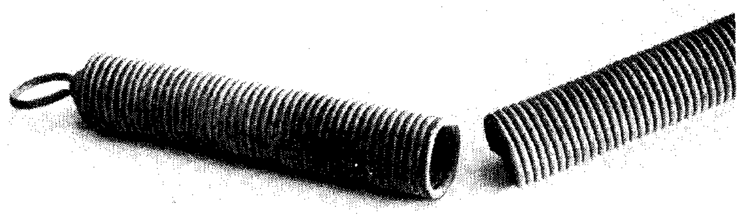
Below-Ground Maintenance and Repair



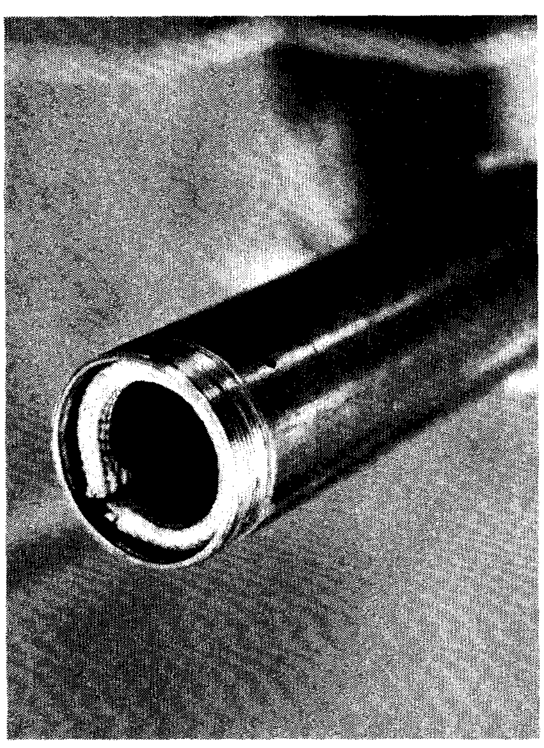
Repairs require removal of the complete below-ground assembly. The valves use O-ring seals which are easy to replace once the cylinder has been dismantled. If the spring is retained, it is likely to demand frequent replacement; care is then needed to avoid damage to the piston.

Verdict

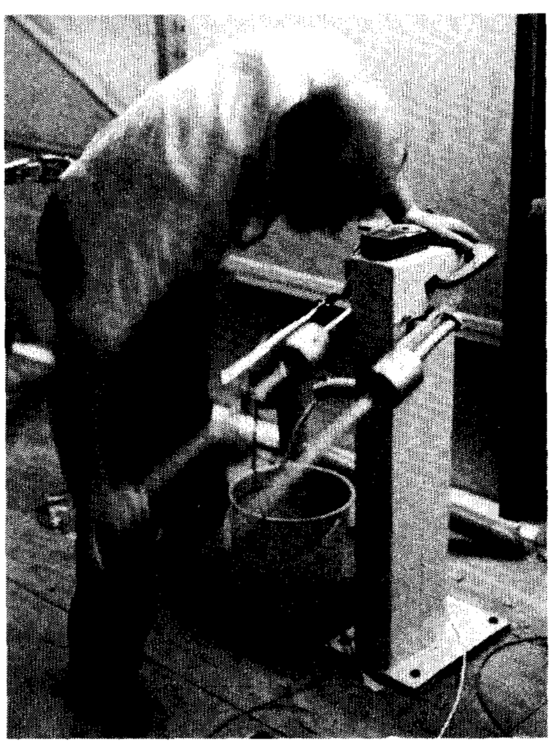
A reasonably robust and generally reliable pump, if the spring were designed out. Potentially suitable for community water supply. Liked by some users. Expensive to buy.



One of the broken plunger return springs.



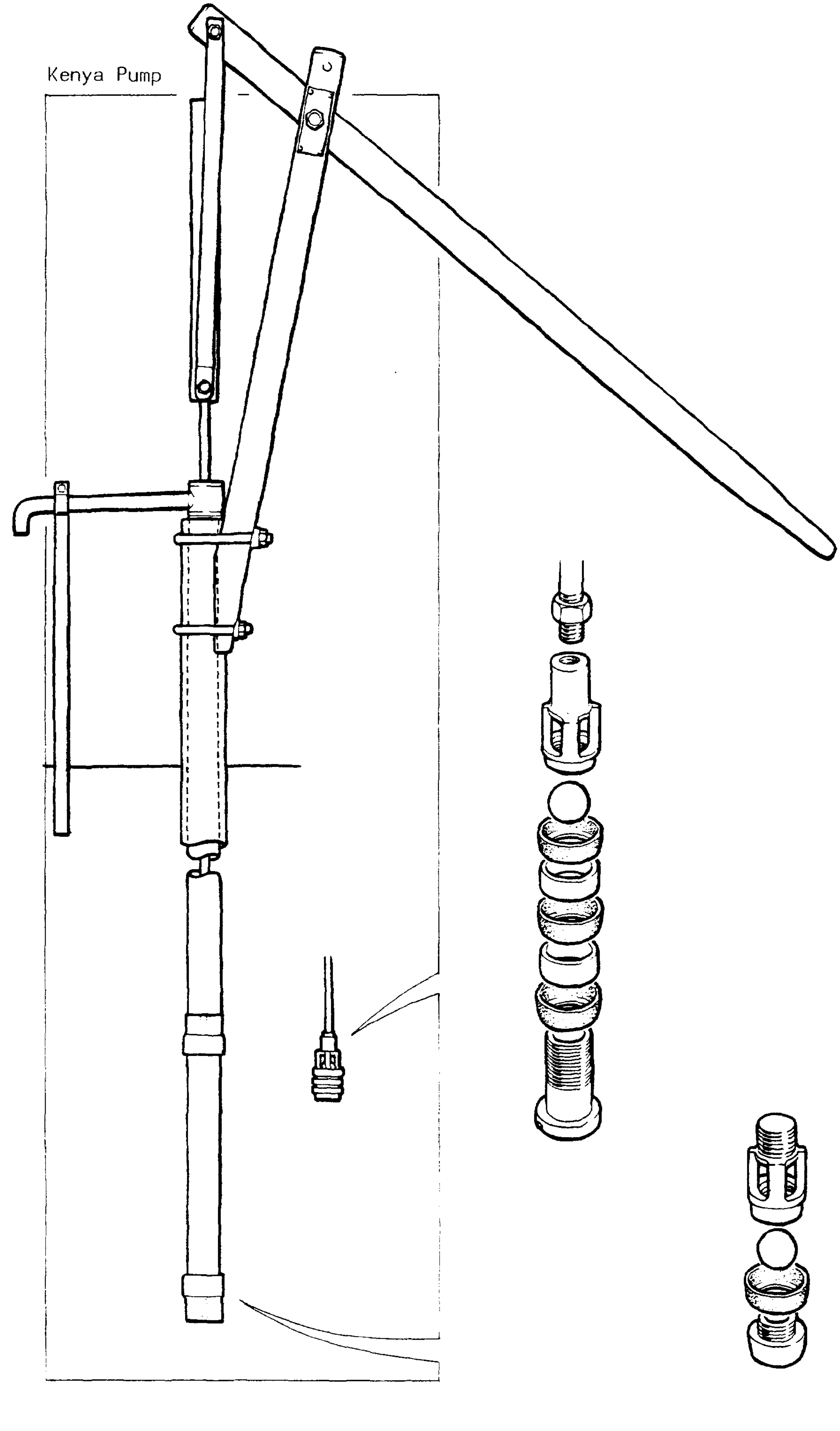
This indicates the wrongly cut piston sealing cord.



Performance testing by one of our expert technologists.

Nepta Pump

Kenya Pump



3.6 Code E ATLAS COPCO KENYA

The Atlas Copco Kenya, made in the country of its name, is a conventional deep-well force pump. The pumpstand is designed to an established, almost traditional, pattern. It is made of wood, steel and standard galvanised iron pipe and pipe fittings. The pumpstand is over six feet tall. The pumpstand is designed to clamp onto a 4 inch well casing.

The cylinder is seamless brass tube, the plunger has three cup leathers and both plunger and foot valves contain stainless steel balls. The foot valve has a screw thread to allow it to be attached to the plunger, so that both plunger and foot valve may be extracted without removing the cylinder or rising main, provided at least 2.5 inch pipe is used.

The pumpstand weighs 67 kg, the cylinder assembly 6.5 kg. The pump rods are 0.5 inch nominal bore galvanised steel pipe within 2.5 inch nominal bore rising main. The maximum outside diameter of the below-ground assembly is 84 mm.

Packaging

The pumps were securely packed in a robust plywood packing case bound with steel strapping. Although strong enough to resist rough treatment the size and weight of the package might make it difficult to man-handle.

Condition as Received

The pumps were received in working order. However, in one sample the spout was partially blocked by surplus zinc from galvanising, which would have restricted the outflow of water, and there was rust on the pump rod connecting tubes on both samples.

Installation and Maintenance Information

None supplied with the pump.

Manufacturing

The Kenya pumphead requires basic skills in steel fabrication, foundry work, simple machining and woodwork. The pump body is suitable for manufacture in developing countries where timber of suitable quality is readily available. The cylinder needs greater skills in manufacture than the pumphead.

Safety

The U-bolts attaching the wooden fulcrum upright to the rising main have unnecessarily long ends which have not been deburred.

The reciprocating links could be dangerous to bystanders or children.

There are potential finger-traps between the handle and the fulcrum upright.

Suggested Design Improvements

The angle between the fulcrum upright and the well casing should be better controlled to minimise the angular movement of the connecting links. The bracket used on the Shinyanga pump version would be much more satisfactory.

The end-plate of the rod connecting pipe should be thicker, to provide more thread for attaching the pump rod.

The lower pivots on the connecting pipe should be shorter, to minimise the overhang. This may be achieved by omitting the existing spacers, reversing the connecting links and using shorter threaded studs. Alternatively, the studs might be replaced by short L-shaped lengths of bar welded to the tube.

The valves would be more efficient if their lift were limited to one quarter of their effective diameter. The valve seats should be either sharp or chamfered, not radiused.

We are awaiting the manufacturer's comments.

Users

At its highest point, the handle of this pump was out of reach of several of the children, and awkward for some smaller women. Full strokes needed exaggerated body movements with a change of grip, from pull to push, in mid-stroke.

Endurance

The pump was tested at 40 strokes per minute at a simulated head of 45 metres.

Within 200 hours of the start of the 4000 hour endurance test, the pump rod connecting tube, and the guide tube on which it slides, were worn through. This rapid wear was caused by misalignment of the connecting links. Alignment of these links depends on the angle of the timber upright, and that in turn depends on the accuracy of the groove cut in its base. This groove had been roughly cut, and as a result the connecting tube was constantly biased to one side. Wedges were inserted between the upright and the well casing to minimise the out-of-line forces in the connecting links.

Later, at 1350 hours, the connecting tube and guide tube had worn through once again. One of the pivot stubs on the connecting tube had stripped a thread, biasing the connecting tube to one side. Because of this the pivot stubs were modified in accordance with our suggested design improvement, and no further problem occurred here during the rest of the 4000 hour endurance period.

The handle was turned over at 2153 hours, to even out wear in the pivot holes.

In the final inspection, the valve cages were worn where the valve balls had hammered them, and the plunger valve seat was pitted. The cylinder bore had been slightly scratched by sand but was generally in good condition. All the moving parts on the pumpstand were worn. The piston rod was substantially corroded, but there was little corrosion elsewhere.

Performance when New

Volume flow was unaffected by operating speed or depth, between 0.75 and 0.78 litre per stroke.

The work input requirement varied from a minimum of 119 Joules per stroke at 7 metres depth to a maximum of 528 Joules per stroke at 45 metres. The maximum operating force at 7 metres barely exceeded 10 kgf, increasing to between 35 and 40 kgf at 45 metres.

Efficiency improved with depth, from a minimum of 37% at 7 metres to a maximum of 67% at 45 metres.

Performance after 4000 hours Endurance

Volume flow was unchanged after endurance testing. The work input requirement increased somewhat, varying between a minimum of 195 Joules per stroke at 7 metres to a maximum of 594 Joules per stroke at 45 metres. Maximum operating forces also increased: typically 15 kgf at 7 metres and over 40 kgf at 45 metres probably due to lack of lubrication.

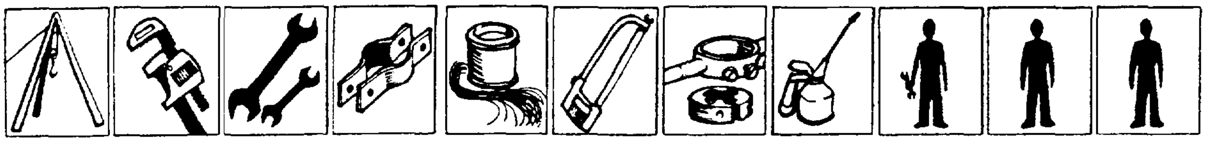
Efficiency was therefore somewhat lower, varying between a minimum of 24% at 7 metres and a maximum of 58% at 45 metres.

Abuse Tests

The Kenya pump was undamaged by both the handle and body side impact tests. In the handle impact test, some of the energy was absorbed by the pump slipping round the well casing.

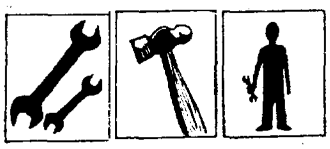
The pump did not break down in the handle shock test, but a burr formed on the bottom of the pump rod connecting tube which caused noticeable wear of the guide tube.

Installation



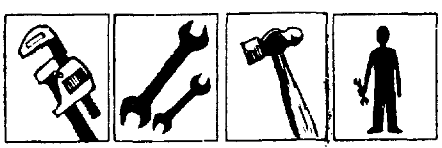
The 4 inch well casing must protrude above ground, to attach the fulcrum upright. The spout support should be concreted in. The below ground assembly will be heavy if 2.5 inch galvanised iron rising main is used. Assembly would be straightforward with good diagrammatic instructions.

Pumpstand Maintenance and Repair



The design of this pumpstand lends itself to innovative repair using indigenous materials; this should not be difficult.

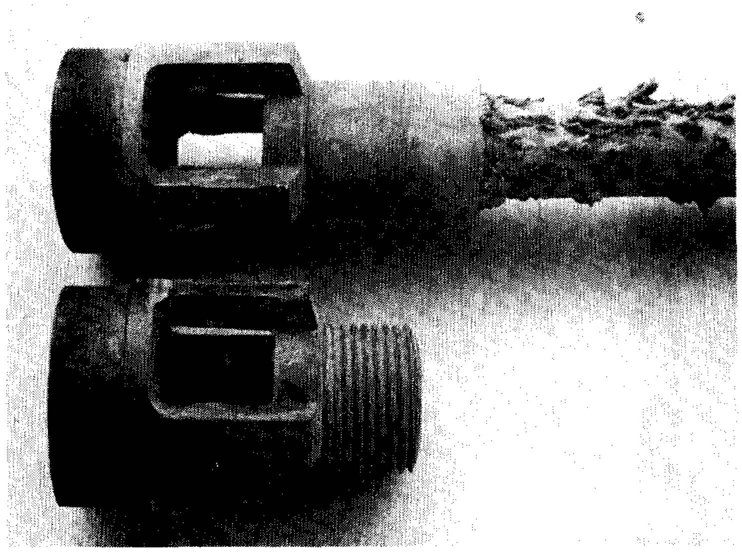
Below-Ground Maintenance and Repair



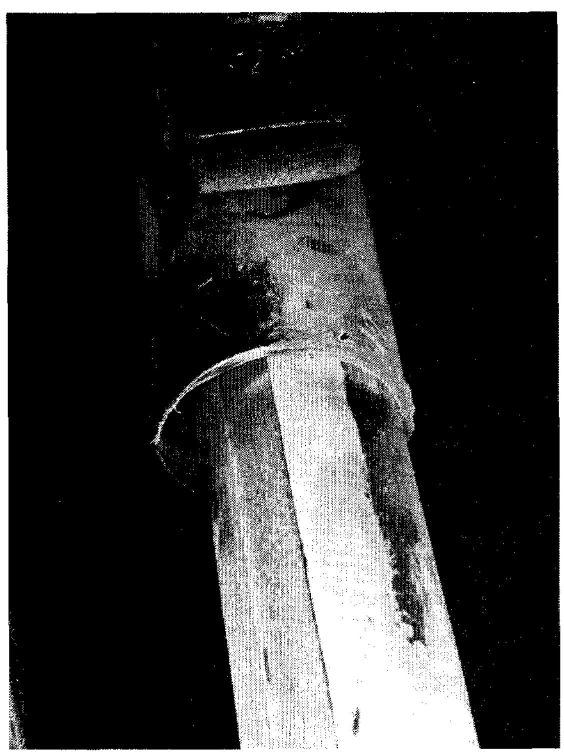
Provided 2.5 inch rising main is used, the plunger and foot valve may be extracted without removing the rising main, so lifting tackle would not be needed. It may be difficult to dislodge the foot valve, however.

Verdict

A simple but cumbersome pump. Likely to need frequent maintenance above ground, much of which could be avoided by small design changes. Possibly suitable for community water supply, and could be largely maintained locally. Approaching a VLOM pump, but requires that at least the upper portion of the well casing be made of seel. Expensive to buy.

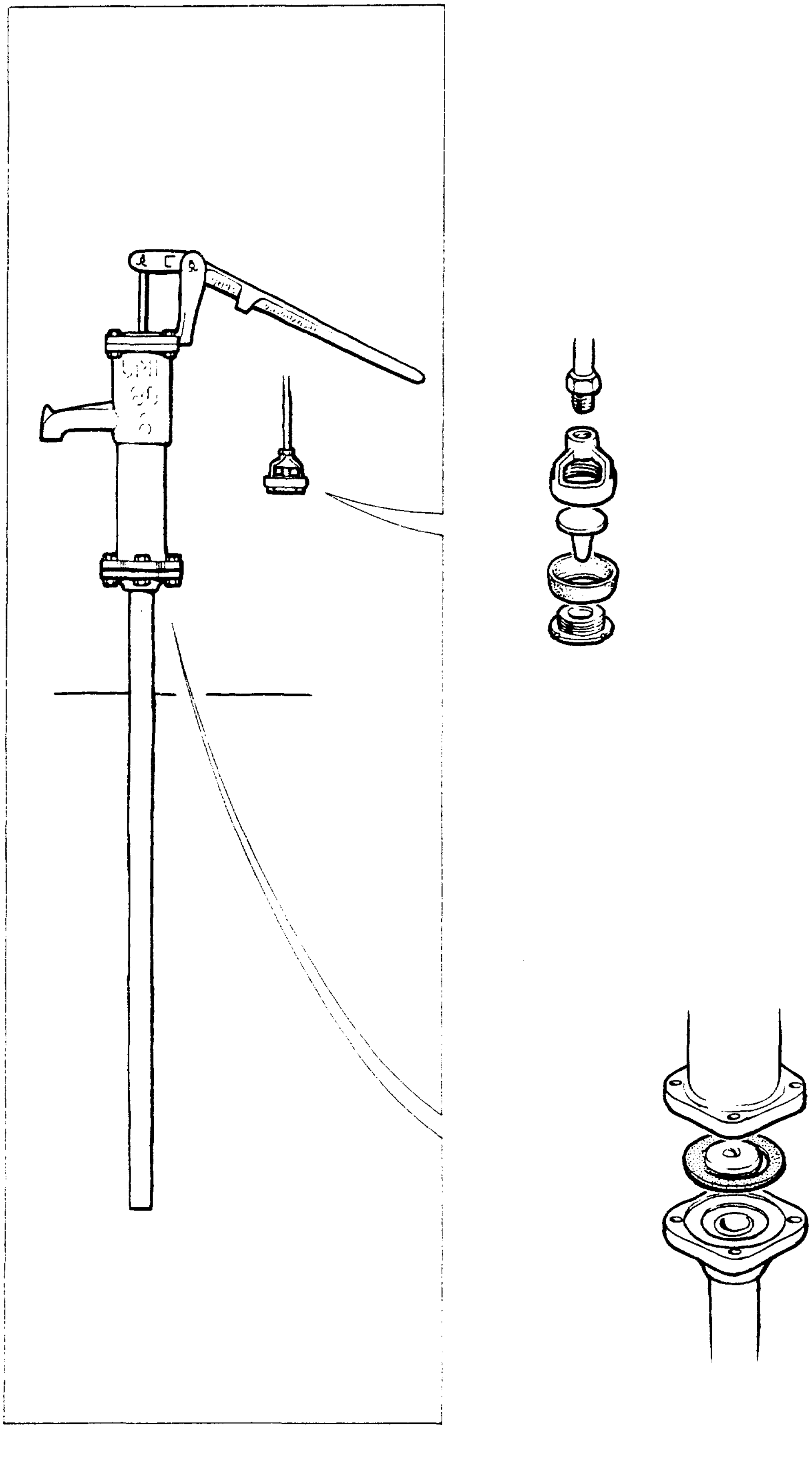


Both plunger and foot valve cages show signs of wear or distortion due to the hammering of the steel ball valve.



Wear of the guide tube and connecting tube after about 200 hours.

New No. 6 Pump



3.7 Code F BANGLADESH NEW No.6

The New No.6 is a shallow-well suction pump, made in Bangladesh and constructed almost entirely of cast iron. It is mounted directly onto a 1.5 inch rising main. The plunger uses a moulded PVC cup washer. The check valve is a simple leather flap, weighted with cast iron.

It appears crude and rather rough at first sight, but is commendably simple and robust.

The pump weighs 31 kg, and uses standard 1.5 inch nominal bore galvanised iron pipe.

Packaging

The pumps were in a single wooden packing case with corrugated cardboard lining.

The cardboard liner would be adversely affected by water, but it and its contents were well supported by the wooden case.

Condition as Received

Both samples were received in working order. However, both pump tops were loose, spring washers had been placed under the bolt heads rather than under the nuts. In one sample, the halves of the plunger were not tightly screwed together, and a locknut on the piston rod was not tight. Although not of immediate significance, both these defects might cause premature failure of the pump if not remedied before installation.

Installation and Maintenance Information

None supplied with the pump. Subsequently a maintenance leaflet was received which contained very helpful diagrams.

Manufacturing

Where adequate skills in iron foundry work and basic machining are available, the New No.6 is particularly well suited for manufacture in a developing country.

Safety

The split pins used to retain the handle pivot shafts should be carefully fitted to minimise any potential safety hazard from their sharp ends.

In use the end of the handle will become polished. Because the handle is low at the bottom of the stroke there is a potential risk that users' hands will slip off.

Suggested Design Improvements

A sliding plate on the connecting rod (in the manner of Code L) would help to prevent contamination.

The diameter of the rising main should be increased and/or cast mounting lugs should be provided on the pumpstand.

The quality of the bore should be improved to avoid rapid wear of the cup washers.

The handle casting pattern should be modified to provide a small bulge at the end.

Users

Many users were pleasantly surprised by this pump's performance, contrasted with its crude appearance. It delivered plenty of water for each stroke, and the handle movement allowed arms, shoulders, back and legs to contribute. Some disliked the roughness of the handle.

Endurance

The pumps was tested at 30 strokes per minute at 7 metres head.

The original cup washer and plunger valve were badly worn after 1000 hours, and were replaced. The cup washer failure was probably due to the initial roughness of the bore. The replacements lasted the remaining 3000 hours of the test programme, though both were badly worn at the end. The check valve was also replaced at 1000 hours, and the replacement also lasted out the remainder of the 4000 hours.

The final inspection revealed wear in the handle pivot shafts and the associated holes in the handle, pump top and connecting rod eye. The pump was still working however, and will probably continue for some time.

Corrosion was extensive. The cast iron of the pumpstand has no protective coating and was rusting wherever it had gotten wet. Because of rust, the plunger was impossible to dismantle and the retaining screw could not be removed from the check valve weight.

The cylinder was in good condition at the end of the test. The original machining marks in the bore were still clearly visible although the high spots had been removed.

Performance when New

Cavitation was evident when operating the pump faster than 30 strokes per minute or so. Volume flow was high and substantially constant, between 1.2 and 1.3 litres per stroke.

The work input requirement was a minimum of 121 Joules per stroke at 30 strokes per minute, and maximum of 148 Joules per stroke at 20 strokes per minute. The maximum operating efforts were well below 20 kgf.

Efficiency was a maximum of 67% for 30 strokes per minute, a minimum of 59% for 20 strokes per minute.

Performance after 4000 hours Endurance

Volume flow was substantially reduced after endurance testing, only 0.48 litre per stroke at 23 strokes per minute, increasing to 1.01 litres per stroke at 30 strokes per minute.

The work input requirements were somewhat less however, 73 Joules per stroke at 23 strokes per minute and 129 Joules per stroke at 30 strokes per minute. Maximum operating efforts remained well below 20 kgf.

Direct comparison with the efficiency measurements when new cannot be made since the cup washers and foot valve were replaced at 1000 hours.

Efficiency after 3000 hours of use of the new components was 45% at 23 strokes per minute and 53% at 30 strokes per minute.

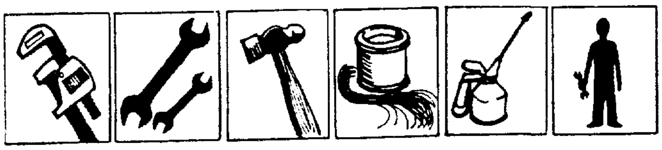
These results reflect the wear in the cup washer and valves.

Abuse Tests

The pump failed in one of the side impact tests. In the body test, the thread n the pumpstand base was partially stripped at an impact of 300 Joules on he centre of the pumpstand. However, plenty of thread remained, and the pump could have been remounted and re-used. In the test on the handle, the pumpstand simply turned on its mounting thread to absorb the impact.

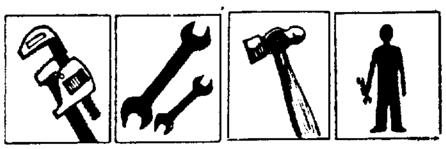
In the handle shock test, the pump completed its allotted 72,000 cycles without failure.

Installation



The drop pipe must be securely installed to support the pumpstand, otherwise this suction pump is easy to install. Only basic tools and skills are required.

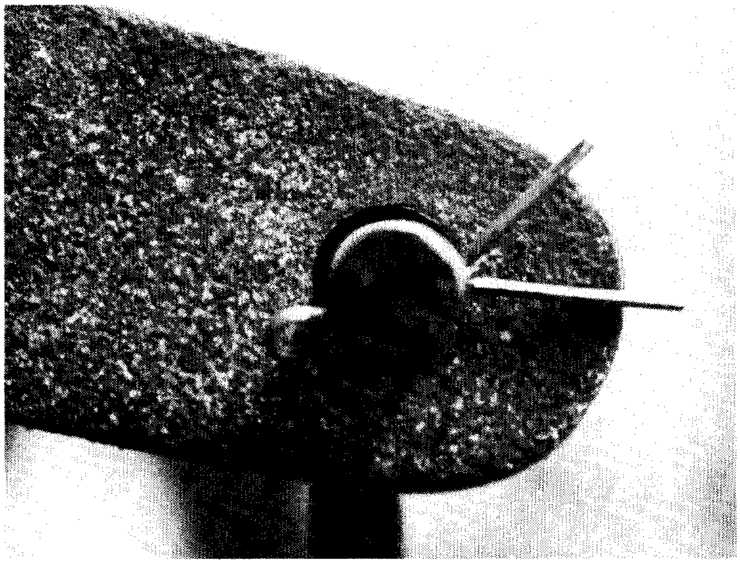
Maintenance and Repairs



This pump is likely to require frequent attention to the plunger and check valve, but is very simple. Most jobs can be done with flat spanners and pliers. A pipe wrench may be needed to dismantle the plunger, which may become heavily corroded.

Verdict

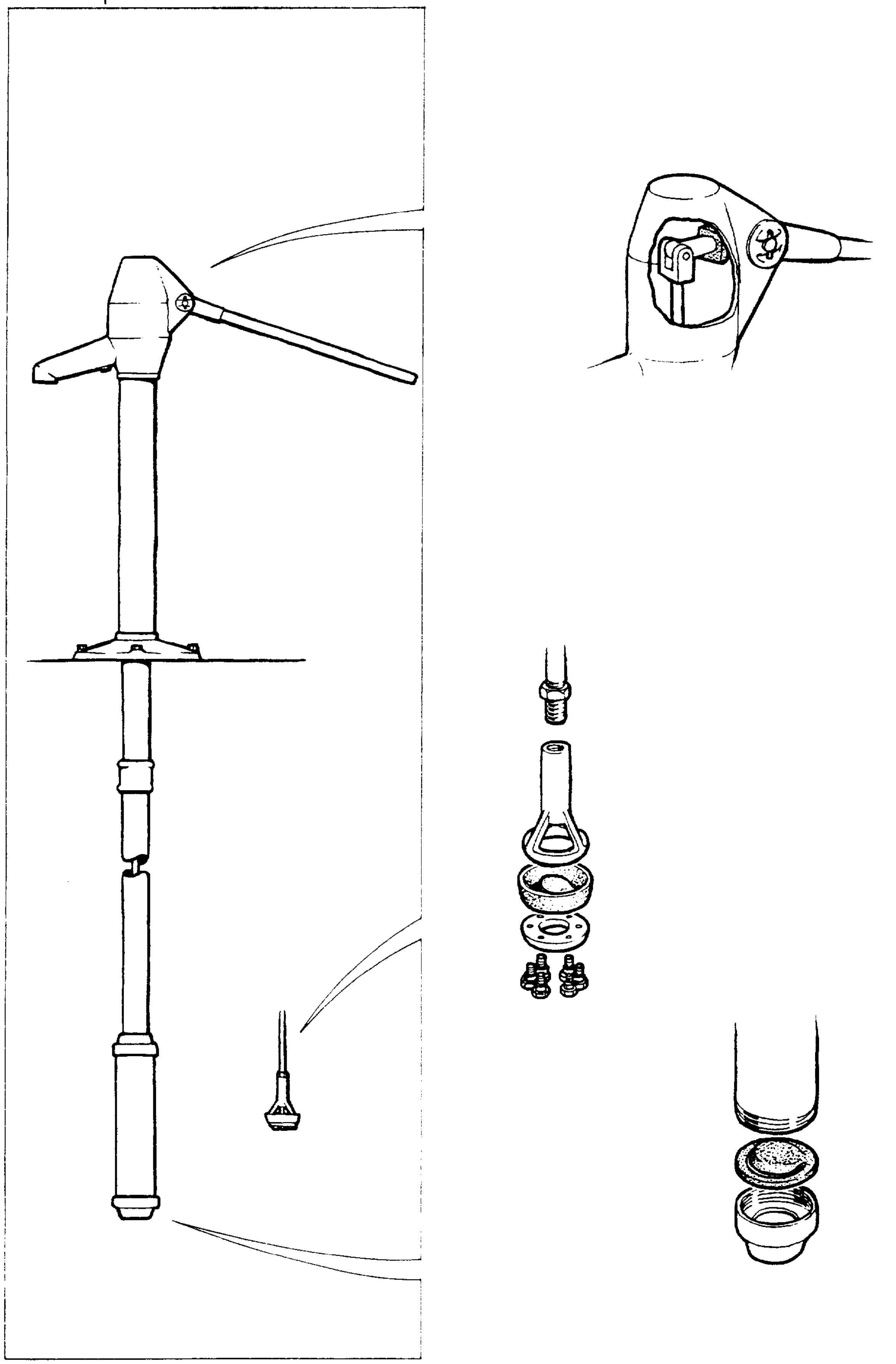
A very simple, cheap, and sturdy suction pump. Needs to be primed and therefore susceptible to contamination and abuse. Initial roughness of the bore causes early failure of the cup washer and should be improved. Likely to wear considerably when heavily used.



This shows the deliberate clearance designed
in the pin and handle, and also indicates the
dangerously sharp tails of the split pins.

Some wear on the handle pivot
after 4000 hours.

Nira Pump



3.8 Code G NIRA AF-76

The Nira is a deep-well force pump, made in Finland. The pumpstand has a tubular steel column with a cast iron base, and a cast iron handle mount and spout assembly. The handle was originally steel bar but has since been changed to steel tube. The steel parts of the pumpstand are galvanised, the iron castings are protected by a nylon coating.

The 76 mm bore cylinder is seamless brass tube and unusually thin - too thin to accept a thread for the end caps, so that threaded collars have to be soft-soldered to each end. With this size cylinder the manufacturer now recommends depths not greater than 18 metres. The cup washer and plunger valve are combined in a single rubber moulding. The foot valve is of similar design, also moulded in rubber.

The pumpstand weighs 29.5 kg, the cylinder assembly 4.0 kg. The pump uses 10mm stainless steel rods within 2 inch nominal bore galvanised iron rising main. The maximum outside diameter of the below-ground assembly is 95 mm.

Packaging

Delivered in a single large wooden packing case 3.5 m long.

The packaging was strong but its size and weight would make it difficult to man-handle. On the other hand, by packing all the components in a single case, the chance of components being separated is much reduced.

Condition as Received

Both pumpstands were in working order as received. However, one cylinder was externally damaged causing distortion of the bore, and several fixings were insufficiently tight. Although the pumps were in working order, these defects would be likely to cause premature failure if not remedied before installation.

Installation and Maintenance Information

A promotional leaflet was supplied with the pumps. It included an annotated sketch of the components, but was not very helpful.

Manufacturing

Although no specialised processes are required, the Nira is not an ideal design for manufacture in a developing country. Considerable skill in foundry work is demanded, particularly for the pumpstand top, and in steel fabrication, machining and rubber moulding.

Safety

There are no significant safety hazards in this pump.

Nira Pump

Suggested Design Improvements

A thicker cylinder wall would be less easily dented and would allow integral threads at each end, thereby eliminating the need for soft-soldered end spigots.

Valve lift should be reduced, ideally to one quarter of the diameter. The manufacturer has adopted this suggestion.

In the newer, tubular handle, the core should be a tighter fit in the outer tube, otherwise the core provides little support.

A stiffer base casting would be advantageous.

The manufacturer now uses stainless shouldered fixing screws with hexagon heads in the piston to control the compression of the rubber moulding.

Users

Children and small women found this pump difficult because of the high levels of effort required. Many children found it difficult to bring their weight to bear on the handle at the start of the downstroke.

Endurance

The Nira was tested at 40 strokes per minute at a simulated depth of 36 metres, the maximum specified by the manufacturer. The handle broke several times within the 4000 hours. The original, round bar handle broke after only 314 hours. A new tubular handle was supplied by the manufacturer, but that in turn broke after a further 2200 hours or so, and a second sample 189 hours later. One of the tubular handles was repaired by welding and completed the remainder of the 4000 hour test. In response, the manufacturer now recommends the 76 mm cylinder for a maximum depth of 18 metres, and will offer a 50 mm cylinder for greater depths.

At the 1000 hour intermediate inspection, all the setscrews used to assemble the plunger were badly corroded, and the head of one screw had broken off. Because of this the plunger could not be dismantled and was therefore replaced complete.

In the final inspection, little wear was found in the valves, cup seal, cylinder and handle bearings. The six setscrews in the plunger were corroded but unbroken. There was no significant corrosion elsewhere.

Performance when New

Volume flow tended to decrease with depth, from a maximum of 0.65 litre per stroke at 7 metres to a minimum of 0.59 litre per stroke at 45 metres.

The work input requirement varied from a minimum of 55 Joules per stroke at 7 metres, through approximately 250 Joules per stroke at 25 metres to a maximum of 404 Joules per stroke at 45 metres. Maximum operating efforts were generally less than 10 kgf at 7 metres, but increased to 40 kgf at 25 metres and over 60 kgf at 45 metres.

The maximum efficiency was 76% at 7 metres depth and it was not much reduced at 25 metres. At 45 metres it was still as high as 66%.

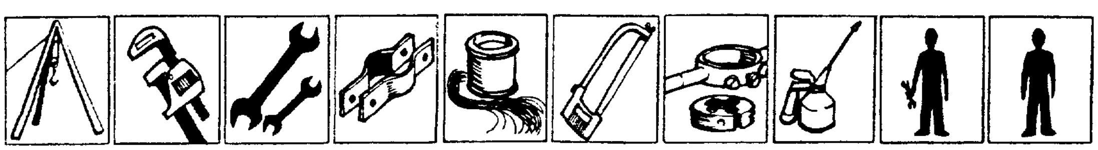
Performance after 4000 hours Endurance

Performance after endurance was virtually unchanged.

Abuse Tests

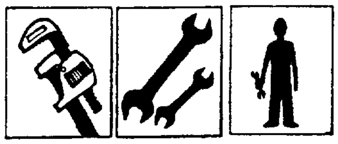
In the side impact test on the handle, the pump top absorbed the impact by rotating the screw threads on the pumpstand column. In the body test, the baseplate cracked at an impact of 400 Joules on the centre of the pumpstand. In the handle shock test the pump completed its allotted 96,000 cycles without failure.

Installation



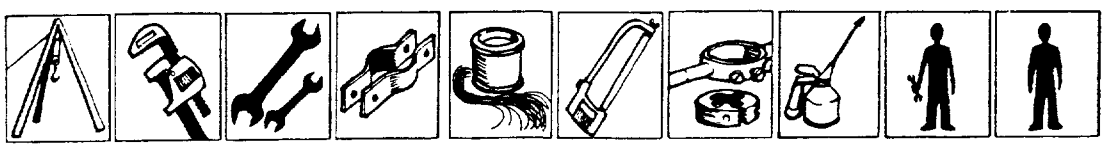
The manufacturer supplied thread locking compound with the test samples. A grease gun is needed to lubricate the handle bearing. The below-ground assembly will be heavy, but in other respects installation is straightforward providing care is taken in handling the cylinder to avoid damaging the thin wall.

Pumpstand Maintenance and Repair



The pumpstand is easy to dismantle, and does not need to be removed from the wellhead. The handle bearings would be easy to replace in a workshop; in the field, replacement of the complete fulcrum casting might be required.

Below-Ground Maintenance and Repair

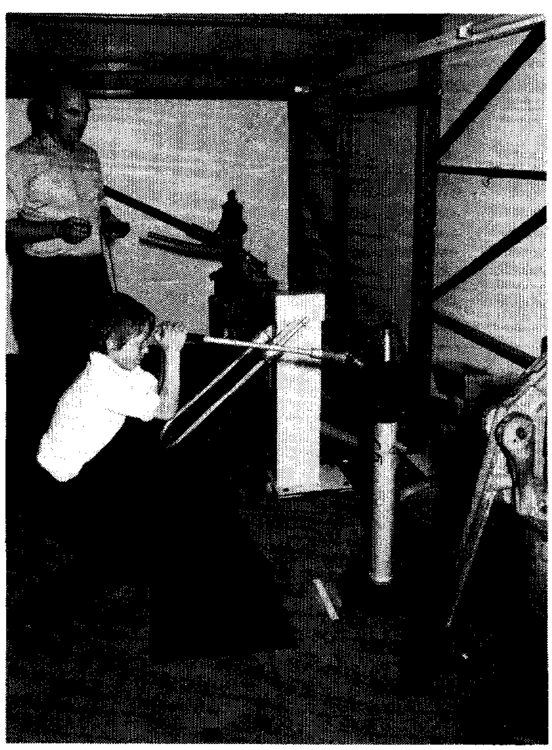


Repairs require removal of the complete below-ground assembly. For plunger seals and foot valve, manufacturer's spares are essential. Again, care is needed in handling the cylinder to avoid damaging the thin wall.

Verdict

The manufacturer now recommends a maximum depth of 18 metres, using the 3 inch cylinder. Some small design changes and a thicker cylinder wall could make this a robust pump, possibly suitable for community water supply. Moderately priced.

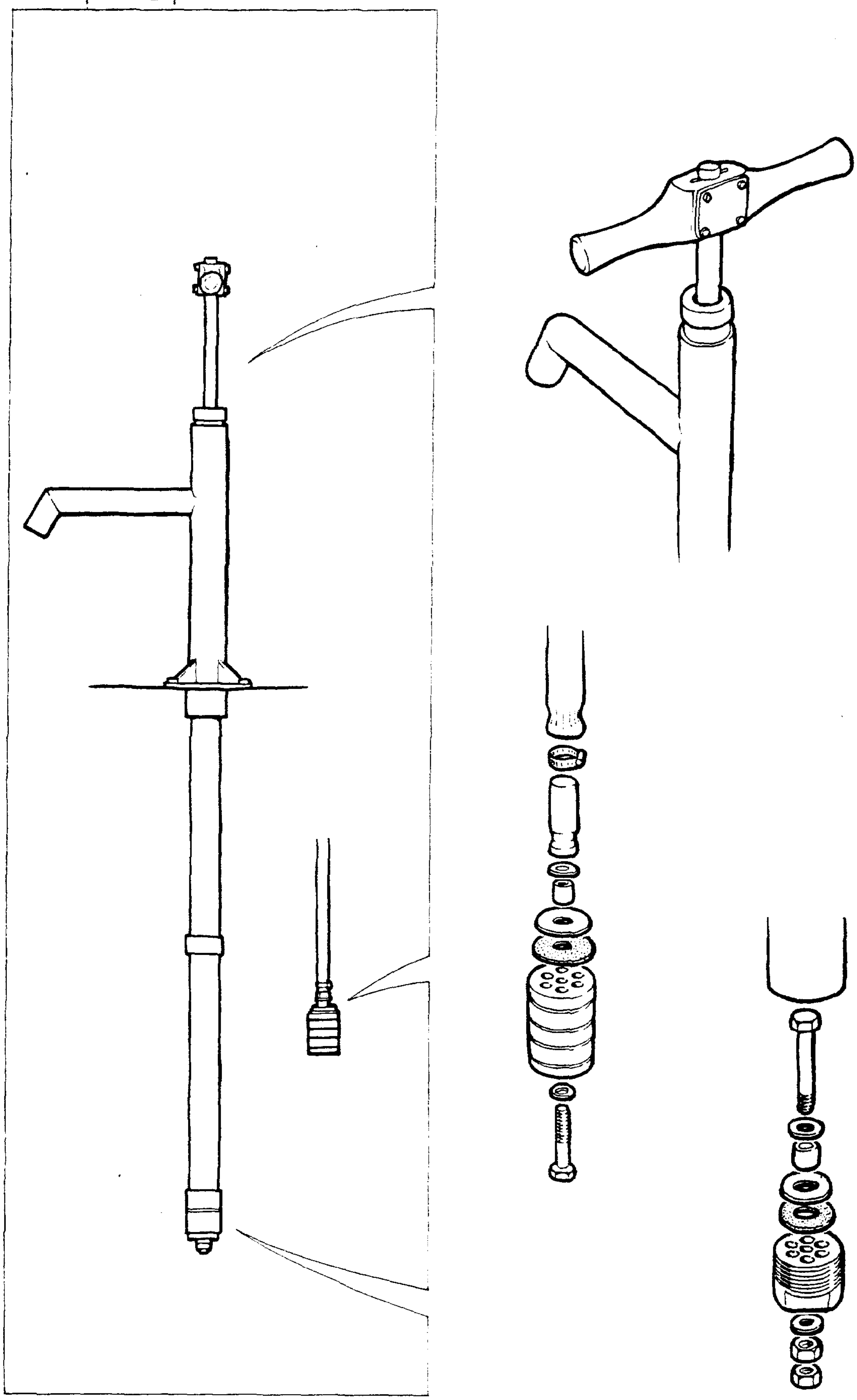
Original broken and corroded plunger
fixing screws now replaced by stainless
steel shouldered screws.



Hard work!

Nira Pump

Ethiopia Pump



3.9 Code H ETHIOPIA TYPE BP50

The Ethiopia Type BP50 is a shallow-well force pump, making extensive use of plastics below ground. For shallow wells a simple T-handle is attached to the top of the pump rod for direct action pumping. For depths greater than 12 metres, the pumpstand has a lever.

The pumpstand is fabricated from steel tube and plate. The rising main is 2 inch uPVC pipe, and is itself the cylinder. The maximum outside diameter of the below-ground assembly is 75 mm. The piston has no separate seals; it is turned from high density polyethylene, and has a simple rubber flap valve backed by a steel washer. The foot valve is similar, its housing made from standard pipe couplings. The rods are also uPVC water pipe, stiffened with steel at the top. The handle is wood.

The pumpstand weighs 11.3 kg. A complete below-ground assembly for 10 metres depth would weigh less than 20 kg.

Packaging

The pumps arrived in a single wooden packing case. A cardboard carton within the case protected the plungers and valve assemblies. The case was relatively easy to manhandle.

Condition as Received

Both samples were received in good working order.

Installation and Maintenance Information

A technical report and engineering drawings were sent with the pumps; both accurately described the samples. The technical report was interesting, the drawings helpful in installing the pump. It would be important however, to know what literature would be generally supplied with the pump.

Manufacturing

The Ethiopia pump requires basic skills in steel fabrication, machining, woodwork, and in manipulation of uPVC pipe. It is particularly suitable for manufacture in a developing country.

Safety

There is a potential finger trap between the handle and the top of the pumpstand, but this is not a major hazard since the handle of this pump offers no mechanical advantage.

Suggested Design Improvements

The handle should be more securely attached to the pump rod. This might be achieved by using a single bolt, slightly off-centre, locating in a groove cut in the pump rod.

The baseplate should be stiffer.

Users

Many users found it difficult to operate, especially short children. Most of the effort had to be supplied by the arms and shoulders only. Several smaller children found the handle difficult to lift, and changed their grip between up- and down-strokes. Some could lift the handle only by sliding their forearms beneath it until it rested in the crook of their elbows, then arching their backs. This was a very awkward movement and resulted in very short strokes. Users with such difficulties tended to make matters worse by pulling unevenly on the two sides of the handle, increasing the friction in the bush at the top of the pumpstand.

Endurance

The pump was tested at 40 strokes per minute at 7 metres head and it completed the 4000 hour endurance test without failure. Wear in the piston tended to increase the end float of the centre bolt, and remedial action was taken at the 1000 hour intermediate inspections. The intermediate check tests of volume flow also revealed progressive loss of cylinder performance.

In the final inspection, most parts of the piston were clearly worn, particularly those parts forming the valve. Although still operating, the performance had fallen off considerably. The piston diameter had worn by 0.3 mm or so, and the 'cylinder' by about 1 mm on diameter. Particles of sand were embedded in the HDPE piston. The pump rod bush in the pumpstand was worn, but this did not affect the performance.

Performance when New

Volume flow varied little with speed, between 0.60 and 0.63 litre per stroke.

The work input requirement increased with speed, from 112 Joules per stroke at 30 strokes per minute to 141 Joules per stroke at 50 strokes per minute. The maximum operating effort was approximately 30 kgf, on the upstroke.

Efficiency decreased with speed, from 36% at 30 strokes per minute to 30% at 50 strokes per minute.

Performance after 4000 hours Endurance

Volume flow was markedly reduced, particularly at low operating speeds. At 21 strokes per minute the pump averaged 0.15 litre per stroke, rising to 0.41 litre per stroke at 49 strokes per minute. Work input varied from 82 Joules per stroke at 21 strokes per minute to 155 Joules per stroke at 49 strokes per minute. Efficiency varied from 12% to 18% for the same operating speeds.

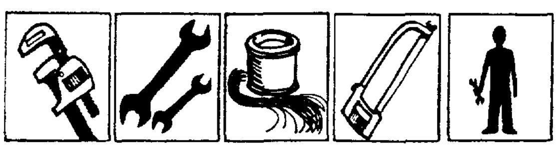
At speeds below 17 strokes per minute or so, the pump produced no water at all.

Abuse Tests

The handle impact test was not applicable to this pump. In the side impact test on the body of the pumpstand, successive impacts produced progressive distortion of the baseplate.

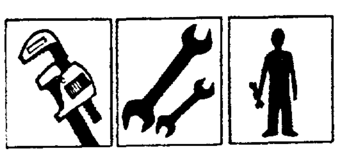
In the handle shock test, the pump completed its allotted 96,000 cycles without failure.

Installation



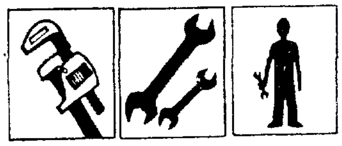
This pump is light and easy to handle; the main requirement for skill is in making satisfactory joints in uPVC pipe.

Pumpstand Maintenance and Repair



Very straightforward. The most likely maintenance requirement will be replacement of the top bush, and this is easy.

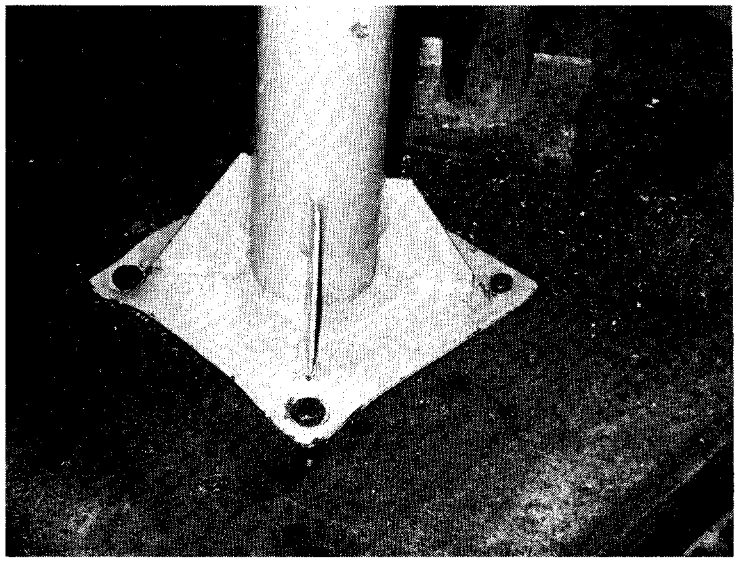
Below-Ground Maintenance and Repair



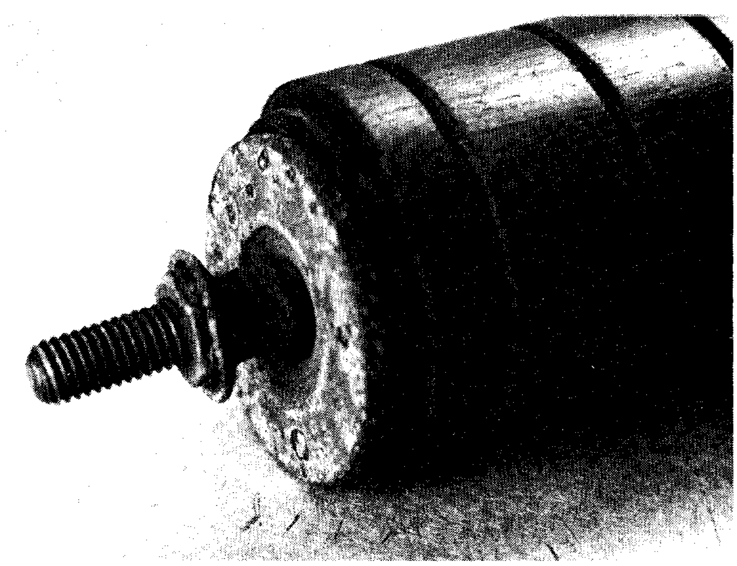
The plunger may be removed very easily: only the top bush in the pumpstand need be removed. Care will be needed in handling the pump rods, however, and it may be prudent to have sockets and solvent cement on hand to repair accidental breaks. The length of the pump rods may require frequent alteration to compensate for wear in the rising main. Lifting tackle would not be needed to extract the rising main.

Verdict

A simple, cheap, shallow-well force pump, though some users found it difficult to operate in the direct action mode. Does not require priming and therefore not susceptible to contamination. Lightweight and easy to remove without lifting tackle. Approaching a VLOM. Potentially suitable for community water supply in shallow water depths.

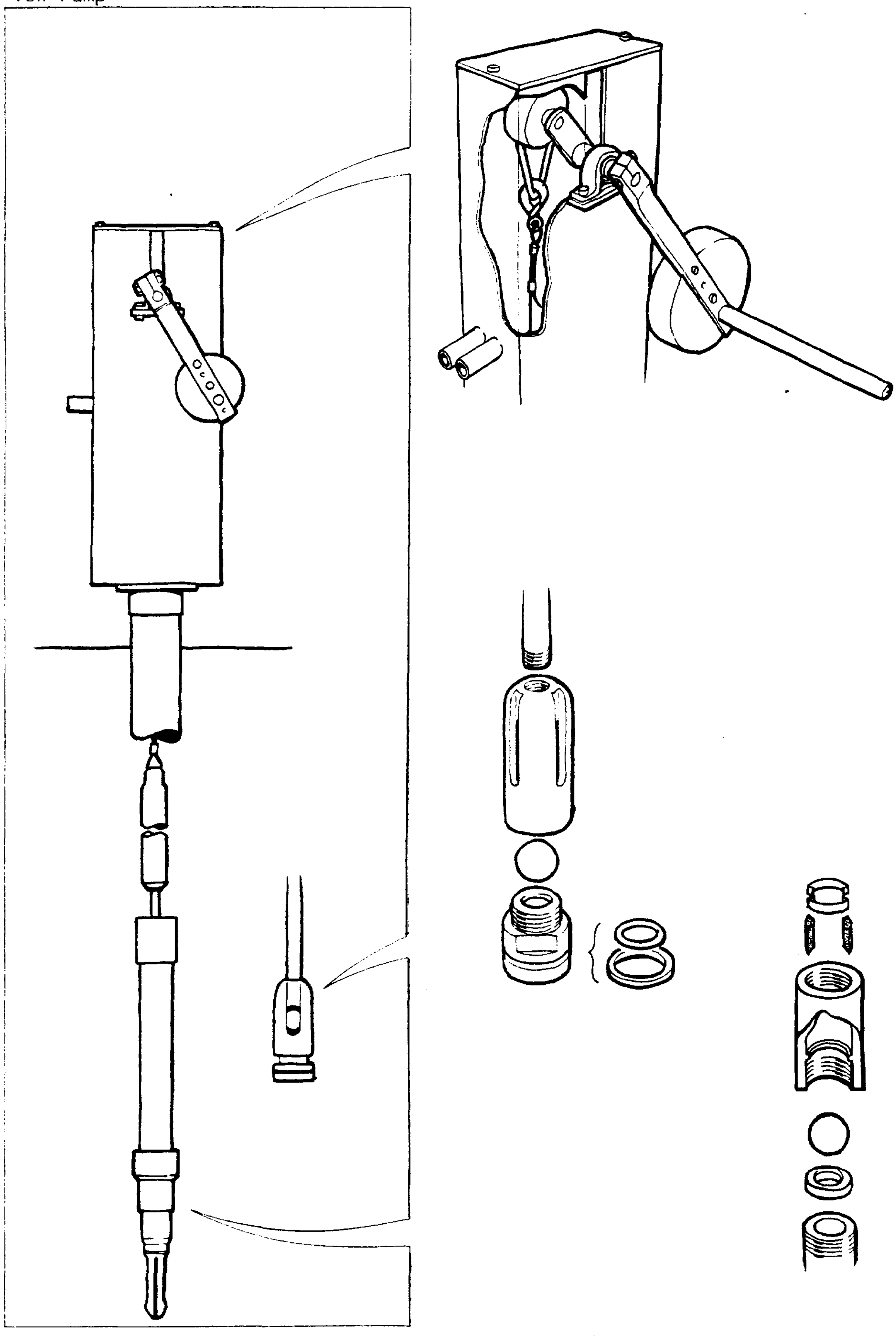


The easily distorted baseplate after 400 Joules impact force resulting in bad wellhead sealing.



After 4000 hours the end float had become excessive and the centre hole in the plunger had worn.

Vew Pump



3.10 Code J VEREINIGTE EDELSTAHLWERKE (VEW) A18

The VEW A18, made in Austria, is a reciprocating, deep-well force pump, with a rotary operating mechanism. The pump uses a cable rather than rods. The pumpstand is fabricated from stainless steel plate, with ball races for the crank pin and journals. As delivered, the top of the cable was attached to a saddle with the outer ring of two ball races running in a track in the crank pin. After early failures were revealed in the endurance test, the manufacturer has now adopted a fully enclosed crank 'big end', as illustrated. The handle counterweights were originally fitted on separate arms, at 90° to the handles themselves. The twin handles make the pump suitable for operation by two people, and two spouts are provided.

The heavy cylinder can be withdrawn through the 4 inch rising main and snap fits in a fixture at the bottom of the rising main. The maximum outside diameter of the below-ground assembly is 127 mm. The plunger seal is PTFE, backed by a concealed rubber O-ring. The plunger and foot valves use stainless steel balls.

The pumpstand weighs 84.8 kg, the cylinder assembly 19.8 kg.

Packaging

These pumps were delivered in a single wooden packing case, with internal reinforcements to secure the contents. All the below-ground components were wrapped in a strong waxed protective fabric.

The package was robust but awkwardly long - 4 m, and very heavy indeed, 372 kg. It would be very difficult to handle without mechanical assistance.

Condition as Received

The pumps were generally in good condition as received, though the handles of both pumps had been slightly misaligned in assembly.

Installation and Maintenance Information

Useful information supplied, but further illustrations would be advantageous.

Manufacturing

The VEW is not suitable for manufacture in a developing country. A considerable amount of bar and plate stainless steel are required. Both the cylinder and, to a lesser extent, the pumpstand, require sophisticated manufacturing technologies and strict quality control.

Safety

The newer design of handles have reduced the safety hazard from the rotating counterweights. However, the rotating handles on this pump could be hazardous to both users and bystanders. The handles have high momentum at normal operating speeds.

Suggested Design Improvements

The manufacturer has adopted a number of suggestions, including the following:

(a) Changing the crankshaft plummer blocks to a heavier pattern and redesigning the crankshaft "big end" assembly.

(b) Changing the cable to the type designed for hoists and lifts, which will not twist under tension.

(c) Supplying polished solid handles

(d) Attaching the handles more securely to the ends of the crankshaft and repositioning the counterweights

Other Suggestions

The outlet spouts should be either longer and more widely separated to allow two containers to be filled simultaneously or a single spout provided. Use of push-fit plastic tube is not recommended because of ease of removal.

We would suggest that many of the components could be designed for less extravagant use of costly materials.

Users

Users found this pump difficult to operate. Users with enough strength and bodyweight could attain sufficient momentum to keep the handle turning smoothly. Most could not, and found it difficult to 'time' their efforts on the handle. Several children could not operate the pump at all. However, it should be noted that this pump lends itself to operation by two people.

Our testing staff has found the pump easier to operate with the modified handles and re-positioned counterweights.

Endurance

The pump was tested at 40 revolutions per minute at a simulated head of 45 metres and failed after only 152 hours. The tendency of the operating cable to twist under tension had made the bearing saddle run out of true, causing rapid wear of the saddle and the crankshaft. Both were replaced, and a swivel was fitted in the cable. The handle broke at 277 hours, and the replacement bearing saddle and crankshaft were worn out after 598 hours.

The manufacturer's response was commendably quick and the modifications have been noted earlier. The modified handles and crankshaft 'big end' completed the test programme without failure.

In the final inspection, the plunger seal was found to be worn out, the plunger body was worn and also the plunger rod where it passed through the cylinder top. The cylinder bore was in good condition. The inside of the rising main and the receiver for the cylinder snap fitting were rusty. There was some play in the 'big end' but in all other respects the pumpstand was in good condition.

Performance when New

Volume flow decreased slightly with depth, from a maximum of 0.69 litre per revolution at 7 metres to a minimum of 0.62 litre per revolution at 45 metres.

The work input requirement was dependent on both speed and depth. The minimum was 87 Joules per revolution at 7 metres and the maximum 765 Joules per revolution at 45 metres, both at 50 revolutions per minute. The maximum operating efforts were around 10 kgf at 7 metres, up to 60 kgf at 45 metres.

Efficiency varied markedly with speed for different depths. At 7 metres, the maximum efficiency was 53% at 50 revolutions per minute. At 25 metres, the best result was 59% at 40 revolutions per minute. At 45 metres, the maximum efficiency was 63% at 30 revolutions per minute.

Performance after 4000 hours Endurance

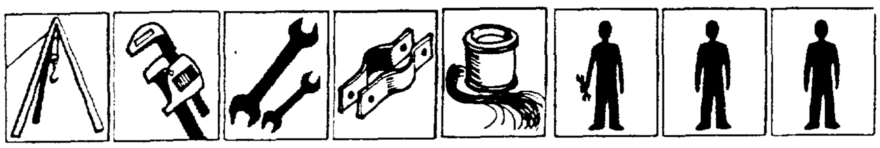
Wear of the plunger seal resulted in lower volume flow after endurance, particularly at lower operating speeds. At 19 revolutions per minute and 45 metres, volume flow was 0.31 litre per minute, increasing to 0.54 litre per revolution at 53 revolutions per minute.

The work input requirement had increased at 7 metres depth, but had decreased at 45 metres to between 317 and 337 Joules per revolution. Efficiency was therefore reduced at 7 metres, to 21%, but at 45 metres was 43% at 19 revolutions per minute, rising to 71% at 53 revolutions per minute.

Abuse Tests

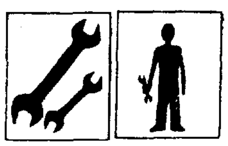
The side impact test on the handle was not applicable to this pump. The pump sustained no damage in the side impact test on the body of the pumpstand.

Installation



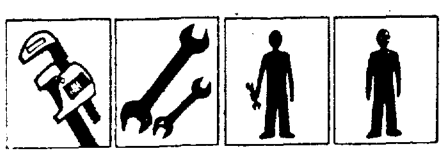
Heavy lifting tackle will be essential to handle the 4-inch rising main, and could not readily be substituted by extra manpower. A cable-cutting tool will be needed. The pipe wrenches must be large enough to cope with 4 inch pipe. The base of the pumpstand is threaded 4 inch API and not to the more common ISO Standard pipe thread.

Pumpstand Maintenance and Repair



In its modified form, the pumpstand is unlikely to demand frequent attention. The crankshaft assembly must be replaced as a unit, however. The pumpstand need not be removed from the wellhead.

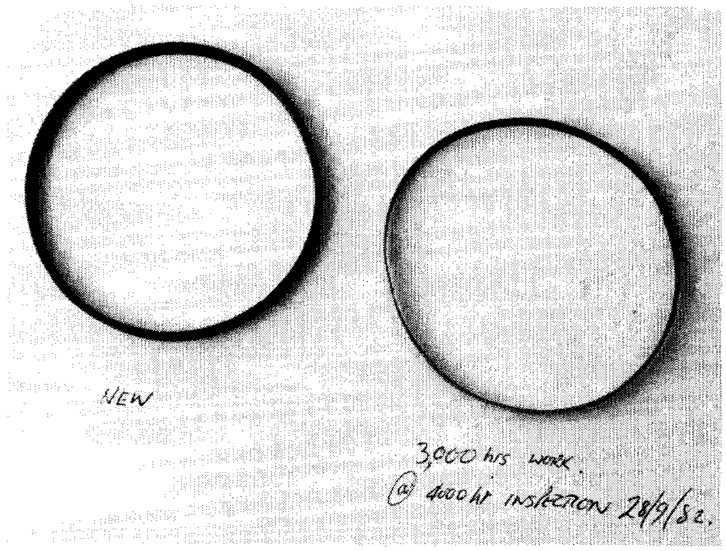
Below-Ground Maintenance and Repair



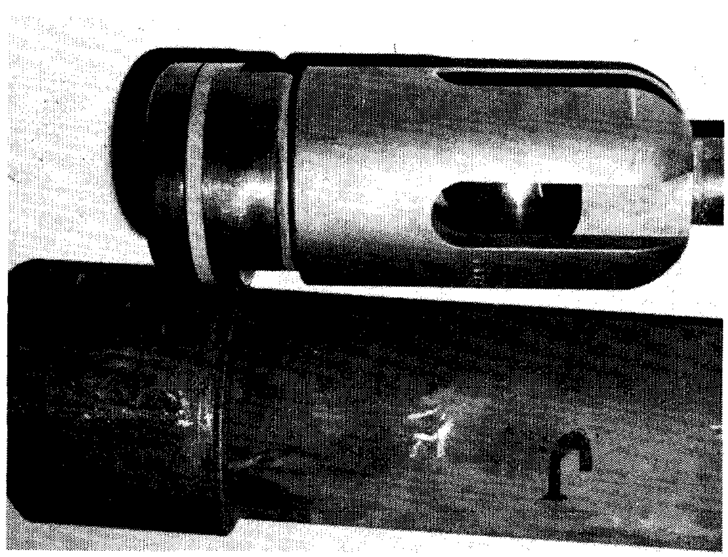
The cylinder may require replacement of the plunger seal. The manufacturer does not recommend this to be carried out on site. Replacement of the complete cylinder is preferred. The cylinder assembly can be extracted without removing the rising main, using the operating cable. The cylinder is heavy, but it may be possible to improvise the crankshaft assembly as a simple lifting tackle. If the cable breaks, it may be difficult to extract the cylinder.

Verdict

Very expensive. Robust as modified by the manufacturer. Awkward to use, but designed to be operated by 2 people. Potentially suitable for community water supply. When the plunger seal wears, the complete cylinder must be replaced. Needs very heavy lifting tackle for installation, and may not be suitable for small diameter boreholes.

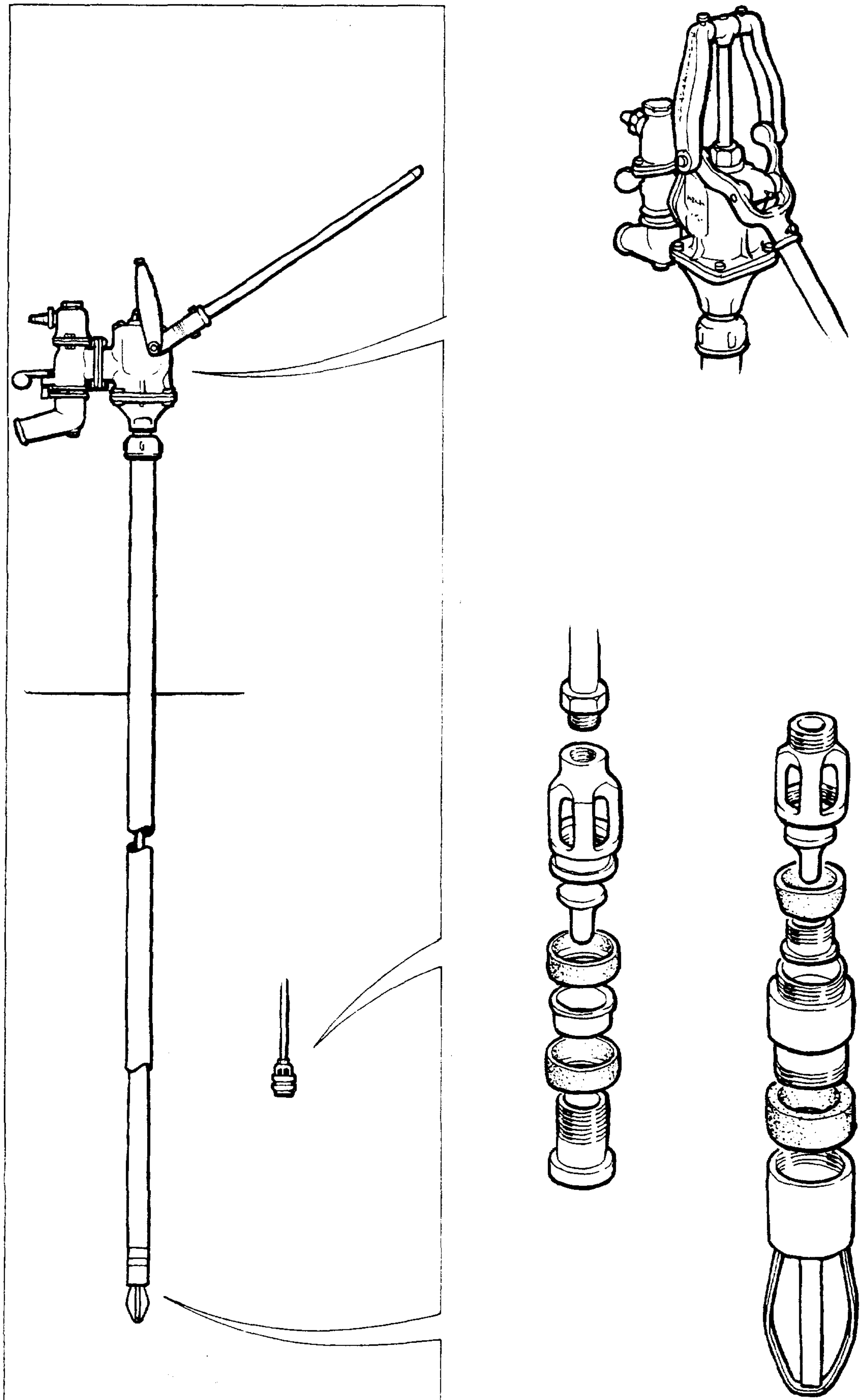


This shows the wear on the plunger seal after 3000 hours endurance test.



The seal is fitted in a machine groove in the plunger and is virtually impossible to replace in the field.

Jetmatic Pump



3.11 Code K JETMATIC

The Jetmatic pump is made in the Philippines, under licence from Kawamoto Pumps of Japan, and is very similar to the Dragon pump. Like the Dragon, it can be supplied either as a shallow-well suction pump or as a deep-well force pump. We have tested the pump in its deep-well configuration. Unlike the Dragon, the shallow-well cylinder is not retained. The pumpstand is therefore very compact, and simply fits on the protruding end of the rising main which must be at least 440 mm above ground, to prevent the handle touching the ground at the lowest point of its travel.

The pumpstand is principally cast iron, with a discharge valve in the spout allowing either free discharge or delivery under pressure through a hose or pipe. The tubular steel handle moves though an unusually wide arc of 178°.

The deep-well cylinder is unusually small, only 46 mm bore, to fit inside 2 inch rising main, which is very much smaller than the cylinder used in the Dragon pump. At the lower end of the cylinder are two steel loops which appear to be designed to grip the inside of the rising main. Turning the cylinder clockwise then expands a rubber ring which anchors and seals the cylinder against the inside of the rising main. The foot valve has a tapered rubber ring which fits a machined taper in the base of the cylinder. The piston can be screwed onto the foot valve to remove it, without removing the cylinder. In other respects the plunger is conventional, and has two leather cup seals.

The pumpstand weighs 16.3 kg, the cylinder assembly 3 kg. We used 0.5 inch diameter pump rods, none were supplied with the pumps, and 2 inch nominal bore galvanised iron rising main. The maximum outside diameter of the below-ground assembly is 74 mm.

Packaging

The pumps arrived in a wooden packing case, with internal reinforcements to separate and secure the contents. The case was lined with moisture-proof plastic membrane.

Condition as Received

In both sample cylinders, the cup seal retainers were not tight, possibly because the leather had dried out and shrunk in transit. Otherwise the pumps were in good working order.

Installation and Maintenance Information

None supplied with the pump.

Manufacturing

The Jetmatic pump requires a moderate level of foundry skill, and the ability to carry out simple machining. The handle linkage demands careful manufacturing quality control to ensure easy assembly and satisfactory operation. It may be suitable for manufacture in some developing countries, but is not ideal.

Safety

The end of the tubular steel handle is sharp and could be dangerous if the easily removed rubber cap were lost. The handle fulcrum pinch bolt forms a finger trap.

Suggested Design Improvements

The free end of the handle should be belled out and smoothed and the rubber end cap omitted.

The wishbone link may be easier to manufacture in a developing country as two joggled steel strips.

The handle fulcrum pinch bolt should be moved 90° to the underside, or replaced by two circlips on the shaft, similar to those on the wishbone link pivots.

The height of the top housing should be reduced to:

(a) eliminate the counterbore in the gland nut
(b) eliminate unnecessary machining of the pivot casting
(c) increase the length of thread attaching the connecting rod to the pivot casting.

The discharge valve should be removed as a cost-saving and only supplied if needed.

All pump body flanges should be flat or increased in thickness as they are unsupported and can be broken by over-tightening the fixing bolts.

The lift of both piston and foot valves should be much reduced, ideally to one quarter of the effective diameter.

The manufacturer has acknowledged these suggestions and his detailed comments are awaited.

As a 2 inch rising main is necessary to allow the cylinder to pass through for maintenance, the diameter of the bottom of the pumpstand should be modified to 2 inch ISO Standard pipe thread.

Users

This pump is similar to the Dragon pump, and users had similar problems. An additional difficulty arose because vigorous operation of the pump often caused the outlet discharge valve to drop, shutting off the spout which may blow the gaskets. Generally the rate of delivery was not considered to be very good.

Endurance

The pump was tested at 40 strokes per minute at a simulated head of 45 metres and failed at 280 hours when the cylinder was dislodged within the rising main. It was refitted and the problem did not recur.

The pump failed at 3149 and 3875 hours when the pump rod broke within the thread. Components of the handle mechanism had to be replaced after 1000 hours because of wear, though the replacement parts survived until the end of the 4000 hour test programme. At each intermediate inspection, the spout discharge valve was found to be seized through lack of use, and was freed off.

In the final inspection, the foot valve, plunger, leather cup seals and cylinder were all in good condition, with few signs of wear. The gland nut was badly worn.

The piston rod and the steel loops on the cylinder anchor were corroded.

Performance when New

Volume flow was virtually unaffected by operating speed or depth, between 0.27 and 0.29 litre per stroke, for a full stroke of the handle.

The work input requirement varied from a minimum of 50 Joules per stroke at 7 metres depth to a maximum of 173 Joules per stroke at 45 metres. The maximum operating effort was less than 5 kgf at 7 metres, and little more than 10 kgf at 45 metres.

Efficiency varied from a mimimum of 32% at 7 metres to a maximum of 77% at 45 metres.

As the stroke length was the same as for the Dragon, a test with a partial stroke was not carried out since the same marginal improvement could be expected.

Performance after 4000 hours Endurance

Volume flow remained unchanged after endurance, and the work input requirement was reduced, to a maximum of 149 Joules per stroke at 45 metres. Maximum operating effort remained little more than 10 kgf at 45 metres.

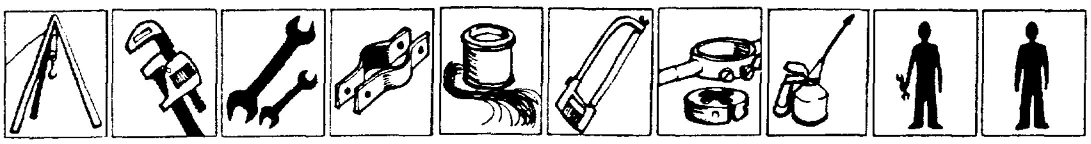
Efficiency had therefore improved, a minimum of 42% at 7 metres and a maximum 91% at 45 metres.

Abuse Tests

In the side impact test on the handle, the impact energy was absorbed by the pumpstand turning on its mounting thread. In the body test, the supporting rising main began to bend at an impact 200 Joules, and at 300 Joules the pipe was sufficiently bent to prevent movement of the pump rod.

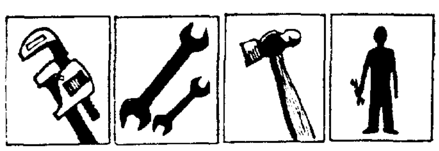
In the handle shock test, after 13,341 cycles the fixings attaching the body of the pumpstand to the base casting had loosened, allowing the joint to leak. The pump failed after 79,383 cycles when the thread in the base casting was partially stripped producing bad leakage.

Installation



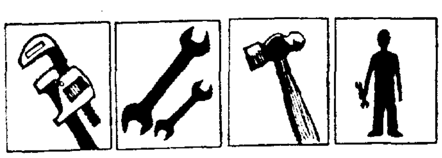
The rising main must be secure in the wellhead, to support the pumpstand. It should protrude sufficiently to allow clearance under the spout for the tallest vessel likely to be used. Installing the pumpstand only on an existing rising main would be a simple, one-man task. The rising main should be 2 inch diameter, to allow the cylinder to pass through for maintenance. The bottom of the pumpstand is threaded 1.25 ANPT not the more common ISO Standard pipe thread.

Pumpstand Maintenance and Repair



The pumpstand may require frequent attention to worn handle components and the gland nut.

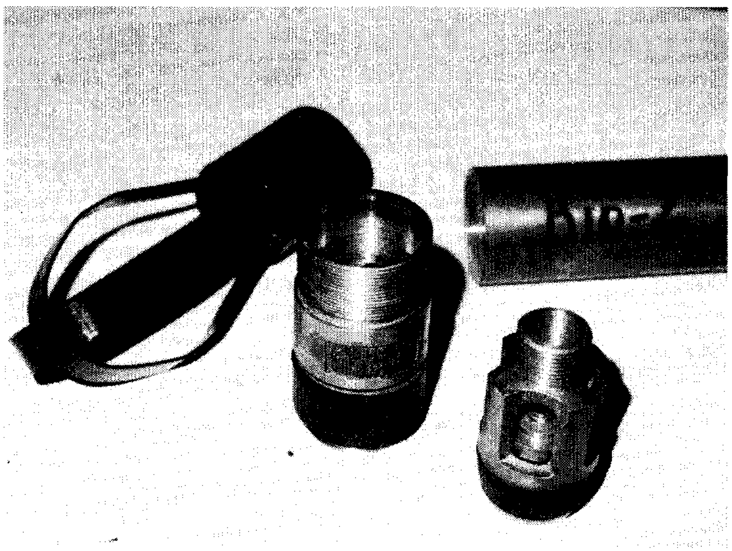
Below-Ground Maintenance and Repair



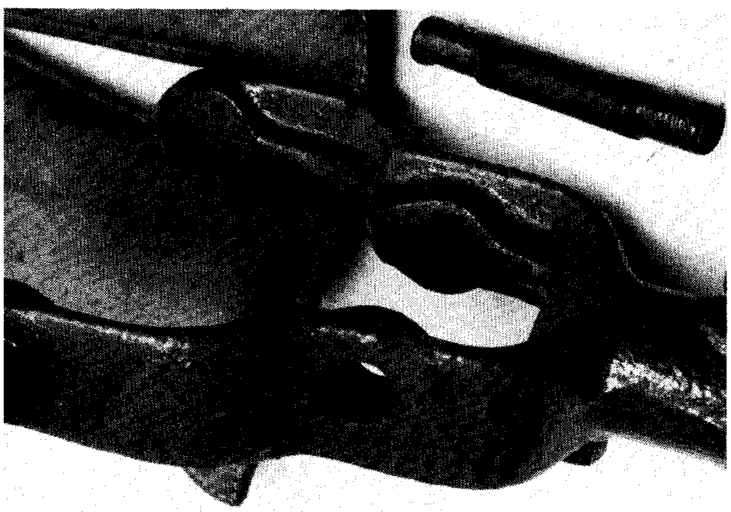
The foot valve and plunger may be extracted through the rising main, provided pipe of at least 2 inch diameter is used, and lifting tackle would not be required. The pumpstand must first be removed, however.

<u>Verdict</u>

This pump was designed for family use, possibly serving up to 15 people, and is unlikely to be sufficiently robust for community water supply, from deep wells. The rate of delivery is low, and intensive use will produce rapid wear and failure in the moving parts of the pumpstand. The plunger and foot valve can be extracted without removing the cylinder or rising main. Cheap to buy.

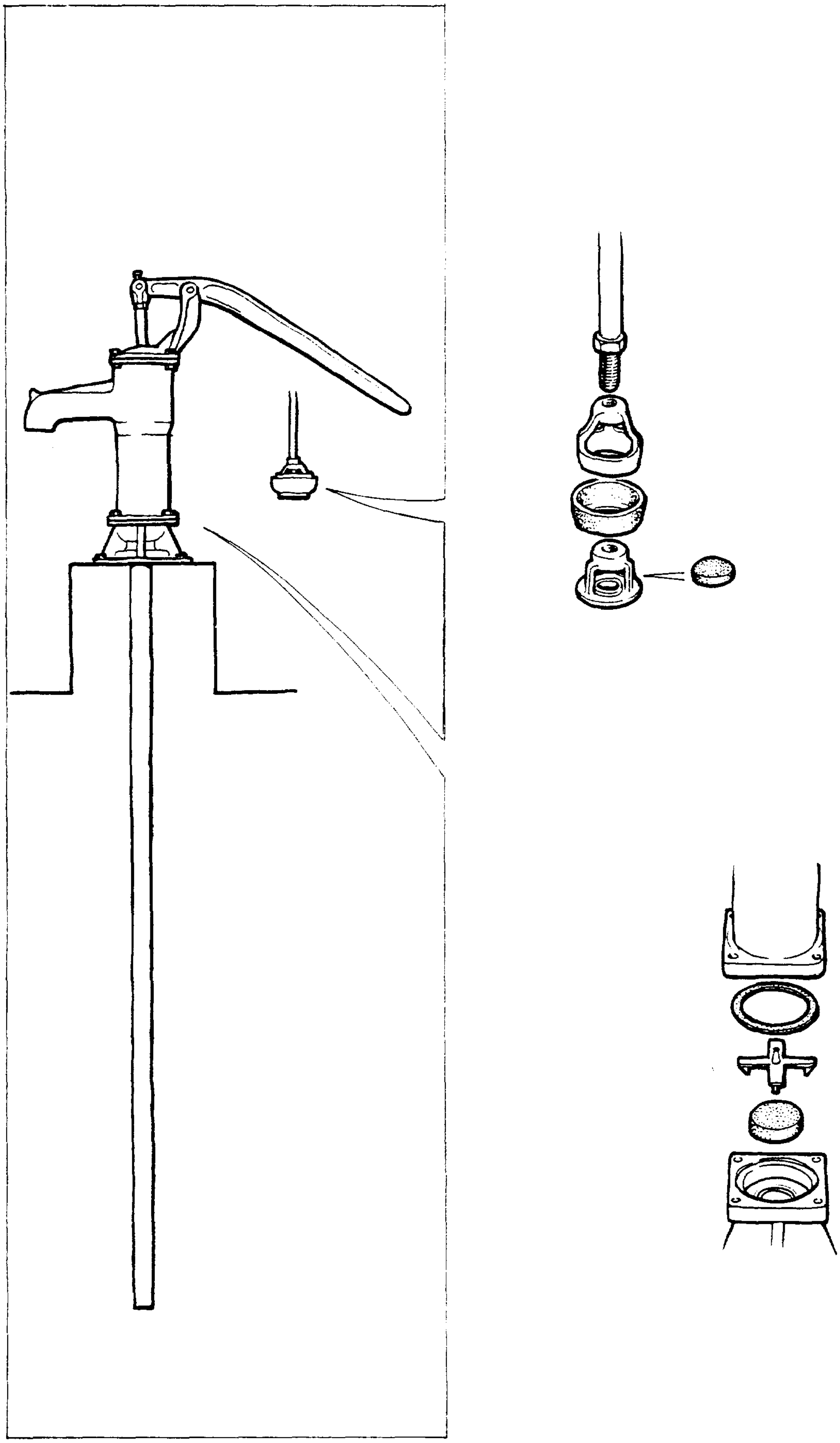


The components making up the cylinder anchor in the rising main together with the retractable foot valve.



This shows the worn pivot pin and holes in the handle fork casting after 1000 hours.

Bandung Pump



3.12 Code L BANDUNG SHALLOW-WELL PUMP

The Bandung is a shallow-well suction pump. It is mainly constructed of cast iron, with an enamelled steel cylinder liner. The plunger uses a moulded rubber cup washer, and rubber discs are used as plunger and check valves.

The pump weighs 25.5 kg, and uses standard 1.25 inch nominal bore galvanised iron drop pipe.

Packaging

The packaging in which these pumps were delivered was very unsuitable.

Each pump was wrapped in pieces of corrugated cardboard and then in a plastic sack.

The handles of both pumps, and a third spare handle, were broken in transit, and the cylinder top casting of one pump was cracked.

These components were replaced by the manufacturer, who said that the pumps left the factory packed together in a wooden crate. They were separated by the carrier, presumably because their weight as a single consignment was too great.

Condition as Received

Neither sample was received in working order, because of the broken handles. In addition, one retaining bolt for the connecting rod pivot shaft was broken, and one check valve seat was unevenly coated with filler and paint, preventing a satisfactory seal against the rubber valve block. Even if the handles had been delivered unbroken, the pumps would still have been unusable.

Installation and Maintenance Information

None supplied with the pump.

Manufacturing

Where adequate skills in iron foundry work, simple sheet metalwork and basic machining are available, the Bandung is well-suited for manufacture in a developing country, but demands stricter quality control during manufacture than the Bangladesh New No. 6, which is of similar design.

Safety

There is a potential finger trap between the connecting rod fork and the top of the pumpstand.

Suggested Design Improvements

The relative positions of the fork and eye in the connecting rod and handle should be reversed - i.e. the handle should be forked, with an eye on the end of the connecting rod.

The webs on the cylinder top casting should be extended to make it more robust.

The handle should be more robustly designed or made in a more resilient material.

The design of the plunger should be changed to control the compression of the cup washer, to reduce the tendency of the rubber to extrude outwards.

Users

Few users criticised this pump, though few singled it out for praise. The handle movement allowed many muscle groups to contribute to operating the pump.

Endurance

The pump was tested at 30 strokes per minute at 7 metres head. The cup washer was replaced three times in the 4000 hour endurance test programme, and the last replacement was found to be in poor condition in the final inspection. The seal tended to extrude into the clearance between the plunger and the cylinder wall, and split as a result. The two halves of the plunger were modified so that the cup washer was 'nipped' near its outer edge; this prevented the outward extrusion of the rubber. The last replacement cup washer did not split in over 1000 hours. However, the final inspection revealed cracks in the upper surface of the cup washer, although it was still working.

The pump proved difficult to prime after the 3000 hour check, but this was corrected by simply turning over the check valve block. Both valve blocks showed signs of wear in the final inspection, but were in working order.

The cylinder was in good condition at the end of the test, with no signs of wear.

The handle pivot pins, and their corresponding holes, were worn but still serviceable at the end of the test.

Bandung Pump

Performance when New

Cavitation was evident when the pump was operated faster than approximately 30 strokes per minute. In spite of that, the pump produced 1.04 litre of water per stroke at 40 strokes per minute, against 0.95 litre per stroke at 20 strokes per minute.

The work input requirement varied little with speed, at around 100 Joules per stroke. The maximum operating effort was less than 20 kgf.

Efficiency was 69% independent of operating speed.

Performance after 4000 hours Endurance

Volume flow had improved slightly after endurance testing, being 1.02 litres per stroke at 21 strokes per minute and 1.04 litres per stroke at 41 strokes per minute.

The work input requirement had increased rather more, being 109 Joules per stroke at 21 strokes per minute and 137 Joules per stroke at 41 strokes per minute. The maximum operating effort remained at less than 20 kgf.

Since the cup washers had to be changed three times during the endurance test, comparison with the performance when new cannot be made.

Efficiency was reduced, varying between 65% at 21 strokes per minute to 50% at 41 strokes per minute.

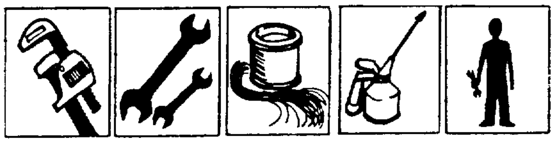
These results were obtained with the last replacement cup washer. In the check test at 1000 hours, with a split cup washer, the volume flow had fallen to 0.58 litre per stroke at 20 strokes per minute.

Abuse Tests

The Bandung pump failed in the side impact tests. In the test on the handle, the pump top casting broke at an impact of 150 Joules on the handle, though the handle itself survived. In the body test, the base casting fragmented at an impact of 500 Joules on the centre of the pump-stand.

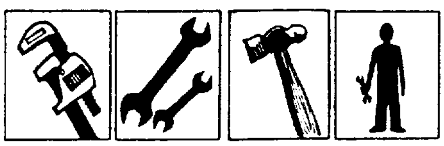
In the handle shock test, the handle fulcrum extension broke away from the pump top casting after 19543 cycles, and the test was terminated. The handle itself was undamaged.

Installation



Very straightforward.

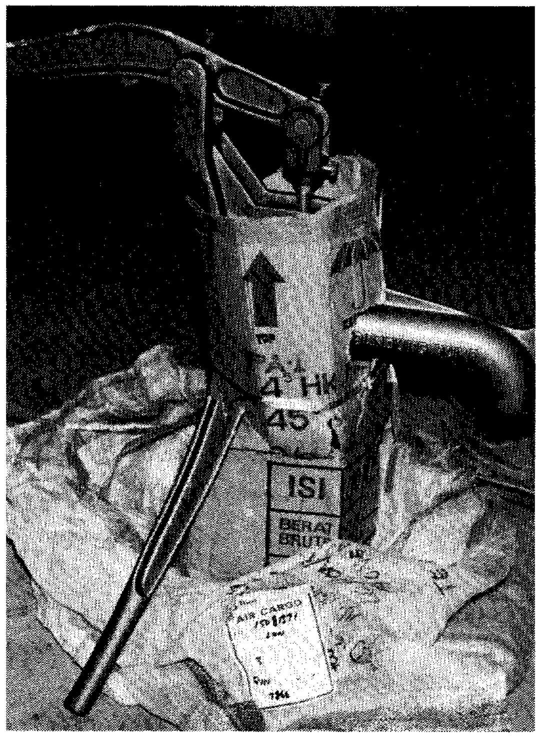
Maintenance and Repair



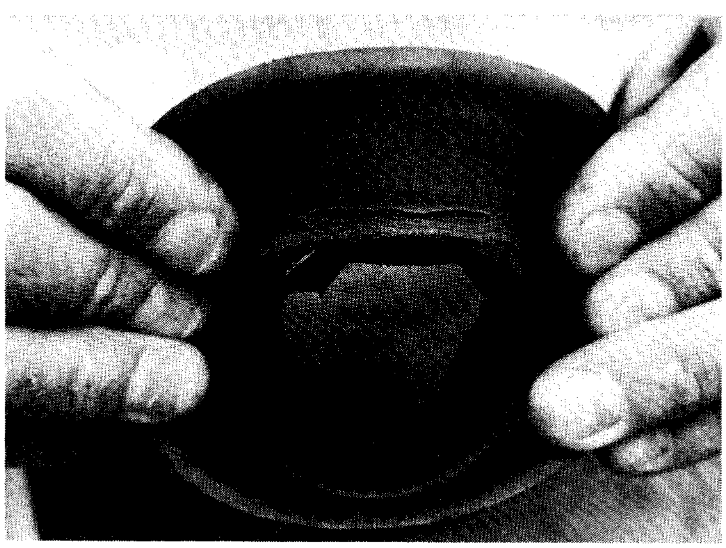
The pump may require frequent attention, but most tasks are simple and could be accomplished with a few spanners. A drift and hammer may be needed to remove the pivot pins, however, and a pipe wrench to dismantle the plunger.

Verdict

Susceptible to accidental damage. Requires priming and therefore susceptible to contamination. Would be more reliable with design changes, particularly related to plunger design. Cheap.



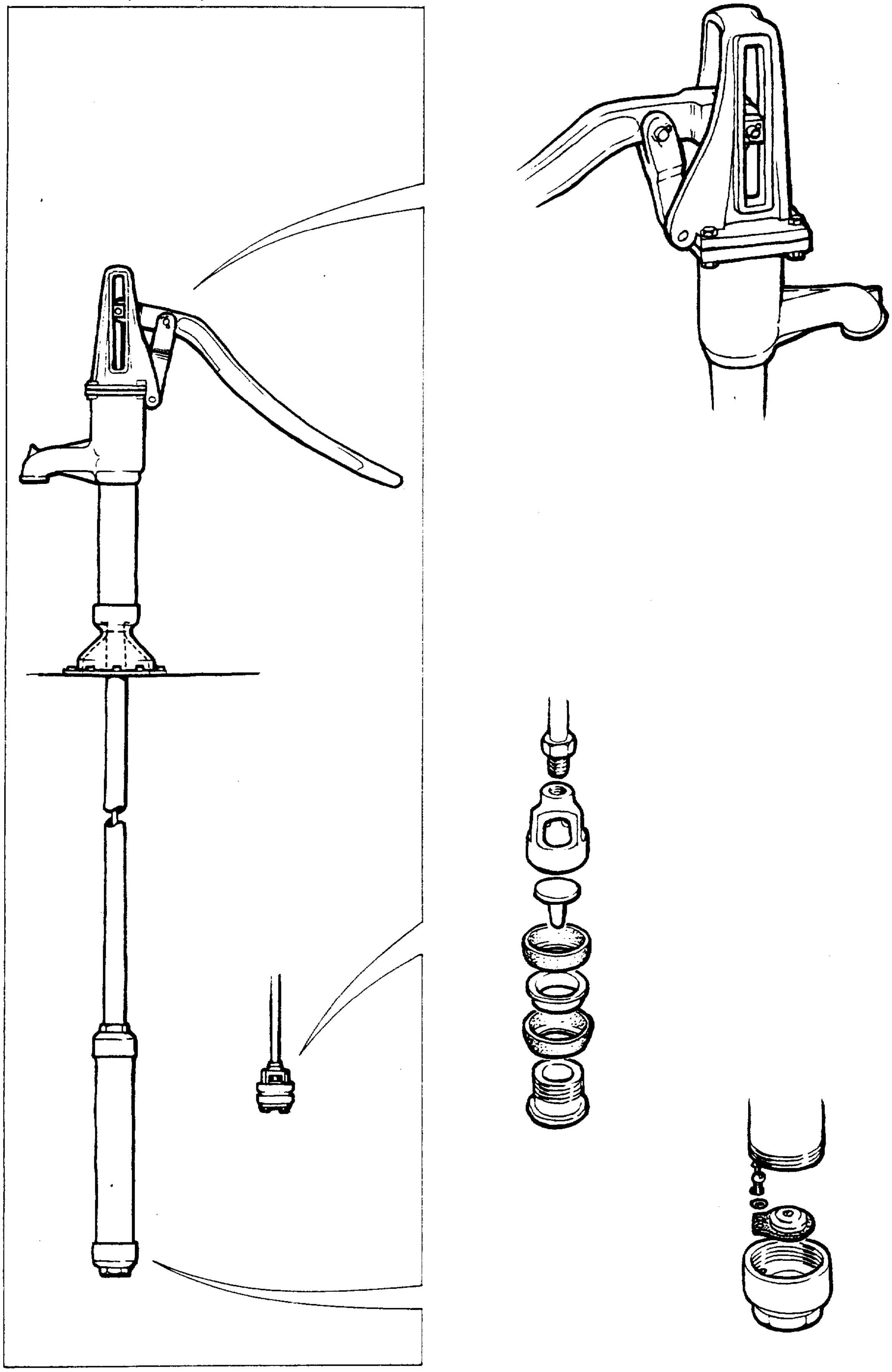
Very poor packaging allowed breakage of the three cast iron handles, and cracked pump top on one pump.



This shows the split in the cup washer due to inadequate design of the plunger.

Bandung Pump

Sumber Banyu Pump



3.13 Code M SUMBER BANYU ("SB")

This pump was a derivative deep-well design from AID/Battelle for manufacture in developing countries. The pumps tested were made in Indonesia. The pumpstand is almost entirely cast iron, though the column is a length of steel tube threaded at each end. It features a crosshead mechanism to guide the top of the pump rod.

The cylinder design is conventional, except that uPVC tube is used in place of the more usual seamless brass tube, with cast iron end caps. Two leather cup seals are used on the plunger. The foot valve is a simple flap of leather with a cast iron weight.

The pumpstand weighs 39.5 kg, the cylinder assembly 5.5 kg. The rising main is standard 1.25 inch nominal bore galvanised iron pipe. The maximum outside diameter of the below-ground assembly is 100 mm. Neither rising main nor pump rods were supplied with the pumps.

Packaging

These pumps were delivered in a slatted wooden packing case. The package weighed 191 kg and might be awkward to man-handle for overland transportation.

Condition as Received

Both samples were generally in good condition as received, though the cup seal retainers on both pumps were insufficiently tight. This may have been due to drying out of the leather in transit.

Installation and Maintenance Information

None supplied with the pump.

Manufacturing

Where facilities and skills in foundry work and simple machining are available, this pump may be suitable for manufacture in a developing country. However, the handle mechanism and the crosshead assembly demand careful quality control to ensure proper assembly and smooth running. In the samples supplied, the components of the two pumps were not interchangeable, and spares did not fit either pump.

No jigs and fixtures appear to have been used in the manufacture of this pumphead. This is essential to ensure interchangeability of spares.

Safety

There are potential finger traps between the pump top and the sliding guide blocks at the top and bottom of the handle stroke.

Suggested Design Improvements

The bearing bushes in the handle and associated links are of doubtful benefit - the cast iron would provide a satisfactory bearing surface for the steel shafts.

The lift of the piston valve should be reduced, ideally to one quarter of its effective diameter, and its location improved.

A handle made from a more resilient material would be less prone to accidental damage.

The foot valve should be redesigned to avoid early failure.

It is recommended that the design of the handle fulcrum be simplified, and the crosshead mechanism eliminated.

No reaction to the above suggestions has yet been received from the manufacturer.

Users

Most users seemed to operate this pump without difficulty. Many muscle groups could be called into play without exaggerated body movements.

Endurance

The pump was tested at 40 strokes per minute initially at a simulated head of 45 metres

The pump failed several times in the endurance test, due to rapid wear of linkages in the pumpstand, broken rods and worn-out foot valves. After five failures in the first 1000 hours, the simulated head was reduced to 30 metres.

The handle, fulcrum link, connecting rod eye and their associated pivot pins wore rapidly, and had to be replaced several times in 4000 hours. The pump rod broke six times, twice in the connecting rod at the top, twice in the piston rod, and twice in the intermediate rods. The connecting rod and piston rod were supplied with the pumps. The plunger rod breakages were caused by failures of the foot valve. In each case, the leather had rotted away allowing the cast iron weight to foul the plunger.

In the final inspection, the plunger and cup seals were still in good condition, and the cylinder bore was polished but otherwise showed few signs of wear. The crosshead blocks and guides were worn but still serviceable. All other moving parts had been replaced at some stage during the 4000 hours. The cylinder end caps were heavily rusted.

Sumber Banyu Pump

The hardness of the bushes and pins was measured and found to be between 80 and 86 Rockwell B on the bushes, and between 72 and 76 Rockwell B on the pins. The original AID/Battelle specification of 60 Rockwell C for bushings and 40 Rockwell C for the pins had not been followed.

The leather cup seal/uPVC cylinder combination wore well in these tests.

Performance when New

Volume flow was unaffected by operating speed or depth, between 0.80 and 0.86 litre per stroke.

The work input requirement varied from a minimum of 100 Joules per stroke at 7 metres through 300 Joules at 25 metres to a maximum of 536 Joules per stroke at 45 metres. The maximum operating effort was little more than 10 kgf at 7 metres, increasing to 50 kgf or so at 45 metres.

Efficiency improved with depth, from a minimum of 52% at 7 metres, through 65% at 25 metres to a maximum of 76% at 45 metres.

Performance after 4000 hours Endurance

Volume flow was unaffected by the endurance test. At 7 metres, the work input requirement was unchanged, at 25 metres it had decreased slightly to a maximum of 285 Joules per stroke. Maximum operating effort at 25 metres was 30 kgf.

Efficiency had also improved at 25 metres, to a maximum of 78%.

Abuse Tests

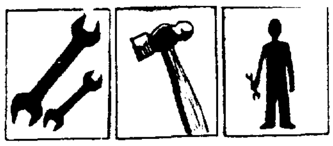
In the side impact test on the handle, the pump absorbed the impact by rotating the screw threads on the steel column. In the body test, the base casting broke at an impact of 400 Joules at the centre of the pumpstand. There was evidence of porosity in the casting at the point of fracture.

In the handle shock test, the handle broke after 5389 cycles. There was evidence of faults in the casting at the point of fracture, probably originating in manufacture.

Installation

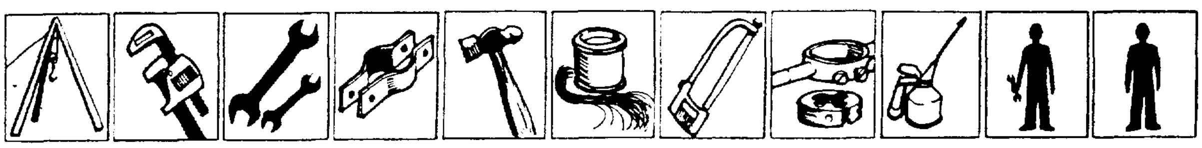
The pumpstand may require some re-working of the various handle components to ensure smooth operation.

Pumpstand Maintenance and Repair



The pumpstand is likely to require frequent attention to the handle, fulcrum link and connecting rod eye, and their respective pivot pins. Most tasks are easy, requiring spanners and pliers only, though a drift and hammer may be needed to remove the pivot pins. Our experience suggests that replacement parts may not be interchangeable with the original components, possibly making on-site repair impossible.

Below-Ground Maintenance and Repair

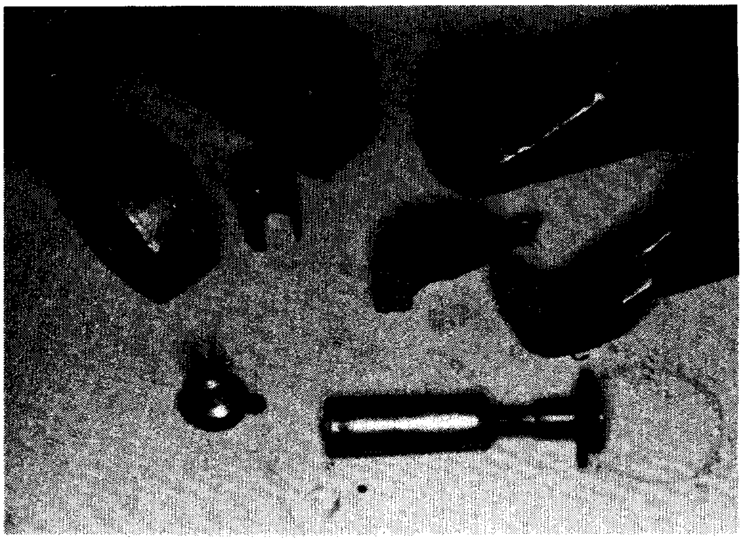


The pump is likely to require frequent attention to the foot valves and to broken pump rod joints. Below-ground repairs require removal of the complete below-ground assembly.

Verdict

Not a reliable pump for deep-well use. Intensive use will produce rapid wear in the moving parts of the pumpstand. Manufacturing needs much better quality control to ensure interchangability of parts. Leather foot valve undependable. Needs modification to be suitable for community water supply. Inexpensive.

It is understood that improved manufacturing techniques have now been instituted but the latest products have not been seen by us or tested.



Very severe wear after 248 hours at 45 m depth.

Corroded and worn foot valve components
which resulted in breakage of the plunger rod.

Sumber Banyu Pump

ABSTRACT OF ODA HANDPUMP FINAL REPORT JANUARY 1981

Please Note:

This information has been included for sake of completeness and represents the situation in 1981.

However, it should be remembered that many manufacturers have now modified their pumps as a result of both laboratory tests and field information.

ABSTRACT OF ODA - HANDPUMPS LABORATORY TESTING

CODE	Manufacturer (Country of origin)	Model	Deep/ shallow	Ex-Factory Cost per pump *	Type of pump	Ease of Maintenance & repair ^
A	Petropump (Sweden)	Type 95	Deep	£221.5 (excluding pipe)	Hand-operated diaphragmatic hose	3
B	Vergnet (France)	Hydropompe Type AC 2	Deep	£421.7 (complete to 50m)	Foot-operated hydraulic operation, diaphragmatic hose	4
C	Dempster (USA)	23 F(CS)	Deep	£56.5 (excl. pipe and rod)	Hand-operated lift pump	2
D	Mono (England)	ES 30		£370.4 (complete to 10m)	Hand-operated rotary, helical screw-type operation	2
E	Climax (England)	Not stated	Deep	£730.9 (complete to 21m)	Hand-operated flywheel-lift pump	1
F	Godwin (England)	W1 H51	Deep	£865.5 (complete to 21m)	Hand-operated geared lift pump	1
G	ABI (Ivory Coast)	Type M	Deep	£358.3 (Excl. pipe & rod)	Hand-operated lift pump	2
H	GSW (Beatty) (Canada)	1205	Deep	£163 (Excl. pipe and rod)	Hand-operated lift-pump	2
J	Monarch (Canada)	P 3	Deep	£359 (complete to 30m)	Hand-operated lift pump	2
K	Kangaroo (Holland)	Not stated	Deep	£282.5 (complete to 20m)	Foot/Spring-operated lift pump	2
L	India (India)	Mark II	Deep	£64.9 (excl. pipe and rod)	Hand-operated lift pump	2
M	Consallen (England)	L D 5	Deep	£296.8 (complete to 20m)	Hand-operated lift pump	3

* Price basis late 1977/early 1978 equivalent in £

FINAL REPORT JANUARY 1981

Results of Endurance Test

Hours	Failures	Performance	Reliability	Wear
670	Pumping element disconnected. 962/ nut on handle loose. 1636/ pumping element split. 2848/pumping element failed. 3212/pumping element split	Adequate but low efficiency	Somewhat variable	Likely to be small
1317 2000	Significant wear in pedal rod guide Pedal rod guide worn right through	Acceptable, low efficiency	Fairly good	
930	Pump rod broken. 1130/pump rod broke again. 3037/split pin on hand fulcrum bearing fractured	Good	Poor	
	No failures occured. (However, continual oil leakage from gearbox)	Poor	Very good	
1323	Water leaking from pumpstand inspection covers. 1355/ Handle fractured	Good	Very good	Likely to be minimal
	No failures occurred	Adequate	Excellent	
	No failures occurred	Good	Good in test but sharp metal/metal stops may cause field problems	Unlikely to cause problems
	No failures occured	Fairly good	Quite good	
2772 3692	Wooden handle loose. Pump rod top guide bush worn through	Good	Quite good	
251 400	Spring in pumpstand broken No spares, pump removed from test	Poor	Very poor	
	No failures occurred	Fairly good	Excellent	Unlikely to be a problem
	No failures occurred	Quite good	Very Good	

^ Rating : 1 poor, 5 very good

World Bank Publications of Related Interest

Laboratory Testing, Field Trials, and Technological Development

Contains results of laboratory tests carried out on twelve hand pumps for the World Bank and presents recommendations for improvements in performance, safety, and durability.

Rural Water Supply Handpumps Project Report Number 1. March 1982. 122 pages (including 3 appendixes).

Stock No. WS-8202. $5.00.

Municipal Water Supply Project Analysis: Case Studies

Frank H. Lamson-Scribner, Jr., and John Huang, editors

Eight case studies and fourteen exercises dealing with the water and wastewater disposal sector.

World Bank (EDI), 1977. ix + 520 pages. (Available from ILS, 1715 Connecticut Avenue, N.W., Washington, D.C. 20009, U.S.A.)

$8.50 paperback.

Village Water Supply

Describes technical aspects, costs, and institutional problems related to supplying water for domestic use in rural areas and proposes guidelines for future World Bank lending in this sector.

A World Bank Paper. March 1976. 98 pages (including 4 annexes). English, French, and Spanish.

Stock Nos. PP-7602-E, PP-7602-F, PP-7602-S. $5.00.

Village Water Supply: Economics and Policy in the Developing World

Robert J. Saunders and Jeremy J. Warford

Addresses the problem of potable water supply and waste disposal in rural areas of developing countries where the majority of the poor tend to be found. Emphasizes the economic, social, financial, and administrative issues that characterize village water supply and sanitation programs.

The Johns Hopkins University Press, 1976. 292 pages (including 4 appendixes, bibliography, index).

LC 76-11758. ISBN 0-8018-1876-1, $21.00 (£12.70) hardcover.

French: L'alimentation en eau des communautés rurales: économie et politique générale dans le monde en développement. *Economica, 1978.*

ISBN 2-7178-0022-0, 45 francs.

Spanish: Agua para zonas rurales y poblados: economía y política en el mundo en desarrollo. *Editorial Tecnos, 1977.*

ISBN 84-309-0708-4, 575 pesetas.

World Bank Studies in Water Supply and Sanitation

The United States has designated the 1980s as the International Drinking Water Supply and Sanitation Decade. Its goal is to provide two of the most fundamental human needs—safe water and sanitary disposal of human wastes—to all people. To help usher in this important period of international research and cooperation, the World Bank published two volumes on appropriate technology for water supply and waste disposal systems in developing countries. Since the technology for supplying water is better understood, the emphasis in these volumes is on sanitation and waste reclamation technologies, their contributions to better health, and how they are affected by water service levels and the ability and willingness of communities to pay for the systems.

Number 1: Appropriate Sanitation Alternatives: A Technical and Economic Appraisal

John M. Kalbermatten, DeAnne S. Julius, and Charles G. Gunnerson

This volume summarizes the technical, economic, environmental, health, and sociocultural findings of the World Bank's research program on appropriate sanitation alternatives and discusses the aspects of program planning that are necessary to implement these findings. It is directed primarily toward planning officials and sector policy advisers for developing countries.

The Johns Hopkins University Press, 1982. 172 pages (including bibliography, index).

LC 80-8963. ISBN 0-8018-2578-4, $12.95 (£9.10) paperback.

Number 2: Appropriate Sanitation Alternatives: A Planning and Design Manual

John M. Kalbermatten, DeAnne S. Julius, Charles G. Gunnerson, and D. Duncan Mara

This manual presents the latest field results of the research, summarizes selected portions of other publications on sanitation program planning, and describes the engineering details of alternative sanitation technologies and how they can be upgraded.

The Johns Hopkins University Press, 1982. 172 pages (including bibliography, index).

LC 80-8963. ISBN 0-8018-2584-9, $15.00 (£10.50) paperback.

Appropriate Technology for Water Supply and Sanitation

Volume 1: Technical and Economic Options

John M. Kalbermatten, DeAnne S. Julius, and Charles G. Gunnerson

Reports technical, economic, health, and social findings of the research project on "appropriate technology" and discusses the program planning necessary to implement technologies available to provide socially and environmentally acceptable low-cost water supply and waste disposal.

December 1980. 122 pages (including bibliography).

Stock No. WS-8002. Free of charge.

Volume 1a: A Summary of Technical and Economic Options

John M. Kalbermatten, DeAnne S. Julius, and Charles G. Gunnerson

A summary of the final report on appropriate technology for water supply and waste disposal in developing countries, a World Bank research project undertaken by the Energy, Water, and Telecommunications Department in 1976–1978.

December 1980. 38 pages. English, French.

Stock No. WS-8003. $3.00.

Volume 1b: Sanitation Alternative for Low-Income Communities—A Brief Introduction

D. Duncan Mara

Describes, in non-technical language, the various low-cost sanitation technologies that are currently available for low-income communities in developing countries and presents a general methodology for low-cost sanitation program planning.

February 1982. 48 pages.

Stock No. WS-8201. $3.00.

Volume 2: A Planner's Guide

John M. Kalbermatten, DeAnne S. Julius, D. Duncan Mara, and Charles G. Gunnerson

Provides information and instructions on how to design and implement appropriate technology projects based on the findings reported in *Volume 1: Technical and Economic Options.*

December 1980. 194 pages (including references).

Stock No. WS-8004. $5.00.

Volume 3: Health Aspects of Excreta and Sullage Management—A State-of-the-Art Review

Richard G. Feachem, David J. Bradley, Hemda Garelick, and D. Duncan Mara

Provides information on the ways in which particular excreta disposal and reuse technologies affect the survival and dissemination of pathogens. It is intended for planners, engineers, economists, and health workers.

December 1980. 303 pages (including 14 appendixes, references).

Stock No. WS-8005. $15.00.

Volume 4: Low-Cost Technology Options for Sanitation—a State-of-the-Art Review and Annotated Bibliography

Witold Rybczynski, Chongrak Polprasert, and Michael McGarry

A comprehensive bibliography that describes alternative approaches to the collection, treatment, reuse, and disposal of wastes.

A joint World Bank/International Development Research Centre publication. 1978. Available from International Development Research Centre (IDRC), P.O. Box 8500, Ottawa K1G 3H9, Ontario (Canada).

Volume 5: Sociocultural Aspects of Water Supply and Excreta Disposal

Mary Elmendorf and Patricia Buckles

This report was prepared as part of the World Bank research project concerning appropriate technology for water supply and waste disposal. Social and cultural factors influencing responses to water supply and excreta disposal technologies are investigated in seven case studies of communities in the rural and urban fringe areas of Latin America.

December 1980. 67 pages (including 3 annexes, references). English and Spanish.

Stock No. WS-8006. $3.00.

Volume 10: Night-Soil Composting

Hillel I. Shuval, Charles G. Gunnerson, and DeAnne S. Julius

Describes a safe, inexpensive treatment method for night-soil composting that is ideally suited for developing countries because of its simplicity in operation, limited need for mechanical equipment, low cost, and its effectiveness in inactivating pathogens.

December 1981. 81 pages (including bibliography, 2 appendixes).

Stock No. WS-8101. $3.00.

Volume 11: A Sanitation Field Manual

John M. Kalbermatten, DeAnne S. Julius, and Charles G. Gunnerson

December 1980. 87 pages.

Stock No. WS-8007. $3.00.

A Model for the Development of a Self-Help Water Supply Program

Colin Glennie

Presents one version of a practical model for developing, with high community participation, water supply programs in developing countries. Consideration is also given to sanitation program development and practical guidelines for program development are included. One of a series of informal Working Papers prepared by the Technology Advisory Group, established under UNDP's Global Project, executed by the World Bank.

Technology Advisory Group Working Paper Number 1. October 1982. 45 pages (including 2 annexes, references).

ISBN 0-8213-0077-6. $3.00.

World Bank Research in Water Supply and Sanitation—Summary of Selected Publications

A bibliography summarizing the papers in the Water Supply and Sanitation Series, as well as the World Bank studies in Water Supply and Sanitation published for the World Bank by The Johns Hopkins University Press.

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