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# ...r Supply ...pumps Project

## Laboratory Testing, Field Trials and Technological Development

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Interregional
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GLO 79/010
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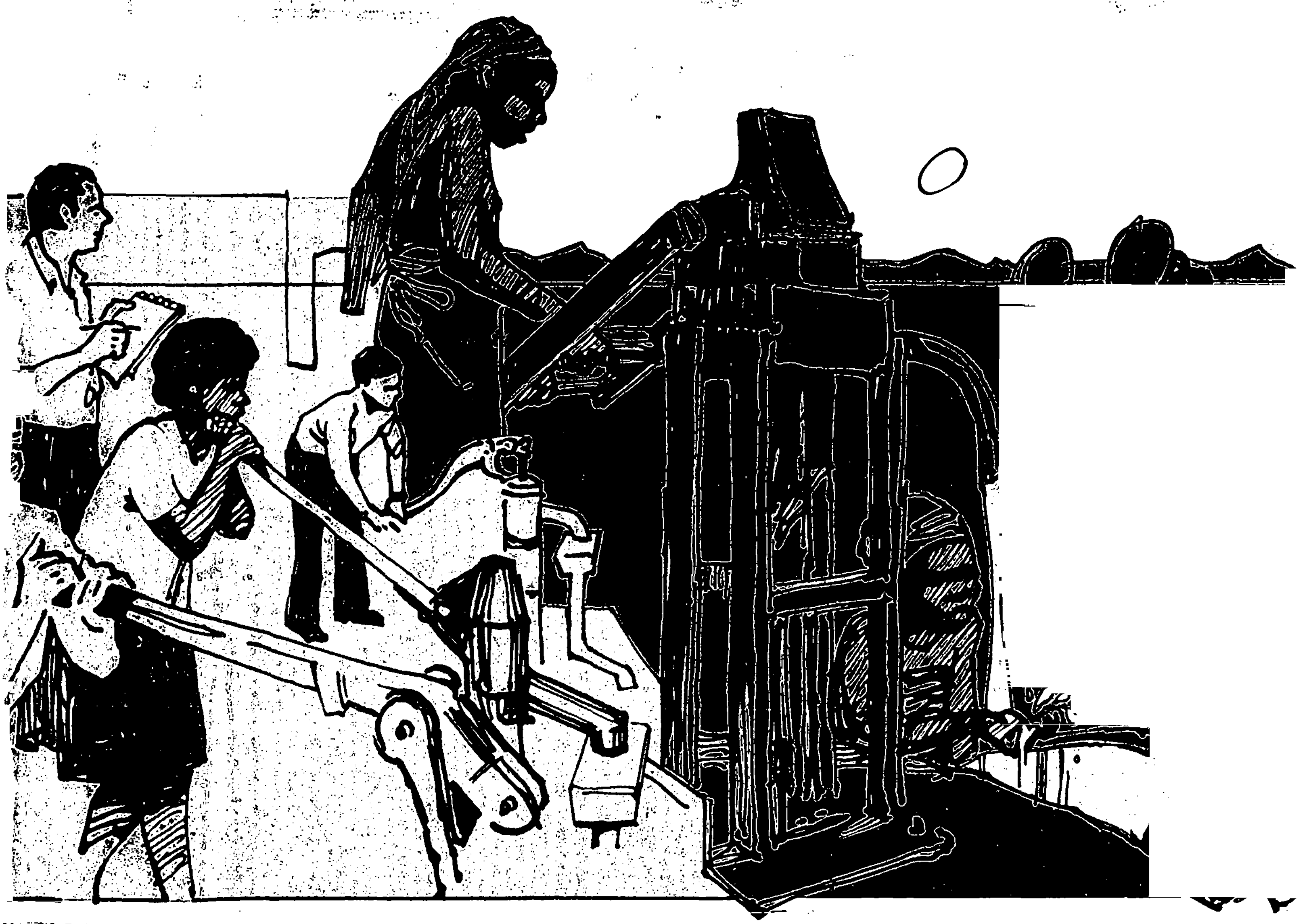

Report No. 1
March 1982

A joint United Nations Development Program and World Bank Contribution
to the International Drinking Water Supply and Sanitation Decade

1981-1990

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UNDP/WORLD BANK - RURAL WATER
SUPPLY HANDPUMPS PROGRAMME

(Laboratory testing, field trials and technological development; UNDP GLO/79/010, INT/81/026)

More than seventy five percent of over two billion people in the developing countries do not have access to adequate water supply and sanitation facilities. The more than 1500 million people who lack these basic services include 1200 million in the rural areas.

The importance of providing safe water to these people 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 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 projet". The World Bank, with responsibility assigned to the office of the senior adviser for water and wastes, was selected to be the executing agency to undertake the handpump 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, of Harpenden, U.K.

The aim of the test is to examine a wide range of handpumps to assist in the selection of pumps for further field trials and at the same time to provide information to all interested manufacturers to assist them in the production of more efficient and more reliable pumps. 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 manufacturing of improved and more reliable handpumps in developing countries, pumps that can be maintained by trained village operators (VLOM pumps - Village Level Operation and Maintenance).

The attached report of laboratory tests is the first to be published under this project. We shall be grateful for any comments and additional contributions to the report and to the programme.

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CA
TESTING
AND
RESEARCH

1981-1990

# INTERIM REPORT A9940/2

# LABORATORY TESTS ON HAND-OPERATED WATER PUMPS FOR USE IN DEVELOPING COUNTRIES

FEBRUARY 1982

This interim report contains results of Laboratory tests carried out on 12 hand pumps for the World Bank. Various recommendations have been made for improvements in performance, safety and durability. These recommendations will be strengthened when the final results of the 200 day endurance test have been completed and analysed. A final report will be issued in November, 1982.

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A.9940/2

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CONTENTS PAGE

# INTRODUCTION

## History

In 1977 the Overseas Development Administration of the UK Government were anxious to respond to growing criticism of field failures of handpumps which had been provided as aid to Developing Countries. They also wanted to obtain better "value for money" in their purchases of handpumps. CA Testing & Research Laboratories were approached for assistance since they were an independent organisation with many years of practical experience in comparative testing and product assessment. CATR devised a comprehensive and long-term testing programme for hand- and foot-operated pumps, using novel testing techniques and obtained a great deal of information which had not previously been available to institutional buyers. The ODA also required the technical data on performance, manufacturing quality, engineering design assessment, ergonomic and user information, abuse and endurance tests to be sent to the manufacturers of the pumps to assist them in improving the quality and reliability of their products.

## Pumps Selected for ODA Test

The products tested were all deep-well models and were a mixture of traditional and newer designs of both hand- and foot-operated types. The selection was made from 8 countries as the following list indicates:

| | | |
|---|---|---|
| Petropump Type 95 | - | Sweden |
| Vergnet Type AC2 (foot-operated) | - | France |
| Dempster 23F | - | USA |
| Mono ES30 | - | UK |
| Climax | - | UK |
| Godwin W1H 51 | - | UK |
| Abi Type M | - | Africa |
| GSW (Beatty) 1205 | - | Canada |
| Monarch P3 | - | Canada |
| Kangaroo (foot-operated) | - | Africa |
| India Mk II | - | India |
| Consallen LD5 | - | UK |

.../

Testing & Research Conference

In 1979 an International Conference on Testing and Evaluation of Handpumps was run jointly by the International Reference Centre and CA Testing & Research in Harpenden, to which delegates from Developing Countries, aid organisations and the World Bank were invited.

With the impending start of the International Decade of Drinking Water & Sanitation, the World Bank considered that pump evaluation should be continued, but with the inclusion of more samples from manufacturers in Developing Countries. Results could then be sent back to manufacturers to help them identify and remove weak points of design and of manufacturing techniques so that improved and more reliable pumps could be produced.

World Bank/UNDP Sponsored Laboratory Testing

In 1980 the World Bank contracted CA Testing & Research to carry out a further series of tests on handpumps and with the experience from the ODA testing programme a new pump-testing tower was built at their Gosfield Laboratory site in Essex, UK. Following discussions between the World Bank, UNICEF, IRC and other aid organisations, 12 brands of deep and shallow-well pumps were selected for testing.

| | | |
|---|---|---|
| Korat 608 Al (deep-well) | - | Thailand |
| Bandung (shallow-well) | - | Indonesia |
| Briau Nepta (deep-well) | - | France |
| Nira AF-76 (deep-well) | - | Finland |
| New No. 6 (shallow-well) | - | Bangladesh |
| Moyno IV 2b (deep-well) | - | USA |
| Kawamoto Dragon No. 2 (shallow-well with deep-well conversion and tested in this form) | - | Japan |
| IDRC Ethiopia Type BP (shallow well) | - | Ethiopia |
| VEW (deep-well) | - | Austria |
| AID/Battelle (deep-well) | - | Indonesia |
| Atlas Copco (deep-well) | - | Kenya |
| Jet-matic (deep-well) | - | Philippines |

Other pumps have since been nominated for testing: Volanta - The Netherlands, Abi-Vergnet - Ivory Coast, New Petro Pump - Sweden, modified AID/Battelle - Plastic deep-well pump - Malawi. It is hoped that a sixth will be identified so that the next batch of pumps can be started early in 1982.

.../

Laboratory evaluation of handpumps under properly controlled conditions is cheaper and quicker to carry out than field trials which, by their very nature are likely to be far less controlled. Engineering assessments can indicate potential areas of weakness and provide manufacturers with early warning of failure, and endurance tests can telescope 3 years of field use into a 6 month period. However, field trials are indispensable for providing wide-scale information on real-use situations to compare with the laboratory results. Hopefully the initial laboratory testing will have filtered out the most unsuitable pumps and will have already stimulated manufacturers to make changes based on the initial laboratory assessments.

SUMMARY OF TERMS of REFERENCE

1. Initial inspection - packaging
   - literature
   - pumps

2. Construction and Installation - technical drawings
   - photographs
   - tabulation of components

3. Engineering/Design Assessment - materials
   - manufacturing processes and skills
   - ease of maintenance and repair
   - resistance to contamination and abuse
   - potential safety hazards
   - suggested design improvements

4. Ergonomics - handle heights
   - mechanical advantage of handle
   - angular movement of handle
   - exit water pattern

5. User Tests - 10 groups of men, women and children of varying heights and weights

6. Performance tests - leakage
   - volume flow, work input and efficiency

7. Endurance tests - 4 stages of 1000 hours each, using 4 different and increasingly severe qualities of water
   - dismantling and inspection

8. Abuse tests - simulation of impact loads

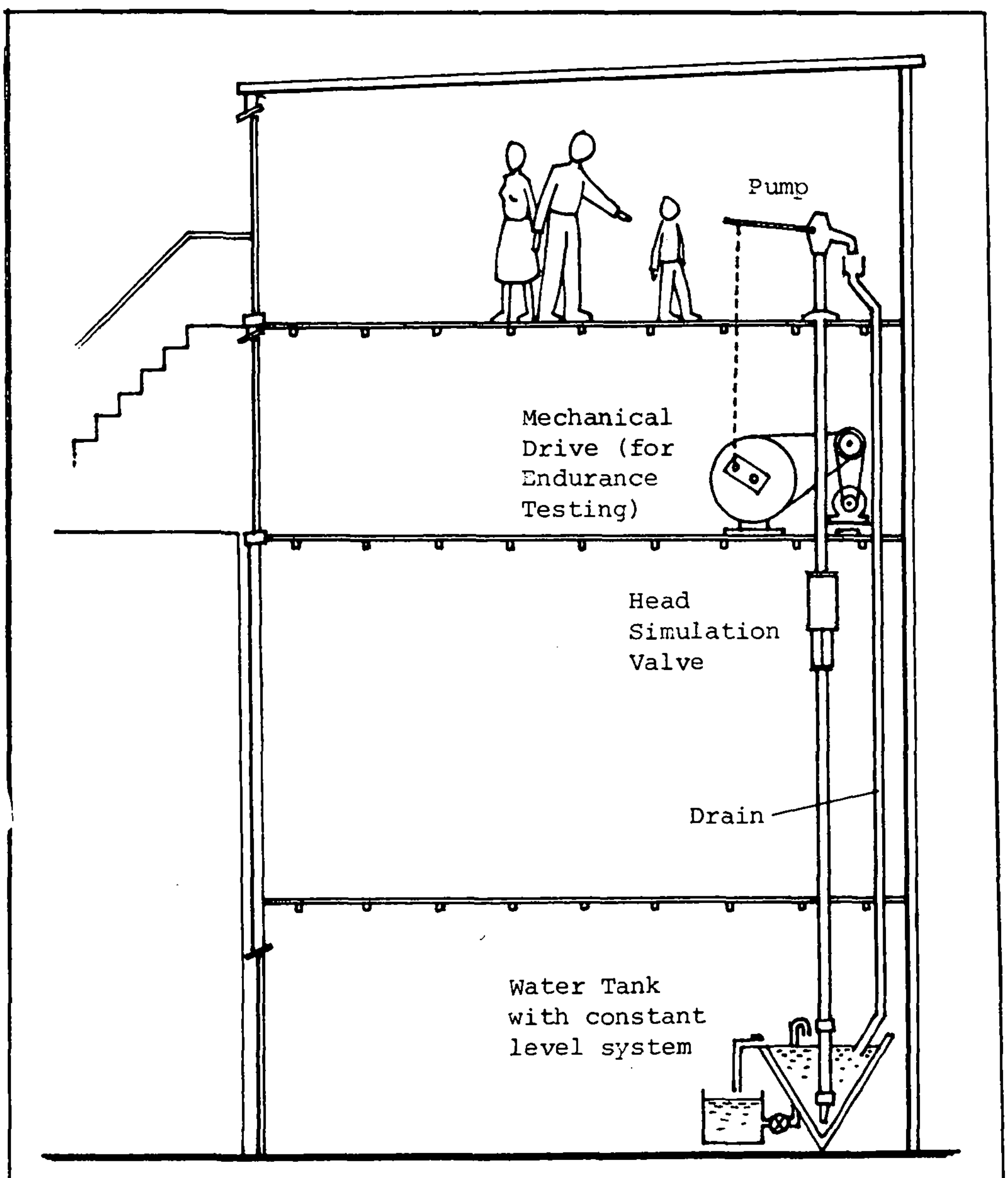
9. Review - ease of pump installation
   - ease of maintenance and repair

INSTALLATION for TESTING

The pumps have been installed on the top floor of a purpose-built 10 metre tower. They are arranged in two batches of six, with a motor and tank for each batch. For clarity, the illustration below shows only one pump, motor and tank

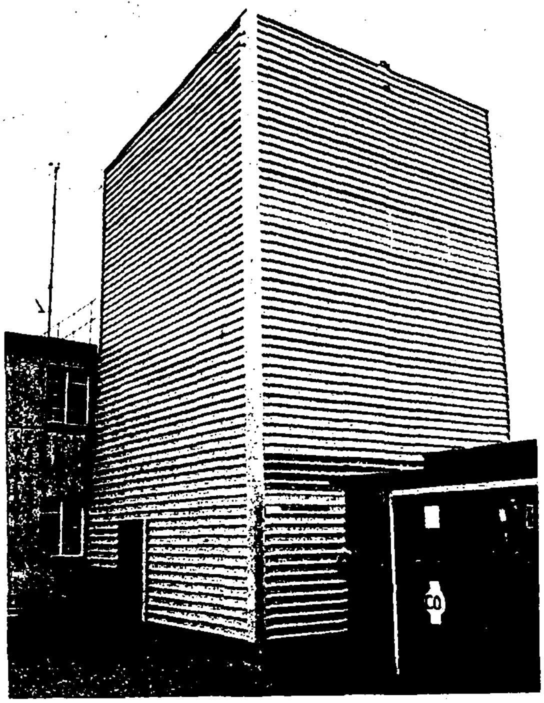
The floor beneath the pumps houses the mechanical drive which will be used for the forthcoming endurance tests. Beneath that, each pump is fitted with an adjustable valve designed to simulate well depths down to 45 metres.

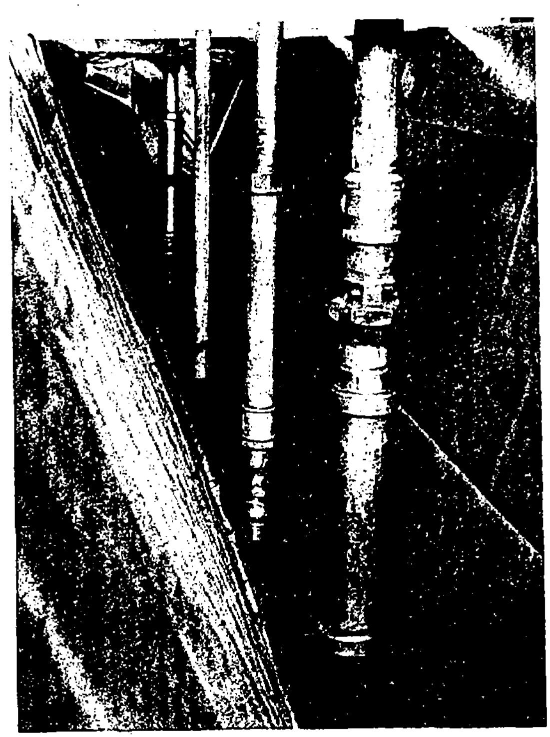
The level of water in the tank on the ground floor is maintained by a pump and constant level device.



INSTALLATION FOR TESTING - cont.

The photographs show (clockwise, from top left) the exterior of the tower; some of the installed pumps on the top floor; the drive mechanisms; inside the tank (before filling with water):





BATCH 1 PUMPS
*************

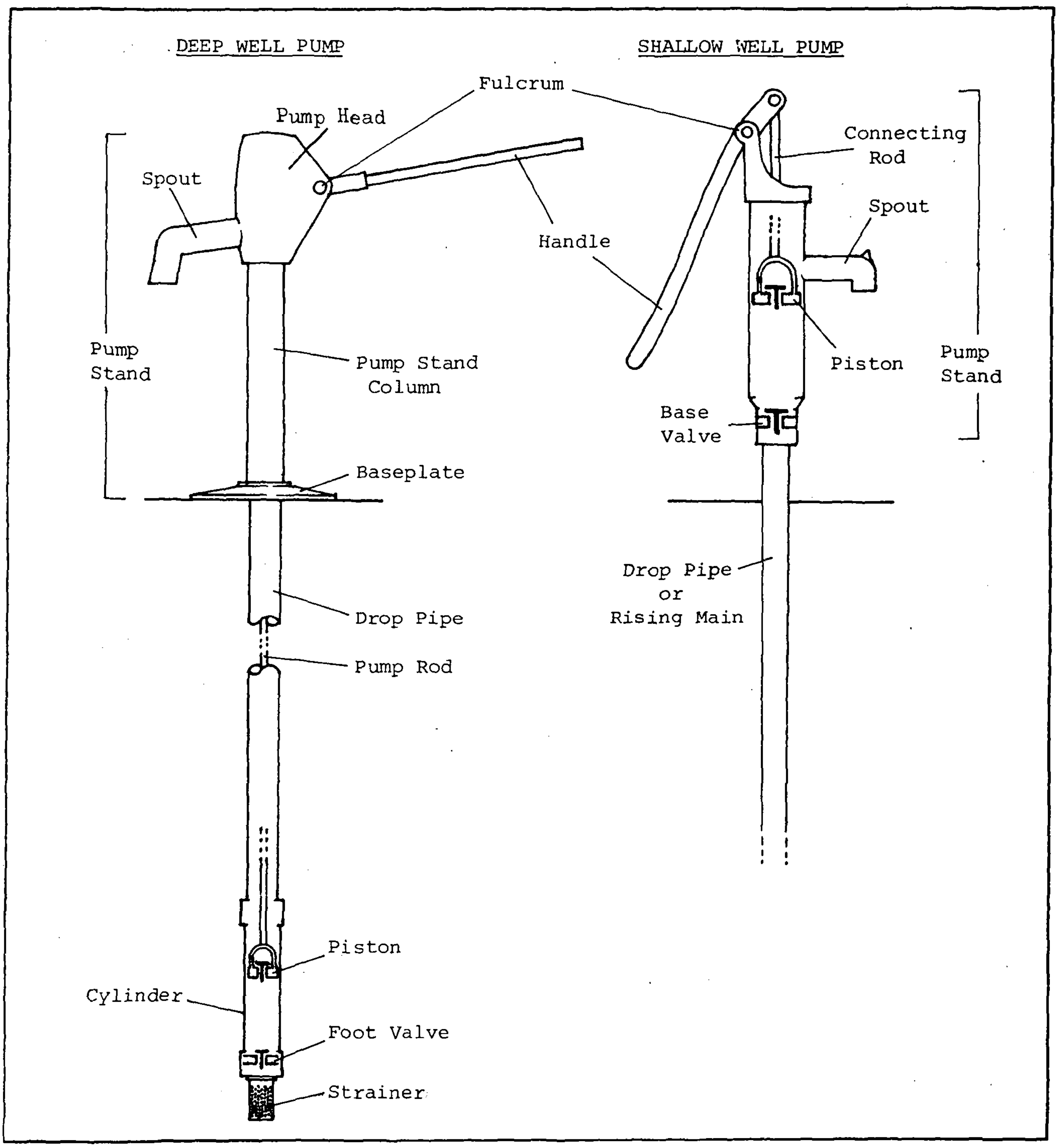
| CODE | MANUFACTURER | MODEL | DEEP OR SHALLOW WELL | FREE DISCHARGE OR DELIVERY LIFT | COUNTRY OF ORIGIN |
|---|---|---|---|---|---|
| A | Saha Kolkarn | Korat 608 608 A-1 | Deep | Delivery Lift | Thailand |
| C | Robbins and Myers | Moyno IV 2.6 | Deep | Delivery Lift | U.S.A. |
| D | Briau SA | Nepta | Deep | Free discharge | France |
| F | UNICEF | New No. 6 | Shallow | Free discharge | Bangladesh |
| G | Vammalan Konepaja Oy | Nira AF-76 | Deep | Free discharge | Finland |
| L | UNICEF | Bandung | Shallow | Free discharge | Indonesia |

BATCH 2 PUMPS
*************

| CODE | MANUFACTURER | MODEL | DEEP OR SHALLOW WELL | FREE DISCHARGE OR DELIVERY LIFT | COUNTRY OF ORIGIN |
|---|---|---|---|---|---|
| B | Kawamoto | Dragon No. 2 (D) | Deep | Delivery Lift | Japan |
| E | Atlas Copco | Kenya | Deep | Free Discharge | Kenya |
| H | IDRC Ethiopia | type BP | Shallow | Free Discharge | Ethiopia |
| J | Vereinigte Edelstahlwerke | A18 | Deep | Free Discharge | Austria |
| K | Sea Commercial Co. | Jetmatic | Deep | Delivery Lift | Philippines |
| M | [3] | AID/ Battelle | Deep | Free Discharge | Indonesia |

<u>For your convenience this table is duplicated in the last page to be unfolded while reading the report.</u>

BASIC PUMP NOMENCLATURE



# B A T C H  1

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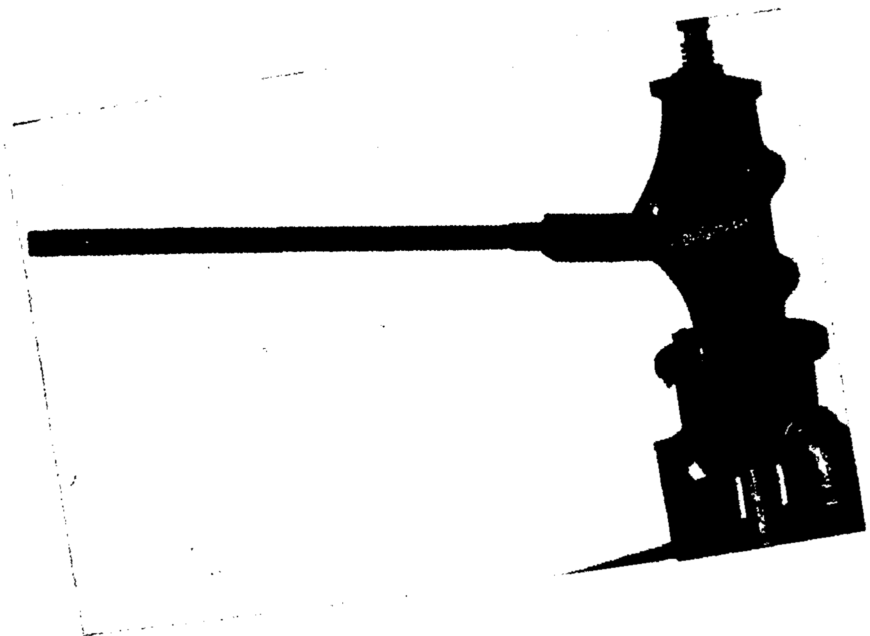
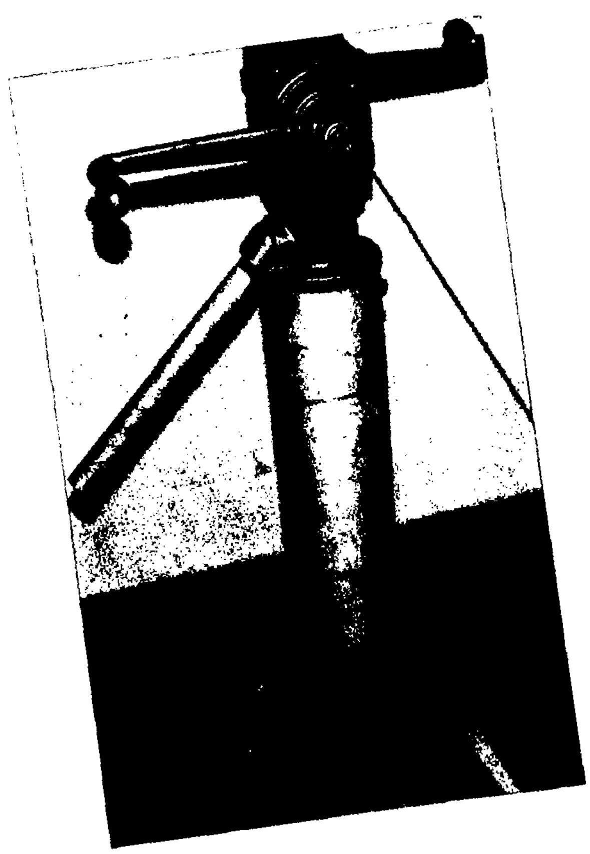
CODES  A , C , D , F , G , L

TABLE 1: Brand List of Pumps in Batch 1

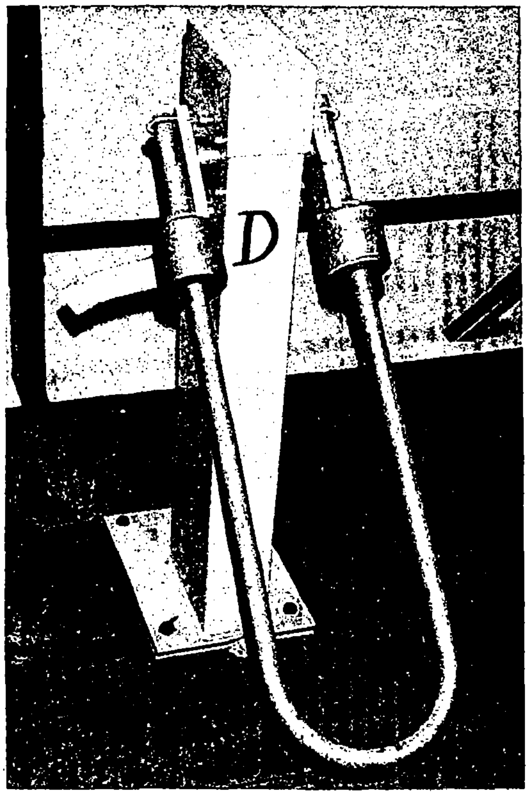
| CODE | MANUFACTURER | MODEL | DEEP OR SHALLOW WELL | FREE DISCHARGE OR DELIVERY LIFT (1) | COUNTRY OF ORIGIN |
|---|---|---|---|---|---|
| A | Saha Kolkarn | Korat 608 608 A-1 | Deep | Delivery Lift | Thailand |
| C | Robbins and Myers | Moyno IV 2.6 | Deep | Delivery Lift | U.S.A. |
| D | Briau SA | Nepta | Deep | Free discharge | France |
| F | UNICEF | New No. 6 | Shallow | Free discharge | Bangladesh |
| G | Vammalan Konepaja Oy | Nira AF-76 | Deep | Free discharge | Finland |
| L | UNICEF | Bandung | Shallow | Free discharge | Indonesia |



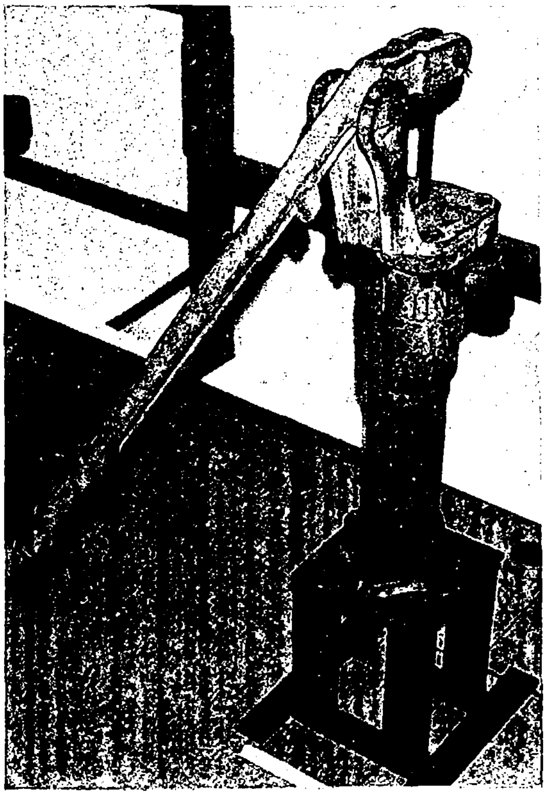
Code A



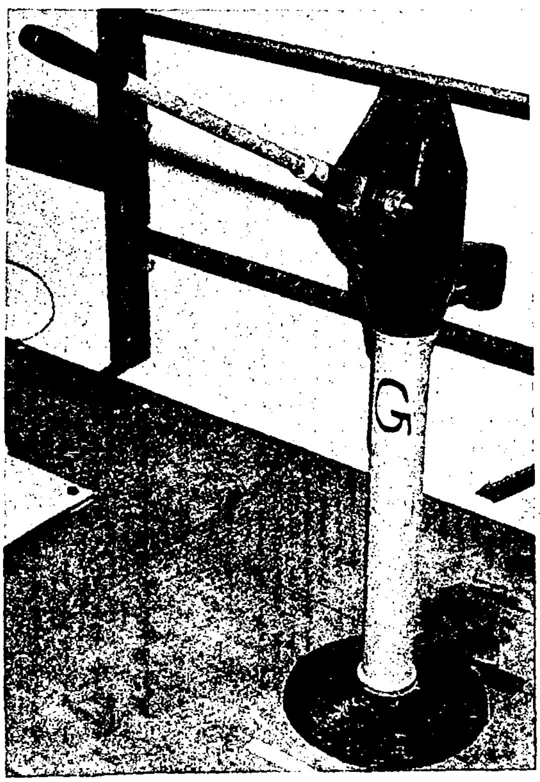
Code C



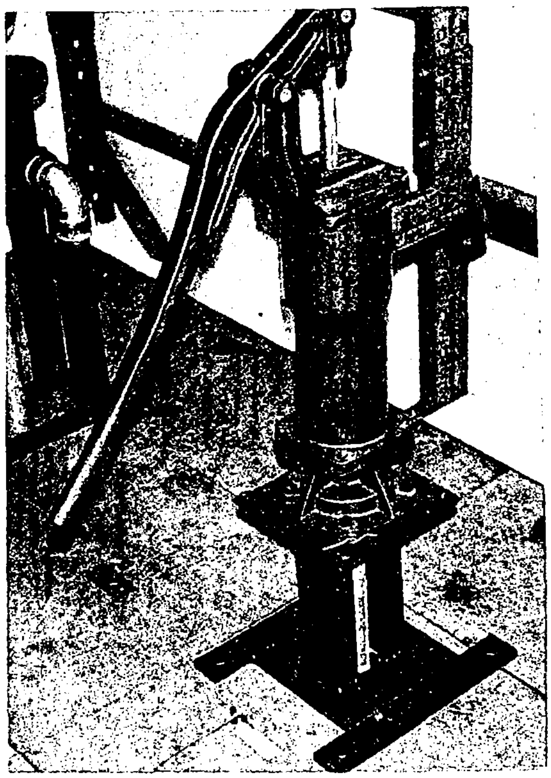

Code D



Code F




Code G



Code L

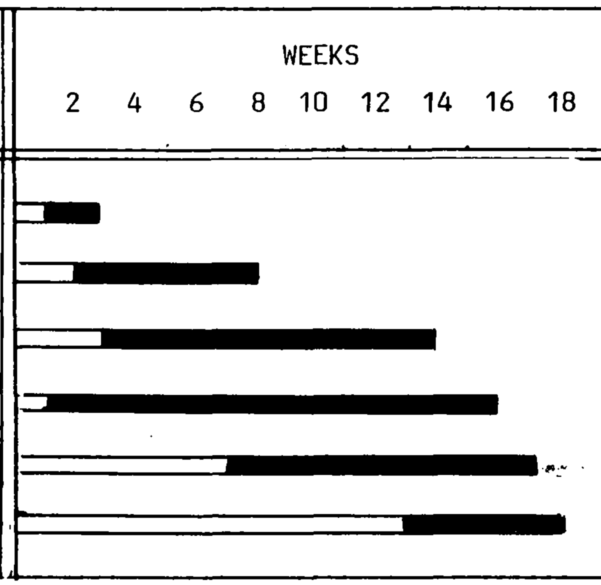
1. ORDERING and DELIVERY

Codes A, C, D and G were obtained through an independent procurement agency. Codes F and L were obtained through the appropriate UNICEF Supply Sections. These precautions were taken to ensure that the manufacturers were not aware that their pumps were to be used as test samples.

Each manufacturer was first asked to quote for the cost of two pumps and their transportation to the UK. When the quotation was received the pumps were ordered and letters of credit established in the countries of manufacture. Table 2 below shows the times in weeks from request to receipt of the quotation, and then from order to delivery of the pumps:

TABLE 2: Ordering and Delivery of Pumps

| CODE | QUOTATION (weeks) | DELIVERY of PUMPS (weeks) |
|---|---|---|
| G | 1 | 2 |
| A | 2 | 6 |
| C | 3 | 11 |
| D | 1 | 15 (1) |
| L | 7 | 10 |
| F | 13 | 5 |




Request to receipt of quotation

Order to delivery of pumps

(1) Sent by sea freight - all other codes sent air freight

2. COST of PUMPS (including Carriage, Insurance etc.)

Table 3 details the costs of the various pumps.

TABLE 3 : Cost of Pumps

| CODE | FOR TWO PUMPS TOTAL COST CIF London | EX-FACTORY COST | EX-FACTORY COST PER PUMP Equivalent in US $ (1) |
|---|---|---|---|
| F | US $ 464.00 | $ 40.00 (2) | $ 20 |
| L | S/pore $ 1288.39 | S/pore $ 233.32 | $ 54 |
| A | £ 825.58 | £ 297.89 (3) | $ 295 |
| G | £ 588.55 | £ 333.16 (3) | $ 330 |
| C | US $1906.94 | $ 1281.05 (3) | $ 641 |
| D | FF 11600 | FF 10200 (3) (4) | $ 910 |

(1) Financial Times, 5th June 1981 : £1.00 = $ 1.980
$1.00 = S/pore $ 2.157
$1.00 = FF 5.6025

(2) Supplied free of charge by UNICEF, Dacca, but quoted at $ 20 each

(3) Price includes drop pipes and pump rods

(4) Estimated - precise ex-factory cost not clear from invoice.

# 3. INSPECTION and MEASUREMENT

## 3.1 PACKAGING

Table 4 summarises the packaging in which the pumps were delivered. The suitability of each pump's packaging for export and for crude overland transportation were assessed against the following 5-point scale:

| Very Suitable | | | | Very Unsuitable |
|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 |

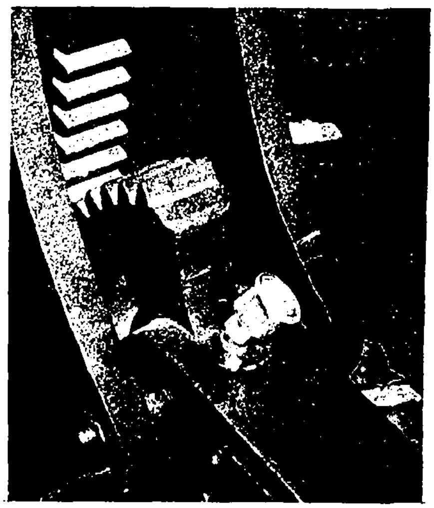
TABLE 4 : Packaging

| CODE | BRIEF DESCRIPTION of PACKAGING | SUITABILITY | |
|---|---|---|---|
| | | for EXPORT | for OVERLAND TRANSPORTATION |
| A | 2 wooden packing cases | 4 | 3 |
| C | 2 heavy-duty corrugated cardboard cartons with wooden reinforcements | 4 | 4 |
| D | 3 wooden packing cases - pipes uncased but ends protected | 5 | 5 |
| F | Open wooden packing case with corrugated cardboard liner | 5 | 5 |
| G | Wooden packing case | 4 | 3 |
| L | Loose-weave plastic sacks - pumps within wrapped in corrugated cardboard (1) | 1 | 1 |

(1) The manufacturer claims that these pumps left the factory packed in a wooden crate and were separated by the carrier.

3.1 PACKAGING - cont.

CODE A Delivered in two wooden packing cases, one containing the pump stands, the other the handles, pipes and pump rods.



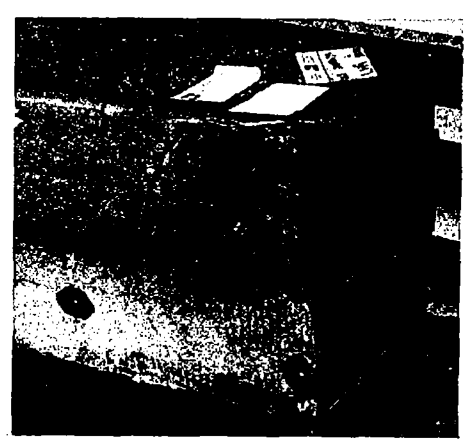
The case containing the pump stands had been damaged and the grease cups on the handles of both pumps were broken

(See photograph, left).

CODE C These pumps were packed in two cartons made from heavy-duty corrugated cardboard (approx. 12 mm thick). The carton containing the pump stands 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.

The photograph (right) shows part of one of the cartons after six weeks exposure to mixed weather.

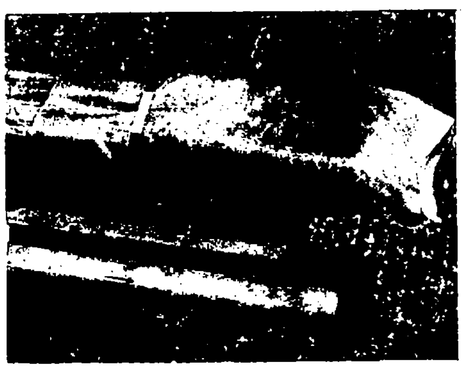


3.1 PACKAGING - cont.

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

The photograph (right) shows the packing case in which the pump stands were delivered.

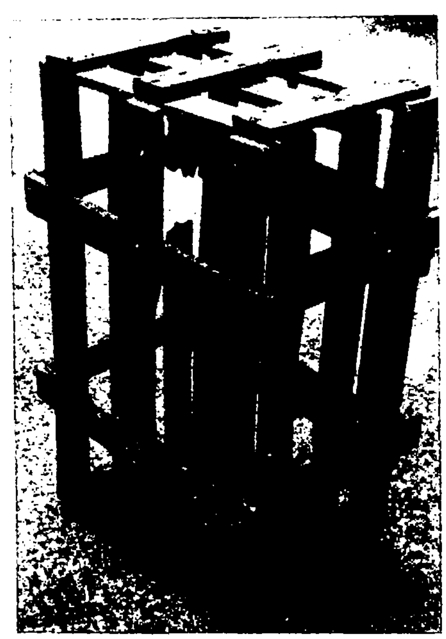
The pumps were not entirely free from damage, however. The spout of one pump stand had rubbed on the packing case, damaging the plastic coating.



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 (left).

CODE F These shallow well pumps were well packaged, in a single wooden packing case (right) 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.



3.1 PACKAGING - cont.

CODE G

Delivered in a single large wooden packing case (left) 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.

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

As the photograph (right) shows, 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 have been replaced by the manufacturer, who has said that the pumps left the factory packed together in a wooden crate. They were separated by the carrier, presumably because of their weight as a single consignment.

# 3. INSPECTION

## 3.2 DEFECTS on DELIVERY

All the pumps were inspected for defects on delivery - the results are summarised in Table 5 :

TABLE 5 : Defects on Delivery

| CODE | COMPONENT or FEATURE | NO. of PUMPS AFFECTED | DEFECTS |
|---|---|---|---|
| A | Grease cups | 2 | Broken |
| | Upper connecting rod nut | 1 | Misaligned thread |
| | Lower rack roller | 1 | Seized - not rotating |
| | Handle | 1 | Small split along half its length |
| | Foot valve | 1 | Rubber washer squeezed out of joint |
| | Various | 2 | Minor surface corrosion on unprotected ferrous surfaces |
| C | Strainer | 1 | Bent, but functional, and could be straightened |
| D | Spout | 1 | Plastic coating damaged |
| | Pistons | 2 | Not assembled tightly |
| | Piston rod to pump rod joint | 1 | Not tight enough |
| F | Piston to rod joint | 1 | Locknut not tight enough |
| | Piston | 1 | End cap not tight enough |
| | Cylinder tops | 2 | Loose - spring washers had been placed under the bolt heads; should be under the nuts |
| G | Handle to pump rod joint | 1 | Locknut not tight enough |
| | Cylinder | 1 | Externally damaged causing distortion of the bore |
| | Piston | 1 | Fixings not tight, thread for pump rod misaligned |
| L | Handles (3) | 2 | Broken |
| | Cylinder top | 1 | Cracked |
| | Connecting rod pivot shaft | 1 | Retaining bolt broken |
| | Base valve seat | 1 | Unevenly coated with filler and paint (1) |

(1) This was subsequently found to interfere with the action of the valve, making the pump difficult to prime, and was therefore removed.

3.2 DEFECTS on DELIVERY - cont.

Only in the case of Code L, where all the three handles supplied were broken, were the pumps incapable of functioning as received. Codes A, D, F and G, although functional, might be expected to give trouble before long if the defects were not remedied.

It is clear that pumps, and more especially deep well cylinder assemblies, should be carefully checked before being installed.

## 3.3 LITERATURE

Only Codes D and G were supplied with literature.

CODE D The literature with Code D gave comprehensive instructions for installing the pumps. The instructions were in French only, but were well illustrated. The literature was enclosed in polythene stapled to the inside of the pumpstands' packing case, and proved very helpful during installation.

CODE G The literature with Code G was not very helpful, consisting only of a promotional leaflet and an annotated sketch of the components. There were no instructions for either installation or use of the pump.

ALL OTHER CODES For the installation of other pumps reference was made to any available information, whether from manufacturers or other sources (reports of field projects etc.) but all too often this information was sketchy and sometimes ambiguous.

It is recommended that all pumps should be supplied with instructions for installation and use - clear illustrations are of particular importance.

## 3.4 WEIGHTS AND MEASURES

3.4.1 The principal weights and dimensions are detailed in Table 6

TABLE 6 : Principal Weights and Dimensions

| CODE | WEIGHTS (kg) | | | | NOMINAL CYLINDER BORE (mm) | ACTUAL PUMP STROKE (mm) | NOMINAL VOLUME PER STROKE (ml) | DROP PIPE SIZE (inch) | PUMP ROD DIA. |
|---|---|---|---|---|---|---|---|---|---|
| | PUMP STAND | CYLINDER | DROP(1) PIPE (per m) | PUMP(1) ROD (per m) | | | | | |
| A | 47.0(2) | 5.5 | 3.8 | 1.1 | 76 | 80 | 363 | 1½ | ½ in |
| C | 48.0 | 16.0 | 3.5 | 1.2 | n/a | n/a | - | 1¼ | ½ in |
| D | 41.5 | 15.5 | 2.9 | 0.7 | 50 | 203 | 399 | 1¼ | 10 mm |
| F | 31.0 | n/a | 3.8 | n/a | 90 | 219 | 1393 | 1½ | n/a |
| G | 29.5 | 4.0 | 5.2 | 0.7 | 76 | 127 | 576 | 2 | 10 mm |
| L | 25.5 | n/a | 2.9 | n/a | 96 | 135 | 977 | 1¼ | n/a |

n/a = not applicable

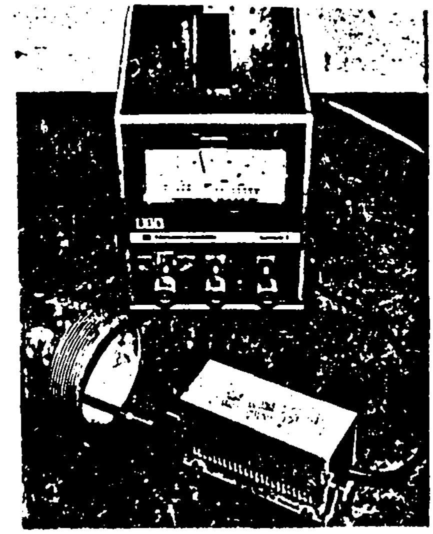
(1) Including couplings

(2) Not including spout (none supplied) but with handle

3.4 WEIGHTS and MEASURES - cont.

3.4.2 CYLINDER BORES

The cylinder bores were measured at five points along their length; a second series of measurements was then taken at right angles to the first.



No significant taper or ovality was found in any of the samples.

The surface roughness average (Ra) was measured in three places in a direction parallel to the cylinder axis (right)

The results are shown in Table 7.

TABLE 7 : Principal Weights and Dimensions

| CODE | CYLINDER BORE SURFACE | ROUGHNESS AVERAGE (μm) (1) | | | |
|---|---|---|---|---|---|
| | | TEST 1 | TEST 2 | TEST 3 | MEAN |
| A7 | Extruded brass | 0.05 | 0.05 | 0.07 | 0.06 |
| A8 | Extruded brass | 0.08 | 0.07 | 0.08 | 0.08 |
| C | | Not applicable (2) | | | |
| D5 | Extruded brass | 0.05 | 0.06 | 0.06 | 0.06 |
| D6 | Extruded brass | 0.22 | 0.18 | 0.22 | 0.21 |
| F1 | Machined cast iron | 2.3 | 2.5 | 2.5 | 2.4 |
| F2 | Machined cast iron | 2.0 | 2.5 | 2.8 | 2.4 |
| G5 | Extruded brass | 0.06 | 0.07 | 0.06 | 0.06 |
| G6 | Extruded brass | 0.12 | 0.11 | 0.11 | 0.11 |
| L1 | Enamelled steel | 0.72 | 0.76 | 0.32 | 0.60 |
| L2 | Enamelled steel | 0.18 | 0.40 | 0.40 | 0.33 |

(1) Measured at 0.25 mm cut-off

(2) Helical steel rotor in moulded elastomer stator

3.4 WEIGHTS and MEASURES - cont.

3.4.2 CYLINDER BORES - cont.

The IRC handbook on handpumps (Technical Paper Series, No. 10) suggests that good quality brass cylinders should have a surface finish in the range 0.1 to 0.2 µm, compared with 1.3 to 5.1 µm for good quality machined cast iron.

In the deep-well reciprocating pumps (Codes A, D and G) the maximum usable cylinder length is considerably greater than the pump stroke, enabling the position of the plunger in the cylinder to be adjusted when the cylinder becomes worn.

Table 8 below details the maximum usable cylinder lengths for these pumps, compared with the actual pump strokes

TABLE 8 : Pump Stroke and Usable Cylinder Length

| CODE | PUMP STROKE (mm) | MAXIMUM USABLE CYLINDER LENGTH (mm) |
|---|---|---|
| A | 80 | 255 |
| D | 203 | 620 |
| G | 127 | 310 |

Blank

## 3.4 WEIGHTS and MEASURES - cont.

### 3.4.3 ERGONOMIC MEASUREMENTS

Where such information was available, pumps were installed at their manufacturers' recommended heights.

Pumps for which this information was not available were installed so that the mid-point of handle operation was as close as possible to 0.9 m from floor level, subject to a maximum spout height of approximately 0.6 m (right). These preferred heights were suggested by previous user tests of handpumps (Report No. Z.9923).

Various ergonomic measurements were taken and these are detailed in Table 9.

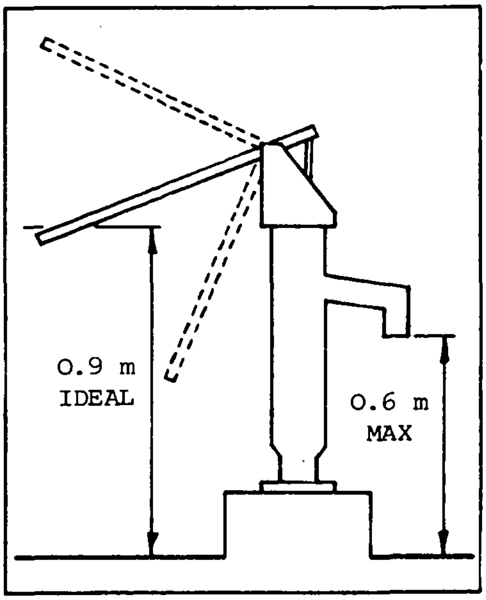



TABLE 9: Ergonomic Measurements

| CODE | HANDLE HEIGHT MAX (1) (mm) | HANDLE HEIGHT MIN (1) (mm) | PLINTH HEIGHT (mm) | ANGULAR MOVEMENT OF HANDLE (degrees) | HANDLE HEIGHT (mm) | VELOCITY RATIO OF HANDLE | HEIGHT OF SPOUT (mm) |
|---|---|---|---|---|---|---|---|
| A | 1365 | 485 | 500 | 50 | 1055 | 10.8:1 | 490 |
| C | 1244 | 738 | 0 | 360 | 253 | - | 563 |
| D | 1413 | 190 | 0 | 104 | 780 | 7.0:1 | 530 |
| F | 1190 | 400 | 280 | 100 | 595 | 4.7:1 | 583 |
| G | 1155 | 542 | 0 | 58 | 623 | 5.0:1 | 603 |
| L | 1107 | 465 | 300 | 69 | 565 | 5.0:1 | 605 |

(1) Measured without compressing bump stops (where fitted)

## 4. ENGINEERING ASSESSMENT

Each brand of pump has been subjected to detailed engineering assessment. Pumps were stripped down into their component parts and each part examined for suitability of design, choice of materials and manufacturing process and workmanship. The assembled pump was then assessed for potential safety hazards, resistance to contamination by foreign matter and surface water, resistance to abuse (including pilferage) and ease of maintenance and repair. The manufacturing processes, and the levels of skill required, were summarised for each pump. Finally, suggestions for improvements to the design were outlined.

### 4.1 MATERIALS

The materials used for the principal components of each pump are detailed in Table 10:

TABLE 10: Materials

| CODE | COMPONENT | MATERIAL(S) |
|---|---|---|
| A | Pumpstand body | Cast iron |
| | Quadrant and rack | Cast iron |
| | Handle | Wood |
| | Cylinder | Extruded brass |
| | Piston | Cast gunmetal or bronze |
| | Cup seals | Leather |
| | Foot valve | Cast gunmetal and leather |
| | Drop pipe | Galvanised steel |
| | Pump rods | Mild steel |
| C | Pumpstand column | Fabricated steel, galvanised |
| | Pump top (gearbox) | Cast steel |
| | Handles | Cast steel |
| | Gears | Mild steel |
| | Rotor | Steel, hard chrome-plated |
| | Stator | Moulded elastomer in steel tube |
| | Foot valve | Gunmetal with brass strainer |
| | Drop pipe | Galvanised steel |
| | Pump rods | Galvanised steel |
| D | Pumpstand | Fabricated steel, nylon-coated |
| | Handle and counterweights | Steel, galvanised |
| | Quadrant assembly | Fabricated steel, galvanised |
| | Cylinder | Extruded brass |
| | Piston | Cast gunmetal or brass |
| | Piston seals | Textile cord |
| | Drop pipe | Galvanised steel |
| | Pump rods | Stainless steel with polyester cable coupling at pumpstand |

TABLE 10: Materials (cont)

| CODE | COMPONENT | MATERIAL(S) |
|---|---|---|
| F | Pumpstand | Cast iron |
| | Handle | Cast iron |
| | Piston | Cast iron |
| | Cup seal | Moulded PVC |
| | Base valve | Leather |
| G | Pumpstand column | Steel, galvanised |
| | Pump top | Cast iron |
| | Handle | Mild steel |
| | Fulcrum link | Cast gunmetal |
| | Pivot pin | Stainless steel |
| | Pump rod fork | Hot pressed brass |
| | Cylinder | Brass, with soft-soldered end spigots |
| | Piston | Cast bronze with brass valve seat |
| | Cup seal | Moulded rubber |
| | Foot valve | Moulded rubber |
| | Drop pipe | Galvanised steel |
| | Pump rods | Stainless steel |
| L | Pumpstand | Cast iron with enamelled steel cylinder liner |
| | Handle | Cast iron |
| | Piston | Cast iron |
| | Cup seal | Moulded rubber |
| | Base valve | Rubber with moulded plastic cage |

## 4. ENGINEERING ASSESSMENT - cont.

### 4.2 MANUFACTURING PROCESSES and SKILLS

Table 11 summarises the processes and levels of skill required to manufacture each pump.

For each process required the table shows a skill rating based on the following 5-point scale:

| Very High Skill | | | | Very Low Skill |
|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 |

The "score" in the final column is obtained by simply adding together the ratings for each pump: it provides a very rough comparative measure of the levels of technology required to manufacture each brand of pump.

TABLE 11: Manufacturing Processes and Skills

| CODE | IRON FOUNDRY | BRASS/GUNMETAL FOUNDRY | STEEL FORGING and WELDING | HOT BRASS PRESSING | SHEET METAL FORMING | SIMPLE MACHINING (1) | COMPLEX MACHINING (2) | LEATHER CUTTING and FORMING | RUBBER/PLASTICS MOULDING | WOODWORK | SOFT SOLDERING | HARD CHROME PLATING | SPECIALISED PROCESSES | "SCORE" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 3 | 3 | - | - | - | 2 | - | 2 | - | 1 | - | - | - | 11 |
| C | 4 | - | 3 | - | - | - | 5 | - | 5 | - | - | 5 | 5 | 27 |
| D | - | 3 | 4 | - | 3 | 3 | 3 | - | 1 | - | - | - | - | 17 |
| F | 2 | - | 2 | - | - | 2 | - | 2 | 2 | - | - | - | - | 10 |
| G | 4 | 2 | 4 | 3 | - | 3 | - | - | 2 | - | 2 | - | - | 20 |
| L | 3 | - | 3 | - | 3 | 3 | - | - | 3 | - | - | - | - | 15 |

(1) Turning, drilling, tapping etc.

(2) Gear cutting etc.

4. ENGINEERING ASSESSMENT - cont.

4.3 MAINTENANCE and REPAIR

Table 12 summarises the assessments of the likely ease of maintenance and repair of each pump.

The ratings are based on a 5-point scale:

| Very Easy | | | | Very Difficult |
|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 |

TABLE 12 : Ease of Maintenance and Repair

| CODE | RATING | COMMENTS |
|---|---|---|
| A | 4 | Could easily be maintained using locally available materials and components |
| C | 1 | Likely to require little maintenance but, when required, needs specialised tools and components and considerable skill |
| D | 2 | Likely to require little maintenance, except for cable in pumpstand and tension spring in cylinder, but needs specialised components |
| F | 5 | Maintenance minimal and very easy |
| G | 3 | Not easy to maintain, some specialist tools, materials and components would be required. Needs a grease gun |
| L | 4 | Little maintenance likely to be required, but less easy than Code F |

4. ENGINEERING ASSESSMENT - cont.

## 4.4 RESISTANCE to CONTAMINATION

Table 13 summarises the assessment of each pump for resistance to contamination by foreign matter and surface water.

The ratings shown are based on a 5-point scale:

| Very Good | | | | Very Poor |
|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 |

TABLE 13: Resistance to Contamination

| CODE | RATING | COMMENTS |
|---|---|---|
| A | 3 | Care needed to seal pump to well head |
| C | 3 | Well head must be adequately sealed against ground water |
| D | 4 | Depends on seal at well head - otherwise satisfactory |
| F | 2 | Pumpstand open at top (where connecting rod passes through pump top) |
| G | 4 | If mounted at ground level could be affected by surface water - otherwise very sanitary |
| L | 3 | Better than Code F - sliding plate provides some protection |

## 4. ENGINEERING ASSESSMENT - cont.

### 4.5 RESISTANCE to ABUSE

Table 14 summarises the assessment of each pump for likely resistance to abuse - pilferage, accidental impacts, heavy-handed usage etc.

The ratings shown are based on a 5-point scale:

| Very Good | | | | Very Poor |
|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 |

TABLE 14: Likely Resistance to Abuse

| CODE | RATING | COMMENTS |
|---|---|---|
| A | 3 | Many easily removed nuts and bolts - otherwise robust and handle would be easy to replace |
| C | 4 | Fixings very secure - generally strong and robust |
| D | 4 | Rather thin baseplate could be susceptible to abuse - fixings mostly secure |
| F | 2 | Cast iron handle and pump top susceptible to accidental damage - attachment to rising main potentially weak, whole pump might be too easily detached. Pins and bolts too easy to remove |
| G | 4 | Pump head could be unscrewed from column but otherwise fixings secure. Handle quite easy to remove - would not be easy to improvise a replacement |
| L | 2 | Handle and pump top susceptible to accidental damage. No lock washers on fixings |

## 4. ENGINEERING ASSESSMENT - cont.

### 4.6 POTENTIAL SAFETY HAZARDS

Table 15 summarises the potential safety hazards identified for each pump.

TABLE 15: Potential Safety Hazards

| CODE | FEATURE | HAZARD |
|---|---|---|
| A | Quadrant and rack<br>Pump head bolts | Finger traps<br>Sharp edges |
| C | Spout end | Sharp edges |
| D | Handle and pumpstand<br>Handle | Finger traps<br>Very heavy |
| F | Split pins | Sharp ends |
| G | Handle | Sharp edges |
| L | Connecting rod fork | Finger trap |

CODE A The quadrant and rack on this pump present a very dangerous potential finger trap (see photograph, right), particularly in view of the large mechanical advantage of the handle.

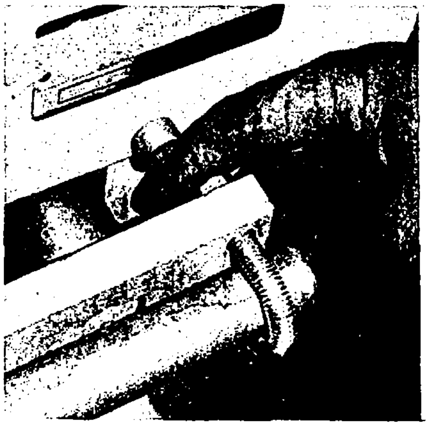
The bolts used to assemble the pumpstand have sharp raw ends.

CODE C The spout on this pump is a length of galvanised steel pipe - the sawn end is sharp and potentially dangerous.

4. <u>ENGINEERING ASSESSMENT</u> - cont.

4.6 <u>POTENTIAL SAFETY HAZARDS</u> - cont.

CODE D The handle on this pump is particularly heavy and would be dangerous if the operating cable were to break in use.

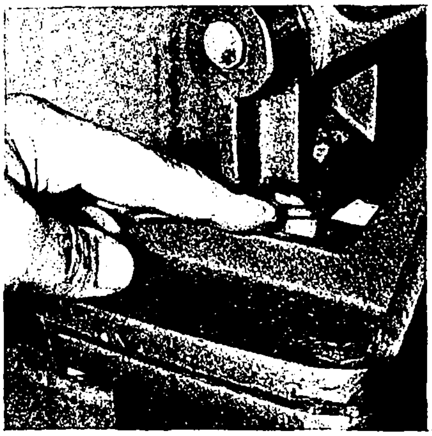


There are a number of potential finger traps between the handle and the pumpstand (left) - increased clearances would help considerably.

CODE F Split pins, with sharp ends, are used to retain the pivot pins for the handle.

CODE G The handle on this pump has a sharp burr on the shoulder, near the handle pivot. The rubber grip may also conceal sharp edges.

CODE L There is a potential finger trap between the connecting rod fork and the top of the pump stand (right).



4. ENGINEERING ASSESSMENT - cont.

## 4.7 SUGGESTED DESIGN IMPROVEMENTS

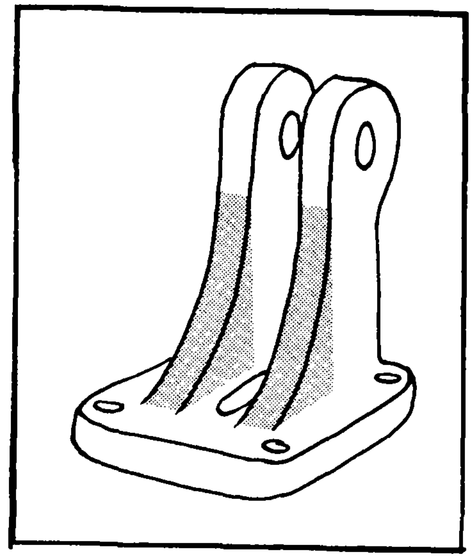
CODE A

1. The piston valve lift should be reduced (ideally to one quarter of its diameter) and its lateral location improved. Its efficiency may also be improved by providing a leather or rubber valve seat.

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

3. The quadrant and rack present a considerable safety hazard and should be shrouded.

   This could be achieved either by modifying the casting patterns for the pumphead side plates (see sketch,right) or by adding simple sheet metal covers.

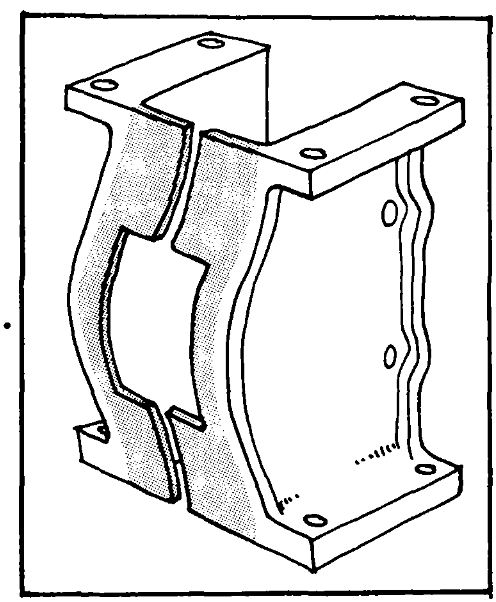


CODE C The handles would be easier to use if rotating handgrips were provided.

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

CODE F

1. The cylinder top casting should be robustly webbed at the roots of the fulcrum extensions (see sketch, right).



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

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

4. The handle should be more robustly designed or made in a more resilient material (such as wood).

4. ENGINEERING ASSESSMENT - cont.

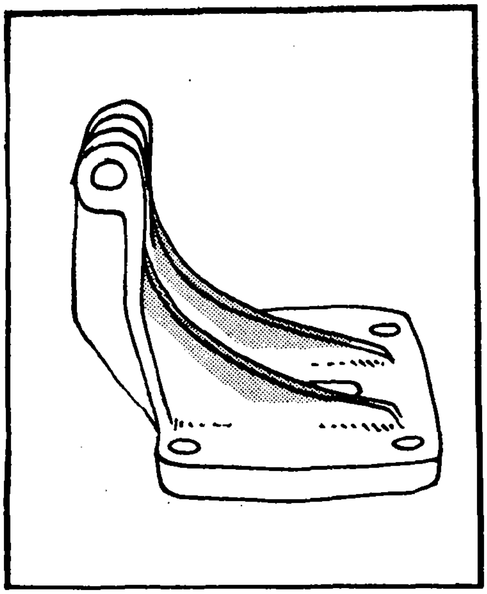
## 4.7 SUGGESTED DESIGN IMPROVEMENTS

CODE G

1. 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.
2. Valve lift should be reduced (ideally to one quarter of the diameter).
3. The handle would be more secure if the welded collar were omitted and a locknut used instead.

CODE L

1. 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.
2. The webs on the cylinder top casting should be extended (see sketch, right).
3. The handle should be more robustly designed or made in a more resilient material (such as wood).



# 5. USER TRIAL

## 5.1 METHOD

The installed pumps were assessed by 60 users - men, women and children. Adults were divided into equal groups of short, medium and tall stature, and children (all 11 years old or thereabouts) into short and tall groups:

| | | |
|---|---|---|
| 6 | MEN | under 1.68 m |
| 6 | MEN | between 1.68 and 1.79 m |
| 6 | MEN | over 1.79 m |
| 6 | WOMEN | under 1.63 m |
| 6 | WOMEN | between 1.63 and 1.69 m |
| 6 | WOMEN | over 1.69 m |
| 6 | BOYS | between 1.35 and 1.49 m |
| 6 | BOYS | between 1.50 and 1.65 m |
| 6 | GIRLS | between 1.35 and 1.49 m |
| 6 | GIRLS | between 1.50 and 1.65 m |
| 60 | | |

The users were asked to fill a 10 litre bucket with each pump and answer questions about the height and comfort of the handle, the effort required and the overall ease of use. Each user had an opportunity to familiarise him/herself with each pump before being asked to fill the bucket. The photograph below shows a group of children during this initial stage.

5. USER TRIAL (cont)

The users were instructed to work the pumps in a predetermined controlled random order.

For this trial the shallow well pumps were operated at a 7 metre head. The deep well pumps were set at a simulated head of 20 metres.

## 5.2 Statistical Analysis of User Responses

The users' responses are summarised in Table 16 . Further details of the statistical analysis, and of the responses of particular groups, can be found in Appendix I.

TABLE 16 : Summary of User Responses : Batch 1

| | QUESTION | Better ← Approximate Mean for Question → Worse | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | Suitability of Handle height | D | | L,F | C,G | | A | |
| 2 | Comfort of Handle | | D,G,A, L | | F | | C | |
| 3 | Effort Required to work pump | L,F,D | | A | | G | | C |
| 4 | Overall, how easy to operate pump | L,F | | D,A | | G | | C |

## 5.3 OBSERVATIONS

As the user trial progressed, it became increasingly clear that objective observation of the users could yield useful information, in addition to their questionnaire responses.

Users clearly found some pumps easier to operate than others, and in several instances the reasons for their likes and dislikes were plain to see.

CODE A Many users complained that the handle of this 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; most of the effort had to be supplied by arms and shoulders only.

CODE C This pump was consistently disliked, especially by smaller users. Most of the effort must be supplied by the arms and shoulders only, with 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 the 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 only one did not revert to two-handle operation. The rough, non-rotating handgrips were consistently criticised.

CODE D Many users complained that the handle of this pump was too low, and this was compounded by other difficulties. The handle moves through a wide arc, $104^{\circ}$ 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 found the exaggerated body movements uncomfortable.

CODE F 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.

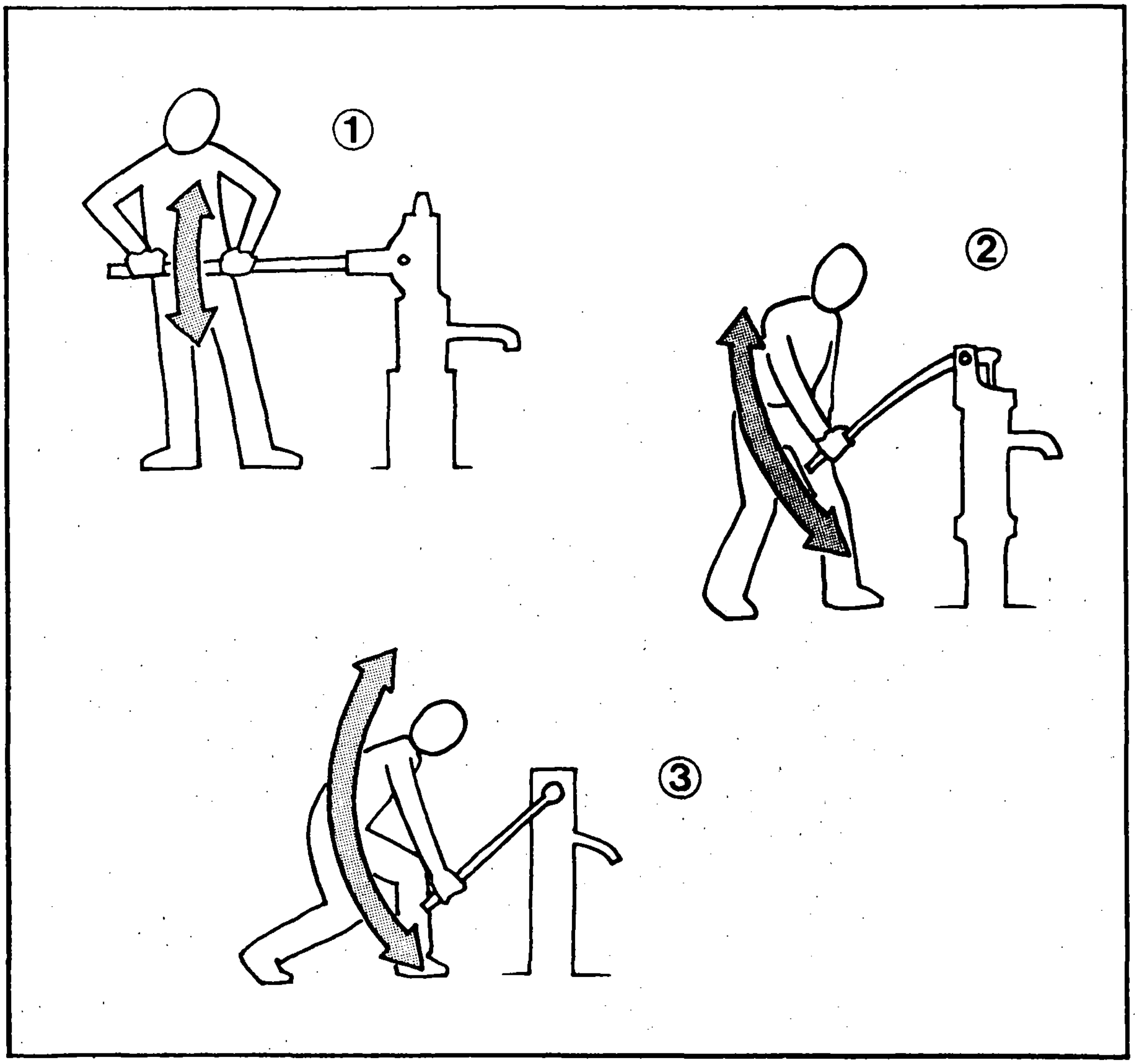
CODE G Children and small women found this pump difficult because of the high levels of effort required. Many children found it difficult to bring their weight to bear on the handle at the start of the downstroke.

CODE L 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.

## 5.4 GENERAL COMMENTS

All groups of users seemed to be most comfortable with pumps where a variety of muscle groups could be used to share the effort, provided that exaggerated body movements were not required.

In the illustration below, pump 1 demands relatively short, vertical handle movements, so that most of the operating effort must be supplied by arms and shoulders only. Pump 2, by contrast, has both vertical and horizontal components in the motion of the handle and allows the user to bring several muscle groups into play. Pump 3 demands the use of several muscle groups, but also exaggerated body movements.



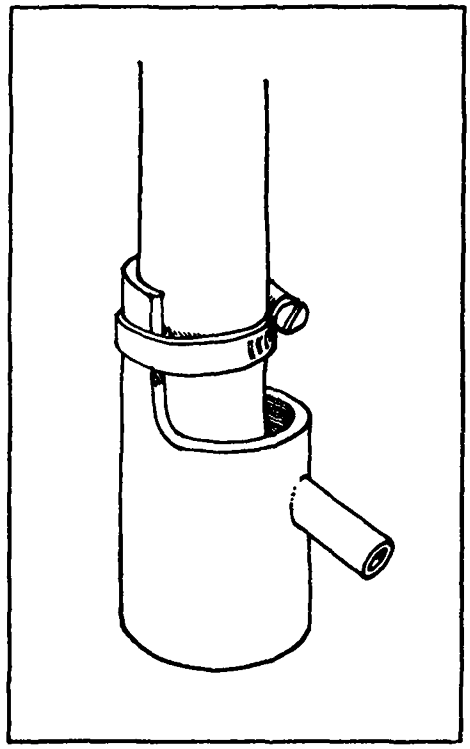
# 6. PUMP PERFORMANCE

## 6.1 LEAKAGE TESTS

The leakage through each pump was assessed by first operating the pumps to ensure that they were fully charged with water and then draining the tank. The amount of water leaking past the foot valve in 10 minutes was then measured.

All the pumps were tested at a head of 7 m, the deep well pumps were also tested at 25 and 45 m. These heads were simulated by sealing the rising mains and injecting compressed air.

The shallow well suction pumps, Codes F and L, were fitted with small "Eureka cans" (right) before draining the tank, to retain the column of water in the rising main.



## 6. PUMP PERFORMANCE

### 6.1 LEAKAGE TESTS (cont)

Table 17 details the results of the leakage tests:

TABLE 17 : Leakage Tests

| CODE | 7 m HEAD | | 25 m HEAD | | 45 m HEAD | |
|---|---|---|---|---|---|---|
| | LEAKAGE (ml) in 10 min | LEAKAGE RATE (ml/min) | LEAKAGE (ml) in 10 min | LEAKAGE RATE (ml/min) | LEAKAGE (ml) in 10 min | LEAKAGE RATE (ml/min) |
| A | < 1 | N/S | 17 | 1.7 | 44 | 4.4 |
| C | < 1 | N/S | < 1 | N/S | < 1 | N/S |
| D | < 1 | N/S | < 1 | N/S | < 1 | N/S |
| F | 2.5 | 0.25 | - | - | - | - |
| G | 1 | 0.1 | < 1 | N/S | < 1 | N/S |
| L | 6.0 | 0.60 | - | - | - | - |

N/S = not significant, less than 0.1 ml/minute

At the higher pressures, Code A was found to be leaking from the upper cylinder cap; the casting was porous. A Purple Alert [1] was raised to highlight this defect - see Appendix III. All the spare castings supplied, both tops and bottoms, were also found to be porous. The original casting was sealed with shellac for the remaining performance and endurance tests. Once the cap was sealed, the leakage from the foot valve was found to be not significant - i.e. less than 0.1 ml/minute.

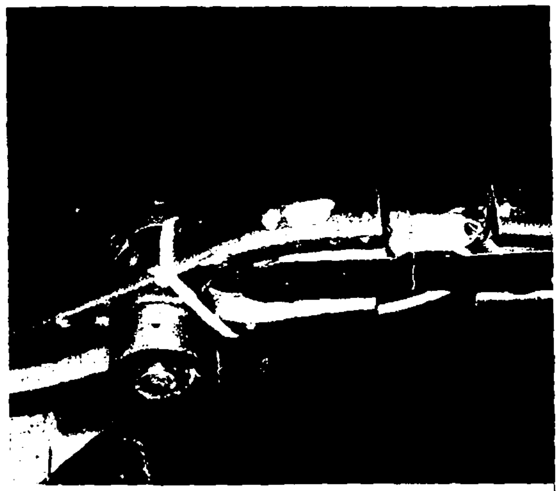
[1] A Laboratory procedure designed to highlight and verify an especially poor test result.

# 6. PUMP PERFORMANCE

## 6.2 VOLUME FLOW, OPERATIONAL FORCES and EFFICIENCY

Measurements of volume flow, operational forces and pump efficiency were combined in a single test method.

Strain gauges were attached to the handles of each pump to measure the applied forces. The photograph (right) shows the gauges attached.
A rotary potentiometer fixed to the body of the pump measured the angular movement of the handle.



The outputs from the strain gauges and from the rotary potentiometer were fed, via an interface unit, to a microcomputer. The computer was programmed to record the data and calculate the work done on the pump as the product of the applied force and the displacement of the handle. The weight of water produced in each test was entered into the computer. Pump efficiency was defined as the ratio (per cent) of the useful work output (i.e. water raised) to the total work done on the pump, thus:

$$\text{Eff.} = \frac{Mh}{\Sigma Fd} \times 100\%$$

where $M$ = mass of water raised (kg)
$h$ = head (m)
$F$ = applied force (kgf)
$d$ = handle displacement (m)

so that $\Sigma Fd$ = sum of the products of the applied forces and displacements
= work done on pump
$Mh$ = work done by the pump

# 6. PUMP PERFORMANCE

## 6.2 VOLUME FLOW, OPERATIONAL FORCES and EFFICIENCY (cont)

The strain gauges were calibrated for each pump by noting the outputs corresponding to known weights, suspended from the handle, at a fixed distance from the fulcrum when it was locked in a horizontal position. The rotary potentiometer was calibrated by noting the outputs for the upper and lower limits of handle travel, and the handle's length. This calibration procedure was built into the computer programme and preceded each test.

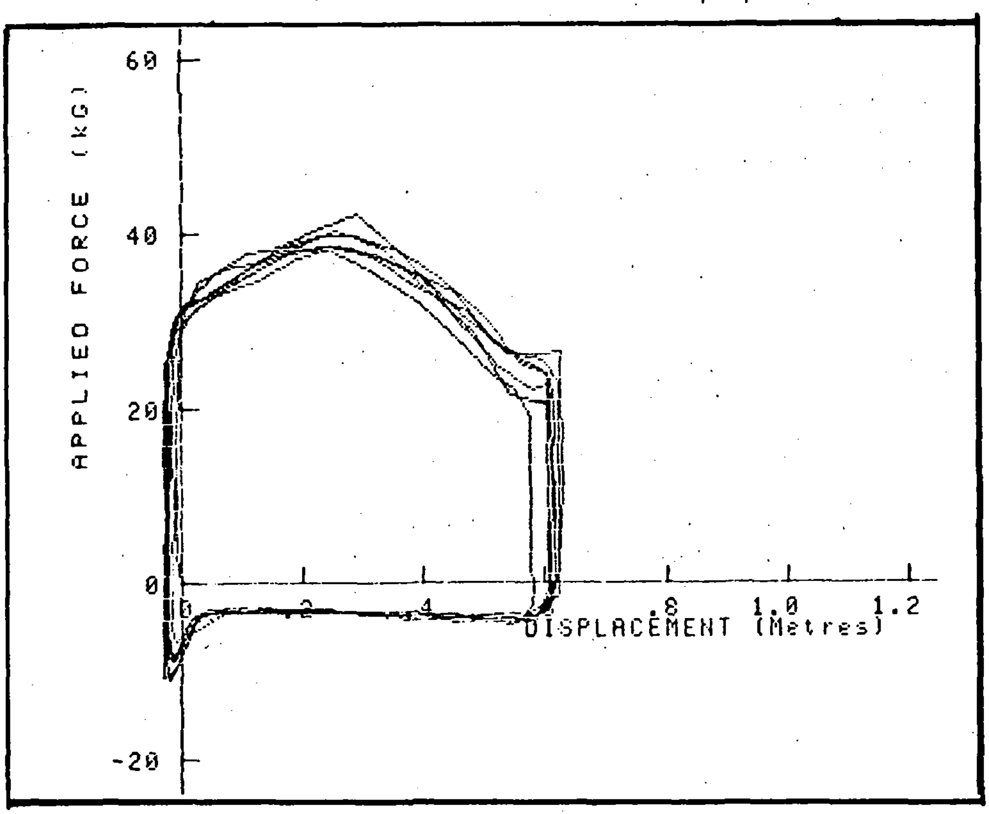
Each pump was operated at three speeds, normally 30, 40 and 50 strokes or revolutions of the handle per minute. Where 50 strokes/min would be impractical or unrealistic, 20, 30 and 40 strokes/min were used.* All the pumps were operated at a 7m head, the deep well pumps also at simulated heads of 25 and 45 m.

The same person carried out all the tests, using a metronome to control his pumping rate.

For all the reciprocating pumps, each test comprised twenty full strokes. For the rotary pump, Code C, the tests were limited by the 10-turn rotary potentiometer to 9 complete revolutions.

The computer subsequently plotted the applied force against the displacement of the handle for each test. A typical result for a reciprocating pump is illustrated below. Successive strokes retrace the force/displacement loop. The area inside the loop represents the work done on the pump.

* i.e. Codes F and L, the shallow well suction pumps.



## 6.2 VOLUME FLOW, OPERATION FORCES and EFFICIENCY

Tables 18 (a), (b) and (c) summarise the performance test results for average volume per stroke, average work done per stroke and overall efficiency.

TABLE 18: Pump Performance Summary

(a) AVERAGE VOLUME per STROKE or REVOLUTION (litres)

| HEAD (metres) | 7 | | | | 25 | | | | 45 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUMPING RATE (strokes or revs/min) / PUMP CODE | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 |
| A | - | 0.39 | 0.40 | 0.40 | - | 0.36 | 0.35 | 0.35 | - | 0.34 | 0.35 | 0.36 |
| C | - | 0.23 | 0.23 | 0.23 | - | 0.20 | 0.20 | 0.20 | - | 0.15 | 0.15 | 0.16 |
| D | - | 0.39 | 0.40 | 0.39 | - | 0.38 | 0.39 | 0.40 | - | 0.38 | 0.39 | 0.39 |
| F | 1.30 | 1.20 | 1.29 | - | - | - | - | - | - | - | - | - |
| G | - | 0.62 | 0.63 | 0.65 | - | 0.64 | 0.65 | 0.65 | - | 0.60 | 0.59 | 0.59 |
| L | 0.95 | 0.96 | 1.04 | - | - | - | - | - | - | - | - | - |

TABLE 18: Pump Performance Summary (cont)

(b) AVERAGE WORK DONE on PUMP per STROKE or REVOLUTION (Joules)

| HEAD (metres) | 7 | | | | 25 | | | | 45 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUMPING RATE (strokes or revs/min) / PUMP CODE | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 |
| A | - | 57 | 50 | 54 | - | 175 | 159 | 152 | - | 218 | 200 | 196 |
| C | - | 130 | 144 | 140 | - | 139 | 152 | 166 | - | 195 | 209 | 198 |
| D | - | 51 | 45 | 43 | - | 130 | 123 | 120 | - | 206 | 216 | 180 |
| F | 148 | 121 | 134 | - | - | - | - | - | - | - | - | - |
| G | - | 55 | 59 | 72 | - | 264 | 209 | 254 | - | 395 | 398 | 404 |
| L | 94 | 93 | 102 | - | - | - | - | - | - | - | - | - |

(c) AVERAGE EFFICIENCY (%)

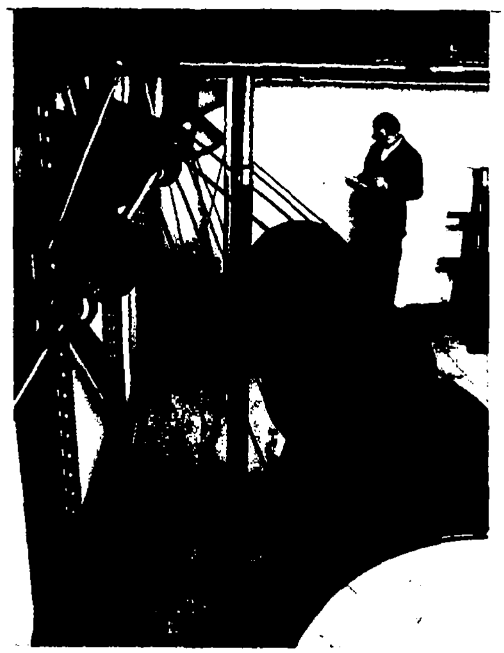
| HEAD (metres) | 7 | | | | 25 | | | | 45 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUMPING RATE (Strokes or revs/min) / PUMP CODE | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 |
| A | - | 46 | 53 | 50 | - | 50 | 53 | 56 | - | 68 | 76 | 80 |
| C | - | 11 | 10 | 11 | - | 35 | 32 | 29 | - | 34 | 31 | 36 |
| D | - | 52 | 60 | 61 | - | 71 | 76 | 80 | - | 81 | 78 | 94 |
| F | 59 | 67 | 65 | - | - | - | - | - | - | - | - | - |
| G | - | 76 | 71 | 61 | - | 59 | 75 | 63 | - | 66 | 65 | 63 |
| L | 69 | 70 | 70 | - | - | - | - | - | - | - | - | - |

# 7. ENDURANCE - The First 1000 Hours

## 7.1 THE ENDURANCE TEST PROGRAMME

The complete pump endurance programme demands 4000 hours of operation - some 10 million strokes for most pumps - in four stages of 1000 hours each. For the first stage clean, hard water was used, pH ~ 7.2. Further stages will use increasingly severe qualities of water.

All six pumps are driven by a single electric motor, via a countershaft (right). Belts from the countershaft turn large wooden pulleys from which connecting rods or secondary belts operate the ~~pump~~ handles on the floor above.



This mechanism moves the handles of the reciprocating pumps in simple harmonic motion and so imposes no shock loads.

The pumps are operated at the highest speed likely to be used in practice. For the deep well pumps in Batch 1, Codes A, C, D and G, it was considered that this should be 40 strokes or revolutions per minute. The shallow well pumps, Codes F and L, are driven at 30 strokes per minute.* The operating speed for these suction pumps was discussed in the first Interim Report, A.4990/1.

The shallow well pumps operate at the installation's actual head of 7 m. The head simulation valves on the deep well pumps have been set at their manufacturers' recommended maximum depths: 45 m for Codes A, C and D; 36 m for Code G.

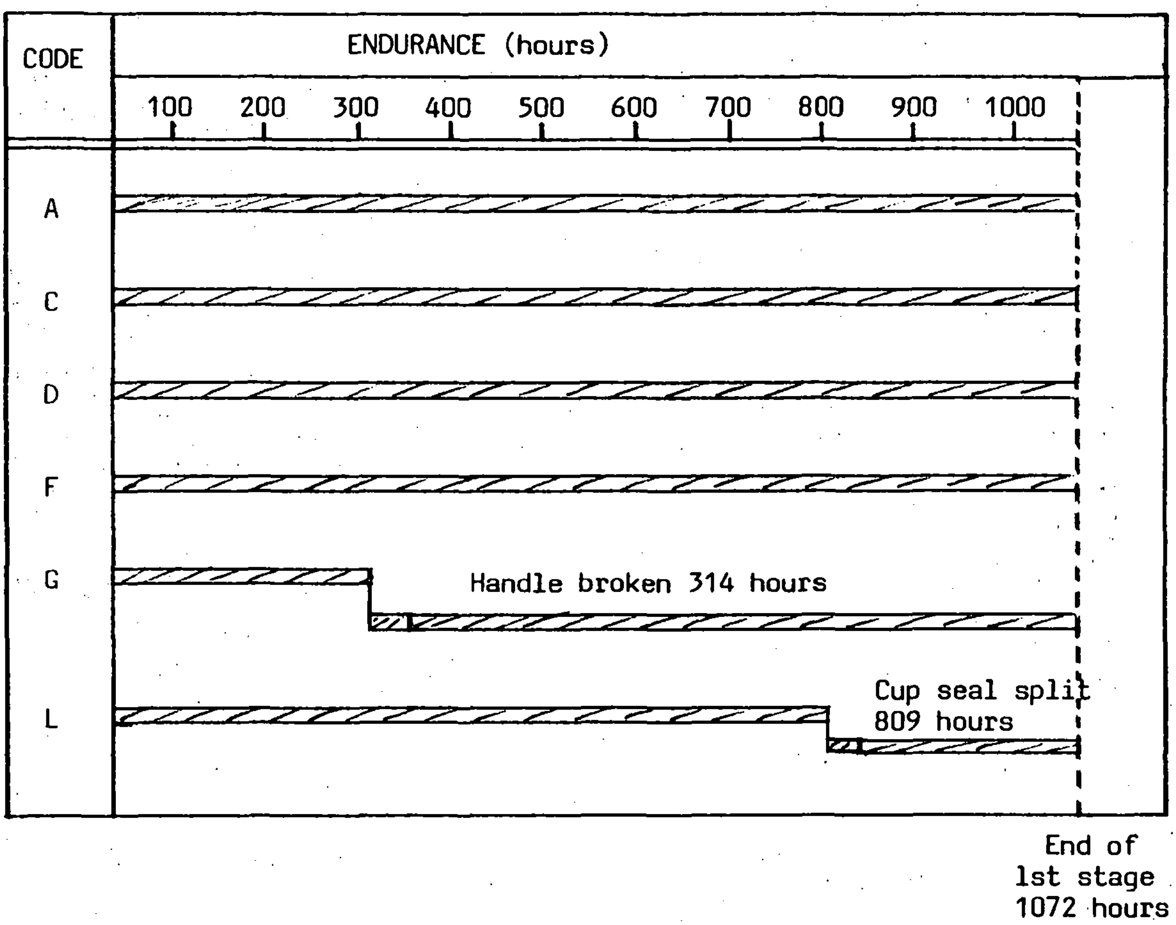
The pumps were lubricated at the beginning of the test but thereafter receive only minimal maintenance. The outflow of water from each pump is detected by float sensors in the hoppers beneath each spout. The pumps are operated continuously until failure of a pump is detected by the absence of water. When a pump fails, all six pumps in the batch are stopped - this ensures that all the pumps are operated for the same total time.

* See Scarlet Alert, Appendix II

## 7.2 FAILURES WITHIN THE FIRST 1000 HOURS

There were two pump failures within the 1st 1000 hours of endurance testing for Batch 1:

TABLE 19 : Endurance Testing



## 7.2 FAILURES WITHIN THE FIRST 1000 HOURS (cont)

The progress of each pump throughout the 1000 hours is summarised below:-

CODE A Considerable wear of both the quadrant and rack, depositing metal swarf on the pump top but no stoppage.

CODE C No apparent problems

CODE D Handle pivot bearings noisy, in need of lubrication; an increasingly loud knock from pump throughout test, but no stoppage. See section 7.5

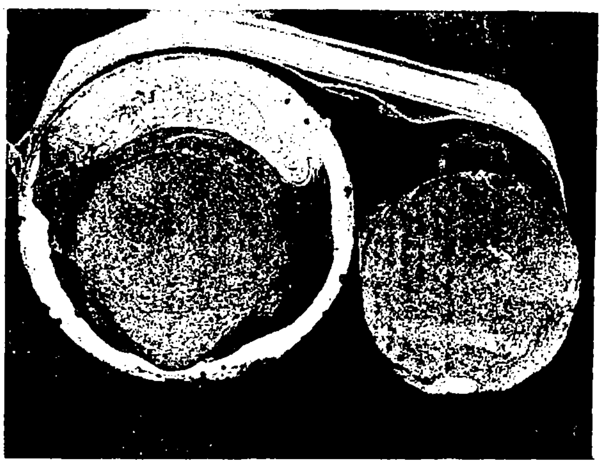
CODE F No apparent problems

CODE G Broken handle at 314 hours. The handle had broken in a region of high stress, near the welded collar at the inboard end.

7.2 FAILURES WITHIN THE FIRST 1000 HOURS (cont)

CODE G (cont)

The break appeared to have propagated from a small surface imperfection - either a weld spatter or a spot where the welder had struck his arc, at the top of the photograph (right).



The handle was replaced with that from the second sample pump. The manufacturer later supplied new tubular handles designed in response to similar breakages in the field. A tubular handle was fitted at 751 hours.

CODE L Cup seal split at 809 hours - spare cup seal fitted to continue test.

## 7.3 VOLUME FLOW

At the end of the 1000 hours, the volume of water delivered by each pump was measured and compared with the original performance tests. The results are summarised in Table 20 below:

TABLE 20 : Volume/Stroke

| CODE | ORIGINAL VOLUME FLOW RESULTS | | | | | VOLUME FLOW AFTER 1000 HOURS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | HEAD (m) | VOLUME/STROKE (litres) AT STROKE RATES (strokes or rev/min) of: | | | | HEAD (m) | VOLUME/STROKE (litres) AT STROKE RATES (strokes or rev/min) of: | | | |
| | | 20 | 30 | 40 | 50 | | 20 | 30 | 40 | 50 |
| A | 45 | - | 0.34 | 0.35 | 0.36 | 45 | - | 0.38 | 0.38 | 0.39 |
| C | 45 | - | 0.15 | 0.15 | 0.16 | 45 | - | 0.14 | 0.16 | 0.17 |
| D | 45 | - | 0.38 | 0.39 | 0.39 | 45 | - | 0.38 | 0.38 | 0.37 |
| F | 7 | 1.31 | 1.20 | 1.29 | - | 7 | 0.58 | 0.86 | 1.05 | - |
| G | 25 | - | 0.64 | 0.65 | 0.65 | 36 | - | 0.67 | 0.67 | 0.70 |
| L | 7 | 0.95 | 0.96 | 1.04 | - | 7 | 1.02 | 1.12 | 1.07 | - |

For several pumps, the volume flow had increased, presumably as valves had bedded in and become more efficient. But Code F showed a marked deterioration in performance.

7.3 VOLUME FLOW (cont)

The Code F pump was dismantled. The cup seal seemed rather stiff and the piston valve was mis-shapen.

The cup seal only was replaced but this produced no significant improvement. The complete piston assembly was replaced and the pump retested. This restored the pump's performance.

7.4 LEAKAGE TESTS

Each pump was tested for leakage past the foot valve for a head of 7 m. The results are summarised in Table 21

TABLE 21: Leakage Tests

| CODE | ORIGINAL RESULTS | | AFTER 1000 HOURS | |
|---|---|---|---|---|
| | LEAKAGE in 10 min (ml) | LEAKAGE RATE (ml/min) | LEAKAGE in 10 min (ml) | LEAKAGE RATE (ml/min) |
| A | < 1 | N/S | 2.0 | 0.2 |
| C | < 1 | N/S | < 1 | N/S |
| D | < 1 | N/S | < 1 | N/S |
| F | 2.5 | 0.25 | 4.0 | 4.0 |
| G | 1 | 0.1 | < 1 | N/S |
| L | 6.0 | 0.6 | 1.0 | 0.1 |

N/S = not significant, i.e. less than 0.1 ml/minute

The check valve in Code F was replaced as a result of this test. After allowing 15 minutes for the new valve to settle in the pump was retested and found to be leaking at the rate of 1.3 ml/minute.

## 7.5 CYLINDER INSPECTION

The cylinders of the pumps were removed, dismantled and inspected for corrosion and general condition. The results are summarised below for each pump:

CODE A

1. A nut had become detached from the upper of the two foot valves and was lodged in the lower. It was refitted.

2. The rubber seat on the lower foot valve was noticeably worn but nevertheless appeared still to be in working order. It was not replaced.

3. The head of the piston valve was noticeably worn on its diameter but appeared still to be in working order. It was not replaced.

4. No significant corrosion was seen on any brass or gunmetal component, but the connecting rod lock nut, of zinc-coated steel, had a heavy corrosive deposit. It abuts the cast gunmetal piston body.

## 7.5 CYLINDER INSPECTION

CODE C

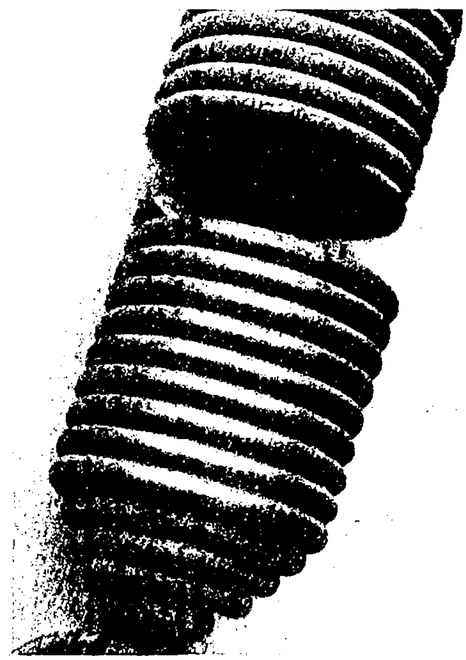
1. The chrome-plated steel rotor was scored in two places. A sharp piece of swarf was found embedded in the elastomeric stator and removed.

2. No significant corrosion.

CODE D

1. The return spring wa found to be broken (right). This would account f the "knocking" heard during testing. The spring was replaced.

2. No significant corrosion.



## 7.5 CYLINDER INSPECTION

CODE F

1. Most parts beginning to rust.
2. Cylinder bore noticeably less rough than when new - 0.24 μm Ra compared with the original 2.4 μm.

CODE G

1. One of the six setscrews in the piston had broken (right).
2. All the setscrews had a heavy deposit. The complete piston assembly was replaced.
3. No other significant corrosion.

CODE L

1. Both valves in good working order.
2. Some rust on piston rod and sliding cover plate.

A.9940/2
46-b

BATCH 2
**************

CODES B , E , H , K , J , M

BATCH 2: Codes B, E, H, J, K, M

CONTENTS PAGE(S)

BATCH 2: (cont)

TABLE 22: Brand List of Pumps in Batch 2

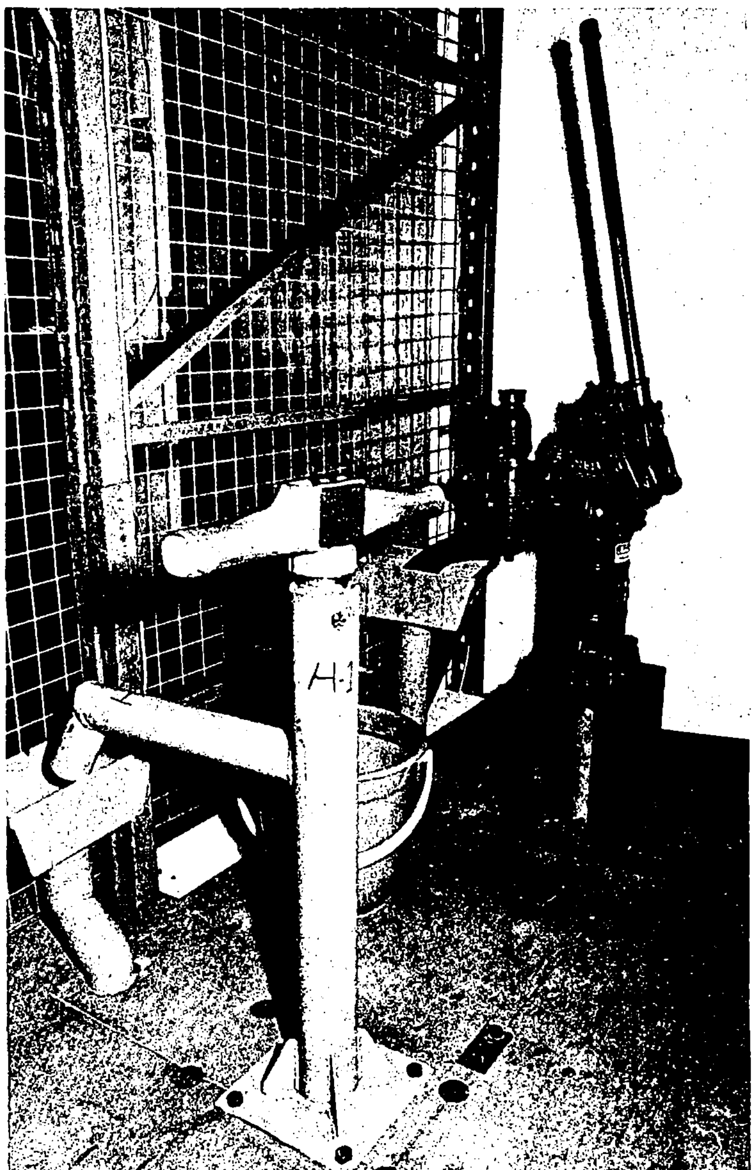
| CODE | MANUFACTURER | MODEL | DEEP OR SHALLOW WELL | FREE DISCHARGE OR DELIVERY LIFT | COUNTRY OF ORIGIN |
|---|---|---|---|---|---|
| B | Kawamoto | Dragon No. 2 (D) | Deep (1) | Delivery Lift | Japan |
| E | Atlas Copco | Kenya | Deep | Free Discharge | Kenya |
| H | IDRC Ethiopia | type BP | Shallow (2) | Free Discharge | Ethiopia |
| J | Vereinigte Edelstahlwerke | A18 | Deep | Free Discharge | Austria |
| K | Sea Commercial Co. | Jetmatic | Deep | Delivery Lift | Philippines |
| M | [3] | AID/ Battelle | Deep | Free Discharge | Indonesia |

(1) Supplied as complete shallow well pumps with additional components for conversion to deep well use.

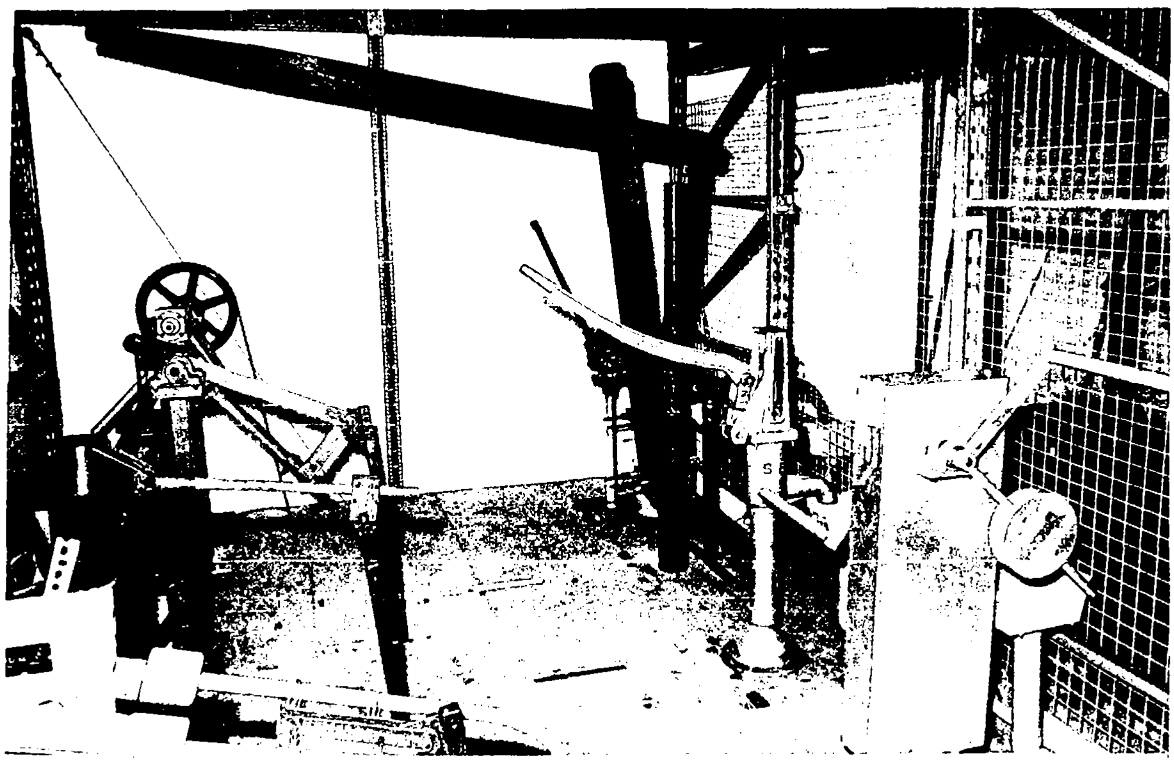
(2) 12m nominal maximum depth

(3) Information not supplied

BELOW: From front to back: Codes H and B



BELOW: Four of the Batch 2 pumps, on the right-hand side.
From front to back: Codes J, M, E and K



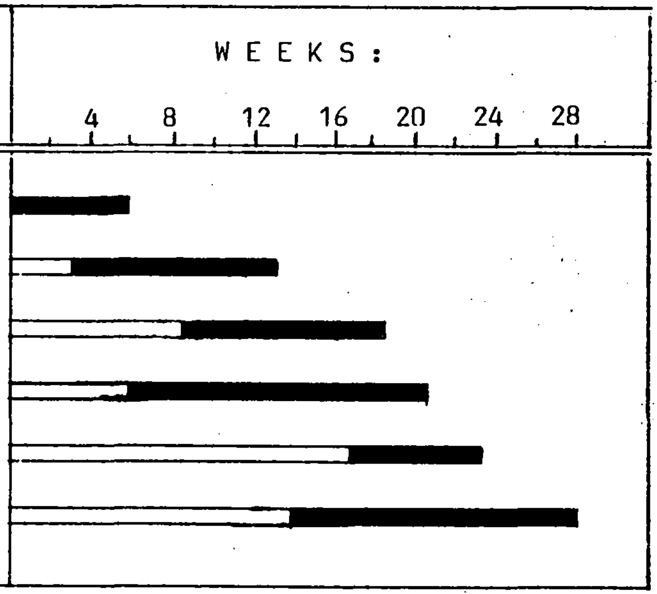
1. ORDERING AND DELIVERY OF PUMPS

Codes B, E, J and K were obtained through an independent agency. Codes H and M were obtained through the appropriate UNICEF Supply Sections. These precautions were taken to ensure that the manufacturers were not aware that their pumps were to be used as test samples.

Each manufacturer was first asked to quote for the cost of two pumps and their transportation to the UK. When the quotation was received the pumps were ordered and letters of credit established in the countries of manufacture. Table 23 below shows the times in weeks from request to receipt of the quotation, and then from order to delivery of the pumps:

TABLE 23: Ordering and Delivery of Pumps

| CODE | QUOTATION (weeks) | DELIVERY of PUMPS (weeks) |
|---|---|---|
| H | [1] | 6 |
| K | 3 | 10 |
| J | 9 | 10 |
| M | 6 | 15 |
| B | 17 | 5 |
| E | 14 | 12 |




Request to receipt of quotation

Order to delivery of pumps

[1] These pumps were supplied free of charge through UNICEF and a quotation was therefore not requested.

## 2. COST OF PUMPS (including Carriage, Insurance etc.)

Table 24 details the costs of the pumps in Batch 2:

TABLE 24: Costs of Pumps

| CODE | FOR TWO PUMPS | | EX-FACTORY COST PER PUMP |
|---|---|---|---|
| | TOTAL COST CIF London | EX-FACTORY COST | Equivalent in US $ [1] |
| K | US $ 593 | US $ 76.50 | $ 38 |
| H | [2] | US $ 150 [3] | $ 75 |
| M | US $ 1879 | US $ 240 | $ 120 |
| B | £608 | £188 | $ 184 |
| E | Kenya Shillings 17480 | Kenya Shillings 13400 | $ 669 |
| J | Austrian Schillings 49370 | Austrian Schillings 40196 [4] | $ 1286 |

[1] London exchange rates, 30.11.81

£0.511 )
Kenya shillings 10.02 ) = US $ 1.00
Austrian Schillings 15.63 )

[2] Supplied carriage paid

[3] Supplied free of charge but valued at US $ 150 by UNICEF, Addis Ababa

[4] Price includes operating cables and counterweights

NB: None of these pumps was supplied with drop pipes or pump rods.

Blank

# 3. INSPECTION AND MEASUREMENT

## 3.1 PACKAGING

Table 25 summarises the packaging in which the pumps were delivered. The suitability of the packaging of each pump for export and for crude overland transportation was assessed against the following 5 point scale:

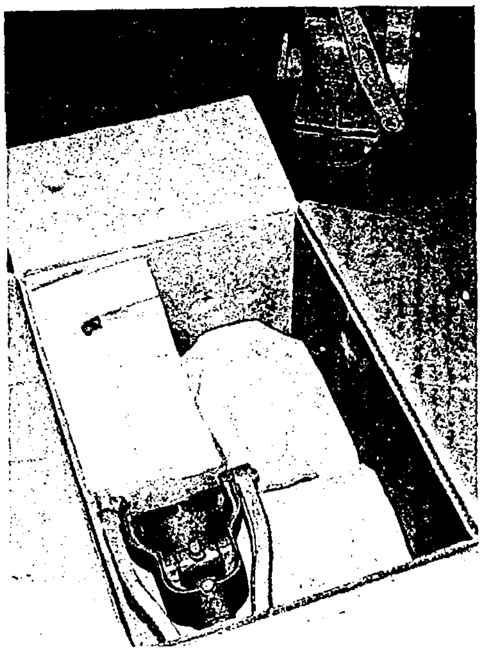
| Very Suitable | | | | Very Unsuitable |
|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 |

TABLE 25: Packaging

| CODE | BRIEF DESCRIPTION of PACKAGING | SUITABILITY for EXPORT | SUITABILITY for OVERLAND TRANSPORTATION |
|---|---|---|---|
| B | Neatly and securely packed in two corrugated cardboard cartons | 5 | 4 |
| E | Plywood packing case bound with steel strapping | 5 | 5 |
| H | Wooden packing case with cardboard carton inside containing pistons and valves | 5 | 5 |
| J | Large wooden packing case with internal reinforcements | 5 | 3 |
| K | Wooden packing case with internal reinforcements - lined with plastic film | 5 | 5 |
| M | Slatted wooden packing case | 5 | 5 |

3.1 PACKAGING - cont

CODE B These 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 (left), 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.

CODE E These 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, 171 kg, might make it difficult to man-handle.

CODE H These pumps arrived in a single wooden packing case. A cardboard carton within the case protected the pistons and valve assemblies. The case weighed 56 kg. and would be relatively easy to man-handle.

3.1 PACKAGING - cont

CODE J These pumps were delivered in a single large 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.

CODE K These 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.

CODE M These pumps were delivered in a slatted wooden packing case. At 191 kg, the package might be awkward to man-handle for overland transportation.

## 3.2 DEFECTS on DELIVERY

All the pumps were inspected for defects on delivery; the results are summarised in Table 26.

TABLE 26 Defects on Delivery

| CODE | COMPONENT or FEATURE | NO. of PUMPS AFFECTED | DEFECTS |
|---|---|---|---|
| B | - | - | - |
| E | Spout | 1 | Heavy internal deposit [1] |
| | Pump rod connecting tube | 2 | Rust near welds |
| | Split pins | 2 | Rusty |
| H | - | - | - |
| J | Handles | 2 | Not assembled square |
| K | Cup seal retainer | 2 | Not tight [2] |
| M | Cup seal retainer | 2 | Not tight [2] |

[1] Appears to be surplus zinc from galvanising

[2] May be due to shrinkage of the leather cup washers

\- No defective component

None of these defects would make the pumps incapable of functioning in the condition in which they were received. However, the partially-blocked spout of one of the Code E pumps would significantly impede the outflow of water. The defects on Codes K and M might be expected to give trouble before long if they were not remedied. The misaligned handles on Code J would only affect the user's relationship with the pump, not the functioning of the pump itself.

## 3.3 LITERATURE

Only Code H was supplied with accompanying literature.

| | |
|---|---|
| Code H | A technical report and engineering drawings were sent with the Code H pumps; both accurately described the samples received. The technical report was interesting, the drawings very useful. |
| ALL OTHER CODES | For the installation of other pumps reference was made to any available information, whether from manufacturers or other sources such as reports of field projects etc. but all too often this information was sketchy and sometimes ambiguous. |
| | It is recommended that all pumps should be supplied with instructions for installation and use; clear illustrations are of particular importance. |

Blank

## 3.4 WEIGHTS AND MEASURES

3.4.1 The principal weights and dimensions are detailed in Table 27.

TABLE 27: Principal Weights and Dimensions

| CODE | WEIGHTS (kg) | | | | NOMINAL CYLINDER BORE (mm) | ACTUAL PUMP STROKE (mm) | NOMINAL VOLUME/ STROKE (ml) | DROP PIPE SIZE (inch) | PUMP ROD DIA. |
|---|---|---|---|---|---|---|---|---|---|
| | PUMP STAND | CYLINDER | DROP PIPE (per m) [1] [3] | PUMP ROD (per m) [1][3] | | | | | |
| B [2] | 19.0 | 5.0 | 2.9 | 1.1 | 63 | 180 | 561 | 1¼ | ½ in |
| E | 67.0 | 6.5 | 5.2 | 1.5 | 59 | 295 | 807 | 2 | 21.5mm [8] |
| H | 11.3 | - | 1.4 | 0.4 | 50 [7] | 370 | 726 | 2 | 22mm [4] |
| J | 84.8 | 19.8 | 12 [6] | 0.2 [5] | 70 | 180 | 693 | 4 | - |
| K | 16.3 | 3.0 | 5.2 | 1.1 | 46 | 175 | 291 | 2 | ½ in |
| M | 39.5 | 5.5 | 2.9 | 0.8 | 78 | 180 | 860 | 1¼ | 10mm |

[1] Including couplings

[2] In deep well configuration

[3] None supplied, weight given is for suitable material

[4] ½" bore PVC water pipe

[5] Cable, add 14.0 kg for counterweight, 11.5 kg for strainer assembly

[6] Estimated

[7] 2" rising main used as cylinder

[8] ½" galvanised steel pipe

## 3.4.2 CYLINDER BORES

The cylinder bore diameters were measured at five points along their length; a second series of measurements was then taken at right angles to the first. No significant taper or ovality was found in any of the samples.

The surface roughness average (Ra) was measured in three places in a direction parallel to the cylinder axis (right)

The results are shown in Table 28.

TABLE 28: Cylinder Bore Roughness

| CODE | CYLINDER BORE SURFACE | CUT-OFF (mm) [1] | ROUGHNESS AVERAGE (µm) | | | |
|---|---|---|---|---|---|---|
| | | | TEST 1 | TEST 2 | TEST 3 | MEAN |
| B5 | Extruded brass | 0.25 | 0.10 | 0.08 | 0.08 | 0.09 |
| B6 | | 0.25 | 0.10 | 0.12 | 0.13 | 0.12 |
| E5 | Extruded brass | 0.25 | 0.09 | 0.08 | 0.09 | 0.09 |
| E6 | | 0.25 | 0.12 | 0.14 | 0.12 | 0.13 |
| J9 | Chromed brass | 0.25 | 0.30 | 0.10 | 0.10 | 0.17 |
| J10 | | 0.25 | 0.20 | 0.20 | 0.15 | 0.18 |
| K5 | Extruded brass | 0.25 | 0.03 | 0.04 | 0.02 | 0.03 |
| K6 | | 0.25 | 0.04 | 0.04 | 0.05 | 0.04 |
| M5 | Extruded PVC | 0.80 | 0.70 | 0.60 | 0.80 | 0.70 |
| M6 | | 0.80 | 0.65 | 0.85 | 0.70 | 0.73 |

[1] The length over which the roughness is averaged.

Code H was not supplied with a cylinder; the piston is designed to be used directly on the bore of the 2 inch PVC rising main. The pipe used for testing is very smooth on the exterior but the bore is wavey. The surface roughness average (Ra) measurements were approximately 1.50 µm at a cut-off of 2.5 mm, 0.60 µm at a cut-off of 0.80 mm.

### 3.4.2 CYLINDER BORES

The IRC handbook on handpumps (Technical Paper Series, No. 10) suggests that good quality brass cylinders should have a surface finish in the range 0.1 to 0.2 μm, compared with 1.3 to 5.1 μm for good quality machined cast iron.

In the deep-well reciprocating pumps (Codes E, J, K and M) the maximum usable cylinder length is considerably greater than the pump stroke, enabling the position of the piston in the cylinder to be adjusted when the cylinder becomes worn.

Table 29 below details the maximum usable cylinder lengths for these pumps, compared with the actual pump strokes.

TABLE 29: Pump Stroke and Usable Cylinder Length

| CODE | ACTUAL PUMP STROKE (mm) | MAXIMUM USABLE CYLINDER LENGTH (mm) |
|---|---|---|
| E | 295 | 400 |
| J | 180 | 390 |
| K | 175 | 553 |
| M | 180 | 303 |

In Code B, the cylinder was just long enough to permit a full stroke of the piston.

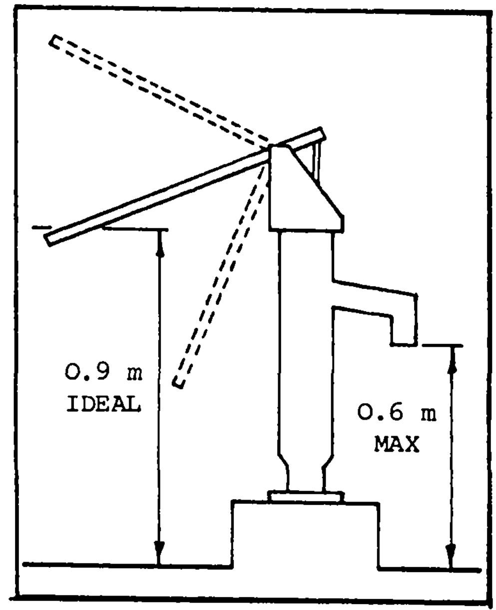
In Code H, the shallow well force pump, the position of the piston may be altered to combat wear by shortening the pump rod. Alternatively, since the "cylinder" is simply the 2" PVC rising main, this could be replaced easily and cheaply.

Blank

### 3.4.3 ERGONOMIC MEASUREMENTS

Where such information was available, pumps were installed at the heights recommended by the manufacturer.

Pumps for which this information was not available were installed so that the mid-point of handle operation was as close as possible to 0.9 m from floor level, subject to a maximum spout height of approximately 0.6 m (right). These preferred heights were suggested by previous user tests of handpumps (Report No. Z:9923).




Various ergonomic measurements were taken and these are detailed in Table 30.

TABLE 30: Ergonomic Measurements

| CODE | HANDLE HEIGHT MAX [1] (mm) | HANDLE HEIGHT MIN [1] (mm) | PLINTH HEIGHT (mm) | ANGULAR MOVEMENT OF HANDLE (degrees) | HANDLE LENGTH (mm) | VELOCITY RATIO OF HANDLE | HEIGHT OF SPOUT (mm) |
|---|---|---|---|---|---|---|---|
| B | 1139 | 95 | 305 | 178 | 660 | 7.8 | 480 |
| E | 2075 | 320 | N/A | 61 | 1740 | 5.5 | 525 |
| H | 1070 | 700 | N/A | 0 | N/A | 1 | 310 |
| J | 1220 | 610 | N/A | 360 | 305 | 3.4 | 620 |
| K | 1410 | 120 | 554 [2] | 174 | 660 | 7.8 | 505 |
| M | 1229 | 250 | N/A | 91 | 860 | 5.8 | 500 |

[1] Measured without compressing bump stops where fitted

[2] Height of protruding rising main

N/A Not applicable

## 4. ENGINEERING ASSESSMENT

Each brand of pump has been subjected to detailed engineering assessment. Pumps were stripped down into their component parts and each part examined for suitability of design, choice of material and manufacturing process and workmanship. The assembled pump was then assessed for potential safety hazards, resistance to contamination by foreign matter and surface water, resistance to abuse, including pilferage, and ease of maintenance and repair. The manufacturing processes, and the levels of skill required, were summarised for each pump. Finally, suggestions for improvements to the design were outlined.

### 4.1 MATERIALS

The materials used for the principal components of each pump are detailed in Table 31.

TABLE 31: Materials

| CODE | COMPONENTS | MATERIAL(S) |
|---|---|---|
| B | Pump head | Cast iron |
| | Handle fork and link | Cast iron |
| | Spout assembly | Cast iron with plastic cap and hose connector and rubber valve |
| | Operating rod | Mild steel |
| | Handle | Steel tube, plastic end cap |
| | Cylinder | Extruded brass, cast iron end caps |
| | Piston | Cast gunmetal |
| | Cup seal | Leather |
| | Foot valve assembly | Cast gunmetal, rubber valve seat |
| E | Fulcrum upright | Wood |
| | Handle | Wood |
| | Outlet elbow and spout | Galvanised steel pipe fittings |
| | Guide tube and links | Mild steel |
| | Cylinder | Extruded brass, gunmetal end caps |
| | Piston | Gunmetal, stainless steel ball valve |
| | Cup seals | Leather |
| | Foot valve | Cast gunmetal, stainless steel ball valve, leather seal |
| | Pump rod | Standard ½ inch galvanised pipe |

TABLE 31: Materials (cont)

| CODE | COMPONENT | MATERIAL(S) |
|---|---|---|
| H | Pumpstand | Steel tube - fabricated |
| | Handle | Wood |
| | Pump rod support | Mild steel |
| | Pump rod bush | HD polyethylene |
| | Piston | HD polyethylene, rubber valve |
| | Foot valve body | Fabricated from standard steel pipe fittings |
| | Foot valve | HD polyethylene, rubber washer |
| | Pump rod | PVC pipe |
| J | Pumpstand | Stainless steel |
| | Handle | Mild steel |
| | Crankshaft | Mild steel |
| | Connecting link | Mild steel |
| | Cylinder | Extruded brass with hard chrome lining |
| | Cylinder end fittings | Stainless steel |
| | Foot valve | Stainless steel |
| | Dip tube | Stainless steel |
| | Piston assembly | Stainless steel body, brass rod, PTFE seal |
| | Cable and counterweight | Stainless steel |
| K | Pump head | Cast iron |
| | Handle fork and link | Cast iron |
| | Spout assembly | Cast iron with rubber valve |
| | Operating rod | Mild steel |
| | Handle | Steel tube, rubber end cap |
| | Cylinder | Extruded brass |
| | Piston | Cast gunmetal or bronze |
| | Cup seals | Leather |
| | Foot valve assembly | Bronze housing, rubber clamp, steel guard |
| M | Pumpstand | Cast iron head, spout and base, steel column |
| | Fulcrum link | Cast iron |
| | Handle | Cast iron |
| | Connecting rod | Mild steel |
| | Cylinder | Extruded PVC, cast iron end caps |
| | Piston assembly | Gunmetal body |
| | Cup seals | Leather |
| | Foot valve | Leather with cast iron weight |

HD = High density

## 4.2 MANUFACTURING PROCESSES and SKILLS

Table 32 summarises the processes and levels of skill required to manufacture each pump.

For each process required the table shows a skill rating based on the following 5 -point scale:

| Very High Skill | | | | Very Low Skill |
|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 |

The "score" in the final column is obtained by simply adding together the ratings for each pump - it provides a very rough comparative measure of the levels of technology required to manufacture each brand of pump.

TABLE 32: Manufacturing Processes and Skills

| CODE | IRON FOUNDRY | BRASS/GUNMETAL FOUNDRY | STEEL FORGING and WELDING | SHEET METAL FORMING | SIMPLE MACHINING [1] | COMPLEX MACHINING [2] | LEATHER CUTTING/ FORMING | RUBBER/PLASTICS MOULDING | WOODWORK | HARD CHROME PLATING | OTHER PLATING | FLAME CUTTING | SPECIALISED PROCESSES | "SCORE" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B | 3 | 3 | - | - | 3 | - | 2 | 2 | - | - | 2 | - | - | 15 |
| E | - | 3 | 2 | - | 3 | - | 2 | - | 3 | - | - | - | - | 13 |
| H | - | - | 3 | - | 3 | - | - | - | 2 | - | - | - | - | 8 |
| J | - | - | 5 | 3 | 4 | - | - | 3 | - | 5 | - | 3 | - | 23 |
| K | 3 | 3 | - | - | 3 | - | 2 | 2 | - | - | - | - | - | 13 |
| M | 4 | 3 | - | - | 3 | - | 2 | - | - | - | - | - | - | 12 |

[1] Turning, drilling, tapping etc.

[2] Gear cutting etc.

## 4.3 MAINTENANCE and REPAIR

Table 33 summarises the assessments of the likely ease of maintenance and repair of each pump.

| The ratings are based on a 5-point scale | Very Easy | | | | Very Difficult |
|---|---|---|---|---|---|
| | 5 | 4 | 3 | 2 | 1 |

TABLE 33: Ease of Maintenance and Repair

| CODE | RATING | COMMENTS |
|---|---|---|
| B | 2 | Handle easy to replace with any suitable material but other repairs likely to be difficult |
| E | 4 | Generally easy to maintain and repair. Foot valve can be extracted without raising cylinder |
| H | 5 | Likely to need very little maintenance, and all operations easy to carry out |
| J | 1 | Generally very difficult. If crankshaft wears it may also be necessary to replace the handles. Below-ground components massive and would require heavy lifting tackle |
| K | 3 | Handle easy to replace with any suitable material. Foot valve can be extracted without raising cylinder |
| M | 3 | Pumpstand easy to maintain but footvalve difficult. Fixing screws likely to corrode |

## 4.4 RESISTANCE TO CONTAMINATION

Table 34 summarises the assessment of each pump for resistance to contamination by foreign matter and surface water.

The ratings shown are based on a 5-point scale (right):

| Very good | | | | Very poor |
|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 |

TABLE 34: Resistance to Contamination

| CODE | RATING | COMMENTS |
|---|---|---|
| B | 2 | Good sealing at top of pump but no attempt to seal wellhead |
| E | 3 | Sealed against surface water but needs a better seal at the top of the 4 inch well casing |
| H | 4 | Generally good; spout could be modified to prevent the "left-hand effect" |
| J | 3 | Short horizontal spouts easily contaminated. Sealed against surface water |
| K | 2 | Good sealing at top of pump but no attempt to seal wellhead |
| M | 3 | Spout could be modified to prevent the "left-hand effect". Sealed against surface water but pump could be contaminated through connecting rod hole. |

## 4.5 RESISTANCE TO ABUSE

Table 35 summarises the assessment of each pump for likely resistance to abuse: pilferage, accidental impacts, heavy-handed usage etc.

The ratings shown are based on a 5-point scale (right):

| Very Good | | | | Very Poor |
|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 |

TABLE 35: Likely Resistance to Abuse

| CODE | RATING | COMMENTS |
|---|---|---|
| B | 2 | Many accessible fixings and components which would be easy to remove. The cast iron fork is a potential weakness |
| E | 2 | Split pins easy to remove, nuts only a little more difficult. Otherwise robust |
| H | 3 | Handle susceptible to impact if left raised; spout rather long. No locking fixings on handle clamp; baseplate rather thin |
| J | 3 | No locking on any nuts or bolts. Handles quite easy to remove. Otherwise very robust |
| K | 2 | Handle fork stronger than Code B. Cast iron hose connector may be susceptible to damage. Potentially weak pumphead mounting supported only by 1¼ inch rising main. |
| M | 3 | Split pins easy to remove, no locking fixings. Handle may be susceptible to impact. Otherwise robust |

## 4.6 POTENTIAL SAFETY HAZARDS

Table 36 summarises the potential safety hazards identified for each pump.

TABLE 36: Potential Safety Hazards

| CODE | FEATURE | HAZARD(S) |
|---|---|---|
| B | Handle<br>Fulcrum pinch bolt | Sharp end<br>Finger trap |
| E | U Bolts<br><br>Connecting links<br>Handle/Upright | Unnecessarily long, burred ends<br><br>Exposed reciprocating parts<br>Finger traps |
| H | Handle/pumpstand | Finger trap |
| J | Handle counterweights | Risks to users and bystanders |
| K | Handle<br>Fulcrum pinch bolt | Sharp end<br>Finger trap |
| M | Crosshead blocks | Finger traps |

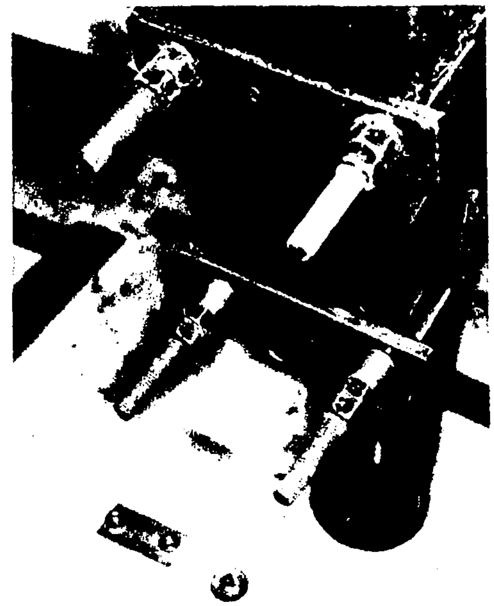
CODE B The tubular steel handle is threaded at the outboard end to accept the moulded plastic cap. The cap is easy to remove and could easily be lost. This exposes the end of the handle which is dangerously sharp because the burrs were not removed after cutting.

The handle fulcrum pinch bolt forms a finger trap.

## 4.6 POTENTIAL SAFETY HAZARDS (Cont)

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

The reciprocating links could be dangerous to bystanders or children.



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

CODE H 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.

CODE J The rotating handle counterweights on this pump could be hazardous to both users and bystanders. The handles have high momentum at normal operating speeds. The handles are screwed onto the ends of the crankshaft without locknuts and could become detached while operating the pump.

CODE K 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.

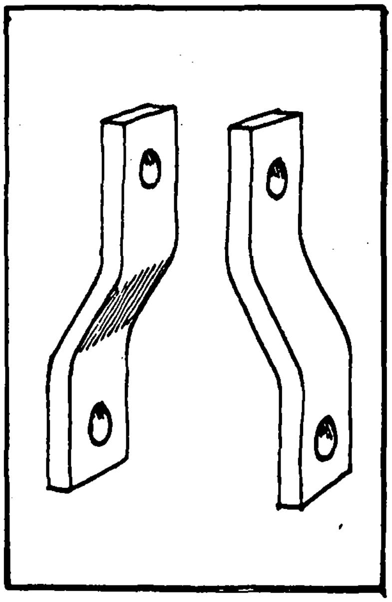
CODE M There are potential finger traps between the pump top and the sliding guide blocks at the top and bottom of the handle stroke.

## 4.7 SUGGESTED DESIGN IMPROVEMENTS

CODE B 1. The free end of the handle should not be threaded but simply smoothed, omitting the plastic end cap.

2. The wishbone link may be better as two joggled steel strips (right).
The handle fulcrum pinch bolt as located at present, forms a finger trap.

The 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.



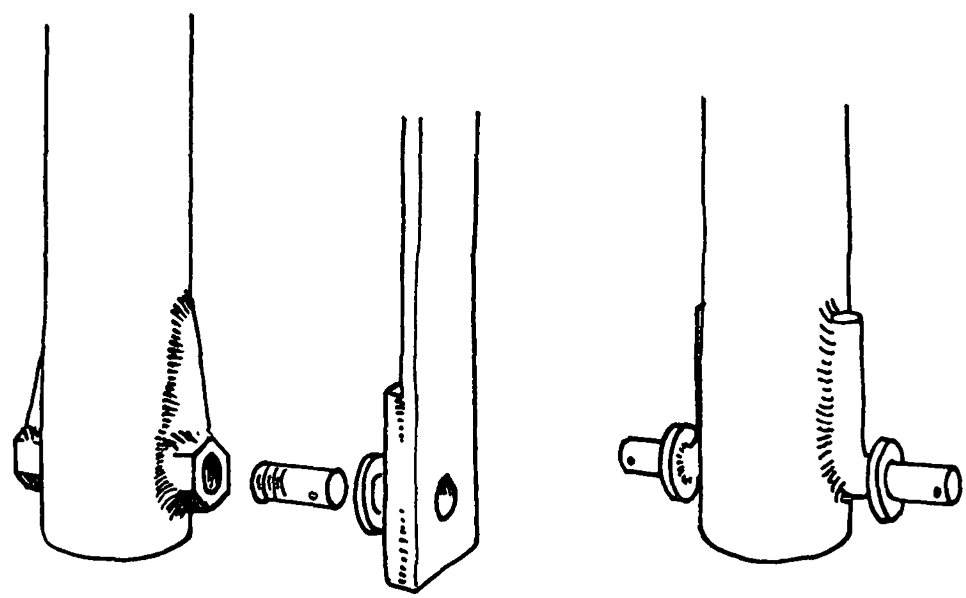
3. The height of the top housing should be reduced to:
(a) eliminate the counterbore in the gland nut
(b) eliminate unnecessary machining of the pivot casting
(c) increase the length of thread attaching the connecting rod to the pivot casting

CODE E 1. The angle between the fulcrum upright and the well casing should be better controlled to minimise the angular movement of the connecting links.

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

4.7 <u>SUGGESTED DESIGN IMPROVEMENTS (cont)</u>

CODE E 3. 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, as in (a) below. Alternatively, the studs might be replaced by short L-shaped lengths of bar welded to the tube, as in (b)

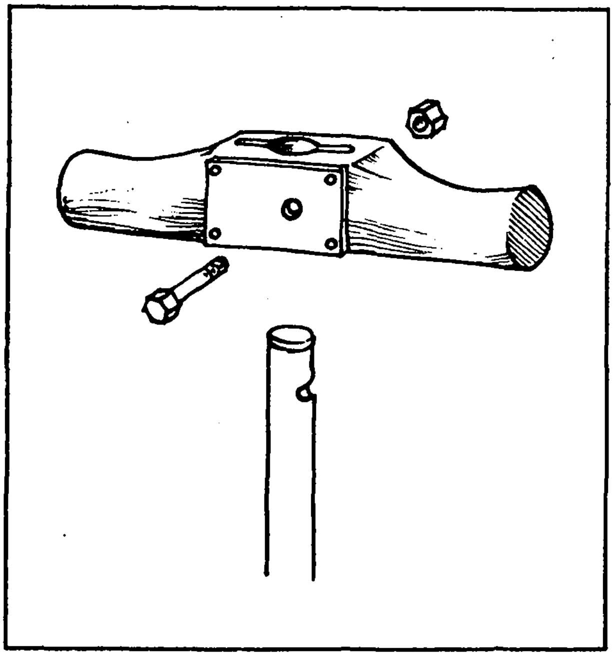


(a) (b)

4. 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 radiussed.

## 4.7 SUGGESTED DESIGN IMPROVEMENTS (Cont)

CODE H The handle should be more securely attached to the pump rod. This might be achieved by using a single bolt, either through the centre-line of both handle and pump rod or slightly off-centre locating in a groove cut in this pump rod (right).



CODE J Many parts of this pump appear to be over-engineered for their purpose, yet it embodies several design weaknesses.

1. The handles should be keyed onto the ends of the crankshaft and secured with stiffnuts or similar fixings.

2. The connecting link bearings should be of the corrosion-resistant type.

3. The quality of the crankshaft plummer blocks should be improved. The pressed housings are weak.

4. The pumpstand volume is unnecessarily large, wasting valuable material.

5. The spouts should be longer and downward-pointing and possibly should be replaced by a single spout or separated to enable two containers to be filled.

6. The cable should be of the type designed for hoists and lifts, which will not twist under tension.

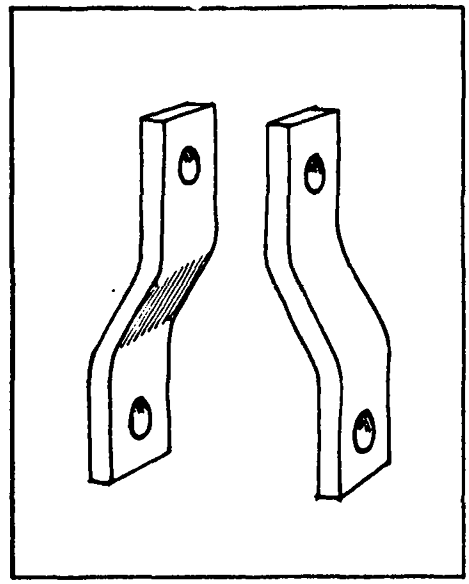
7. Many of the components should be designed for less extravagant use of costly materials.

4.7 SUGGESTED DESIGN IMPROVEMENTS (cont)

CODE K 1. The free end of the handle should be smoothed and the rubber end cap omitted.

2. The wishbone link may be better as two joggled steel strips (right).
The handle fulcrum pinch bolt, as located at present, forms a finger trap.

The 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.

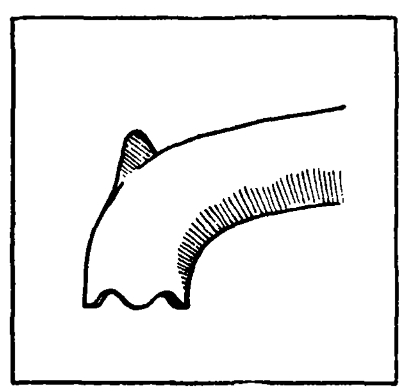


3. The height of the top housing should be reduced to:
(a) eliminate the counterbore in the gland nut
(b) eliminate unnecessary machining of the pivot casting
(c) increase the length of thread attaching the connecting rod to the pivot casting

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

CODE M 1. 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.

2. The spout could be modified as shown (right) to prevent the "left-hand effect" without increasing its cost.



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

4. A handle made from wood or a similar resilient material would be less prone to accidental damage.

Blank

# 5. USER TRIAL

## 5.1 Method

For details of the user trial method, see page 28. The users were instructed to work the pumps in a predetermined controlled random order. For this trial the shallow well pumps were operated at a 7 metre head. The deep well pumps were set at a simulated head of 20 metres.

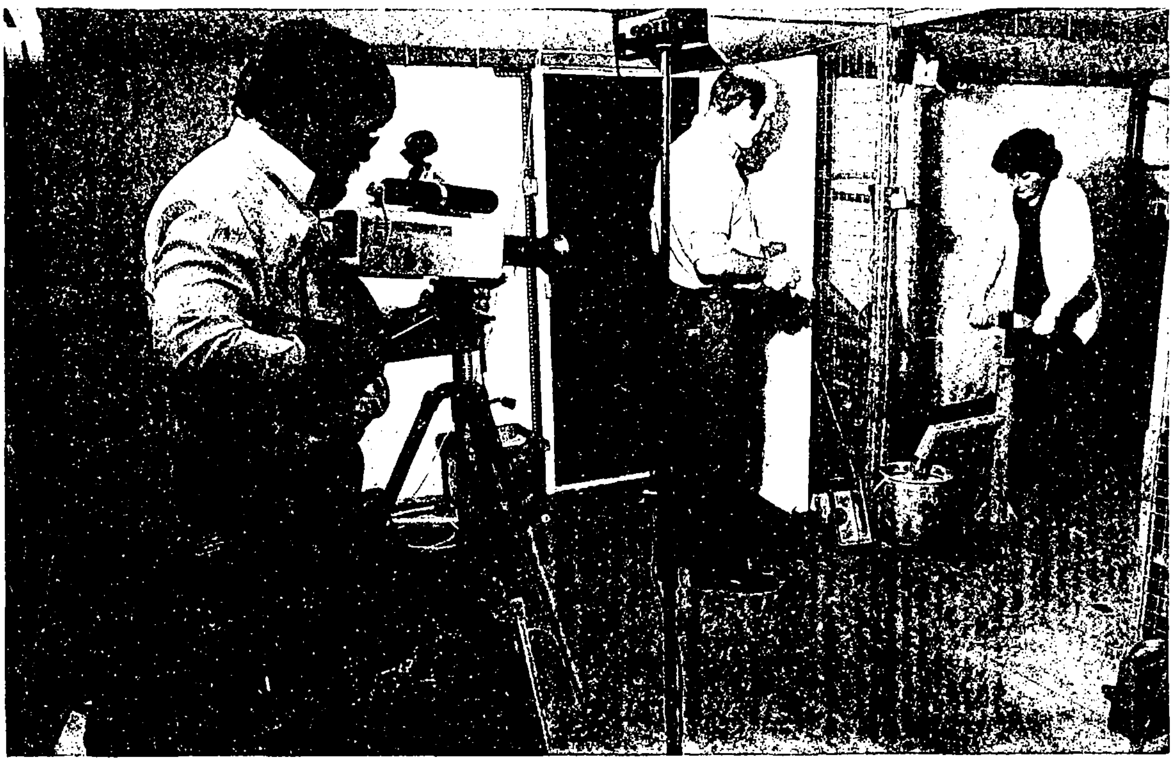
## 5.2 Statistical Analysis of User Responses

The users' responses are summarised in Table 37. Further details of the statistical analysis, and of the responses of particular groups, can be found in Appendix I.

TABLE 37: Summary of User Responses : Batch 2

| | QUESTION | Better ← | | | Approximate Mean for Question ▼ | | | Worse → |
|---|---|---|---|---|---|---|---|---|
| 1 | Suitability of Handle height | K | B,H | | M,J | | E | |
| 2 | Comfort of Handle | | K,M | J,B | E | H | | |
| 3 | Effort required to work pump | K,M | B | | E | | J,H | |
| 4 | Overall, how easy to operate pump | | B | M,K | E | H,J | | |

## 5.3 OBSERVATIONS



Observations of the users in the Batch 2 trial were reinforced by selective video recordings.

CODE B Many users found it difficult to decide on the best method of operation for this pump. The arc of handle movement is particularly large, 178° for a full stroke. In spite of this, some users chose a full stroke but found the exaggerated body movements uncomfortable.

CODE E 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.

CODE H Many users found this pump difficult, 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.

CODE J A difficult pump to use. 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.

CODE K This pump is similar to Code B, and users had similar problems. An additional difficulty arose because vigorous operation of the pump often caused the outlet diverter valve to drop, shutting off the spout. See Purple Alert, Appendix III.

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

## 5.4 GENERAL COMMENTS

As observed in the Batch 1 user trial, the majority of users seemed most comfortable where a variety of muscle groups could be used to share the effort, provided that exaggerated body movements were not required.

The video recordings clearly illustrate the users' difficulties in operating Codes H and J, and to a lesser extent Code E.

Blank

# 6. PERFORMANCE TESTS

## 6.1 LEAKAGE TESTS

The test method is described in the section on Batch 1, page 32.

Table 38 details the results of the leakage tests on Batch 2:

TABLE 38 : Leakage Tests

| CODE | 7 m HEAD | | 25 m HEAD | | 45 m HEAD | |
|---|---|---|---|---|---|---|
| | LEAKAGE (ml) in 10 min | LEAKAGE RATE (ml/min) | LEAKAGE (ml) in 10 min | LEAKAGE RATE (ml/min) | LEAKAGE (ml) in 10 min | LEAKAGE RATE (ml/min) |
| B | < 1 | N/S | < 1 | N/S | < 1 | N/S |
| E | 12.0[1] | 1.2 | 13.3[1] | 1.3 | 5.3[1] | 0.5 |
| H | 1.5 | 0.15 | - | - | - | - |
| J | 1.0 | 0.1 | < 1 | N/S | < 1 | N/S |
| K | 1.0 | 0.1 | < 1 | N/S | < 1 | N/S |
| M | < 1 | N/S | 4.0 | 0.4 | 24.0 | 2.4 |

[1] Averaged results of two series of tests

N/S = not significant, less than 0.1 ml/minute

For Code E, the foot valve from the second sample pump was tested but produced greater leakage than the first; this pump uses a ball valve which may "bed-in" with further use.

The Code M pump uses a weighted leather foot valve. The valve appears to leak around the screw securing the cast iron weight.

## 6.2 VOLUME FLOW, OPERATIONAL FORCES and EFFICIENCY

The test method is described in the section on Batch 1, page 34.

TABLE 39 : Pump Performance Summary

(a) AVERAGE VOLUME per STROKE or REVOLUTION (litres)

| HEAD (metres) | 7 | | | | 25 | | | | 45 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUMPING RATE (strokes or revs/min) / PUMP CODE | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 |
| B f | - | 0.55 | 0.55 | 0.55 | - | 0.54 | 0.54 | 0.54 | 0.52 | 0.53 | 0.53 | - |
| B p | | 0.26 | 0.27 | 0.28 | | | | | | | | |
| E | - | 0.76 | 0.78 | 0.77 | - | 0.75 | 0.77 | 0.76 | 0.77 | 0.75 | 0.76 | - |
| H * | - | 0.60 | 0.62 | 0.63 | - | - | - | - | - | - | - | - |
| J | - | 0.68 | 0.68 | 0.69 | - | 0.65 | 0.65 | 0.66 | - | 0.62 | 0.63 | 0.64 |
| K | - | 0.29 | 0.29 | 0.29 | - | 0.28 | 0.27 | 0.29 | - | 0.28 | 0.28 | 0.28 |
| M | - | 0.83 | 0.86 | 0.85 | - | 0.82 | 0.81 | 0.81 | - | 0.80 | 0.80 | 0.81 |

f = full stroke

p = partial stroke

* Unlike the shallow well suction pumps in Batch 1, Code H is a force pump.

TABLE 39: Performance Summary (cont)

(b) AVERAGE WORK DONE on PUMP per STROKE or REVOLUTION (Joules)

| HEAD (metres) | 7 | | | | 25 | | | | 45 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUMPING RATE (strokes or revs/min) / PUMP CODE | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 |
| B f | - | 122 | 120 | 128 | - | 244 | 252 | 257 | 340 | 358 | 366 | - |
| B p | | 52 | 53 | 55 | | | | | | | | |
| E | - | 119 | 122 | 141 | - | 271 | 300 | 290 | 500 | 493 | 528 | - |
| H | - | 112 | 117 | 141 | - | - | - | - | - | - | - | - |
| J | - | 121 | 93 | 87 | - | 280 | 266 | 339 | - | 429 | 456 | 765 |
| K | - | 60 | 54 | 50 | - | 110 | 103 | 107 | - | 173 | 173 | 161 |
| M | - | 101 | 100 | 111 | - | 290 | 293 | 312 | - | 458 | 480 | 536 |

(c) AVERAGE EFFICIENCY (%)

| HEAD (metres) | 7 | | | | 25 | | | | 45 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUMPING RATE (strokes or revs/min) / PUMP CODE | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 | 20 | 30 | 40 | 50 |
| B f | - | 30 | 31 | 29 | - | 53 | 52 | 51 | 67 | 65 | 63 | - |
| B p | | 33 | 34 | 34 | | | | | | | | |
| E | - | 43 | 43 | 37 | - | 67 | 62 | 63 | 67 | 67 | 63 | - |
| H | - | 36 | 35 | 30 | - | - | - | - | - | - | - | - |
| J | - | 38 | 49 | 53 | - | 56 | 59 | 47 | - | 63 | 60 | 36 |
| K | - | 32 | 36 | 39 | - | 62 | 63 | 66 | - | 71 | 72 | 77 |
| M | - | 55 | 58 | 52 | - | 69 | 67 | 63 | - | 76 | 73 | 66 |

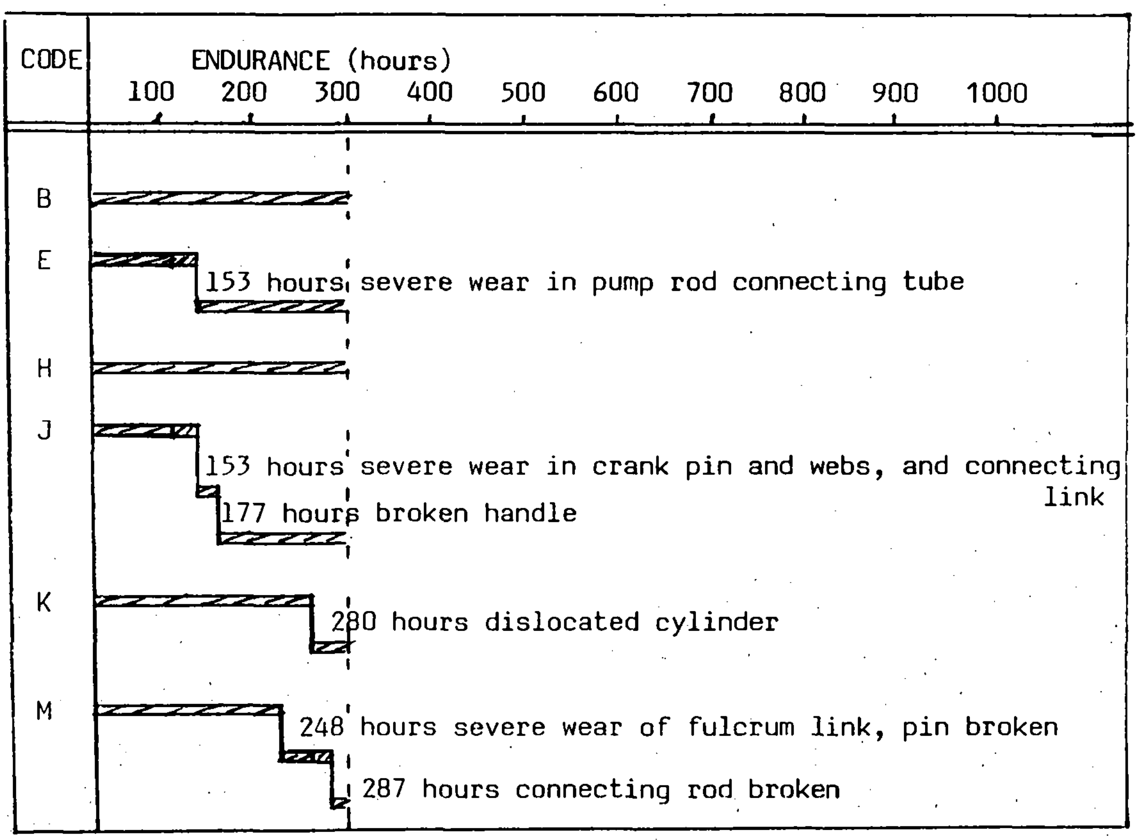
## 7. ENDURANCE

It has been possible to start the Batch 2 endurance testing some four weeks ahead of schedule. At the time of writing the pumps have completed approximately 300 hours of the first 1000 hour stage.

The endurance test procedure has been described in the section on Batch 1, page 38,

In the first few hundred hours, the Batch 2 pumps have proved to be much less reliable than the first batch. The failures to date are summarised in Table 40 :

TABLE 40: Endurance Testing



CODE E See also Purple Alert, Appendix III

The pump rod connecting tube, and the guide tube on which it slides, were both worn through. Substantial amounts of metal dust had been produced, some of which had found their way into the delivered water. The pump has been reassembled using components from the second sample, with wedges to modify the angle of the fulcrum upright in an effort to minimise the out-of-line forces in the connecting links and tube.

CODE J See also Purple Alert, Appendix III

The operating cable of this pump is clearly not of the non-rotating type, which would not twist under tension. On each upstroke, the cable twists, imparting a torsional force on the connecting link on the crank pin and causing it to foul the crank webs. The design of the connecting link is susceptible to torsion in the cable. The link was badly worn and there was imminent danger of catastrophic failure. The pump has been reassembled using components from the second sample, with a swivel interposed between the end of the cable and the connecting link. This has reduced the effect of twist in the cable but has not eliminated it; the swivel can be heard to spin as the tension is released at the start of each downstroke.

The handle had sheared off at its welded root. It has been replaced with a handle from the second sample.

CODE K A Purple Alert is in process of verification.

The cylinder of this pump is secured in the drop pipe by an expanding rubber bush but had been dislodged, preventing effective operation of the pump. The cylinder has been repositioned.

CODE M See also Purple Alerts, Appendix III

The fulcrum link and pin were worn out due to misalignment resulting from poor manufacturing quality. They have been replaced by components from the second sample.

The connecting rod had broken at the root of the thread at the top end. The rod has been turned down prior to threading, leaving a sharp shoulder. This feature had been criticised in the engineering assessment. The rod has been replaced by one from the second sample.

# A P P E N D I C E S

******************

# APPENDIX I

## STATISTICAL ANALYSIS

## of

## USER RESPONSES

BATCH 1

BATCH 2

STATISTICAL ANALYSIS OF USER RESPONSES

For each question, separate two-way analyses of variance have been performed on the results for each group; a combined analysis of variance was also performed to test for overall differences between codes, between groups and for any interaction between codes and groups.

Following a significant difference between codes, the least significant difference and the configuration of codes means were employed to establish clusters of codes: a cluster is a grouping of codes whose means lie relatively near to one another so that:

i two codes from the same cluster are not significantly different.

ii two codes from non-adjacent clusters are significantly different.

iii two codes from adjacent clusters are not necessarily significantly different.

When the configuration of code means demands the violation of any of the above criteria, the offending code(s) are bracketed.

For question 1, the least significant difference from a value of 3 was calculated, a rating of 3 indicated the handle height of a pump was about right. For codes with a value outside 3 ± the least significant difference, was recorded.

Results for Batch 1

The results of the analyses of the four assessments made by the users are summarised by question and by group in Tables 1 - 4.

The mean time taken, and mean number of strokes/revolutions to fill the bucket are shown for each group and code in Tables 5 and 6.

Results for Batch 2

Tables 7-10, and 11, 12 provide comparable information for the Batch 2 pumps.

BATCH 1
*******

TABLE 1 : Suitability of Handle Height : Question 1

| GROUP NO | CLUSTERS ← Too Low—— | | About Right | | | ——Too High→ |
|---|---|---|---|---|---|---|
| 1 TW | D | | C,F,G,L | A | | |
| 2 MW | | D | L,C,F | G | A | |
| 3 SW | | D | F,L | C,A,G | | |
| 4 TM | | D,G | A,F,L,C | | | |
| 5 MM | | D,F | G,L,C | A | | |
| 6 SM | D | | C,F,L | G | A | |
| 7 TB | D | | C,L | A,F,G | | |
| 8 SB | | | D,G | L,C,F | A | |
| 9 TG | D | | L,F | C,G | A | |
| 10 SG | | D | F,L | C,A,G | | |
| OVERALL | D | | L,F | C,G | | A |

BATCH 1
*********

TABLE 2 : Handle Comfort : Question 2

| GROUP NO | CLUSTERS ← BETTER —— approximate mean for question —— WORSE → | | | | | |
|---|---|---|---|---|---|---|
| 1 TW | | | G,A,L,D | | C,F | |
| 2 MW | | D,L | A | F,G | C | |
| 3 SW | | | (D),G,L | A,F | C | |
| 4 TM * | | | A,D,G,L F,C | | | |
| 5 MM * | | (A) | L,G,D,C,F | | | |
| 6 SM | | G | | A,L,D,F | | C |
| 7 TB | | G | | (L),A,D,F | | C |
| 8 SB * | | | D,G,A,C L,F | | | |
| 9 TG | | D | G,L,A | F | C | |
| 10 SG | | | D,L,A,F G,C | | | |
| OVERALL | | D,G,A,L | | F | | C |

* difference not significant

( ) code which does not comply completely with clustering criteria

BATCH 1
*******

TABLE 3: Effort Required to Work Pump : Question 3

| GROUP NO | | CLUSTERS ← BETTER — approximate mean ▼ for question — WORSE → | | | | | |
|---|---|---|---|---|---|---|---|
| 1 TW | | F,L | | D,G,A | C | | |
| 2 MW | | L | D,F | A,G | C | | |
| 3 SW | | L.F | A,D | G | (C) | | |
| 4 TM | | | F,A,D,G,L | | (C) | | |
| 5 MM | | F,L | D,A | G | C | | |
| 6 SM | D | L | F | | A,G | C | |
| 7 TB | | L | D,F,A | | G | C | |
| 8 SB | | D,L | F | (A),G | C | | |
| 9 TG | | F,L,D | A | (G) | C | | |
| 10 SG | | | L,F,D | A,G | C | | |
| OVERALL | L,F,D | | A | | G | | C |

( ) Code which does not comply completely with clustering criteria

BATCH 1
*******

TABLE 4 : How easy to operate pump overall : Question 4

| GROUP NO | | CLUSTERS ← BETTER —— approximate mean for question —— WORSE → | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | TW | | L,F | | G,A | D | C | |
| 2 | MW | | | L,F,D | G,A | | C | |
| 3 | SW | | | L,A,F | D,G | C | | |
| 4 | TM | | | F,L,D,A,G | | (C) | | |
| 5 | MM | | L | F,A,(D) | G,C | | | |
| 6 | SM | | L | F,D,(G) | A | C | | |
| 7 | TB | | L | F,A,D | G | C | | |
| 8 | SB | D | | F,L | A,G | | C | |
| 9 | TG | | L,F | A,D | G | C | | |
| 10 | SG | | D | L,F,A | (G) | C | | |
| OVERALL | | L,F | | D,A | | G | | C |

( ) Code which does not comply completely with clustering criteria

BATCH 1
*******

TABLE 5 : Mean Time Taken to Fill Bucket (seconds)

| GROUP | A | C * | D | F | G | L | OVERALL MEAN FOR GROUP |
|---|---|---|---|---|---|---|---|
| TW | 50.33 | 73.5 | 57.7 | 20.2 | 35.8 | 21.5 | 43.2 |
| MW | 54.5 | 76.2 | 66.5 | 20.2 | 36.7 | 22.4 | 46.1 |
| SW | 48.6 | 68.0 | 54.0 | 21.9 | 30.9 | 22.7 | 41.0 |
| TM | 31.9 | 44.6 | 47.7 | 14.1 | 24.3 | 15.4 | 29.7 |
| MM | 37.6 | 54.2 | 51.2 | 17.0 | 31.5 | 17.6 | 34.9 |
| SM | 42.4 | 55.4 | 46.8 | 15.4 | 26.9 | 16.5 | 33.9 |
| TB | 41.6 | 95.2 | 50.8 | 20.3 | 33.8 | 18.2 | 43.3 |
| SB | 55.0 | 116.5 | 53.0 | 21.3 | 37.5 | 22.7 | 51.0 |
| TG | 58.6 | 99.1 | 69.9 | 23.6 | 43.7 | 25.3 | 53.4 |
| SG | 58.6 | 121.8 | 61.7 | 24.7 | 50.2 | 22.2 | 56.5 |
| OVERALL | 47.9 | 80.4 | 55.9 | 19.9 | 35.1 | 20.5 | 43.3 |

* 2 Women and 4 children found the effort required too great and failed to fill the bucket

Standard statistical techniques were used to estimate the missing values for the analysis.

BATCH 1
*******

TABLE 6 : Mean Number of Strokes/Revolutions to Fill Bucket

| GROUP | A | C * | D | F | G | L |
|---|---|---|---|---|---|---|
| TW | 24.8 | 43.8 | 27.5 | 8.5 | 16.2 | 10.8 |
| MW | 24.8 | 44.2 | 29.2 | 8.2 | 16.2 | 10.2 |
| SW | 28.2 | 38.0 | 36.3 | 10.0 | 18.0 | 12.5 |
| TM | 26.7 | 43.2 | 38.8 | 8.8 | 16.5 | 10.8 |
| MM | 25.2 | 43.2 | 34.8 | 8.5 | 15.5 | 10.7 |
| SM | 24.5 | 43.2 | 32.0 | 7.7 | 15.2 | 10.3 |
| TB | 32.0 | 46.5 | 39.7 | 11.7 | 19.0 | 11.8 |
| SB | 36.5 | 43.0 | 43.2 | 9.8 | 25.7 | 12.0 |
| TG | 29.5 | 44.0 | 48.2 | 10.5 | 24.3 | 13.8 |
| SG | 44.5 | 45.8 | 55.0 | 14.7 | 35.8 | 16.0 |
| OVERALL | 29.7 | 43.5 | 38.5 | 9.8 | 20.2 | 11.9 |

BATCH 2
*******

TABLE 7 : Suitability of Handle Height : Question 1

| GROUP NO | CLUSTERS — Too Low | | About Right | | | Too High — |
|---|---|---|---|---|---|---|
| 1 TW | H | K,B,J | M | | E | |
| 2 MW | | K,B | H,J | M | E | |
| 3 SW | | K,H | B | M,J | | E |
| 4 TM | K,B | | H,J,M | E | | |
| 5 MM | | B | K,H,M | J,E | | |
| 6 SM | K,B | | M,J | H,E | | |
| 7 TB | | | K | H,J,B,M | | E |
| 8 SB | | | H,B,K | M,J | | E |
| 9 TG | | | B,H,K,J | M | | E |
| 10 SG | | | M,H,K,B | | | E,J |
| OVERALL | K | B,H | | M,J | | E |

BATCH 2
*******

TABLE 8 : Handle Comfort : Question 2

| GROUP NO | | CLUSTERS ◄ BETTER — approximate mean for question — WORSE ► | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | TW | | | M,J,K,B, H,E | | | |
| 2 | MW | | | J,K,B,M, E,H | | | |
| 3 | SW | | | M,K | J,E,B | H | |
| 4 | TM | | | J,H,M,E B,K | | | |
| 5 | MM | | | J,M,B,K H,E | | | |
| 6 | SM | | | K,M,J,E, B,H | | | |
| 7 | TB | | | (M),B,K,J | H,E | | |
| 8 | SB | | | K,B,J,E, M,H | | | |
| 9 | TG | | K | E,M,B,J | H | | |
| 10 | SG | | K | B,E,M, | H | J | |
| OVERALL | | | K,M | J,B | E | H | |

( ) Code which does not comply completely with clustering criteria

BATCH 2
********

TABLE 9 : <u>Effort Required to Work Pump</u> : Question 3

| GROUP NO | CLUSTERS ← BETTER — approximate mean for question — WORSE → | | | | | |
|---|---|---|---|---|---|---|
| 1 TW | | M | K,B | J | E,H | |
| 2 MW | | | K,M,B | J,E | H | |
| 3 SW | | K | B,M | E | H,J | |
| 4 TM | | | E,H,K,B, M,J | | | |
| 5 MM | | K | M | B,E | H,J | |
| 6 SM | | | K,M,E,B, J,H | | | |
| 7 TB | | M,K | B,E | J,(H) | | |
| 8 SB | | | K,M,B,E | | H,J | |
| 9 TG | | | E,K,B,M | | J,H | |
| 10 SG | | B,K,M | | E | H,J | |
| OVERALL | K,M | B | | E | | J,H |

( ) Code which does not comply completely with clustering criteria

BATCH 2
********

TABLE 10 : How Easy to Operate Pump Overall : Question 4

| GROUP NO | | CLUSTERS ← BETTER — approximate mean for question — WORSE → | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | TW | | M | B,K | | E,J,H | | |
| 2 | MW | | | M,K,B | J,E | H | | |
| 3 | SW | M | B | K | | E | H,J | |
| 4 | TM | | | M,H,K,B, E,J | | | | |
| 5 | MM | | M | B | E,K | J,H | | |
| 6 | SM | | | M,E,K,B, J,H | | | | |
| 7 | TB | | M | K,B | E,J | H | | |
| 8 | SB | | K,M,B | | E,J | H | | |
| 9 | TG | | K | B,M,E | H,J | | | |
| 10 | SG | | B | M,K | E | H,J | | |
| OVERALL | | M | | B,K | | E | | J,H |

BATCH 2
********

TABLE 11: <u>Mean Time Taken to Fill Bucket</u> (seconds)

| GROUP | B | E | H | J* | K | M | OVERALL MEAN FOR GROUP |
|---|---|---|---|---|---|---|---|
| TW | 55.9 | 46.1 | 37.2 | 31.1 | 83.2 | 28.1 | 46.9 |
| MW | 52.6 | 41.1 | 44.1 | 29.4 | 83.0 | 27.5 | 46.3 |
| SW | 53.1 | 48.4 | 48.7 | 35.4 | 90.9 | 29.5 | 51.0 |
| TM | 50.9 | 39.8 | 22.1 | 17.2 | 77.6 | 23.5 | 38.5 |
| MM | 48.0 | 34.2 | 27.4 | 28.8 | 73.6 | 33.9 | 41.0 |
| SM | 50.2 | 36.3 | 32.6 | 25.7 | 77.7 | 24.6 | 41.2 |
| TB | 47.0 | 42.7 | 41.4 | 41.7 | 72.2 | 25.6 | 45.1 |
| SB | 53.5 | 61.2 | 85.1 | 39.2 | 72.4 | 30.7 | 57.0 |
| TG | 55.4 | 55.2 | 52.7 | 30.6 | 86.5 | 32.3 | 52.1 |
| SG | 60.4 | 69.[illegible] | 96.2 | 34.2 | 101.2 | 41.4 | 67.2 |
| OVERALL | 52.7 | 47.5 | 48.7 | 31.3 | 81.9 | 29.7 | 48.6 |

* 1 Woman and 6 children failed to fill the bucket because they were unable to turn the handle. Standard statistical techniques were used to estimate the missing values for the analysis.

BATCH 2
********

TABLE 12 : Mean Number of Strokes/Revolutions to Fill Bucket

| GROUP | B | E | H | J* | K | M |
|---|---|---|---|---|---|---|
| TW | 24.2 | 15.8 | 20.8 | 14.5 | 45.2 | 13.3 |
| MW | 28.3 | 20.8 | 30.5 | 14.0 | 56.3 | 14.8 |
| SW | 30.5 | 20.5 | 25.3 | 19.3 | 53.7 | 15.5 |
| TM | 33.3 | 19.8 | 16.8 | 15.3 | 51.7 | 14.7 |
| MM | 26.2 | 17.7 | 16.8 | 14.7 | 54.7 | 14.2 |
| SM | 32.7 | 17.3 | 18.5 | 14.7 | 61.3 | 13.8 |
| TB | 36.8 | 26.5 | 33.5 | 13.5 | 72.2 | 17.3 |
| SB | 38.2 | 29.0 | 31.7 | 16.5 | 63.7 | 19.3 |
| TG | 34.2 | 21.5 | 38.3 | 14.7 | 55.8 | 17.2 |
| SG | 46.7 | 43.8 | 62.0 | 24.8 | 81.5 | 27.7 |
| OVERALL | 33.1 | 23.3 | 29.4 | 16.2 | 59.6 | 16.8 |

# APPENDIX II

## SCARLET ALERTS

## APPENDIX II SCARLET ALERT - CODES F and L

A SCARLET ALERT is a Laboratory procedure designed to highlight, verify and then resolve difficulties or potential shortcomings of test methods.

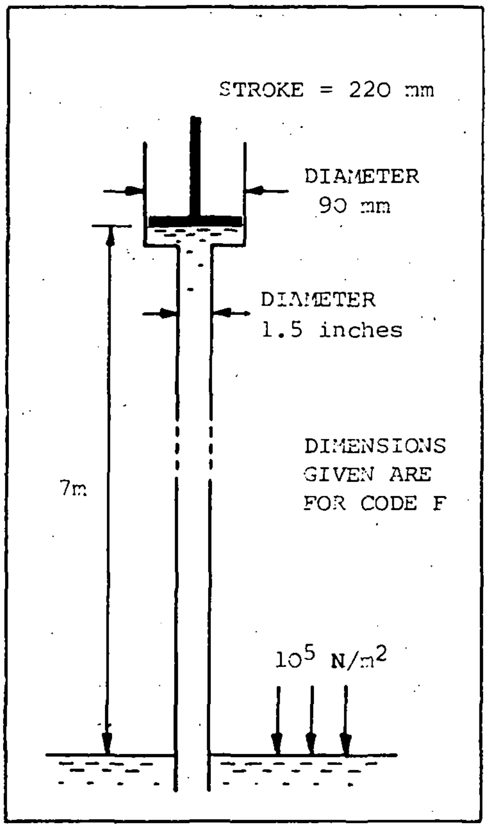
In this case, a Scarlet Alert (page 38 ) was raised in respect of the forthcoming endurance testing of Codes F and L, the two shallow well pumps in the first batch. The Terms of Reference state that the endurance testing will be carried out at 40 strokes per minute. When these pumps were first rigged for mechanical drive, however, they were disturbingly noisy and harsh at this speed. In the user trial, too, some strong users complained that these pumps had a harsh, jerky action.

Further experiments indicated that at speeds greater than 30 strokes per minute, cavitation was occurring beneath the pump piston. This was further supported by theoretical analysis (see next page).

It is therefore recommended that for the endurance tests, the deep well pumps should be operated at 40 strokes per minute, as stated in the Terms of Reference, but the shallow well pumps, Codes F and L, should be operated at 30 strokes per minute. However, since these pumps deliver significantly more water per stroke than any of the deep well pumps, it will not be necessary to extend the duration of the test beyond the stated 4000 hours.

APPENDIX II - cont.

In a shallowwell suction pump, the column of water in the rising main is accelerated by atmospheric pressure ($10^5$ N/m$^2$). But part of this 'atmospheric force' must support the static column of water, and therefore the net accelerating force, F, will in this case be given by:




$$F = 10^5 \times A - 9.81 \times 7 \times 10^3 \times A \quad (N)$$

$$= 3 \times 10^4 \times A$$

where A is the cross-sectional area of the water column.

The mass of water in the column, M, is:

$$M = 7 \times 10^3 \times A \text{ (kg)}$$

The acceleration of the water, a, will be given by a = F/M:

$$a = \frac{3 \times 10^4 \times A}{7 \times 10^3 \times A} = 4.3 \text{ m/s}^2$$

But since the diameter of the cylinder is considerably greater than that of the rising main, the acceleration of the water immediately below the piston will be proportionately less in the ratio of their areas.

Thus: acceleration of water below piston, $a' = 4.3 \times \frac{(1.5 \times 25.4)^2}{90^2}$

$$a' = 0.77 \text{ m/s}^2$$

Note that this does not take into account frictional losses in the pipe or valves and that the actual acceleration is therefore likely to be somewhat less than 0.77 m/s$^2$

If simple harmonic motion of the handle is assumed, at 30 strokes per minute:

frequency, $f = \omega / 2\pi$, $\omega = 0.5 \times 2\pi = \pi$

maximum acceleration, $a_1 = \omega^2 \times \text{amplitude} = \pi^2 \times 0.11$, $a_1 = 1.1$ m/s$^2$

If constant force (and therefore constant acceleration)is assumed throughout the stroke, at 30 strokes per minute:

$$\left.\begin{array}{l} u = 0 \\ t = 1 \text{ second} \\ x = 0.22 \text{ m} \end{array}\right) \begin{array}{l} x = ut + \tfrac{1}{2}at^2 \\ 0.22 = 0 + 0.5\, a_2 \end{array} \qquad a_2 = 0.44 \text{ m/s}^2$$

These results for $a_1$ and $a_2$, both at 30 strokes/minutes, are in broad agreement with a', the maximum acceleration provided by atmospheric pressure. The real-life forces used by a human operator are likely to be more closely related to $a_2$ than to $a_1$.

II/v

SCARLET ALERT

Project No: A.9940........

Project Name: .....W/B PUMPS..................

Sample Code: ..F and L......

P.O.: .............. P.C.: ..JR.......... Raised by: ....JR....... Date: 22.5.81...

REASONS:

Specified endurance test pumping speed (Terms of Reference, item 7, 40 strokes/minute) too fast for shallow well pumps - causes cavitation under piston; this was indicated when pumps were initially mechanised and was confirmed during user trials.

---

Verification Attended by:....DJU............./......JR........../...FPJ.............

* Method of Verification:

| | | |
|---|---|---|
| Visual | Factual | Procedure Checked |
| ~~Retests; see below~~ | | ~~Equipment Checked~~ |
| ~~Standards Checked~~ | | ~~Other: Give details~~ |

---

Other Results Examined: (e.g. Previous internal reports, external reports, etc)

Give Details: Pumps operated at various speeds - pumping rates faster than about 30 strokes/minute produced evidence of cavitation and mechanical distress in both Codes F and L.

See next page

---

Summary of Subsequent Examination/Retest Results:

See Over

---

CONCLUSION:

Recommend that deep well pumps are tested at 40 strokes/min, as specified, but shallow well pumps Codes F and L are tested at 30 strokes/min.

However, since both shallow well pumps deliver considerably more water per stroke than deep well pumps, the timescale of the endurance tests need not be extended (specified as 4000 hours)

---

* RECOMMENDED ACTION

| | |
|---|---|
| Inform PO | ~~No further Action~~ |
| ~~Retain in Project File~~ | |
| ~~Ops. Meeting~~ | ~~PO Contact Manufacturer~~ |
| ~~Obtain Further Samples~~ | ~~Other~~: |

Suggest KJM to discuss with client.

---

HRTL16

Signed: ..[signature]......

* Delete those not applicable

ADDITIONAL RESULTS/COMMENTS



Calculations of the physics, making certain assumptions, also indicate that pumping rates faster than about 30 strokes/min will cause cavitation.

Discussion with Mr S. Arlosoroff - World Bank. June 3/4th 1981

Position explained and Mr. Arlosoroff agreed that Codes F and L should be endurance tested at 30 strokes/min.

Ken Mills

---

NOTES:

To enable the problem to be resolved quickly please ensure that the following are available when the alert is being verified:

1. Copy of Terms of Reference including all amendments.
2. All equipment (as used in the actual test) necessary to repeat the test.
3. Test apparatus set up to enable test to be repeated (if appropriate).
4. Relevant method sheet (HRTL15).
5. Relevant standards.
6. Previous reports, internal or external for reference.
7. Actual test sample(s) which are the subject of the alert.
8. Additional sample(s), where available.

APPENDIX III

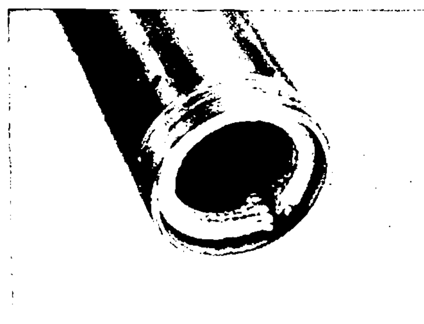
Purple Alerts

APPENDIX III PURPLE ALERT - CODE D

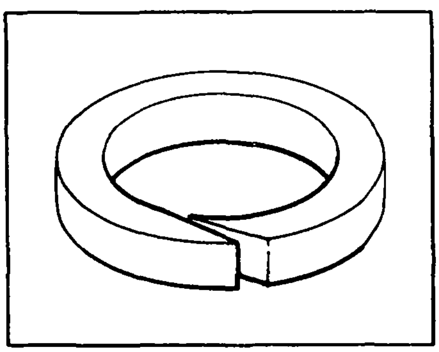
A PURPLE ALERT is a laboratory procedure designed to highlight and verify an especially poor test result or assessment for a particular test sample.

In this case, a Purple Alert was raised to draw attention to poor results for Code D in the performance tests. The cylinder was withdrawn and stripped down. This pump does not use a cup seal on the piston, but instead two rings of gland-packing cord.

It was clear that the lengths of cord used to make these piston rings were too short. Although a snug fit on the piston, they did not fit the cylinder bore, as the photograph shows (right).



New rings were cut (from material supplied with the pumps) to suit the cylinder bore, and with angled joints (below).



The performance of the pump was much improved with these replacement rings, particularly at the simulated 45 m depth.

It is recommended that these pumps should be supplied with rings cut to fit the cylinder bore rather than the piston, and with angled rather than butt joints.

NOTE The results of the performance tests for all the pumps in the first batch will be given in the next report.

# PURPLE ALERT

Project: No: A.9940 Name: W/B PUMPS Code: D

P.O.: W/B P.C.: JR Raised by: FPJ Date: 12.6.81

REASONS:

Very poor performance of pump Code D in performance tests - could not obtain sufficient pressure below head simulation valve to simulate 45 m (63 lb/in$^2$ required - best obtained ~45 lb/in$^2$).

---

Verification Attended by: JR in consultation with DJU / MWC
*Method of Verification:

Visual Factual Procedure checked Retests: see below

~~Equipment checked~~ ~~Standard checked~~ Other: Give details

---

Other Results Examined: (e.g. Previous internal reports, external reports, viz VU, CB, Motor, Autocar)

Give Details: Pump stripped down - piston packing found to be insuffcent to seal piston in cylinder - butt joint noted.
Photograph taken of packing in cylinder, see opposite page

---

Summary of Subsequent Examination/Retest Results:

---

CONCLUSION:

Packing appears to have been cut to suit piston rather than cylinder bore.
Result: piston leaks badly at larger simulated water heads.

---

*RECOMMENDED ACTION

Inform PO ~~No further action~~ ~~Retain in Project File~~

~~P.O contact Manufacturer~~ ~~Obtain further samples~~ ~~Other~~

Packing replaced - length cut to suit cylinder rather than piston, and scarf rather than butt jointed.

Retested with new packing - performance much improved and now capable of simulating 45 m head.

Suggest appropriate recommendation made to manufacturer.

---

*Delete those not applicable

HRTL 16 Signed: D J Unwin Date: 12.6.81

ADDITIONAL RESULTS/COMMENTS

---

NOTES:

To enable the problem to be resolved quickly please ensure that the following are available when the alert is being verified:

1. Copy of Terms of Reference including all amendments.
2. All equipment (as used in the actual test) necessary to repeat the tests.
3. Test apparatus set up to enable test to be repeated (if appropriate).
4. Relevant method sheet (HRTL 15).
5. Relevant standards.
6. Previous reports, internal or external for reference.
7. Actual test sample(s) which are the subject of the alert.
8. Additional sample(s), where available.

PURPLE ALERT

Project: No: A.9940 Name: W/B PUMPS Code: A

P.O.: S.Arlosoroff P.C.: JMR Raised by: JMR Date: 12.8.81

REASONS:

Pump cylinder top casting found to leak during foot valve leakage test - leakage rate 4 ml/minute at simulated 45 m head - leakage due to porosity in the casting.

Cylinder bottom appears sound - does not leak.

---

Verification Attended by: DJU / JMR / FPJ
*Method of Verification:

Visual Factual Procedure checked Retests: see below

Equipment checked ~~Standard checked~~ Other: Give details

---

Other Results Examined: (e.g. Previous internal reports, external reports, viz VU, CB, Motor, Autocar)

Give Details: None

---

Summary of Subsequent Examination/Retest Results:

Remaining 3 cylinder tops also tested and all found to leak.

Remaining 3 cylinder bottoms tested and all found to leak.

---

CONCLUSION:

Casting are imperfect, with areas of gas inclusion - this could be the result of:
(a) inadequate gating or venting,
(b) freezing due to pouring temperature being too low.

See note overleaf.

---

*RECOMMENDED ACTION

Inform PO ~~No further action~~ Retain in Project File

~~P.O~~ contact Manufacturer ~~Obtain further samples~~ Other

(1) Seal one top casting for use in Endurance test (in conjunction with sound bottom casting).
(2) Include in suggestions to manufacturer as a manufacturing improvement (see conclusions).

---

*Delete those not applicable

HRTL 16 Signed: D J Unwin Date: 13.8.81

ADDITIONAL RESULTS/COMMENTS

Although the castings have been shown to be imperfect, the rate of water leakage would not significantly affect the pump's performance, except in terms of the need to prime the pump after periods of non-use.

---

NOTES:

To enable the problem to be resolved quickly please ensure that the following are available when the alert is being verified:

1. Copy of Terms of Reference including all amendments.
2. All equipment (as used in the actual test) necessary to repeat the tests.
3. Test apparatus set up to enable test to be repeated (if appropriate).
4. Relevant method sheet (HRTL 15).
5. Relevant standards.
6. Previous reports, internal or external for reference.
7. Actual test sample(s) which are the subject of the alert.
8. Additional sample(s), where available.

PURPLE ALERT

Project: No: A.9940/2 Name: W/B PUMPS Code: E

P.O.: SA P.C.: JMR Raised by: JMR Date: 10/12/81

REASONS:

Severe wear of pump in endurance testing. Pump rod connecting tube worn right through after 150 hours.

ON VIDEO

---

Verification Attended by: DJU / JMR / FPJ
*Method of Verification:

Visual Factual Procedure checked ~~Retests:~~ see ~~below~~

Equipment checked ~~Standard checked~~ Other: Give details

When dismantled, guide tube also found to be worn through

---

Other Results Examined: (e.g. Previous internal reports, external reports, viz VU, CB, Motor, Autocar)

Give Details: None

---

Summary of Subsequent Examination/~~Retest~~ Results:

Fulcrum upright is not at best angle to minimise out-of-line forces in connecting links and tube.

Design is such that this angle is controlled by a rough-hewn recess in the base of the wooden fulcrum upright.

---

CONCLUSION:

High wear rate was probably caused by out-of-line forces in connecting links and tube. When repairing the pump, fulcrum upright should be aligned to minimise these forces.

---

*RECOMMENDED ACTION

Inform PO ~~No further action~~ Retain in Project File

P.O contact Manufacturer Obtain further appropriate components Other:

1. Investigate whether similar problems have appeared in the field.
2. Reassemble, adjusting angle of fulcrum upright to minimise out-of-line forces in connecting links and tube, to continue endurance testing.

---

*Delete those not applicable

HRTL 16 Signed: D J Unwin Date: 17/12/81

ADDITIONAL RESULTS/COMMENTS

NOTES:

To enable the problem to be resolved quickly please ensure that the following are available when the alert is being verified:

1. Copy of Terms of Reference including all amendments.
2. All equipment (as used in the actual test) necessary to repeat the tests.
3. Test apparatus set up to enable test to be repeated (if appropriate).
4. Relevant method sheet (HRTL 15).
5. Relevant standards.
6. Previous reports, internal or external for reference.
7. Actual test sample(s) which are the subject of the alert.
8. Additional sample(s), where available.

## PURPLE ALERT

Project: No: A.9940/2 Name: W/B PUMPS Code: J

P.O.: SA P.C.: JMR Raised by: JMR Date: 10/12/81

REASONS:

Severe wear of crank pin and webs and connecting link in endurance testing after 150 hours; one bearing axle worn away at end. Test stopped to prevent catastrophic failure.

ON VIDEO

---

Verification Attended by: DJU / JMR / FPJ
*Method of Verification:

Visual Factual Procedure checked ~~Retested see below~~

Equipment checked ~~Standard checked~~ Other: Give details

Cable tested under tension: 8 m of cable twisted approx 7 revolutions under a load of 120 kgf.

---

Other Results Examined: (e.g. Previous internal reports, external reports, viz VU, CB, Motor, Autocar)

Give Details: None

---

Summary of Subsequent Examination/~~Retest~~ Results:

Connecting link has been twisted by torsional forces in the pump's operating cable, causing it to foul on the crank webs.
This pump's design is susceptible to twist in the cable because of the low resistance to torsional forces of the big end bearings on the crank pin, particularly as tension is released at the start of the downstroke.

---

CONCLUSION:

The cable should be of the non-rotating type

---

*RECOMMENDED ACTION

Inform PO ~~No further action~~ Retain in Project File

~~P.O contact Manufacturer~~ Obtain further appropriate components Other:

1. Contact manufacturer
2. Interpose a swivel between the cable and the connecting link to continue endurance testing.

---

*Delete those not applicable

HRTL 16 Signed: D J Unwin Date: 17/12/81

ADDITIONAL RESULTS/COMMENTS

---

NOTES:

To enable the problem to be resolved quickly please ensure that the following are available when the alert is being verified:

1. Copy of Terms of Reference including all amendments.
2. All equipment (as used in the actual test) necessary to repeat the tests.
3. Test apparatus set up to enable test to be repeated (if appropriate).
4. Relevant method sheet (HRTL 15).
5. Relevant standards.
6. Previous reports, internal or external for reference.
7. Actual test sample(s) which are the subject of the alert.
8. Additional sample(s), where available.

PURPLE ALERT

Project: No: A.9940/2 Name: W/B PUMPS Code: K

P.O.: SA P.C.: JMR Raised by: JMR Date: 17/12/81

REASONS:

Outlet diverter valve (for tank filling) can be dislodged by the vibration caused by continuous heavy-handed usage, thereby blocking free discharge spout.

ON VIDEO

---

Verification Attended by: DJU / JMR / FPJ
*Method of Verification:

Visual Factual Procedure checked Retests: see below

Equipment checked ~~Standard checked~~ ~~Other: Give details~~

---

Other Results Examined: (e.g. Previous internal reports, external reports, viz VU, CB, Motor, Autocar)

Give Details: None

---

Summary of Subsequent Examination/Retest Results:

Effect could be repeated consistently.

Code B pump, which is similar, is not affected in the same way because manufacturing quality is better.

---

CONCLUSION:

Suggest manufacturer modifies design or improves manufacturing quality.

---

*RECOMMENDED ACTION

Inform PO ~~No further action~~ Retain in Project File

Contact Manufacturer ~~Obtain further samples~~ ~~Other~~

---

*Delete those not applicable

HRTL 16 Signed: D J Unwin Date: 17/12/81

ADDITIONAL RESULTS/COMMENTS

---

NOTES:

To enable the problem to be resolved quickly please ensure that the following are available when the alert is being verified:

1. Copy of Terms of Reference including all amendments.
2. All equipment (as used in the actual test) necessary to repeat the tests.
3. Test apparatus set up to enable test to be repeated (if appropriate).
4. Relevant method sheet (HRTL 15).
5. Relevant standards.
6. Previous reports, internal or external for reference.
7. Actual test sample(s) which are the subject of the alert.
8. Additional sample(s), where available.

# PURPLE ALERT

Project: No: A.9940/2 Name: W/B PUMPS Code: M

P.O.: SA P.C.: JMR Raised by: JMR Date: 17/12/81

**REASONS:**

Severe wear of pump in endurance testing. Fulcrum link has worn through after 250 hours. Fulcrum pin also very severely worn and broken.

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Verification Attended by: DJU / JMR / FPJ
*Method of Verification:

Visual Factual Procedure checked ~~Retests: see below~~

Equipment checked ~~Standard checked~~ ~~Other: Give details~~

---

Other Results Examined: (e.g. Previous internal reports, external reports, viz VU, CB, Motor, Autocar)

Give Details: None

---

Summary of Subsequent Examination/~~Retest~~ Results:

Components of this pump difficult to align for assembly due to poor quality control over the manufacturing process.

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**CONCLUSION:**

High rate of wear has probably been caused by misalignmentof the components due to poor manufacture.

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*RECOMMENDED ACTION

Inform PO ~~No further action~~ Retain in Project File

P.O contact Manufacturer Obtain further appropriate components Other:

Reassemble using components from second sample to continue endurance testing

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*Delete those not applicable

HRTL 16 Signed: D J Unwin Date: 17/12/81

ADDITIONAL RESULTS/COMMENTS

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NOTES:

To enable the problem to be resolved quickly please ensure that the following are available when the alert is being verified:

1. Copy of Terms of Reference including all amendments.
2. All equipment (as used in the actual test) necessary to repeat the tests.
3. Test apparatus set up to enable test to be repeated (if appropriate).
4. Relevant method sheet (HRTL 15).
5. Relevant standards.
6. Previous reports, internal or external for reference.
7. Actual test sample(s) which are the subject of the alert.
8. Additional sample(s), where available.

## PURPLE ALERT

Project: No: A.9940/2 Name: W/B PUMPS Code: M

P.O.: SA P.C.: JMR Raised by: JMR Date: 17/12/81

REASONS:

Connecting rod broken at root of threads after 290 hours of endurance testing.

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Verification Attended by: DJU / JMR / FPJ
*Method of Verification:

Visual Factual Procedure checked ~~Retests:~~ ~~see below~~

Equipment checked ~~Standard checked~~ ~~Other:~~ ~~Give details~~

---

Other Results Examined: (e.g. Previous internal reports, external reports, viz VU, CB, Motor, Autocar)

Give Details: None

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Summary of Subsequent Examination/Retest Results:

This weakness of design had been noted in the Engineering Assessment.

Connecting rod has been turned down prior to threading, leaving a sharp shoulder.

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CONCLUSION:

Rod should either not be turned down for threading or, if turned, the shoulder should be radiused to prevent concentration of stress.

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*RECOMMENDED ACTION

Inform PO ~~No further action~~ Retain in Project File

Contact Manufacturer ~~Obtain further samples~~ ~~Other~~

---

*Delete those not applicable

HRTL 16 Signed: D J Unwin Date: 17/12/81

ADDITIONAL RESULTS/COMMENTS

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NOTES:

To enable the problem to be resolved quickly please ensure that the following are available when the alert is being verified:

1. Copy of Terms of Reference including all amendments.

2. All equipment (as used in the actual test) necessary to repeat the tests.

3. Test apparatus set up to enable test to be repeated (if appropriate).

4. Relevant method sheet (HRTL 15).

5. Relevant standards.

6. Previous reports, internal or external for reference.

7. Actual test sample(s) which are the subject of the alert.

8. Additional sample(s), where available.

BATCH 1 PUMPS
*************

| CODE | MANUFACTURER | MODEL | DEEP OR SHALLOW WELL | FREE DISCHARGE OR DELIVERY LIFT | COUNTRY OF ORIGIN |
|---|---|---|---|---|---|
| A | Saha Kolkarn | Korat 608<br>608 A-1 | Deep | Delivery Lift | Thailand |
| C | Robbins and Myers | Moyno IV 2.6 | Deep | Delivery Lift | U.S.A. |
| D | Briau SA | Nepta | Deep | Free discharge | France |
| F | UNICEF | New No. 6 | Shallow | Free discharge | Bangladesh |
| G | Vammalan Konepaja Oy | Nira AF-76 | Deep | Free discharge | Finland |
| L | UNICEF | Bandung | Shallow | Free discharge | Indonesia |

BATCH 2 PUMPS
*************

| CODE | MANUFACTURER | MODEL | DEEP OR SHALLOW WELL | FREE DISCHARGE OR DELIVERY LIFT | COUNTRY OF ORIGIN |
|---|---|---|---|---|---|
| B | Kawamoto | Dragon No. 2 (D) | Deep | Delivery Lift | Japan |
| E | Atlas Copco | Kenya | Deep | Free Discharge | Kenya |
| H | IDRC Ethiopia | type BP | Shallow | Free Discharge | Ethiopia |
| J | Vereinigte Edelstahlwerke | A18 | Deep | Free Discharge | Austria |
| K | Sea Commercial Co. | Jetmatic | Deep | Delivery Lift | Philippines |
| M | [3] | AID/ Battelle | Deep | Free Discharge | Indonesia |

**The World Bank** / 1818 H Street, N.W., Washington, D.C. 20433, U.S.A. • Telephone: (202) 477-1234 • Cables: INTBAFRAD

March 30, 1982

Dear Madam/Sir:

Subject: UNDP/World Bank Rural Water Supply Project for the Testing and Technological Development of Handpumps (INT/81/026)

We are enclosing for your review the first report of the Global and Interregional Handpump Project funded by UNDP and executed by the World Bank.

This report describes the interim results of the laboratory testing of a selected group of handpumps. The testing was contracted and conducted by the Consumers' Association Testing and Research Unit, Harpenden, U.K.

The handpumps project is part of the UN effort to achieve the goals of the International Water Supply and Sanitation Decade. These goals call for the provision of adequate drinking water for all people in developing countries by the year 1990. Handpumps installed in wells, where groundwater of appropriate quality is readily available, provide one of the simplest and least costly means of supplying drinking water to rural areas.

The project consists of three phases: laboratory testing, field trials in about fifteen developing countries, and the promotion of the technological development of new types of handpumps that could be maintained at the village level and manufactured in developing countries.

We would be grateful to receive any comments on our report and any data or descriptions you may have from your experiences with installation and performance of handpumps in the field, as well as any information on your plans for future handpump projects.

Sincerely yours,

S. Arlosoroff

S. Arlosoroff
UNDP Projects Manager (T&W)
(Handpumps Testing and Development)
(Integrated Resource Recovery)

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