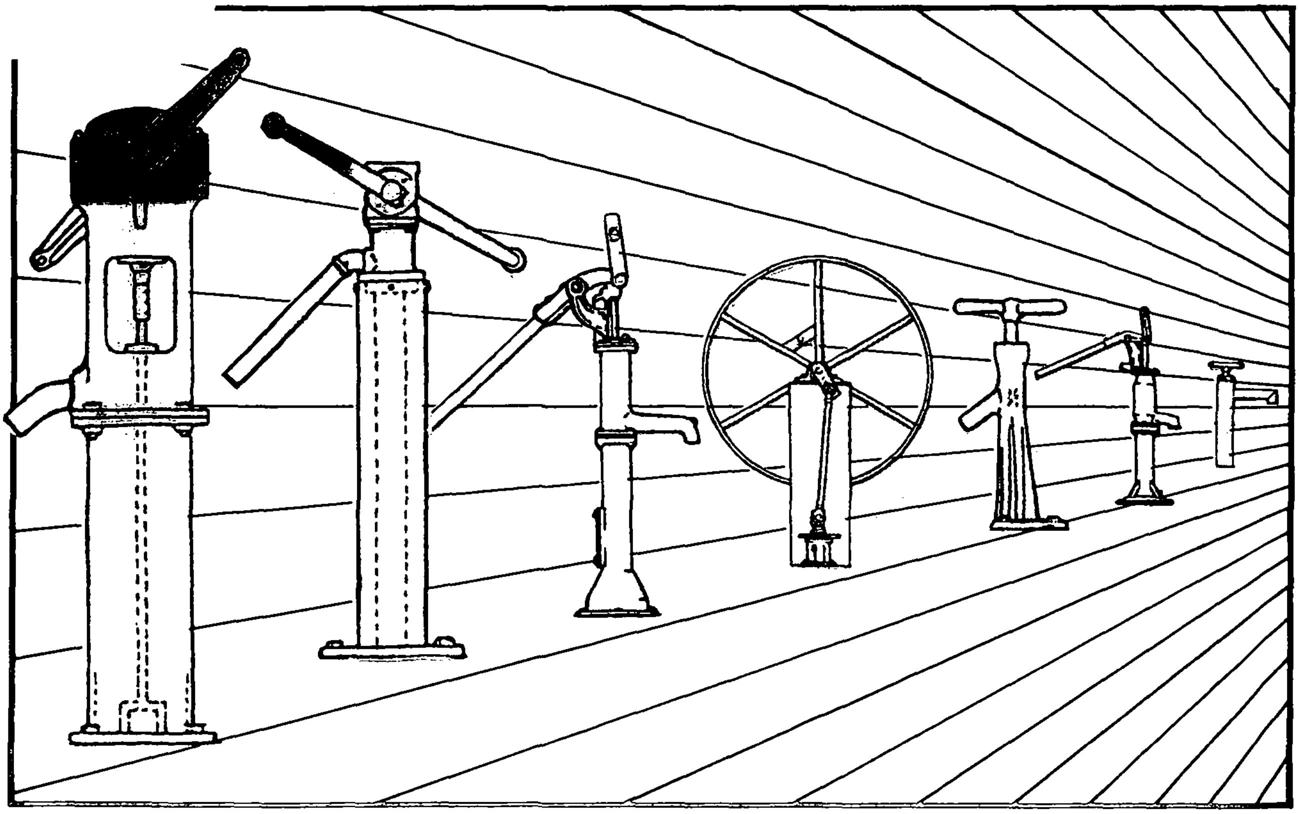
APPLIED RESEARCH AND TECHNOLOGY (WUDAT)—NOTE NO. 2

Rural Water Supply Handpumps Project

Handpump Laboratory Test Results

Consumers' Association Testing and Research Laboratories (CATR)



The World Bank — Water Supply and Urban Development Department

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

LIST OF PUBLICATIONS BY THE WORLD BANK/UNDP HANDPUMPS PROJECT

Progress Reports of the Handpumps Project, which appeared in the World Bank Technical Paper series:

Report No. 1	Laboratory Tests on Hand-Operated Water Pumps for Use in Developing Countries: Interim Report. 1982
Report No. 2	Laboratory Evaluation of Hand-Operated Water Pumps for Use in Developing Countries. 1983 (World Bank Technical Paper No. 6)
Report No. 3	Laboratory Testing of Handpumps for Developing Countries: Final Technical Report. 1984 (World Bank Technical Paper No. 19)
Report No. 4	Handpumps Testing and Development: Progress Report on Field and Laboratory Testing. 1984 (World Bank Technical Paper No. 29)
Report No. 5	Handpumps Testing and Development: Proceedings of a Workshop in China. 1985 (World Bank Technical Paper No. 48)

Applied Research and Technology Notes of the Handpumps Project:

Note No. 1	Sample Bidding Documents for the Procurement of Handpumps, 1986
Note No. 2	Handpump Laboratory Test Results: GSW, Monarch, Monolift, Moyno, Pek, Tara and Volanta Pumps, 1986

APPLIED RESEARCH AND TECHNOLOGY (WUDAT)—NOTE NO. 2

Rural Water Supply Handpumps Project

WORLD BANK/UNDP INT/81/026

Handpump Laboratory Test Results
GSW, Monarch, Monolift, Moyno Pek, Tara and Volanta Pumps

Consumers' Association Testing and Research Laboratories (CATR)

1818 H Street, NW
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PREFACE

This publication is the second in the series of Applied Research and Technology Notes prepared by the World Bank/UNDP Interregional Project for Laboratory and Field Testing and Technological Development of Rural Water Supply Handpumps (UNDP/World Bank INT/81/026). The series is designed to provide the reader with Project findings on specific topics of interest. Annual Progress Reports on overall Project activities will continue to be published as World Bank Technical Papers.

The Handpumps Project was initiated in 1981 under the framework of the International Drinking Water Supply and Sanitation Decade. Project objectives are to reduce the capital and recurrent costs of rural and urban fringe water supply systems, provide wide-scale coverage to the approximately 1.5 billion people who lack this basic service, and bring about an overall improvement in rural water supplies for the millions of people in need throughout the world.

Handpumps installed in wells where groundwater is available are one of the simplest and least costly methods of providing the populations in need with an adequate supply of water in the immediate vicinity of their residences; however, serious technological and reliability problems have arisen with handpumps in the past. These problems are manifested in poor design, unsatisfactory performance, shortened working life and frequent failures. There has been a lack of reliable data on handpump performance, as well as on the comparative performance of different handpump designs. These data are required to facilitate selection from among the array of available handpumps and to provide the mechanism to lead towards improved designs and manufacturing practices. To achieve its objectives and overcome the problems encountered with handpumps in the past, the Project has been conducting systematic laboratory and field tests of a large number of handpumps, with the results provided to manufacturers, governments, aid agencies and other interested parties.

The laboratory tests are being conducted to examine and assist in the selection of a wide range of handpumps for further field trials and to provide information to all manufacturers to assist them in the production of more efficient and reliable pumps. The testing is contracted to the Consumers' Association Testing and Research (CATR) Laboratories in Harpenden, U.K. Recent tests have been commissioned directly by the manufacturers; however, results are made public regardless of sponsorship.

Three previous reports on the laboratory test results have been issued by the Project. The present Note contains the laboratory evaluations and conclusions on seven handpumps which were tested in 1984 and 1985. Comments on this report are most welcome.

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CONTENTS

OVERVIEW OF LABORATORY WORK AT CATR

The Consumers' Association Testing and Research (CATR) Laboratories in the United Kingdom have conducted, until January 1, 1986, laboratory tests of a total of 42 handpumps. This work began in 1977 with tests of 12 pumps sponsored by the Overseas Development Administration of the U.K., the results of which were published in January 1981 1/ Since that time, CATR has undertaken testing of many additional pumps for the World Bank/UNDP Handpumps Project and for manufacturers. Handpumps testing laboratories have also been established with assistance from the Handpumps Project at Beijing and Changsha in the Peoples' Republic of China, and others are being established elsewhere.

The main objectives of laboratory work related to handpumps are the following:

(i) Assist handpump manufacturers in improving the quality of their products.

(ii) Assist authorities and agencies in developing countries in deciding between local manufacturing or importation of handpumps.

(iii) Provide agencies in developing countries with an evaluation of handpumps in order to enable a more informed choice of pump to be made, and to ensure the right pump is selected to suit particular developing country conditions.

Laboratory testing has the advantages, when compared with field testing, of being relatively economical and rapid, logistically simple, and allows different types of pumps to be tested under identical sets of conditions, providing comparable results. Nonetheless, there are many types of faults which will only be exposed under actual use in the field, and therefore pumps which have successfully passed laboratory testing should be further evaluated under field conditions.

In addition to the complete testing of handpumps, CATR also undertakes research and development (R & D) related to their improvement 2/. R & D undertaken in 1984 - 1985 included development of plastic below-ground components, testing of different dry bearing materials,

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1/ The laboratory testing results are published in Reports 1 to 4 of the Handpumps Project. A summary of the results of this O.D.A. sponsored testing appeared on pages 266-267 of the UNDP/World Bank Handpumps Project Report No. 3 (World Bank Technical Paper No. 19).

2/ Laboratory R & D undertaken before 1984 is summarized in the UNDP/World Bank Handpumps Project Report No. 4 (World Bank Technical Paper No. 29).

experimentation with different light-weight pump rod, designs, and preparation of drawings and manufacturing instructions for the Afridev pump. During this period, technical assistance was also provided by CATR to various Handpumps Project activities in the field.

Full-scale laboratory testing of handpumps is done by CATR according to standard conditions and procedures 3/, and the results are published by the Project regardless of who bore the cost of the testing.

Another option is available to manufacturers who want to use the experience and facilities of CATR to receive assistance with their own R & D Work. Such a manufacturer may, at his own expense, contract CATR to undertake R & D related to his pump, with the prior understanding that the results will be confidential and will not be published by the Project, of whether they are favorable or not.

In March 1986, the following pumps were undergoing endurance testing as part of a standard test: Bestobell (Zambia); IDRC-UM (Malaysia); Nira AF84 and AF85 (Finland); and Wavin (The Netherlands).

3/ For CATR Standard Handpump Test Procedure see pp. 149 - 158, World Bank/UNDP Handpumps Project Report No. 4 (World Bank Technical Paper No. 29).

VERDICTS FROM LABORATORY TESTING, 1984-5 PROGRAM

Following are the verdicts from the laboratory testing of the seven pumps in the 1984-5 programme. More complete evaluations are presented in the remaining sections of this note.

Only two of the seven pumps in the 1984-85 program of CATR were tested for the first time, namely the **Pek** and the **Tara.** The other five were improved models of pumps which had been previously tested by CATR. In the case of the **GSW, Monarch**, and **Volanta** pumps, the complete program of tests (including endurance) was carried out to determine whether the major design modifications that had been made by the manufacturer, based largely on the results from the previous laboratory tests, yielded in improved test results. It can be seen below that all three exhibited greater durability, but only the **Volanta** is also suitable for village-level maintenance and repair and, at least in part, for local manufacture--conditions for which it was specifically designed.

The **Monolift** pump had also undergone major changes, intended for operation at a maximum pumping lift of 60m. The results showed considerable improvements in performance and user acceptability, but, in the absence of endurance tests at 60m, did not include a verdict about the pump's durability at that depth. An engineering assessment of the modified version of the **Moyno** pump confirmed that the changes made were unlikely to detract from the performance and endurance test results obtained from the full series of tests that were carried out previously.

GSW (modified)

The handle and pumpstand pedestal need to be strengthened, and the handle bearing arrangement could also be improved. In other respects, the pump proved to be reliable with the 2-inch cylinder supplied with the test samples, though corrosion will be a problem in aggressive water. It was efficient and particularly easy to operate.

It is not suitable for manufacture in developing countries, and the pump meets few of the requirements for village level operation and maintenance.

Monarch (modified)

The cast iron pumpstand pedestal is not strong enough to withstand accidental impacts or abuse. In other respects, the pump proved to be reliable with the 2.25-inch cylinder supplied with the test samples, though corrosion will be a problem in aggressive water. One footvalve would be sufficient. It was easier to operate at 45 metres depth than many other pumps.

It is not suitable for manufacture in developing countries, and meets few of the requirements for village level operation and maintenance.

Monolift (modified)

The Monolift handpump continues to be a robust handpump, potentially suitable for community water supply in developing countries, suited for depths of 20 to 45 metres. The provision of alternative 2:1 drive gears extends the working range of the pump to depths beyond 45 metres. The modifications introduced, since the previous model was tested, make the pump more suitable than before for operation by children. The pump is not suitable for manufacture in developing countries, nor for village-level maintenance and repair. The new version is likely to be as reliable at 45m pumping lift as the previously tested model. In the absence of endurance tests at 60m pumping lift, no recommendations can be made on the pump reliability at that depth.

Moyno (modified)

This was not a full test of the Moyno pump, because such testing had already been done on the US-made model in 1981-82. The differences between the original U.S.-made Moyno pump and the Canadian sample are unlikely to affect pump performance, and can only have a beneficial effect on endurance. The verdict from the 1981-82 tests still applies as follows: A robust pump, in good condition after 4000 hours of endurance testing. The rate of delivery was low, and the pump was hard work to operate at first, though it became slightly less hard with further use. Although generally reliable in these tests, any repairs needed in the field will be difficult and expensive. It may not be ideal for community water supply because of the difficulties of operation and low rate of delivery. Expensive.

Pek

A direct-action pump using tubular aluminium alloy pump "rods" and a small diameter cylinder to achieve operating characteristics suitable for direct action. Simple and lightweight, and therefore very easy to install and to maintain at village level. However, the rate of delivery is low and likely to fall still further as a result of wear. The pump rods were found to be inadequately sealed and susceptible to corrosion, and the ingress of water will dramatically affect the operating characteristics. Tough, wear-resistant pumpstand, but extensive use of polyurethane may make the PEK unsuitable for manufacture in developing countries. Expensive in view of its simplicity.

Tara

A simple, direct-acting handpump, designed to exploit the materials and manufacturing skills indigenous to Bangladesh, with potential for further improvement and wider application. Relatively easy to manufacture, operate, maintain and repair. Leather seal unlikely to cope with sand contamination, but alternative nitrile rubber seal available. Suitable for community water supply from depths of 15 metres or less.

Volanta

The steel rods of the current design are better than cable. The use of hook-and-eye connections is innovative and very convenient for installation and maintenance. However, the rod material must be chosen with care, and good quality control is essential in forming the hooks and eyes.

The design incorporates many useful innovations, including the ability to adjust the stroke length to compensate for water depth and/or local preference, and the elimination of seals in the piston. The pumpstand is very strong. Some children may find the inertia of the flywheel difficult to cope with.

Many parts of the pump are suitable for manufacture in developing countries, though rigorous quality control is essential in making the cylinder assembly. The pump is easier than most to maintain and repair.

LABORATORY EVALUATIONS

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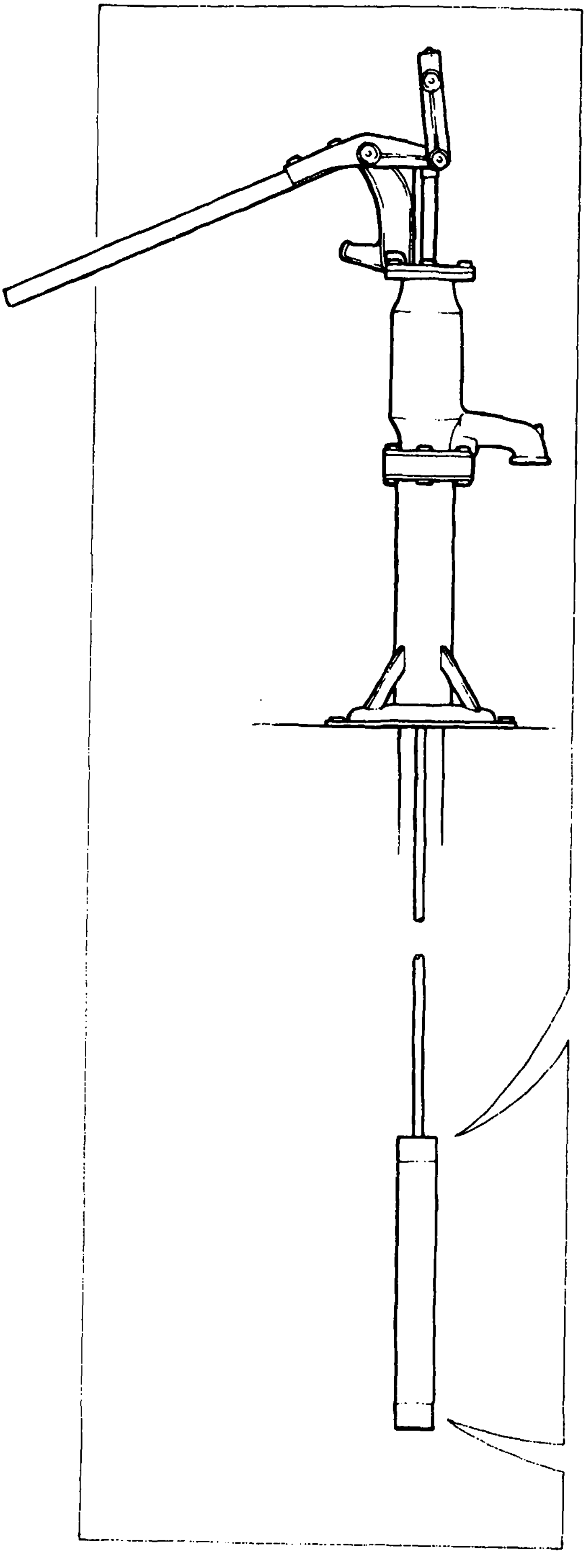
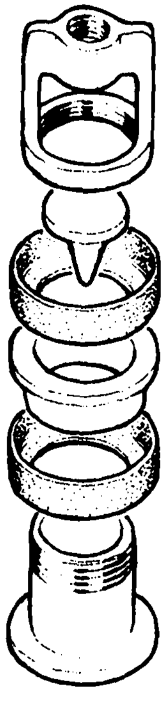
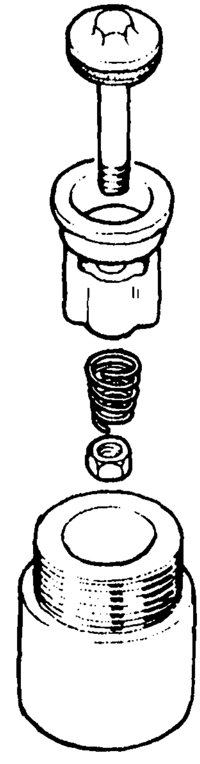






GSW HANDPUMP

1.1 Manufacturer

GSW Water Products Company

Address

599 Hill Street West
FERGUS, Ontario
Canada

1.2 Description

The GSW handpump was tested by CATR in 1979/80, as one of twelve pumps tested on behalf of the Overseas Development Administration. Since then, the manufacturer has introduced a number of modifications to the pump.

The GSW is conventional in design and methods of manufacture. The pumpstand is cast iron, supported on a fabricated steel pedestal. The pump rod is constrained to move in a straight line, and the handle is attached via a swinging link. The handle bearings are sealed ball races. In the current version, the handle fulcrum is fixed. In the earlier version, the pumpstand incorporated guide rods on either side of the pump rod, with the handle fulcrum on a swinging link.

The cylinder is conventional drawn brass tube, with gunmetal piston and foot valve. The piston is fitted with two leather cup seals. The cylinder bore of the samples tested for ODA was 2.5 inches; the current samples were supplied with 2 inch cylinders.

1.3 Price

16 April 1985

C$460 (US$340)

2. INSPECTION

2.1 Packaging

The samples were supplied in cardboard cartons inside slatted wooden crates, with one set of pumpstand assembly and cylinder in each carton. Within the cartons, the various components were securely located by cardboard baffles.

The packaging was robust but easy to man-handle. It was therefore considered to be suitable for export and for crude overland transportation. The cardboard may deteriorate in wet conditions, however.

2.2 Condition as Received

The handle pivot bearings were not tight in one sample. One piston rod had been poorly threaded. One footvalve body was subsequently found to leak.

2.3 **Installation and Maintenance Information**

Instructions for installation were supplied, in English, including cut-away drawings of the pumpstand and the cylinder assembly. The instructions were helpful, but more profuse illustrations, with less reliance on text, would be more appropriate for use in developing countries.

3. WEIGHTS and MEASURES

3.1 Weights

Pumpstand:	25.5 kg (including handle)
Cylinder:	3.5 kg
Rising Main (per m):	not supplied
Pump Rod (per m):	not supplied

3.2 Dimensions

Cylinder bore:	2 inch
Actual pump stroke:	140 mm
Nominal volume/stroke:	280 ml
Rising main size:	1.25 inch (not supplied)
Pump rod diameter:	7/16 inch (not supplied)
Outside diameter of below-ground assembly:	57 mm

3.3 Cylinder Bore

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

The surface roughness (R_a) was measured in three places in a direction parallel to the cylinder axis.

SAMPLE	CYLINDER BORE	ROUGHNESS AVERAGE (μm)			
		TEST 1	TEST 2	TEST 3	MEAN
1	Extruded brass	0.40	0.30	0.30	0.33
2	Extruded brass	0.25	0.30	0.35	0.30

Measured at 0.25 mm cut-off

3.4 Ergonomic Measurements

HANDLE HEIGHT		PLINTH HEIGHT (mm)	ANGULAR MOVEMENT of HANDLE (deg)	HANDLE LENGTH (mm)	VELOCITY RATIO of HANDLE	HEIGHT OF SPOUT (mm)
MAX (mm)	MIN (mm)					
1110	225	[1]	75	835	7.1	485

[1] Supplied with steel pedestal - the pump does not require a plinth to be built up on the well-head.

4. ENGINEERING ASSESSMENT

4.1 Materials of Construction

COMPONENT	MATERIAL(S)
Pumpstand	Cast iron
Handle	Standard steel water pipe
Bearings	Standard sealed ball races
Pumpstand pedestal	Fabricated steel
Rising main	GI pipe (not supplied)
Pump rod	7/16 inch steel (not supplied)
Cylinder barrel	Drawn brass tube
Piston and foot valve	Cast gunmetal
Piston seals	Leather cups

4.2 Manufacturing Techniques

The techniques required to manufacture the pump are listed below:

Above-ground Assembly	Iron foundry General machining Steel pressing and fabrication

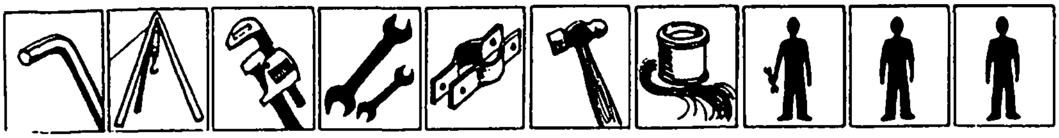
The bearing axes must be parallel to ensure smooth operation of the handle. Good quality control is therefore necessary to ensure accuracy in machining the castings.

Below-ground Assembly	Gunmetal foundry General machining

In general, the requirement for foundry facilities in both iron and gunmetal, and the need for careful quality control in machining, would make the pump unsuitable for manufacture in developing countries.

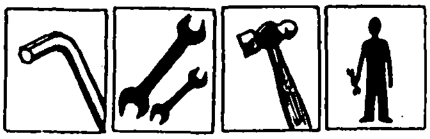
4.3 Ease of Installation, Maintenance and Repair

4.3.1 Ease of Installation



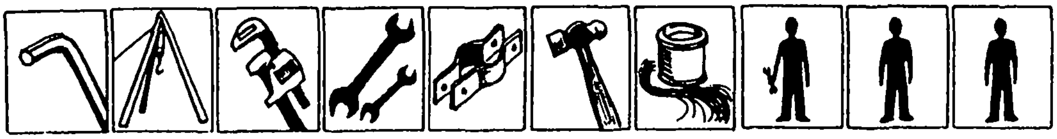
The hexagon keys were supplied with the samples. We understand that the pump is normally used with GI pipe for the rising main, in which case lifting tackle would certainly be required. In some installations, it may be necessary to cut and thread the pump rod.

4.3.2 Ease of Pumpstand Maintenance and Repair



A drift would be required to remove and replace the handle bearings.

4.3.3 Ease of Below-ground Maintenance and Repair



Frequent attention to the below-ground assembly is unlikely to be required. However, the leather cup seals will have to replaced when worn. This requires the entire below-ground assembly to be extracted from the well.

4.4 Resistance to Contamination and Abuse

4.4.1 Resistance to Contamination

Generally good - the pumpstand is more adequately sealed against contamination than many other pumps where the pump rod is exposed. However, care must be taken to seal the well head against surface water, and the spout design makes it easy to block the spout with the palm of the hand, with consequent risks of contamination.

4.4.2 Likely resistance to Abuse

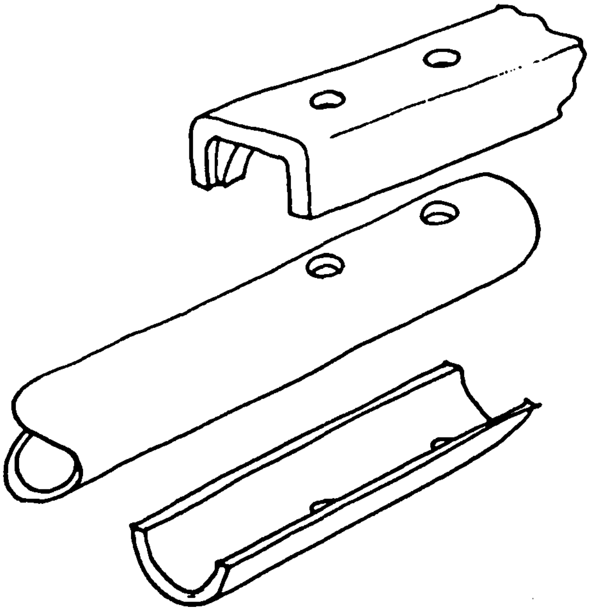
Poor - the handle is not strong enough, and broke in the bump stop test. The base of the fabricated steel pedestal is rather thin, and the pedestal distorted in the side impact test. See Abuse Tests, sections 8.1 and 8.2. The pumpstand castings are generally strong, though the brittle nature of cast iron might be susceptible to abuse.

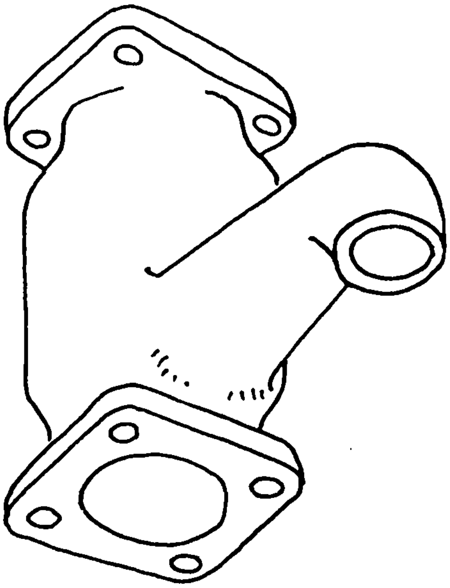
4.5 Potential Safety Hazards

There are a number of potential finger traps around the handle fulcrum components.

4.6 Suggested Design Improvements

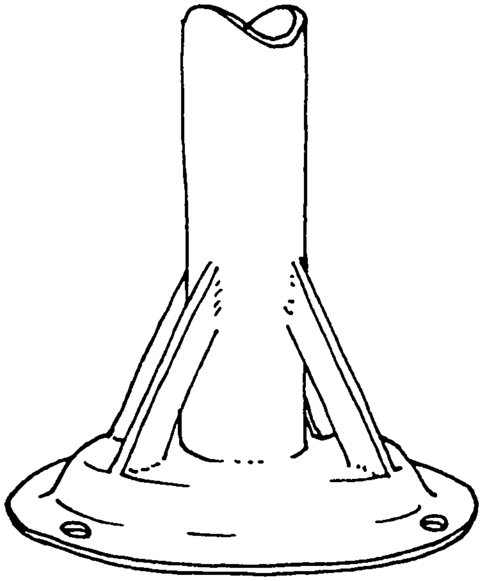
Handle: The handle should be stronger and the method of attachment to the pumpstand should be improved. At present, one fixing is located at the point of maximum bending stress. A rubber buffer on the bump stop would reduce the instantaneous stresses on impact. See sketch, right.



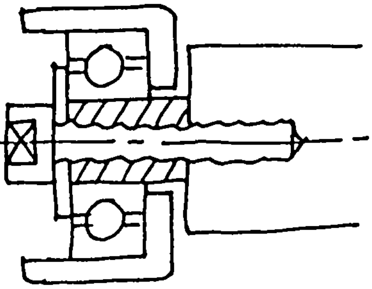


Pumpstand top: The fixing holes should be re-orientated as shown, so that all the setscrews can enter from above into four tapped holes in the pedestal. See sketch, left.

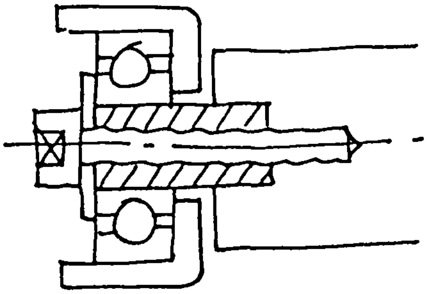
Pumpstand pedestal: The whole pedestal should be strengthened to prevent damage from accidental impacts or abuse. The strengthening ribs should be re-oriented to correspond with the positions of the baseplate fixings, and each rib should extend outwards to the corner of the pressing. See sketch, right.



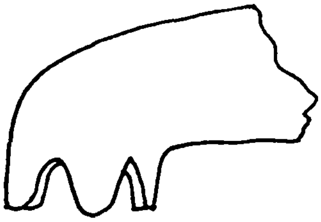
The existing bearing arrangement, see sketch (a), right, can impose high bending stresses on the retaining setscrew, particularly is the screw is insufficiently tight.

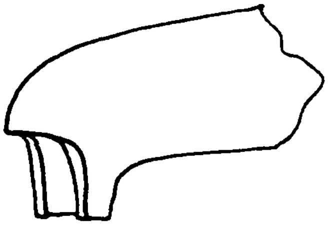

(a)

It would be better for the spacer tube to enter a counterbore, as shown in sketch (b), so that the setscrew is relieved of bending stresses.


(b)

Spout: The spout should be designed to prevent blockage by the palm of the hand. See sketches, below.





5. PUMP PERFORMANCE

5.1 Volume Flow, Work Input and Efficiency

The test method is described in the Test Procedure.

HEAD	7 metres			25 metres			45 metres		
Pumping Rate (cycles per min)	30	40	50	30	40	50	30	40	51
Volume/cycle (litres)	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Flow rate (l/min)	8.6	11.7	14.4	8.7	11.7	14.6	8.8	11.6	14.8
Work input/cycle (J)	37	37	41	87	99	108	144	143	136
Work rate (watts)	18	25	34	43	66	91	73	100	116
Efficiency (per cent)	54	54	49	82	72	66	89	90	94

5.2 Leakage Test

The foot valve on one sample was found to leak between the foot valve body and the lower end cap on the cylinder.

No leakage was observed from the second sample at heads of 7, 25 and 45 metres.

6. ENDURANCE

A detailed description of the endurance test method may be found in the Test Procedure.

General Comments

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

No failures occurred in the 4000 hour test. However, in the first 1000 hours of the test, the pumpstand tended to be noisy. Movement of the bearings in their housings allowed some metal-to-metal contact between the handle and the fulcrum link. The noise subsided after about 1000 hours. At the end of the test, the piston rod was found to be severely corroded immediately above the piston. Some handle bearings were loose in their housings.

Breakdown Incidence Failures are shown in bold type.

Hours:	2105	4194
Start	Inspection and Volume Flow Check	Final Inspection and Pump Performance Test

HOURS

2105 INSPECTION after 2000 HOURS

Pumpstand:	Some wear in pump rod guide bushes. Slight wear on pumpstand as a result of contact from fulcrum link caused by play in bearings.
Cylinder:	Some corrosion of pump rod adjacent to piston. Piston and footvalve in good condition.

4194 FINAL INSPECTION

Pumpstand:	Some handle bearings loose in their housings. Pump rod guide bushes in good condition.
Cylinder:	Severe corrosion of piston rod adjacent to piston. Bore slightly scratched but little wear. Piston and footvalve in good condition.

Estimated total amount of water pumped in 4000 hours... 2.8 million litres

	Volume Flow Tests at 45 m depth (litres/cycle)			Leakage Tests at 7 m (ml/min)
Cycles per minute	30	40	50	
New	0.29	0.29	0.29	None
After 2000 hours	0.28	0.29	0.29	None
After 4000 hours	0.29	0.29	0.29	None

7. PUMP PERFORMANCE after ENDURANCE

HEAD	7 metres			25 metres			45 metres		
Pumping Rate (cycles per min)	30	39	51	30	39	50	30	39	49
Volume/cycle (litres)	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Flow rate (l/min)	8.5	11.3	14.5	8.5	11.2	14.2	8.6	11.1	14.0
Work input/cycle (J)	45	49	49	112	123	126	152	154	175
Work rate (watts)	23	32	41	56	80	105	77	100	143
Efficiency (per cent)	43	40	40	63	57	56	83	82	72

Volume flow was unchanged after endurance testing, but the work input had increased, possibly as a result of increased friction at the cup seals, so that overall efficiency was reduced after endurance testing. Nevertheless, the efficiency at 45 metres depth remained over 70 per cent.

8. ABUSE TESTS

8.1 Impact Tests

This test was carried out after the handle shock test (see below). Using a stronger handle, with improved support at the point of attachment to the pumpstand, the pumpstand was undamaged by impacts to the centre of the pumpstand of up to 300 joules, and impacts to the handle of up to 150 joules.

After impacts of 400 and 500 joules on the body of the pumpstand, distortion of the baseplate and of pedestal tube was observed, so that the body of the pump was seen to be no longer vertical. The pump was still servicable, but out-of-alignment in the pump rods might accelerate wear in the pump rod guide bushes.

After an impact of 200 joules on the handle, the fork at the inner end of the handle was slightly bent. The handle was stiffer to operate but the pump was still servicable.

8.2 Handle Shock Test

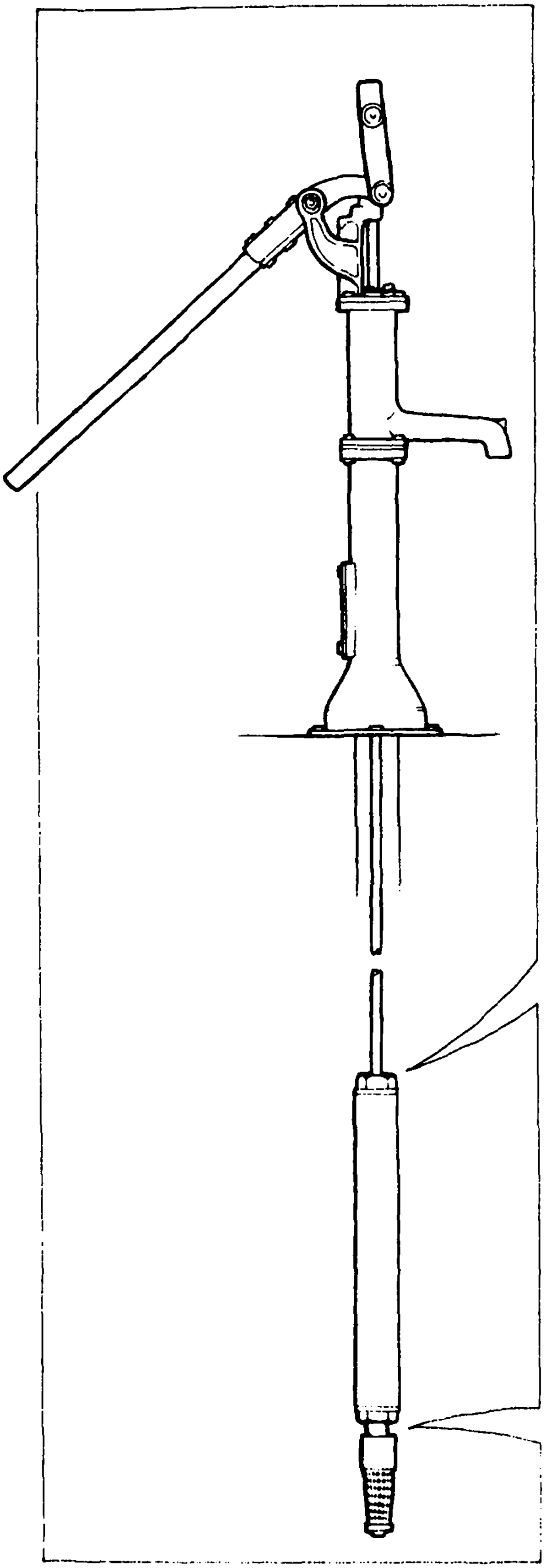
The handle broke at the point of attachment to the pumpstand after 2,519 cycles. The handle was replaced, and a supporting saddle was added (see Suggested Design Improvements, section 4.6). However, this second handle broke after a total of 7,848 cycles. In both bases, the origin of the fracture appeared to be the hole for the outer of the two fixing bolts.

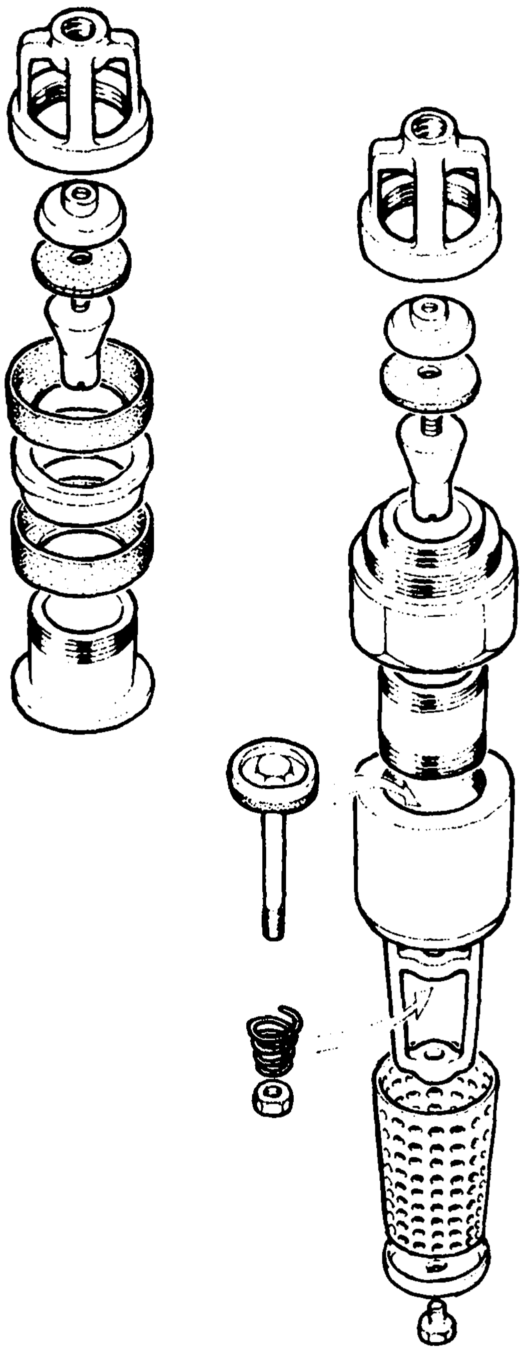
To test the strength of the cast iron components of the handle mechanism, a solid steel handle was fitted. In this condition, the pump completed the remainder of the allotted 96,000 cycles without failure.

9. VERDICT

The handle and pumpstand pedestal need to be strengthened, and the handle bearing arrangement could also be improved. In other respects the pump proved to be reliable with the 2 inch cylinder supplied with the test samples, though corrosion will be a problem in aggressive water. It was efficient and particularly easy to operate.

It is not suitable for manufacture in developing countries, and the pump meets few of the requirements for village level operation and maintenance.





MONARCH P3 HANDPUMP

1.1 Manufacturer

Monarch Industries Limited

Address

889 Erin Street
Winnipeg
Canada

1.2 Description

The Monarch handpump was tested by CATR in 1979/80 as one of twelve pumps tested on behalf of the Overseas Development Administration. Since then, the manufacturer has introduced a number of modifications to the pump.

The Monarch P3 is conventional in design and methods of manufacture. The pumpstand is cast iron, with an integral cast iron pedestal. The pump rod is constrained to move in a straight line, and the handle is attached via a swinging link. The handle bearings are sealed ball races. In the current version, the handle fulcrum shaft is supported at each side of the handle. In the earlier version, the fulcrum was much narrower, inside the handle. The earlier wooden handle has been replaced by steel, and the sintered bronze pump rod guide bushes by plastic mouldings.

The cylinder is conventional drawn brass tube, with a gunmetal piston and a foot valve incorporated in the lower cylinder end cap. A second gunmetal foot valve, with O-ring seal, is fitted below the cylinder. The piston is fitted with two leather cup seals. The cylinder bore of the samples tested for ODA was 2.5 inches; the current samples were supplied with 2.25 inch Clayton Mark cylinders.

1.3 Price

25 Feb. 1985

C$288, lots of 50 (US$206)
C$260, lots of 500 (US$186)

2. INSPECTION

2.1 Packaging

The two sample pumps supplied for testing, together with 24 metres of rising main and pump rod, were delivered in a single plywood packing case. The case was 3.05 metres long, and the consignment weighed 289 kg. Inside the packing case, individual components were protected by corrugated paper.

The packaging was considered very suitable for export, but less suitable for crude overland transportation. The packing case was difficult to manhandle and might be damaged by rough treatment.

2.2 Condition as Received

Some free movement was found in the handle pivot bearings in both samples. The trunnion at the top of the pump rod, by which the pump rod is attached to the handle link, was not square with respect to the pump rod in both samples. See also Engineering Assessment and Endurance.

2.3 Installation and Maintenance Information

Instructions for installation, operation and maintenance of the pump, in English, were received with the samples. A revised owner's manual, in English and French versions, was supplied subsequently. The manual was comprehensive and included several helpful drawings and photographs. The manual also included a useful checklist of common hand pump troubles and remedies.

The manual is an good example of its kind, but a simpler version, relying mainly on illustrations rather than text, would be more appropriate for use at local level in developing countries.

3. WEIGHTS and MEASURES

3.1 Weights

Pumpstand: 36.5 kg (including handle)
Cylinder: 4.9 kg
Rising Main (per m): 4.0 including couplings
Pump Rod (per m): 0.8 including couplings

3.2 Dimensions

Cylinder bore: 2.25 inch
Actual pump stroke: 143 mm
Nominal volume/stroke: 367 ml
Rising main size: 1.5 inch with NPT threads
Pump rod diameter: 7/16 inch
Outside diameter of below-ground assembly: 62 mm

3.3 Cylinder Bores

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

The surface roughness (R_a) was measured in three places in a direction parallel to the cylinder axis.

SAMPLE	CYLINDER BORE	ROUGHNESS AVERAGE (µm)			
		TEST 1	TEST 2	TEST 3	MEAN
1	Extruded brass	0.20	0.20	0.18	0.19
2	Extruded brass	0.20	0.20	0.20	0.20

Measured at 0.25 mm cut-off

3.4 Ergonomic Measurements

HANDLE HEIGHT MAX (mm)	HANDLE HEIGHT MIN (mm)	PLINTH HEIGHT (mm)	ANGULAR MOVEMENT of HANDLE (deg)	HANDLE LENGTH (mm)	VELOCITY RATIO of HANDLE	HEIGHT OF SPOUT (mm)
1000	280	[1]	73	845	5.9	595

[1] Supplied with integral pedestal - the pump does not require a plinth to be built up on the wellhead.

4. ENGINEERING ASSESSMENT

4.1 Materials of Construction

COMPONENT	MATERIAL(S)
Pumpstand	Cast iron
Handle	Standard steel water pipe
Bearings	Standard sealed ball races
Rising main	GI pipe, with NPT threads
Pump rod	7/16 inch steel, electro-galvanised
Cylinder barrel	Drawn brass tube
Piston	Cast gunmetal
Piston seals	Leather cups
Upper footvalve	Cast gunmetal with rubber valve face
Lower footvalve	Cast gunmetal with rubber O-ring seal

4.2 Manufacturing Techniques

The techniques required to manufacture the pump are listed below:

Above-ground	Iron foundry
Assembly	General machining

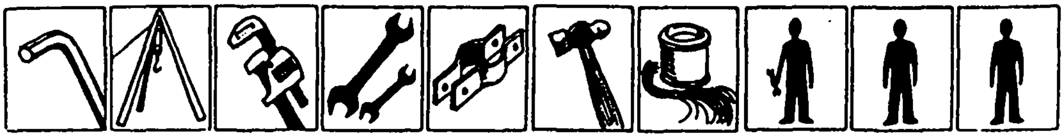
The bearing axes must be parallel to ensure smooth operation of the handle. On the samples supplied, it was noted that the trunnion attached to the top of the pump rod was not square with respect to the rod. Good quality control is essential to ensure accuracy in machining.

Below-ground	Gunmetal foundry
Assembly	General machining

In general, the requirement for foundry facilities in both iron and gunmetal, and the need for careful quality control in machining, would make the pump unsuitable for manufacture in developing countries.

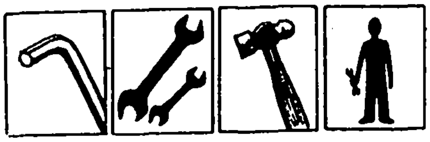
4.3 Ease of Installation, Maintenance and Repair

4.3.1 Ease of Installation



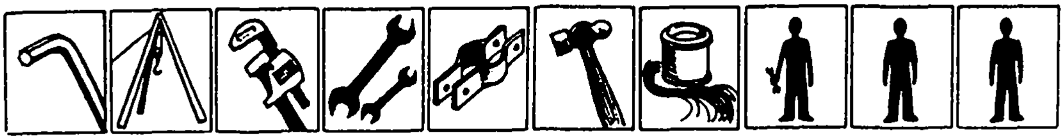
A comprehensive tool kit was supplied with the samples. Because GI pipe is used for the rising main, lifting tackle would certainly be required. In some installations, it may be necessary to cut and thread the pump rod.

4.3.2 Ease of Pumpstand Maintenance and Repair



A drift may be required to remove and replace the handle bearings.

4.3.3 Ease of Below-ground Maintenance and Repair



The use of two foot valves can give rise to unnecessary problems. If the upper foot valve breaks but the lower foot valve continues to function, broken parts are likely to damage the cylinder, piston and seals. To service the foot valve(s), or to replace worn leather cup seals, the entire below-ground assembly must be extracted from the well.

4.4 Resistance to Contamination and Abuse

4.4.1 Resistance to Contamination

Generally good - the pumpstand is more adequately sealed against contamination than many other pumps where the pump rod is exposed. However, care must be taken to seal the well head against ground water, and the spout design makes it easy to block the spout with the palm of the hand, with consequent risks of contamination.

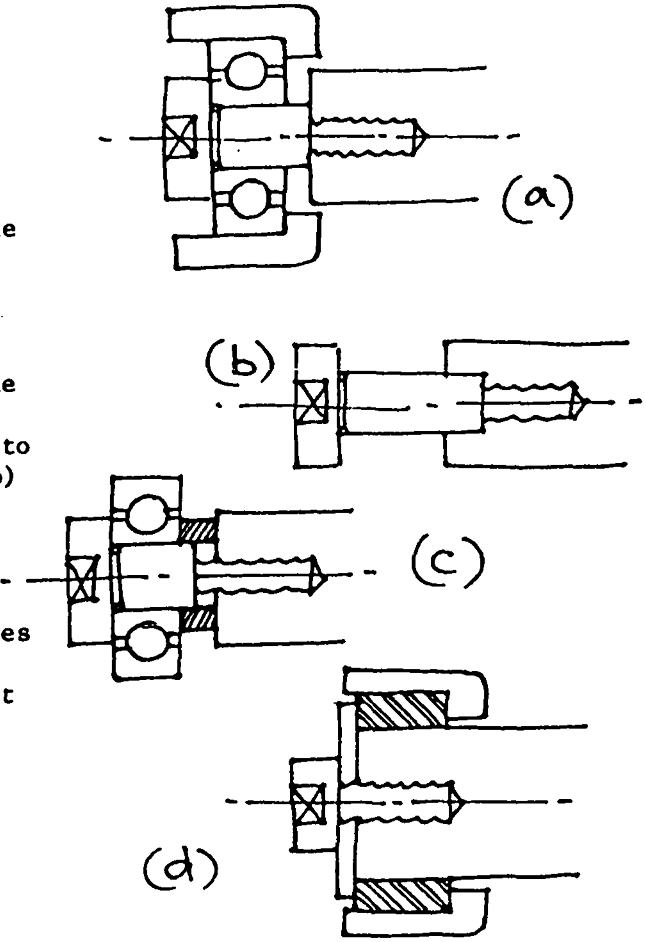
4.4.2 Likely resistance to Abuse

The steel handle is robust, and the current pump top and handle fulcrum are an improvement on the version tested for ODA. However, the cast iron pedestal is brittle, and further weakened by the inspection hole provided near the base. The pedestal broke in the side impact test. See Abuse Tests, section 8.1.

4.5 Potential Safety Hazards

There are a number of potential finger traps around the handle fulcrum components.

4.6 Suggested Design Improvements



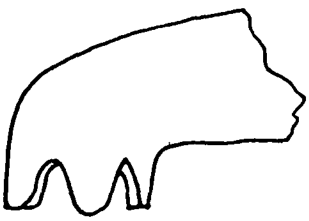
Shoulder Bolts and Handle Bearings: on the samples supplied for testing, the shoulder bolts were susceptible to breakage. The change of diameter between the plain and threaded portions corresponded to the point of maximum stress. See sketch (a), right. It would be better for the plain portion to enter a shallow counterbore, or for spacer tubes to be added, as shown in sketches (b) and (c). Of these, (b) would be the better solution.

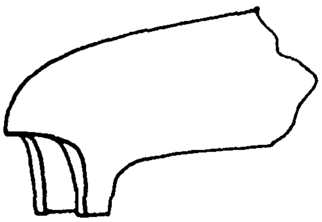
The manufacturer has since considered replacing the ball races with plain bearings in carbon impregnated, high molecular weight polyethylene, and samples of the modified components have been supplied for evaluation. This latest configuration is shown in sketch (d). The shoulder bolts have been eliminated.

Foot valve: the foot valve in the lower end cap of the cylinder should be omitted. The lower foot valve is of better quality. With two foot-valves, it is possible for the upper valve to break up while the lower foot valve continues to function. Fragments of the broken valve can cause severe damage to the piston and cylinder.

Piston: the diameter of the piston should be increased below the cup seals, reducing the clearance between the piston and the cylinder. This will improve the support for the cup seal, and reduce any tendency for the leather to extrude downwards between the piston and cylinder.

Spout: The spout should be designed to prevent blockage by the palm of the hand. See sketches, below.





5. PUMP PERFORMANCE

5.1 Volume Flow, Work Input and Efficiency

The test method is described in the Test Procedure.

HEAD	7 metres			25 metres			45 metres		
Pumping Rate (cycles per min)	30	40	50	30	41	51	30	40	50
Volume/cycle (litres)	0.35	0.35	0.35	0.35	0.36	0.35	0.35	0.35	0.35
Flow rate (l/min)	10.7	14.2	17.6	10.6	14.6	17.9	10.7	14.0	17.7
Work input/cycle (J)	67	64	58	130	134	135	199	207	215
Work rate (watts)	34	43	49	65	91	114	100	137	180
Efficiency (per cent)	36	37	41	67	66	64	78	76	72

5.2 Leakage Test

No significant leakage was observed from the lower footvalve at simulated heads of 7, 25 and 45 metres.

6. ENDURANCE

A detailed description of the endurance test method may be found in the Test Procedure.

General Comments

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

No failures occurred in the 4000 hour test. However, from the start of the test each cycle produced a knock from the handle linkage at the top of the pumpstand. This was caused by the out-of-alignment of the trunnion with respect to the pump rod, which caused sideways movement of the trunnion at each reversal of direction. The knocking gradually dimished during the test. The misalignment of the trunnion caused wear on one side of the pumprod guide bushes. In the final inspection, the handle bearings were found to be loose in the recesses in the castings, and the shoulder bolts were also loose. Some bearings had been rotating in their housings.

At the end of the test, the pump rod was severely corroded immediately above the piston. The iron nipple between the base of the cylinder and the lower footvalve was also severely corroded. The lower cup leather was split.

Breakdown Incidence   Failures are shown in **bold** type.

Hours:	2099	4207
Start	Inspection and Volume Flow Check	Final Inspection and Pump Performance Test

HOURS

2099 INSPECTION after 2000 HOURS

Pumpstand:	Some wear in pump rod guide bushes; knocking from misaligned trunnion reduced as a result.
Cylinder:	Some corrosion of piston rod adjacent to piston, and of nipple connecting lower foot valve to cylinder. Piston and both foot valves in good condition.

4207 FINAL INSPECTION

Pumpstand:	Handle and fulcrum link bearings loose in their housings: some bearings had been rotating in their housings. Wear on one side of pump rod guide bushes caused by misalignment of trunnion.
Cylinder:	Severe corrosion of piston rod adjacent to piston, and of iron nipple connecting lower foot valve to cylinder. Lower cup leather split, otherwise piston and both foot valves in good condition. Cylinder bore slightly scratched but no significant wear.

Estimated total amount of water pumped in 4000 hours... 3.3 million litres

	Volume Flow Tests at 45 m (litres/stroke)			Leakage Tests at 7 m (ml/min)
Cycles per minute	30	40	50	
New	0.35	0.35	0.35	None
After 2000 hours	0.36	0.36	0.36	None
After 4000 hours	0.31	0.32	0.32	None

7. PUMP PERFORMANCE after ENDURANCE

HEAD	7 metres			25 metres			45 metres		
Pumping Rate (cycles per min)	30	40	50	30	40	50	30	39	50
Volume/cycle (litres)	0.33	0.34	0.33	0.30	0.31	0.32	0.31	0.32	0.32
Flow rate (l/min)	9.8	13.0	16.8	9.0	12.6	16.0	9.1	12.5	16.0
Work input/cycle (J)	44	52	45	119	127	133	171	188	188
Work rate (watts)	22	30	43	60	85	112	85	124	157
Efficiency (per cent)	51	45	50	62	60	58	79	75	75

The work input requirement was reduced at all depths after endurance testing. At 25 and 45 metres depth, the volume flow was also reduced, so that overall pump efficiency was substantially unaffected. However, at 7 metres depth, the volume flow was only marginally reduced, with a consequent improvement in overall efficiency. These changes are likely to be attributable to wear of the cup leathers, particularly during the second phase when sand and Kieselguhr were present in the water.

8. Abuse Tests

8.1 Impact Tests

The pumpstand broke above the baseplate at an impact of 150 joules on the centre of the pumpstand. The normal maximum impact energy in this test is 500 joules. The fracture appeared to originate at the inspection hole.

Because of the breakage of the pumpstand, it was not possible to carry out the impact test on the handle.

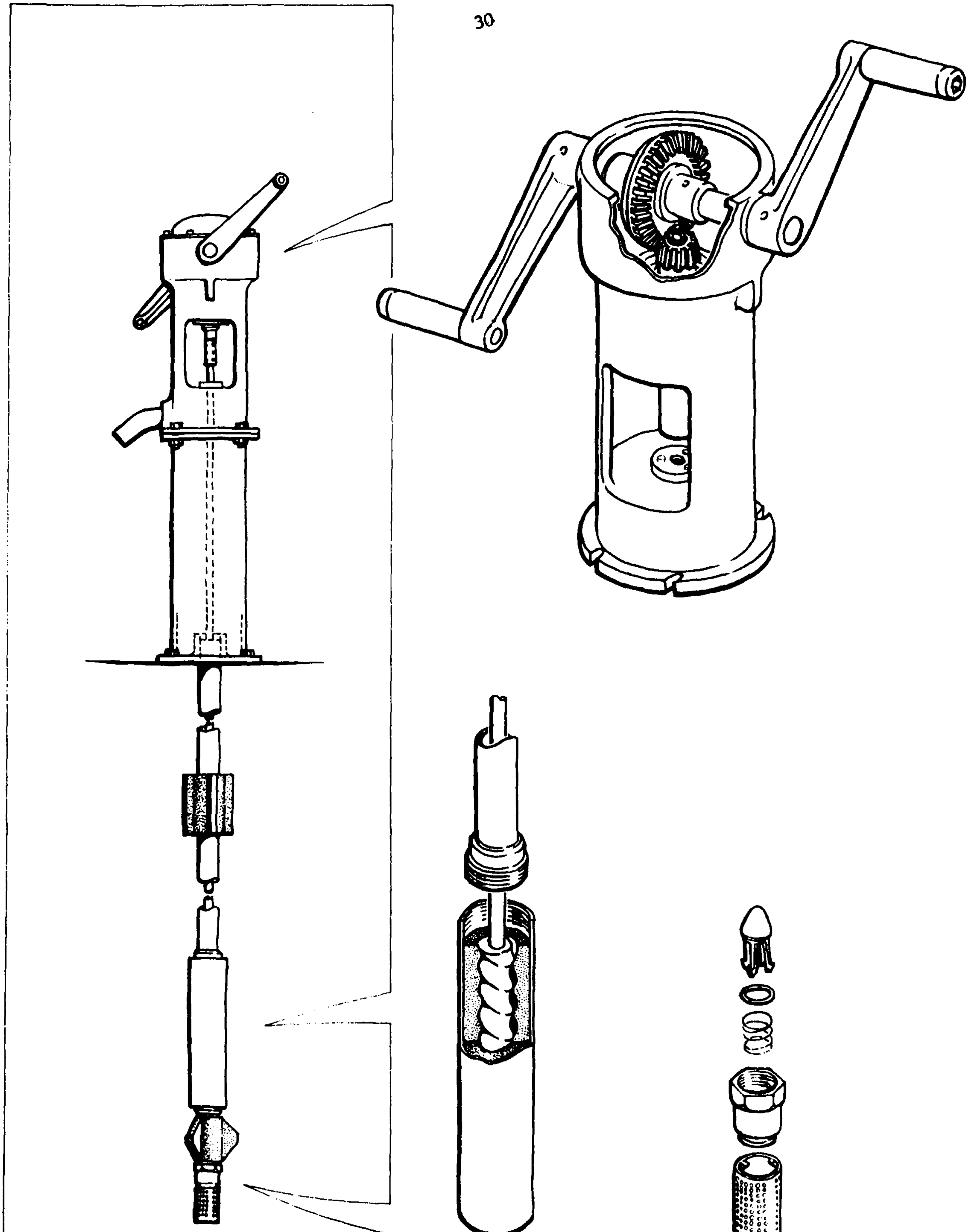
8.2 Handle Shock Test

The pump completed the allotted 96,000 cycles without failure.

9. VERDICT

The cast iron pumpstand pedestal is not strong enough to withstand accidental impacts or abuse. In other respects, the pump proved to be reliable with the 2.25 inch cylinder supplied with the test samples, though corrosion will be a problem in aggressive water. One footvalve would be sufficient. It was easier to operate at 45 metres depth than many other pumps.

It is not suitable for manufacture in developing countries, and meets few of the requirements for village level operation and maintenance.



MONOLIFT DW15/DW24

1.1 Manufacturer	Mono Pumps Limited
Address	Arnfield Works, Martin Street, Audenshaw, Manchester M34 5JA United Kingdom
1.2 Description	The Monolift handpump was previously tested in 1983/84. This report deals with inspection and measurement, performance tests and a user evaluation of a newer, 1984 production version of the pump. Although outwardly similar to the previous sample, the later pump had moulded thermoplastic drive gears with a choice of 3:1 or 2:1 ratios. Previously the pump was offered only with 3:1 gears. The 2:1 ratio is intended particularly for deep-well installations around 60 metres. The pumpstand column had been shortened; the hand grips had been lengthened from 125 to 160 mm, and they were fitted with rotating plastic sleeves. Below-ground, a new stator compound was intended to reduce the break-out torque of the rotor in the stator, thereby improving efficiency by reducing the efforts needed to operate the pump. The new compound also broadened the working temperature range. 'Socla' plastic foot valve was now fitted as standard.
1.3 Price 27 Feb. 85	£324 (US$353), lots of 50

1.4 Principal Materials

Pumpstand drive housing	Cast iron
Driving wheel	Moulded Nylatron
Pinion	Moulded acetal -
Pumpstand column	Fabricated steel
Handgrips	Moulded Nylatron
Bearings	Taper roller bearings
Pump rods	Steel, rolled threads
Rising main	Galvanised steel
Rotor	Stainless steel
Stator	Moulded elastomer
Foot valve	‘Socla’ (plastic)

1.5 Principal Weights

Pumpstand assembly:	52.3 kg
Pump cylinder assembly:	12.0 kg
Rising main (per metre):	4.5 kg
Pump rod (per metre):	1.0 kg

1.6 Ergonomic Measurements

HANDLE HEIGHT (mm)		PLINTH HEIGHT (mm)	HANDLE LENGTH (mm)	SPOUT HEIGHT (mm)
MAX	MIN			
1068	568	368	250	362

2. PUMP PERFORMANCE

Performance tests were carried out for both the 3:1 and 2:1 gear ratios in the pumpstand. For the 2:1 ratio, the performance test was extended to include a simulated depth of 60 metres.

2.1 Leakage

Leakage from the foot valve was tested at pressures corresponding to static heads of 7, 25 and 45 metres. No leakage was observed.

2.2 Volume Flow, Work Input and Efficiency

Water temperature 26 to 32°C throughout.

2.2.1 Drive Gear Ratio 3:1

HEAD	25 metres			45 metres		
Pumping Rate (revs/min)	30	40	50	30	40	50
Volume/rev (litres)	0.40	0.40	0.40	0.39	0.39	0.39
Flow rate (litres/min)	11.9	15.9	19.6	11.8	15.5	19.2
Work input/rev (joules)	212	202	202	267	286	287
Work rate (watts)	106	135	167	136	191	238
Efficiency (per cent)	46	48	48	64	59	59

2.2.2 Drive Gear Ratio 2:1

HEAD	25 metres				45 metres			60 metres		
Pumping Rate (revs per min)	21	30	40	50	30	40	50	31	40	51
Volume/rev (litres)	0.26	0.26	0.26	0.26	0.25	0.26	0.26	0.23	0.23	0.24
Flow rate (l/min)	5.4	8.0	10.5	13.1	7.7	10.4	13.1	7.1	9.3	12.2
Work input/rev (J)	140	121	134	124	191	188	178	221	209	216
Work rate (watts)	48	61	90	102	96	125	149	113	141	185
Efficiency (per cent)	46	53	48	52	59	61	65	62	65	65

2.3 Pump Performance Evaluation

The availability of alternative 3:1 and 2:1 drive ratios has effectively extended the working range of the Monolift handpump. Combined with the latest rotor/stator assembly, the current results indicate equivalent or better pump performance than earlier tests.

In the earlier pump, with 3:1 drive gears, the volume delivered was approximately 0.33 litres per stroke, with an average efficiency of 55 per cent at 45 metres depth. In the current pump, with 3:1 gears the volume delivered was greater than before at approximately 0.39 litres per stroke, with an average efficiency of 61 per cent at 45 metres depth.

With 2:1 drive gears, the volume delivered was approximately 0.25 litres per stroke, with an average efficiency of 62 per cent at 45 metres depth and 64 per cent at 60 meters. The work input per stroke at 60 metres was less than that of the earlier pump at 45 metres.

3. USER ASSESSMENT

3.1 Results of User Trial

USER	AGE (yrs)	WEIGHT (kg)	No.OF REVS. [1]	TIME (sec) [1]
Child	9	27	39	51
Child	9	29	40	46
Child	12	40	39	39
Child	12	42	40	27
Woman	Adult	51	40	41
Woman	Adult	60	42	47
Man	Adult	95	39	29

[1] To fill a 10 litre container

3.2 Observations

Adults:	All the adults were able to fill the 10 litre container without difficulty. Adults seemed noticeably more comfortable using the pump with the new, shorter pedestal, compared to the previous design. The operating efforts were substantially lower for the 2:1 ratio at 60 metres depth than for the 3:1 ratio at 45 metres depth.

Children: Previous user tests were carried out with 3:1 drive gears, and all the children found the pump with 2:1 gears easier to use than before. For children, the reduction in effort by fitting 2:1 drive gears seemed to offer a greater contribution than the lower pedestal to making the pump easier to use. Nevertheless, children seemed more comfortable with the handles at the lower height. Although the longer hand grips should make the pump easier to operate than before with both hands on one side, users preferred to operate the pump with one hand on each handle. The smaller children had to rock from side to side to keep one hand on each handle, but all preferred this method to using both hands on one handle.

4. Design Comments

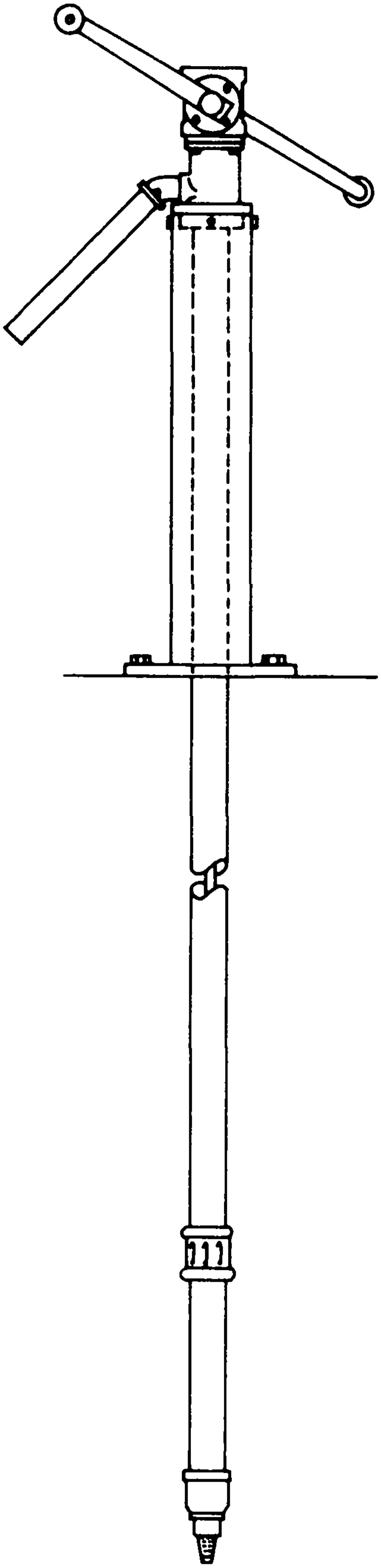
The moulded plastic gears and the proprietary plastic foot valve represent improvements on earlier designs. However, it remains a difficult pump to maintain and repair because of the considerable weight of the below-ground assembly and the necessity to replace rather than service the pumping element when the need arises.

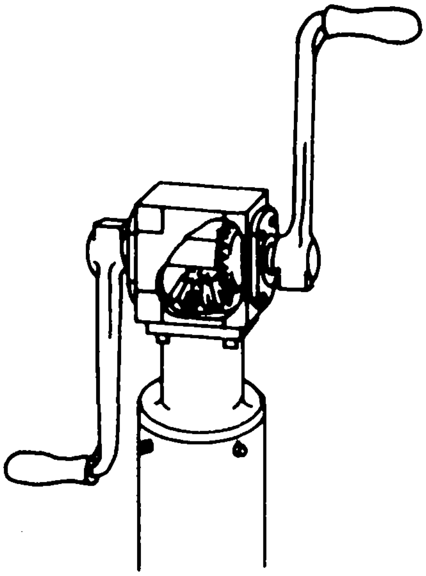
5. Reliability

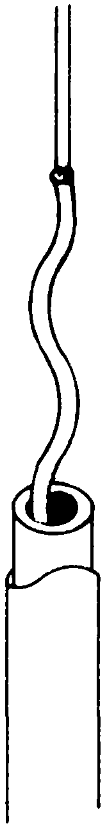
The previously tested model of the Monolift pump proved to be reliable in an endurance test: there is no reason to suppose that the latest version will be less reliable at 45 metres depth. However, if the pump is used at 60 metres depth, the stresses on the pumping element, the pump rods, rising main and their couplings will be substantially greater, with a consequent higher risk of failure. However, it should be noted that the rolled threads used by Mono for the pump rods will be stronger and more reliable than the cut threads found on the majority of handpumps.

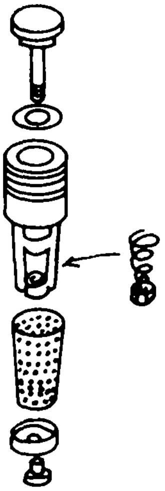
6. VERDICT

The Monolift handpump continues to be a robust handpump, potentially suitable for community water supply in developing countries, suited for depths of 20 to 45 metres. The provision of alternative 2:1 drive gears extends the working range of the pump to depths beyond 45 metres. The modifications introduced since the previous model was tested make the pump more suitable than before for operation by children. The pump is not suitable for manufacture in developing countries, nor for village-level ~~maintenance and repair. The new version~~ is likely to be as reliable at 45 m pumping lift as the previously tested model. In the absence of endurance tests at 60 m pumping lift, no recommendations can be made on the pump's reliability at that depth.









MOYNO HANDPUMP

1.1 Manufacturer

Robbins & Myers Canada, Ltd.

Address

P.O. Box 280
Brantford, Ontario N3T 5N6
Canada

1.2 Description

This was not a full test of the Moyno pump, because such testing had already been done on an earlier model of this pump. The purpose of this engineering assessment was to examine differences between this Canadian manufactured Moyno pump and the U.S.-made samples which were tested in 1981-1982*

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

2. INSPECTION

The pumps and their packaging were inspected for damage in transit. The pumps were found to be in good working order.

3. ENGINEERING ASSESSMENT

In a telex from Robbins and Myers (Canada) Ltd., dated 18 June 1984, a number of modifications were outlined. The stated modifications have now been confirmed by the CATR laboratory. The telex stated the following:

"Observed change in pump rotation is correct for reasons cited. Change was made in early 1981. U.S. supplied pumps also reflect change. All

* The earlier test report was presented in World Bank/UNDP Handpumps Project Report No. 3 (World Bank Technical Paper No. 19), pages 112-121.

engineering and quality control now controlled by myself from Canada. All units ship from Canada unless U.S.A.I.D. orders. Significant upgrading program in progress during past year. Changes include:

- New foot valve: No corrosion, better design.
- Eliminate rubber thrust: New reducer w/cast in place tooling just approved. Sample available if you desire.
- Shorter rotor: Eliminate welded coupling, wench flats on bottom of rotor allow removal of rotor from shaft.
- "This end up" label on stator: From CA Lab Testing.
- Flex rod 7/16 inch with 1/2-inch rolled threads: Improved fatigue resistance.
- Zinc dichromate pump rod plating: Allows corrosion protection over threaded ends.
- Gearbox/disch housing bolts lengthened by 1/4 inch: Gearbox casting modified to accept longer bolts.
- Clutch relocated to inside of gearbox between bearings: Assured lubrication and alignment, 66 percent larger capacity.
- Gearbox sealed to prevent unsightly grease leakage.
- Heavier rings on X shaft to prevent handle movement.
- Rust inhibitor on all unfinished steel.

Unit supplied to CA has 4 inch shorter pump stand. Presently investigating easier operation w/lower height."

3.1 New Foot Valve

The French "Socla" plastic foot valve, fitted to the latest sample, has been tested by us on other pumps and found to be satisfactory. In response to our request, Robbins and Myers subsequently supplied a sample of the latest reducer to which Mr. Lee referred in his telex. This was satisfactory, and has enabled the rubber buffer present on the US-made sample to be eliminated.

3.2 Shorter Rotor

We noted that the latest rotor was approximately 2.5 inches longer than the moulded elastomeric stator. To maintain full contact between the rotor and the stator, the overall length of the pump rod must therefore be maintained within this distance. When assembled to the gearbox, the end of the pump rod will be approximately 2 inches above the top face of the bushing used to couple the rising main to the gearbox assembly. However, the instructions state that it is permissable for the end of the rod to be up to 1.5 inches below the top face of the bushing prior to assembly. It this is the case, the rod will be raised a total of 3.5 inches on assembly, so that bottom of the rotor will be 1 inch above the bottom of the elastomeric stator; i.e. 1 inch of the stator will not be used. This may lead to some loss of efficiency and more importantly to uneven wear of the stator.

The instructions we received had been revised with an additional section to take account of the fact that pump assemblies are now preferably supplied with rods and pipes in matches pairs, to eliminate the need to cut and thread the pump rod during installation. This is to be welcomed, but the interim revision to the instructions could, with great advantage, be made more clear, and we trust careful consideration will be given to this when the instructions are finalized. We understand that new instructions have been drafted by the manufacturer, with an emphasis on illustration rather than description.

3.3 Stator Label

A "this end up" label was fixed to the stator. This would be helpful, but it would be better if the stator were symmetrical end-to-end, which might be achieved by extending the upper end of the stator barrel to make it identical to the lower end. The resultant increase in the overall length of the stator could be compensated by shortening the 2-inch pipe attached immediately above the pumping element assembly.

3.4 Pump Rods

Confirmed at 7/16ths-inch diameter, with rolled 1/2 inch x 13 NC left hand threads, zinc plated after threading. Rolled threads are preferred to cut threads, because of better fatigue resistance.

3.5 Gearbox

The non-return clutch was fitted between the bearings on the gearbox output shaft, which is an improvement on the earlier US-made samples. The fixing bolts had been lengthened to accommodate the increased thickness of the bearing housing. Although not present on the sample supplied, we understand that a roll-pin is now fitted as dowel to resist rotation of the gearbox with respect to the bearing housing, thereby ensuring that the fixing bolts are not subject to shearing forces.

Heavier rings had been fitted to the handle cross-shaft.

3.6 Pumpstand Height

The handle height has been reduced by about 4 inches by shortening the fabricated steel pedestal. It is considered that this will make the pump easier for children and small women to use.

4. CONCLUSION

The US-made Moyno pump completed the earlier endurance test with few signs of wear. The only failure was caused by movement of the rubber buffer below the rotor. The rubber buffer has been eliminated in the Canadian-made samples, however. We understand from the manufacturer that the material used for the current rotor is of equivalent quality to the US-made sample we tested, and therefore it is unlikely that significantly different results would be obtained if the sample supplied were endurance tested.

The performance of the US-made pump was affected by high friction between the rotor and stator. Changing from a right-hand to left-hand helix must have required a new mould for the stator. This might affect the interference between the rotor and stator, and thereby the performance of the pump. However, the rotor was a very tight fit in the stator of the sample supplied, and compares with the initial tightness of the US-made pump. It is therefore unlikely that significantly different results would be obtained from a performance test of the sample supplied.

We consider that the differences between the original US-made Moyno pump and the Canadian sample supplied are unlikely to affect pump performance, and can only have a beneficial effect on endurance. However, we are concerned that the possibility exists to install the pump without full contact between the rotor and the stator, producing uneven wear.

More significantly, our discussion with the manufacturer suggests that the sample supplied may not be representative of current production. In particular, we understand that the manufacturer has made recent modifications to reduce the torque between the rotor and stator. This is likely to have an important effect on pump performance, and also on endurance.

Measurements of the crest-to-crest diameter of the rotor supplied varied from 35.48 to 35.50 mm, with a mean of 39.49 mm (1.555 inches)

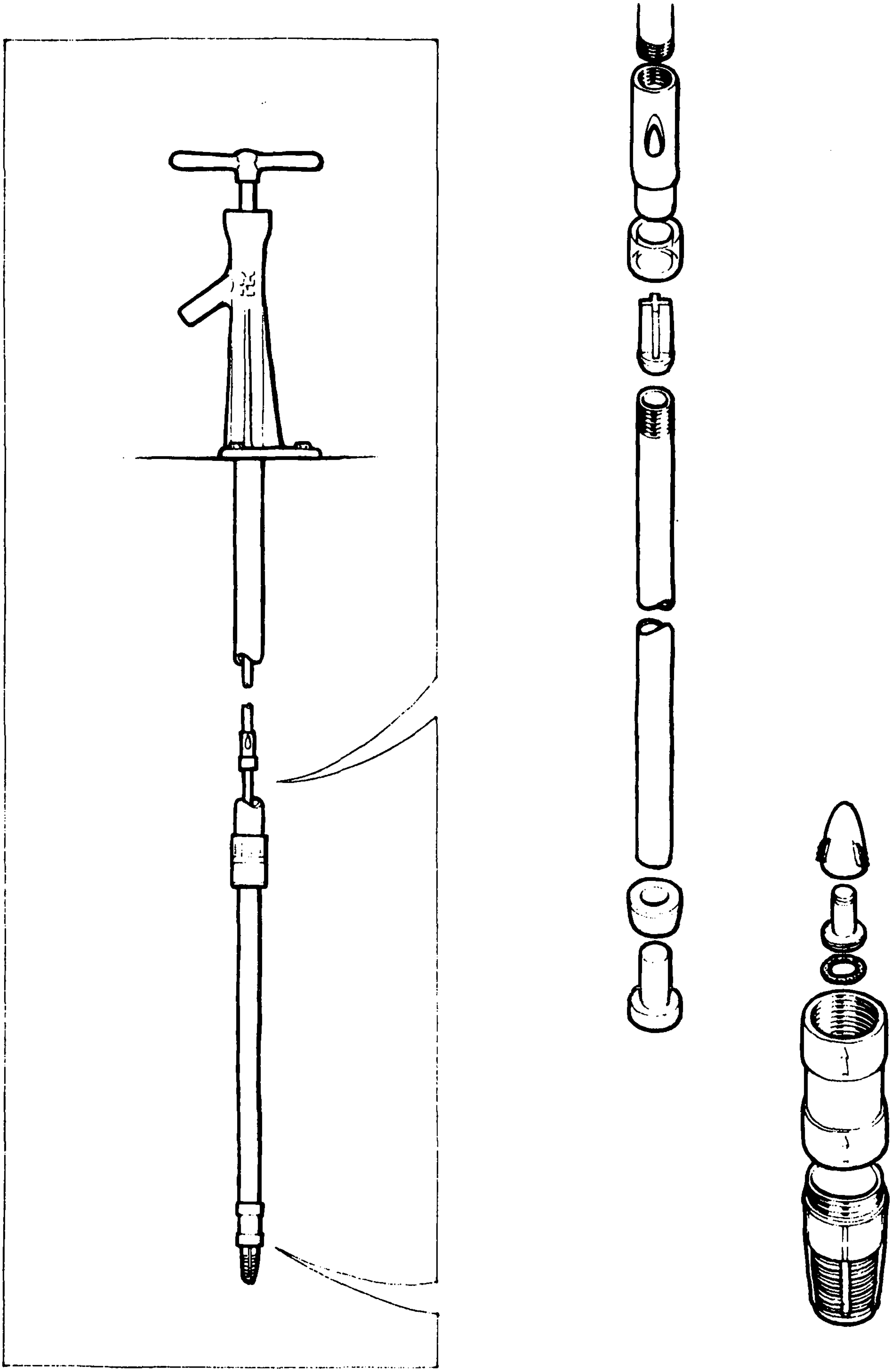
5. RECOMMENDATIONS

We recommend that the manufacturer should check that the method of assembly and the installation instructions will ensure that contact is maintained over the full length of the stator. We also recommend that the instructions should be clarified and simplified. The manufacturer might also consider modifying the stator housing so that it will not matter which way up it is assembled.

If the torque between the rotor and stator has been reduced, then the effect on performance and endurance could be evaluated by laboratory tests. In particular, it would be valuable to test the pump at depths below 45 meters, which could be simulated in the pump testing tower, since field results indicate that US-made pumps may have problems at deep water levels.

6. VERDICT

This was not a full test of the Moyno pump, because such testing had already been done on a U.S.-made model in 1981-82. The differences between the original U.S.-made Moyno pump and the Canadian sample are unlikely to affect pump performance, and can only have a beneficial effect on endurance. The verdict from the 1981-82 tests still applies as follows: A robust pump, in good condition after 4000 hours of endurance testing. The rate of delivery was low, and the pump was hard work to operate at first, though it became slightly less hard with further use. Although generally reliable in these tests, any repairs needed in the field will be difficult and expensive. It may not be ideal for community water supply because of the difficulties of operation and low rate of delivery. Expensive.



PEK HANDPUMP

1.1 **Manufacturer**

Produits pour l'Exhaure de l'Eau Kaine Ltée

Address

1106 Claire Crescent
Lachine, Quebec
H8S 1A1, Canada

1.2 **Description**

The Pek is a direct action force pump, made in Canada. The test sample was a Model P, with cylinder bore of 28 mm designed for a maximum of 25 metres depth. Other variants are available: the Model G with a cylinder bore of 19 mm designed for a maximum depth of 50 metres, and a model with a cylinder of 2.5 inch nominal diameter, for use at 10 metres maximum depth.

The design makes extensive use of polyurethane, a tough, wear-resistant thermoplastic. The pumpstand is cast from polyurethane, and the handle is made from the same material, with an internal steel former. The handle guide bush, the piston seal, the piston valve and the pumprod couplings and guides are also polyurethane. The hollow pump rods are aluminium alloy tube, with the connectors cast on each end. The cylinder barrel is made from stainless steel tube. The footvalve is a proprietary item, made mostly of plastic. The test samples were supplied with "Brady" foot valves, but these have since been superceded by valves made by "Flowmatic" of the USA. The rising main supplied with the test samples was polyethylene tubing in coiled form, but the manufacturer now supplies polypropylene pipe in 3 metre sections, with threaded couplings.

The polyurethane pumpstand flexes in use, in reaction to the out-of-line forces that users tend to apply to direct action pumps.

1.3 **Price (Feb.85)**

US$ 465.00 each, for 50 pumps, complete for installation to 30 metres depth

2. INSPECTION

2.1 Packaging

The pumpstands, cylinders, tools and spares were supplied in a heavy-duty cardboard carton. The rising main was supplied in a coil. The pump rods were bound in a bundle with protection for the ends.
The packaging was considered to be suitable for export and for crude overland transportation. The consignment was light and very easy to man-handle.

2.2 Condition as Received

All the components were received in good working order.

2.3 Installation and Maintenance Information

Instructions for installation, operation and maintenance were supplied, in English, in a booklet. The installation instructions were comprehensive and adequately illustrated by photographs. The schematic drawing of the pump did not accurately represent the cylinders supplied for testing, however.

The instructions for operation and maintenance were very brief.

3. WEIGHTS and MEASURES

3.1 Weights

Pumpstand:	2.8 kg including handle
Cylinder:	2.0 kg
Rising main (per m):	0.4 kg
Pump rod (per m):	0.2 kg

3.2 Dimensions

Nominal cylinder bore:	28 mm
Actual pump stroke:	350 mm
Nominal volume/cycle:	216 ml
Rising main size:	32 mm (1.25 inch)
Pump rod diameter:	19 mm O/D tube
Maximum diameter of below-ground assembly:	55 mm

3.3 Cylinder Bores

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

The surface roughness (R_a) was measured in three planes in a direction parallel to the cylinder axis.

SAMPLE	CYLINDER BORE	ROUGHNESS AVERAGE (R_a)			
		TEST 1	TEST 2	TEST 3	MEAN
1	Stainless steel tube	0.20	0.23	0.24	0.22
2	Stainless steel tube	0.30	0.36	0.32	0.33

Measured at 0.25 mm cut-off

3.4 Ergonomic Measurements

HANDLE HEIGHT		PLINTH HEIGHT (mm)	HEIGHT of SPOUT (mm)
MAX. (mm)	MIN. (mm)		
980	630	[1]	335

[1] The manufacturer's manual does not envisage that a plinth will be required. However, in view of the relatively low spout, some user communities may require a plinth to achieve sufficient clearance under the spout for larger water containers.

4. ENGINEERING ASSESSMENT

4.1 Materials of Construction

COMPONENT	MATERIAL(S)
Pumpstand body	Polyurethane
Handle	Polyurethane on steel former
Handle bush	Polyurethane
Rising main	Polyethylene [1]
Pump rod	Aluminium alloy tube polyurethane connectors
Cylinder body	Stainless steel tube
Piston	Aluminium alloy
Piston seal	Polyurethane

[1] the test samples were supplied with polyethylene rising main in a coil. However, the manufacturer now supplies pumps with polypropylene rising main in 3 metre sections, with thermally-formed threads.

4.2 Manufacturing Techniques

The manufacturing techniques required to make the pump are listed below:

Above-ground Assembly	Casting in polyurethane Simple steel fabrication

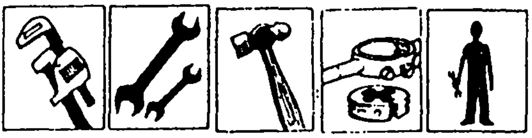
Manufacture of the pumpstand required complex moulding tools, experience in the use of polyurethane and generous supplies of raw material. It is therefore unlikely to be suitable for manufacture in the majority of developing countries.

Below-ground Assembly	Casting in polyurethane Turning, threading etc.

Like the pumpstand, manufacture of the polyurethane components may be difficult in developing countries.

4.3 Ease of Installation, Maintenance and Repair

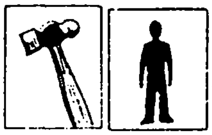
4.3.1 Ease of Installation



The lightness of the complete pump assembly makes it very easy to install. The pump can be assembled with few tools. A special spanner was supplied to tighten the handle guide bush, together with a pipe threading die for the rising main, a chain wrench and an adjustable spanner. The only other tool which was required was a knife or saw to cut the rising main to length.

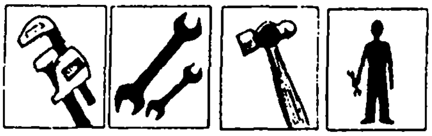
Pumps are now supplied with polypropylene rising main in 3 metre sections, with threads thermally formed at each end to fit simple, moulded couplings. With polypropylene rising main, therefore, there will be no need for a die to thread the pipe.

4.3.2 Ease of Pumpstand Maintenance and Repair



Very little maintenance is likely to be required on the pumpstand. The handle bush may be tightened using the special spanner supplied to compensate for initial wear. In the longer term, the bush may need to be replaced, but this is a simple operation. No lubrication is required.

4.3.3 Ease of Below-ground Maintenance and Repair



The below-ground assembly is light and therefore particularly easy to extract for maintenance or repair. "Brady" footvalves are likely to be unreliable due to breakage of the valve spring. The piston seal will require regular replacement as a result of wear.

4.4 Resistance to Contamination and Abuse

4.4.1 Resistance to Contamination

Considerable care is needed to ensure an adequate seal against ground water at the well head. There is some risk of contamination through the handle guide bush once wear has enlarged the central hole.

4.4.2 Likely Resistance to Abuse

There are no exposed fastenings other than those by which the pumpstand is attached to the well head. However, it would be relatively easy to push sticks and stones into the spout, with consequent risks of damage to the below-ground parts of the pump. In the longer term, the flexing of the pumpstand which tends to occur in normal use may give rise to fatigue failure of the polyurethane. The impact resistance of the pumpstand was good -- see 7.1.

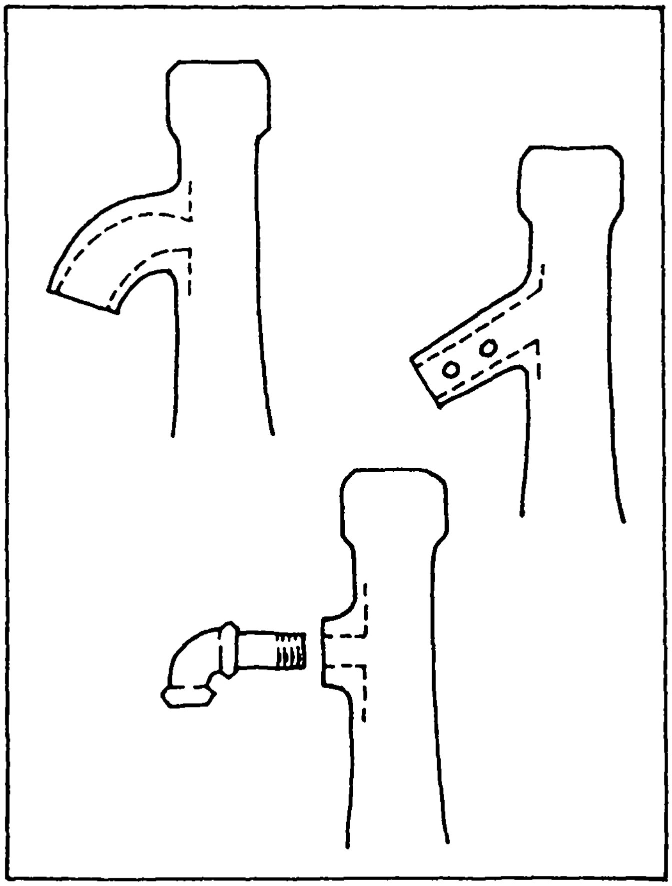
4.5 Potential Safety Hazards

There might be a potential finger trap between the handle and the guide bush on the top of the pumpstand. However, since this is in full view of the pump operator, and there is no mechanical advantage, this is unlikely to present a hazard.

4.6 Suggested Design Improvements

Spout: The current design makes it easy for children to push sticks and stones into the spout, with consequent risks of contamination and of damage to the below-ground parts. A curved spout would alleviate this problem, and could be moulded if the curve was designed for the core to be withdrawn. Alternatively, a rod or a number of rods could be inserted across the spout, or a threaded boss could be provided on the pumpstand, to accept a separate spout. A separate spout would have the disadvantage that it could be easily removed, however.

See sketches, right.



Pump Rods: The pump rods supplied with the test samples were found to be susceptible to leakage at the end connections and as a result of corrosion of the aluminium alloy. To prevent the pump rods filling with water, it may be possible to fill the pump rods with a closed-cell polymer foam.

Footvalve: The springs in the "Brady" footvalves supplied with the test samples were unreliable. The "Socla" footvalve has proved to be reliable with other pumps. The manufacturer now supplies pumps with "Flowmatic" footvalves, which are similar in design to the "Socla".

Plinth: Some user communities may prefer the pump to be mounted on a plinth, to provide sufficient clearance under the spout for larger water containers. If suitably designed, a plinth might have a further benefit of minimising the risks of contamination by surface water.

5. PUMP PERFORMANCE

5.1 Volume Flow, Work Input and Efficiency

Pump performance was measured in a borehole, for water depths of 15 metres and 25 metres. At 15 metres water depth, measurements were made at cylinder depths of 20 metres and 30 metres. At 25 metres water depth, the cylinder was installed at 30 metres depth.

HEAD	15 metres						25 metres		
CYLINDER DEPTH	20 metres			30 metres			30 metres		
Pumping Rate (cycles/min)	30	40	51	30	41	50	30	40	51
Volume per cycle (litres)	0.19	0.20	0.20	0.20	0.20	0.21	0.20	0.20	0.20
Flow Rate (litres/min)	5.8	7.8	9.9	5.9	8.3	10.3	5.9	7.8	10.3
Work input per cycle (J)	62	59	57	67	66	65	83	80	80
Work Rate (W)	31	39	48	34	45	54	41	53	68
Efficiency (per cent)	46	49	50	43	45	47	57	59	61

When the performance tests had been completed and the pump was removed from the borehole, one of the end connectors of one rod was found to have leaked so that the rod contained a small quantity of water.

5.2 Footvalve Leakage Test

No leakage was observed from the footvalve for heads of 7, 25 and 45 metres.

6. NOTE ON USER TEST

A user test may form part of the CATR handpump test programme, using the pump installed in the tower and a simulated depth of 20 metres. Special arrangements were made to simulate the effect of the lightweight pump rods in the Pek pump for the endurance test at 25 metres depth. However, it was not possible to set up operating conditions in the pump installed in the tower which would be realistic for the wide range of speeds and modes of operation that are involved in a user test.

7. ENDURANCE

The pump was tested at 40 cycles per minute at a simulated head of 25 metres. A head simulation valve is normally used to simulate at the piston the pumping pressure appropriate to operation at the chosen depth. However, for this direct action pump, it was necessary also to simulate the effect of an appropriate length of hollow pump rods, since these are of relatively low mass and high displacement. An adjustable device was installed between the cylinder and the head simulation valve to increase the compressive force on the downward part of the pumping cycle, and the head simulation valve was adjusted to reduce the upward operating force. Both devices were adjusted simultaneously to achieve operating forces and work rates equivalent to those obtained in the performance tests where the pump was installed in a borehole.

The mechanical drive was set up to simulate the out-of-line forces typically applied by users when operating the pump. An examination of several users indicated that most people pulled the pump handle about 30 mm from the centreline of movement during the pumping cycle. This offset was reproduced in the mechanical drive.

General Comments

Relatively little wear was observed in the handle bush, despite the out-of-line arrangement described above. There was no appreciable wear of the pump handle.

The "Brady" footvalves supplied with the test samples proved to be unreliable. At the routine inspection after 2000 hours, the spring in the footvalve was corroded and had broken into several fragments. The valve continued to function, however, and the pump had not failed. The replacement spring failed after about 600 hours, however, and this time lodged the valve open, causing the pump to fail. The pump failed again when the second replacement spring broke after a further 600 hours. The "Brady" valve was replaced by a "Socla" valve of similar size. PEK now supply pumps with a "Flowmatic" footvalve which is similar in design to the "Socla".

At the end of the endurance test, the pump rods were found to contain water. The principal leaks were at the ends of the rods, where the moulded connectors were attached, but there was also evidence of leaks associated with corrosion pits in the aluminium rods. In real installations, leaky rods which fill with water will dramatically change the characteristics of the pump, increasing the force required on the upward part of the pumping cycle.

After 2000 hours, volume flow was only slightly reduced, indicating little wear of the piston seal. At the end of the second phase, however, during which sand and Kieselguhr were present in the water, the piston seal was virtually worn out, so that the volumes delivered were very much reduced.

Breakdown Incidence

Breakdowns are shown in **bold** type

Hours:	2089	**2687**	**3274**	**4170**
Inspection and full performance test	Inspection and volume flow check	**Foot valve lodged open by broken spring**	**Foot valve lodged open by broken spring: "Socla" valve fitted**	Inspection and full performance test **Piston seal almost worn out** **Pump rods leaking**

Details of the Endurance Test

Breakdowns are shown in **bold** type

2089 Inspection after first 2000 hour stage:

(a) Footvalve spring corroded and broken into several fragments, though valve still working - replaced by spring from second sample
(b) Some localised corrosion on aluminium pump rods
(c) Slight wear on piston valve seat
(d) Slight wear on handle bush in pumpstand

2687 Foot valve lodged open by broken spring - pump failed - new spring fitted

Estimated amount of water pumped to failure... 1.3 million litres

3274 Foot valve lodged open by broken spring - pump failed - "Socla" foot valve fitted

Estimated additional amount of water pumped to failure... 0.3 million litres

4170 FINAL INSPECTION:

(a) Piston seal virtually worn out - volume flow very much reduced
(b) All pump rods contain water - leaking at ends and corrosion pits
(c) Cylinder bore in good condition - polished in working portion
(d) Considerable wear of handle guide bush, but still serviceable
(e) Pumpstand cracked below spout and in thread at base

Estimated total amount of water pumped in 4000 hours... 1.9 million litres

	Volume flow at 25 m (litres/cycle)			Leakage at 25 m (ml/min)
Approx. cycles/minute	30	40	50	
New	0.20	0.20	0.20	n/s
After 2000 hrs	0.18	0.19	0.19	n/s
After 4000 hrs	0.03	0.07	0.11	n/s

n/s = not significant: less than 0.1 ml per minute

Pump Performance after Endurance Test

HEAD	25 metres				
CYLINDER DEPTH	30 metres				
Pumping Rate (cycles/min)	21	30	40	52	61
Volume per cycle (litres)	less than 0.01	0.03	0.07	0.11	0.11
Flow Rate (litres/min)	—	0.9	2.9	5.9	6.9
Work input per cycle (J)	—	129	133	149	168
Work Rate (W)	—	64	88	129	171
Efficiency (per cent)	—	6	13	19	17

These results illustrate the effect of wear on the piston seal. The volumes delivered by the pump, and hence the efficiency, were substantially reduced after endurance testing. The trickle of water produced at 20 cycles per minute was insufficient to measure.

8. ABUSE TESTS

8.1 Side Impact Tests

The pump was tested with the handle fully extended (the normal condition of the pump when not in use), and with one length of rising main and pump rod attached. The pendulum was adjusted to make impact with the top of the pumpstand.

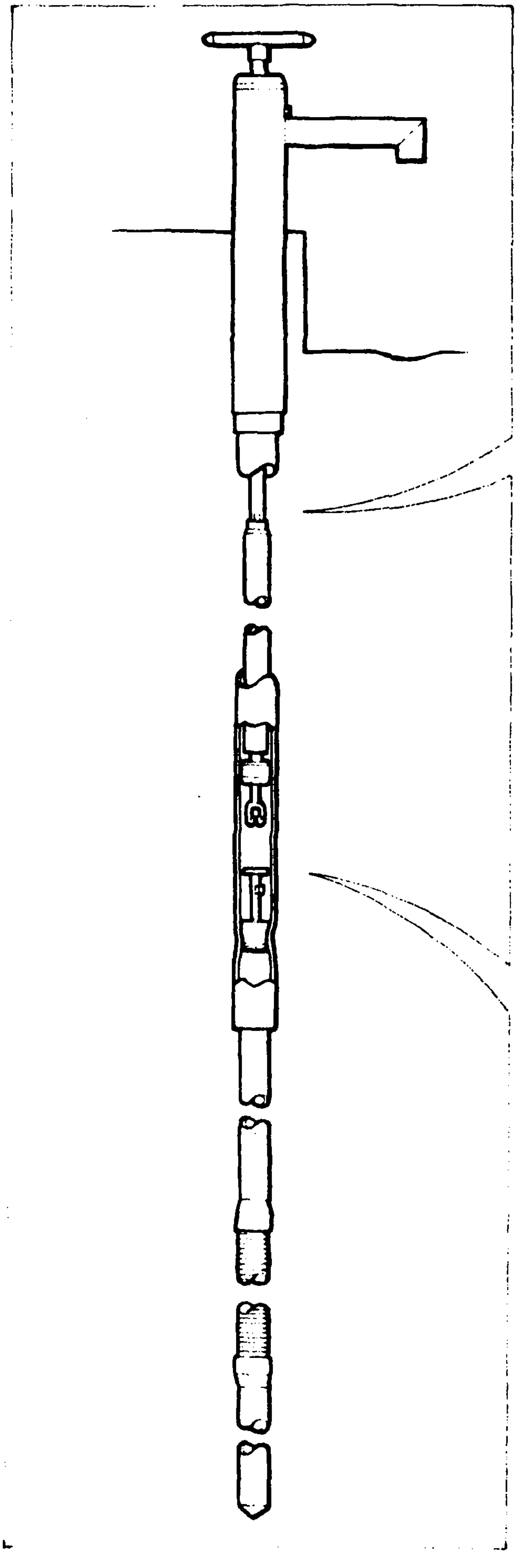
The pump was undamaged by impacts up to 200 joules. At 300 joules and above, the pump rod bent as the pumpstand flexed to absorb the impact. However, even after an impact of 500 joules, the pump rod could be straightened by hand sufficiently to be re-usable.

8.2 Handle Shock Test

The pump completed the allotted 96,000 cycles with no apparent damage.

9. VERDICT

A direct-action pump using tubular aluminium alloy pump "rods" and a small diameter cylinder to achieve operating characteristics suitable for direct action. Simple and lightweight, and therefore very easy to install and to maintain at village level. However, the rate of delivery is low and likely to fall still further as a result of wear. The pump rods were found to be inadequately sealed and susceptible to corrosion, and the ingress of water will dramatically affect the operating characteristics. Tough, wear-resistant pumpstand, but extensive use of polyurethane may make the PEK unsuitable for manufacture in developing countries. Expensive in view of its simplicity.



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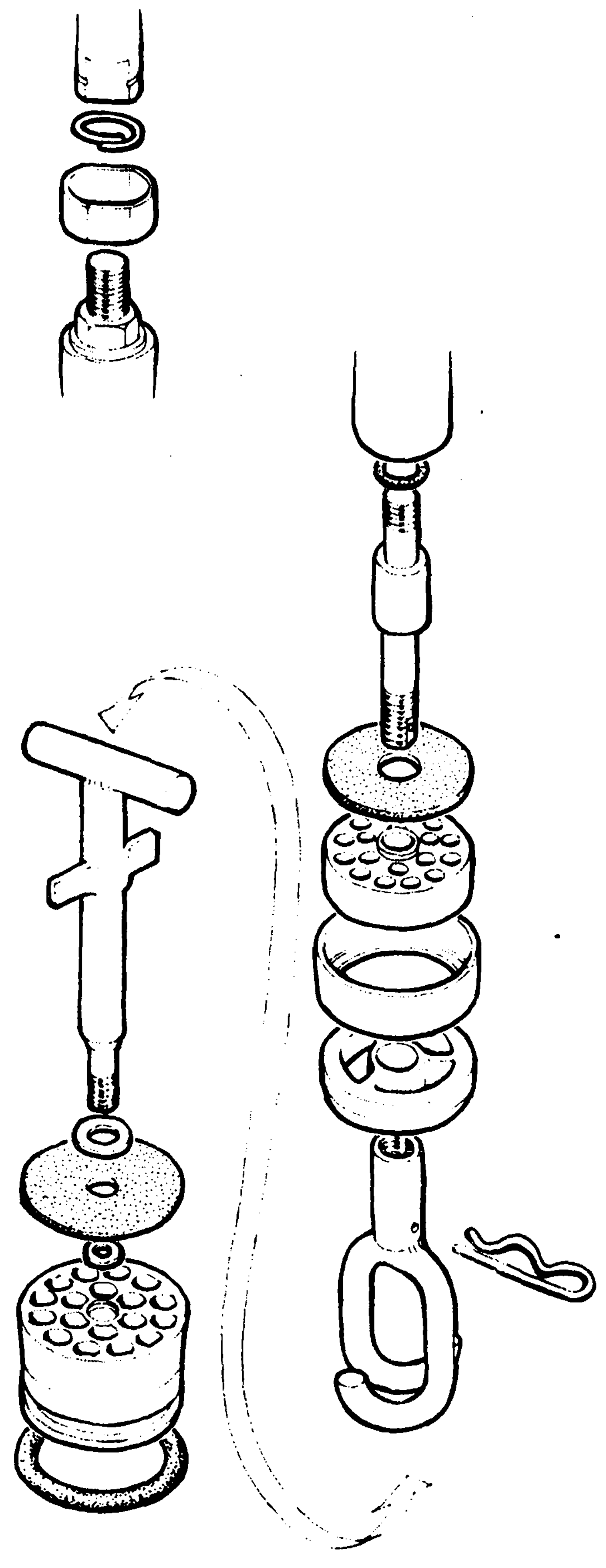


TARA HANDPUMP

1.1. Manufacturer Mirpur Agricultural Workshop & Training School

Address Pallabi, Dhaka - 16, Bangladesh

1.2 Description

The Tara handpump has been designed and manufactured in Bangladesh. It is a direct action pump with submerged cylinder with light-weight, high-displacement pump rods. The Tara is intended for small diameter tube-wells and for a maximum water depth of about 15 meters.

The pumpstand casing is fabricated from steel. The handle and the emergent section of pump rod are galvanized steel pipe. The pump rod guide bush is oil-impregnated hard wood.

When used in a small diameter tube-well, the rising main also serves as the well casing. Both the pump rod and rising main are standard uPVC pipe, with solvent cemented joints. One end of each length of pipe is thermally formed into a bell-mouth into which the next section is cemented. The joints must face downwards on the rising main, to enable the piston to be extracted. Threaded connectors are used at the top and bottom of the pump rod, with an ingenious locking mechanism at the connection to be handle.

The cylinder is also uPVC pipe, of the same outside diameter as the rising main, but greater wall thickness. The piston is machined from aluminum, with a simple rubber flap, but is moulded in plastic. It fits in a taper thermally formed in the cylinder pipe. Fittings on the piston and foot valve enable them to be coupled together and removed for maintenance or repair without extracting the rising main. The test samples were supplied with leather cup seals, though an alternative cup seal moulded in nitrile rubber was also supplied. The piston and foot valve can be supplied with stainless steel spindles for use in aggressive water.

The piston and cylinder may be set at any depth below the water table. However, it is noteworthy that a decision has been taken in Bangladesh, for future installations, to set the piston and cylinder at a depth of 15 meters, regardless of the depth to the water table (with the restriction that the pump not be used for lifts of more than 15 meters). This is to be done in local conditions where tubewells are manually constructed to a depth several meters beyond the water table, and where the water table itself fluctuates greatly with the seasons.

Note: Since the 1985 prototype samples were supplied for this test programme, a number of modifications have been introduced to the Tara pump, and further modifications are under review. The 1986 production model will have a flanged pumpstand bolted to the concrete base slab, a plastic piston, and other modifications. Tentatively, the 1987 model may have a 50 mm cylinder I.D. instead of the current 54 mm I.D., which will reduce the required upstroke force, but will also reduce the discharge per stroke by about 14 percent.

A number of other design changes are under review, including the use of a stainless steel liner for the cylinder, proprietary moulded lip seals and sacrificial pump rod guides.

2. INSPECTION

2.1 Packaging

The test samples were delivered in a slatted wooden case, lined with corrugated cardboard. Inside, individual components were securely wrapped in sacking and packed with wood shavings.

The packaging was considered very suitable for export and for crude overland transportation.

Cylinder pipes were supplied, but uPVC pipe for the rising main and pump rod was bought locally.

2.2 Condition as Received

Both pumps were received in good condition, but a small retaining clip for one piston was missing.

2.3 Installation and Maintenance Information

Instructions in English for installation and maintenance were supplied in an album of drawings describing the pump. This included a useful annotated general assembly drawing, engineering drawings of all the parts, a statement of the concepts underlying the design, pipe specifications and an analysis of the pumping forces, in addition to installation and maintenance information.

This booklet was comprehensive, interesting and useful. However, a separate booklet, dealing only with installation and maintenance and conveying the necessary information by illustrations rather than text would be more appropriate for use at village level.

Specific instructions for installation were supplied subsequently. In English, with clear line drawings showing the correct assembly, they form a step-by-step guide from identifying and preparing a suitable site, to installing and using the pump.

3. WEIGHTS and MEASURES

3.1 Weights

Pumpstand assembly:	7.6 kg	
Cylinder assembly:	1.5 kg	
Rising main (per metre):	0.7 kg)	bought in
Pump rod (per metre):	0.5 kg)	the U.K.

3.2 Dimensions

Nominal cylinder bore: 54 mm
Maximum stroke: 640 mm
Nominal maximum volume/cycle: 1.5 litre
Rising main diameter: 2 inch nominal
(uPVC pipe to BS3505, class C)
Pump rod diameter: 1.25 inch nominal
(uPVC pipe to BS3505, class D)
Maximum diameter of below-ground assembly: 66 mm

3.3 Cylinder Bores

No significant taper was found in either of the test samples. The maximum ovality measured was 0.5 mm, which is unlikely to be significant in view of the method of sealing at the piston.

The surface roughness average (R_a) was measured in three planes in a direction parallel to the cylinder axis.

SAMPLE	CYLINDER BORE	ROUGHNESS AVERAGE (R_a)			
		TEST 1	TEST 2	TEST 3	MEAN
1	Extruded uPVC pipe	0.65	0.50	0.55	0.57
2	Extruded uPVC pipe	0.45	0.44	0.45	0.45

Measured at 0.25 mm cut-off

These results are consistent with tests of other pumps using similar materials.

3.4 Ergonomic Measurements

HANDLE HEIGHT		PLINTH HEIGHT (mm)	HEIGHT OF SPOUT (mm)
MAX. (mm)	MIN. (mm)		
1000	360	-	350

The Tara pump is normally installed on a plinth which allows the operator to stand above ground level, but which also provides clearance under the spout of the pump for large water vessels. The measurements given assume that a plinth has been constructed in accordance with the installation instructions.

4. ENGINEERING ASSESSMENTS

4.1 Materials of Construction

COMPONENT	MATERIAL(S)
Pumpstand	Mild steel, painted
Handle	Galvanised steel pipe
Handle bush	Oil soaked hard wood
Rising Main/Cylinder	Standard uPVC pipe
Pump Rod	Standard uPVC pipe
Piston	Aluminium (1986 model will use plastic)
Piston cup seal	Leather or nitrile rubber
Foot valve body	Moulded high-density polyethylene
Valve flaps	Rubber sheet

4.2 Manufacturing Techniques

Above-ground Assembly	Steel fabrication Machining of steel and timber

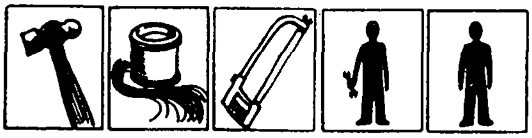
Manufacture of the pumpstand could be undertaken in the majority of developing countries. The techniques are basic and straightforward.

Below-ground Assembly	Manipulation of uPVC pipe Machining of aluminium Simple plastic moulding Light steel fabrication

In Bangladesh, the plastic mouldings are produced on a simple press. The uPVC is thermally formed by heating it in oil to make both the bell-mouths on the pipes and the taper seat for the foot valve; this method was also used for the pump rod joints in the test sample. The machining and fabrication are straightforward, though careful quality control is necessary. The design provides considerable scope for alternative methods of manufacture if these are more appropriate in particular countries.

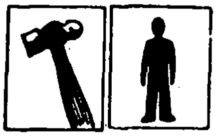
4.3 Ease of Installation, Maintenance and Repair

4.3.1 Ease of Installation



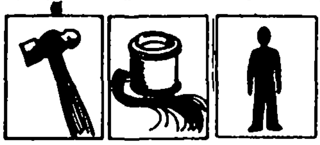
Only simple hand tools are required, and all the components are light and easy to handle. Considerable care is needed to ensure that the joints in the pump rod are water-tight.

4.3.2 Ease of Pumpstand Maintenance and Repair



The pumpstand is very simple to maintain, using only a few simple hand tools. No lubrication is required, and the only component likely to need periodic replacement is the wooden bush.

4.3.3 Ease of Below-ground Maintenance and Repair



The piston and foot valve can be easily removed for maintenance without extracting the rising main, although some care is necessary to avoid breaking the rising main as it is extracted. A support, in the form of a nearby tree or house, will be helpful.

4.4 Resistance to Contamination and Abuse

4.4.1 Resistance to Contamination

The recommended plinth ensures an adequate seal against waste water around the well head. There is some risk of contamination through the handle guide bush once wear has enlarged the central hole.

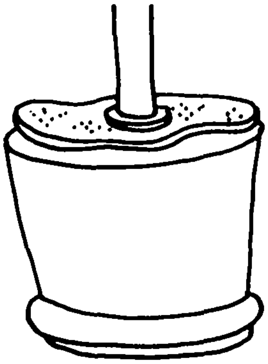
4.4.2 Likely Resistance to Abuse

There are no exposed fastenings on the pumpstand, but the handle guide bush has been designed to be easy to remove for maintenance. This could make the pump susceptible to pilferage or vandalism in some applications.

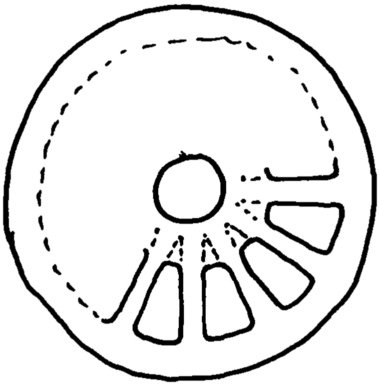
4.5 Potential Safety Hazards

There might be a potential finger trap between the handle and the guide bush at the top of the pumpstand. However, since this is in full view of the pump operator, and there is no mechanical advantage, this is unlikely to present a hazard.

Foot Valve: The shoulder on the foot valve is too short, preventing the rod from being fully tightened and causing the rubber to distort. It is worth noting that it is unnecessary for the rubber disc to be gripped at all as the water pressure will ensure that it closes on the return stroke.



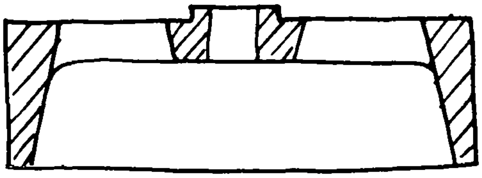
Therefore, the shoulder should be somewhat longer to accommodate variations in the thickness of the rubber sheet from which the valve is cut.



Piston Moulding: The shoulder on the piston is narrow. It could be increased in diameter but this would require an increase in the diameter of the rod, or the addition of a washer.

The moulded holes could be trunkated at the vertices to accommodate this, with no significant loss of open area (see sketch, left).

Piston: The existing design is easily modified to make it suitable for either leather or nitrile rubber cup seals. There is no obvious method of avoiding the need to drill the aluminium valve seat. However, the other cast aluminium component shows that the potential exists to cast in valve ports. As the ports need to be smaller in the upper casting, to prevent the valve rubber being distorted, the length of the holes to be cast must be reduced. If the underside of the casting is recessed as shown (left) and the pattern is made with a generous draw angle, it should be easy to produce a casting with several narrow triangular ports. As cast there may be excessive flash at the top face, but since this is machined it will be removed during that operation.

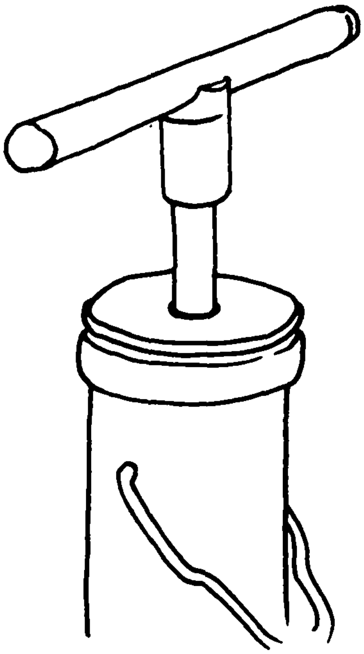


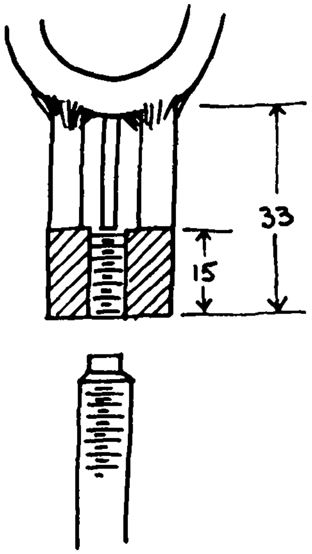
4.6 Suggested Design Improvements

Wooden Bush: the method of locking the wooden guide bush in the top of the pumpstand is simple and effective.

If it is desirable to retain the plastic sleeve which prevents nipping the fingers of the operator between the handle and the guide bush, but to avoid shearing the flange of the bush, then a large steel washer can be placed on the pump rod (see sketch, right).

The diameter of the washer must be at least that of the outside of the wooden bush.



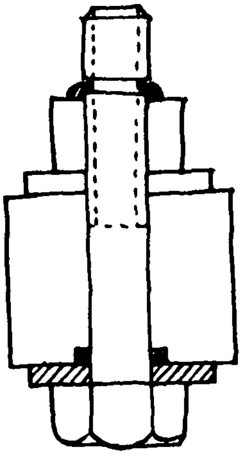


Lifting Eye Boss: variations of piston thickness can be accommodated by increasing the length of the lifting eye boss (see sketch, left). To avoid the weld making the end threads unusable and also to reduce the tapping length, the cross-slotted end should be counter-drilled to thread clearing size.

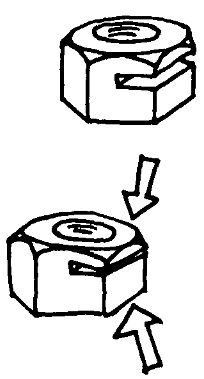
The end of the bolt should be chamfered to make it easier to engage in the boss.

Rod Connector: On the rod end, it might be better if a large washer of similar size to that under the nut was fitted to the head of the bolt, to increase the bearing area on the uPVC (see sketch, right).

If the nut and/or bolt are manufactured from bar then hexagonal heads are unnecessary: two flats produced by ganged cutters would be sufficient, with a saving in machining costs.



It may be adequate to dispense with the tack welds to secure the nut and use all-steel spring nuts. These are a commercial item, or can readily be made from standard nuts (see sketch, right).



5. PUMP PERFORMANCE

5.1 Volume Flow, Work Input and Efficiency

Pump performance was measured in a borehole, for water depths of 7 and 15 metres. At both depths, the cylinder was immersed 5 metres below the water level.

It was not realistic to use the maximum handle stroke available. The stroke used for all the tests was about 0.5 metres, but this was not controlled by external stops and there was therefore some variation in the volume delivered per cycle in the various tests.

HEAD	7 metres			15 metres				
Pumping rate (cycles/min)	21	30	40	16	20	24	28	39
Volume per cycle (litres)	1.16	1.20	1.21	1.16	1.16	1.18	1.16	1.22
Flow rate (litres/min)	23.7	35.8	47.8	18.1	23.0	27.9	31.9	47.7
Work input per cycle (J)	155	184	209	276	293	314	330	399
Work rate (W)	53	91	138	72	97	124	152	259
Efficiency (per cent)	51	45	40	62	58	55	52	45

At 7 metres depth, the required handle forces were approximately 20 kgf, in both directions, at 21 cycles per minute, increasing to about 30 kgf at 40 cycles per minute.

At 15 metres depth, the required handle forces were approximately 25 kgf downwards and 30 kgf upwards at 16 cycles per minute, increasing to about 40 kgf in both directions at 28 cycles per minute and 50 kgf in both directions at 39 cycles per minute.

5.2 Foot Valve Leakage Test

No leakage was observed from the foot valve for heads of 7 and 15 metres.

6. USER TEST

The proportions of the Tara pump, and the distribution of effort between the upward and downward parts of the pumping cycle, were found to be generally well-suited to direct action, although the required lift at 15 metres depth, with 5 metres of cylinder immersion, could be difficult for children. Greater immersion would reduce the lifting force, however, at the expense of an increase in the downward force. The relatively low minimum handle height, combined with the large potential maximum stroke, should make the pump suitable for both children and adults.

7. ENDURANCE

The pump was tested at approximately 30 cycles per minute at a simulated head of 15 metres. A head simulation valve is normally used to simulate at the piston the pumping pressure appropriate to operation at the chosen depth. However, for this direct action pump, it was necessary also to simulate the effect of an appropriate length of pump rods, since these are of relatively low mass and high displacement. An adjustable device was installed between the cylinder and the head simulation valve to increase the compressive force on the downward part of the pumping cycle, and the head simulation valve was adjusted to reduce the upward operating force. Both devices were adjusted simultaneously to achieve operating forces and work rates equivalent to those obtained in the performance tests where the pump was installed in a borehole.

The mechanical drive was set up to simulate the out-of-line forces typically applied by users when operating the pump.

General Comments

At the inspection after the first 2000 hours of the test, the rubber flap on the foot valve was found to have been cut by the edges of the valve ports. The valve was not leaking, but the damage was such that it was considered necessary to replace the rubber flap. With this exception, the pump completed the initial 2000 hours, in clean water, without failure.

After about 150 hours of the second phase, however, when sand and Kieselguhr had been added to the water, the pump seized. The cylinder was dismantled and the cause of failure was found to be fragments of uPVC jammed under the leather cup seal. The fragments were fibrous, approximately 10 mm long. A number of potential causes were investigated and eliminated:

(a) Wear of the pump rod against the rising main.

(b) Wear of the rising main caused by the device added to the system to increase the compressive force on the downstroke, simulating the effect of lightweight rods.

(c) Differences in the quality of uPVC pipe made in Bangladesh and the United Kingdom.

Moreover, a number of leather cup seals were fitted, including some originally supplied for testing with the Rower pump, but all failed in the same way. Since other potential causes had been eliminated, the fragments of uPVC were probably caused by the action of sand particles embedded in the leather cup seal.

The leather cup seal was replaced by a moulded nitrile rubber cup seal. This required some modification to the piston, to ensure the correct nip on assembly without causing the rubber to extrude outwards.

At the end of the test, the foot valve was found to be leaking badly, due to splits in the valve rubber. The cylinder and the nitrile rubber piston seal were in good condition, however, and continuing to work well.

Breakdown Incidence

Breakdown are shown in **bold** type

Hours:	2150	2292 to 2313	4189
Inspection and full performance test	Inspection and volume flow check **Foot valve rubber failed**	**Cylinder seized repeatedly** **Leather cup seal replaced by nitrile rubber**	Inspection and full performance test **Foot valve rubber failed**

Details of the Endurance Test

Breakdowns are shown in **bold** type

2150 Inspection after first 2000 hour stage:

(a) Handle guide bush worn; handle polished
(b) Leather cup seal distorted but still in working order
(c) Little wear in cylinder bore
(d) Slight corrosion of aluminium components of piston
(e) Foot valve rubber flap cut by edges of valve ports — not leaking but likely to fail soon, and therefore replaced

Estimated amount of water pumped to failure... 4.3 million litres

2292 to 2313 **Pump seized repeatedly: fragments of uPVC caused leather cup seal to jam in cylinder bore.**
Leather cup seal replaced by nitrile rubber, with suitable modification to piston to provide appropriate nip on rubber.

Estimated additional amount of water pumped to failure... 0.3 million litres

4189 FINAL INSPECTION:

(a) Approximately 3 mm wear in handle bush and galvanised finish worn off pump handle -- still servicable, and pumpstand in good condition overall
(b) Pattern of valve ports impressed in piston valve rubber but still in good working order

(c) Nitrile rubber cup seal in good condition with only slight wear at edge of lip -- moulding still correctly located between piston halves: no sign of any tendency to extrude outwards
(d) Little wear in bore of cylinder (fitted at 2313 hours)
(e) Nut on piston spindle rusted on tight -- removed only with difficulty
(f) Foot valve body jammed in taper seat -- O-ring had worked out of groove and past neck in pipe thereby locking valve in place: valve could not be removed from above, and part of flange broke off when hammered out from beneath
(g) Foot valve rubber split around centre fixing -- leaking badly

Estimated additional amount of water pumped to failure... 3.8 million litres

Estimated total amount of water pumped in 4000 hours... 8.4 million litres

	Volume flow at 15 m (litres/cycle)			Leakage at 15 m (ml/min)
Approx. cycles/minute	20	30	40	
New	1.16	1.16	1.22	n/s
After 2000 hrs	1.08	1.18	1.11	n/s
After 4000 hrs	1.09	1.16	1.18	more than 15ml/min

n/s = not significant: less than 0.1 ml per minute

Pump Performance after Endurance Test

Pump performance was measured in a borehole, for water depths of 7 and 15 metres. At both depths, the cylinder was immersed 5 metres below the water level.

It was not realistic to use the maximum handle stroke available. The stroke used for all the tests was about 0.5 metres, but this was not controlled by external stops and there was therefore some variation in the volume delivered per cycle in the various tests.

HEAD	7 metres			15 metres				
Pumping rate (cycles/min)	20	30	43	15	20	27	30	38
Volume per cycle (litres)	0.98	1.11	1.11	0.98	1.09	1.12	1.16	1.18
Flow rate (litres/min)	19.5	33.3	47.6	14.7	21.8	30.4	34.7	44.2
Work input per cycle (J)	147	190	218	225	254	263	287	315
Work rate (W)	49	95	155	56	85	119	143	197
Efficiency (per cent)	46	40	35	64	63	63	59	55

These results are not directly comparable with the performance tests before endurance testing, since the original leather cup seal had been replaced by nitrile rubber. Nevertheless, there are marked similarities between the two sets of results, which indicate that the leather seal produced slightly higher levels of pump efficiency at 7 metres depth, but the nitrile seal offered better efficiency than the leather at 15 metres depth.

Further tests were carried out at 15 metres depth at a stroke length of approximately 0.35 metres. The results indicated slightly lower operating forces on both the upward and downward strokes, and hence slight improvements in overall efficiency.

8. ABUSE TESTS

8.1 Side Impact Test

A side impact test on the handle was not appropriate. In a series of impact tests on the pumpstand, slight bending of the baseplate was observed at an impact of 300 joules, and the degree of bending increased at 400 and 500 joules. None of the original welds appeared to be damaged, however, and the pump was still serviceable.

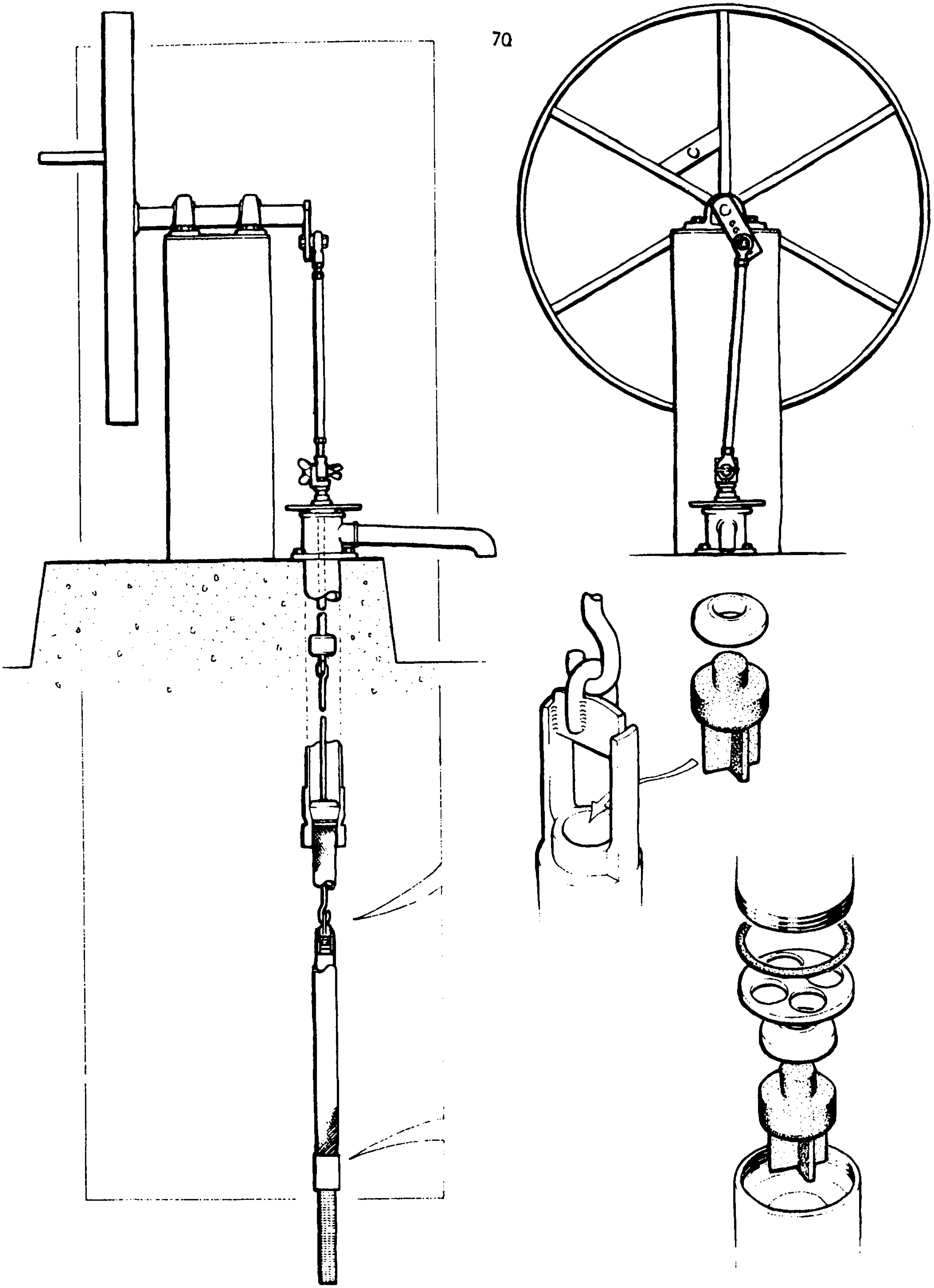
8.2 Handle Shock Test

This test was set up to bang the handle against the lower stop only. The limit to upward movement is determined by the length of the section of pump rod attached to the handle, and this is such that it is very unlikely that anyone would bang the handle against the upper limit while using the pump. The pump completed the allotted 96,000 cycles without failure.

9. VERDICT

A simple, direct-acting handpump, designed to exploit the materials and manufacturing skills indigenous to Bangladesh, with potential for further improvement and wider application. Relatively easy to manufacture, operate, maintain and repair. Leather seal unlikely to cope with sand contamination, but alternative nitrile rubber seal available. Suitable for community water supply from depths of 15 metres or less.

7a



VOLANTA HANDPUMP (1984 Model)

1.1 Manufacturer

Jansen Venneboer b.v.

Address

Industrieweg 4
Postbus 12, 8130 AA Wijhe
The Netherlands

1.2 Description

The Volanta handpump was previously tested by CATR in 1982/83. At that time, two types of cylinder were supplied for testing, both using cable to connect the piston with the pumpstand. Subsequently, the manufacturer adopted the glass-fibre reinforced cylinder with seal-less machined steel plunger as the standard cylinder type. Further modifications were made as a result of the earlier laboratory tests and information from the field. The cylinder taper seat was re-located at the top of the cylinder, to prevent sand-locking, and the cables have been replaced by steel rods with hook-and-eye connections. Brass weights have been added to the moulded rubber valves.

The pumpstand, with its large steel flywheel and adjustable pump stroke to compensate for water depth, is substantially unchanged, except that the outlet spout is now horizontal. The manufacturer now offers a fabricated steel pedestal as an alternative to a cast-in-situ concrete pedestal.

1.3 Price

18 March 1985

In lots of 50 units: DF2340 (US$613)

In lots of 500 units: DF2050 (US$537)

2. INSPECTION

2.1 Packaging

The uPVC rising main and pump rods were delivered in a heavy-duty cardboard carton. The pumpstand was packed in a wooden case, and the remaining pump components were packed in a cardboard carton within the wooden case.

The packaging was considered adequate for export. However, for overland transportation in a developing country the large containers might be difficult to manhandle. Heavy components were loose in the cardboard carton within the wooden case, and could be damaged if the case were treated roughly.

2.2 Condition as Received

All the components as received were apparently in good condition.

Subsequently however, the pump performance tests failed to achieve the levels of performance specified by the manufacturer. Excessive clearances were found to exist between the pistons and cylinder bores of the two sample cylinders supplied (see Cylinders, section 3.3).

A third cylinder was therefore supplied subsequently, for performance and endurance testing.

2.3 Installation and Maintenance Information

Specific installation and maintenance information was not supplied with the pump. However, a leaflet was supplied which described the pump in detail, including several helpful illustrations, together with a set of engineering drawings.

3. WEIGHTS and MEASURES

3.1 Weights

Steel plinth:	57.1 kg
Flywheel and handle:	48.0 kg
Remainder of pumpstand:	42.2 kg
Cylinder:	9.5 kg (including strainer)
Rising Main (per m):	1.7 kg
Pump Rod (per m):	0.4 kg

3.2 Dimensions

Nominal cylinder bore:	50 mm
Actual pump stroke:	Variable
Rising main size:	3 inch nominal bore
Pump rod diameter	8 mm

3.3 Cylinders

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

Piston diameter 49.88 mm, consistent throughout

Cylinder Sample 1 (supplied June 1984)

Cylinder bore (average) 50.18 mm, no significant taper or ovality
Average clearance 0.30 mm

Cylinder Sample 2 (supplied June 1984)

Cylinder bore (average) 50.11 mm, no significant taper or ovality
Average clearance 0.23 mm

The manufacturer's specification is as follows:

Piston diameter	49.85 to 49.88 mm
Cylinder bore	50.03 to 50.04 mm
Clearance	0.15 to 0.18 mm

The manufacturer subsequently supplied a third cylinder sample:

Cylinder Sample 3 (supplied July 1984)

Cylinder bore (average) 50.06 mm, no significant taper or ovality
Average clearance 0.18 mm

This third cylinder was used for all subsequent pump performance tests, and has been installed for endurance testing.

The surface finish of the cylinder bores of all samples was satisfactory.

NOTE: In the samples supplied for testing in May 1982, the average clearances between the pistons and the cylinder bores were 0.20 mm for one sample and 0.25 mm for the second sample.

3.4 Ergonomic Measurements

HANDLE HEIGHT		ANGULAR MOVEMENT of HANDLE (deg)	HANDLE LENGTH (mm)	VELOCITY RATIO of HANDLE	HEIGHT OF SPOUT (mm)
MAX (mm)	MIN (mm)				
1385	875	360	255	[1]	[2]

[1] Variable from 1.6 to 5.6, according to operating depth. Five positions are provided to attach the connecting rod to the crank arm, giving stroke lengths from 90 to 310 mm, to compensate for water depth at different installations. In the previous Volanta pump tested in 1982/83, six positions were provided, with stroke lengths from 100 to 310 mm.

[2] Depends on construction of concrete platform; the manufacturer recommends a platform height of 400 mm.

4. ENGINEERING ASSESSMENT

Refer to UNDP Project Management Report Number 3.

5. PUMP PERFORMANCE

5.1 Test Method

Pump performance was tested over the 48 metre borehole and also in the test tower. The stroke length was adjusted for each test depth in accordance with the manufacturer's recommendations.

The pump was operated for several strokes at speeds of 40, 50 and 60 revolutions per minute, at heads of 25 and 45 metres. Tests were conducted using standing starts and also flying starts. The standing start tests began with the handle at rest; the computer was started and the operator accelerated the pump until the required target speed was reached. After 10 revolutions the operator released the handle which continued to turn due to the inertia stored in the flywheel. Logging of force and displacement data was stopped when the handle came to rest. All the water flowing from the pump was included in the result. For the flying start tests, the operator accelerated the pump to the required speed, and then maintained a constant speed for at least ten revolutions. The outflowing water was diverted into a collecting vessel at the same moment as the computer began to log the data, and after ten revolutions the computer was stopped at the same moment as the water was diverted away from the collecting vessel.

The initial results were unsatisfactory, falling short of the pump performance required by the manufacturer as a result of excessive clearance between the piston and the cylinder bore. A third sample cylinder was therefore supplied (see Cylinders, section 3.3). The following results were obtained using the third sample cylinder.

5.2. Pump Performance over the Borehole

5.2.1 Standing Start

HEAD	25 metres			45 metres		
Stroke (mm)	190			140		
Average pumping rate (revs/min)	34	43	48	34	41	48
Volume/rev (litres)	0.34	0.35	0.35	0.21	0.21	0.23
Volume/min (litres)	12	15	17	7	9	11
Work input/rev (J)	155	155	174	157	156	186
Power input (watts)	88	111	139	89	107	149
Efficiency (per cent)	54	55	49	57	59	54

5.2.2 Flying Start

HEAD	25 metres			45 metres		
Stroke (mm)	190			140		
Average pumping rate (revs/min)	41	52	62	40	50	60
Volume/rev (litres)	0.35	0.36	0.39	0.22	0.22	0.23
Volume/min (litres)	14	19	24	9	11	14
Work input/rev (J)	142	138	147	160	159	154
Power input (watts)	97	120	152	107	133	154
Efficiency (per cent)	60	63	64	59	60	64

5.3 Pump Performance in the Test Tower

5.3.1 Standing Start

HEAD	25 metres			45 metres		
Stroke (mm)	190			140		
Average pumping rate (revs/min)	35	41	46	35	37	48
Volume/rev (litres)	0.35	0.35	0.35	0.23	0.23	0.25
Volume/min (litres	12	14	16	8	9	12
Work input/rev (J)	183	176	181	184	184	194
Power input (watts)	107	120	139	107	113	155
Efficiency (per cent)	46	47	47	54	55	56

5.3.2 Flying Start

HEAD	25 metres			45 metres		
Stroke (mm)	190			140		
Average pumping rate (revs/min)	40	51	61	40	50	61
Volume/rev (litres)	0.34	0.38	0.37	0.24	0.24	0.24
Volume/min (litres)	14	19	23	10	12	15
Work input/rev (J)	179	165	171	188	185	188
Power input (watts)	119	140	174	125	154	191
Efficiency (per cent)	47	55	53	55	57	57

5.4 Leakage Test

No significant leakage was observed at any of the heads tested.

6. USER TRIAL

Refer to UNDP Project Management Report Number 3.

7. ENDURANCE

A detailed description of the endurance test method can be found in the Test Procedure.

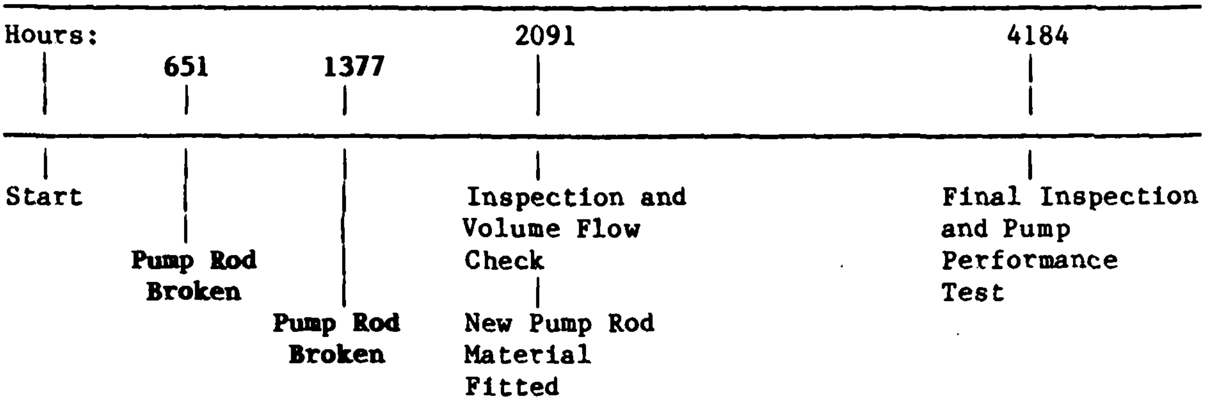
7.1 General Comments

When the pump was installed in the test tower, it was necessary to shorten one length of pump rod and rising main to accommodate the head simulation valve. The rod was shortened by cutting a section out of the centre, threading the ends and re-joining them with a standard tube-nut. The formed eye on the end of the shortened rod broke after 651 hours. The manufacturer was contacted immediately. The broken rod was replaced by a new section of rod, which broke after a further 726 hours. In case the failures had been induced by threading the shortened rods, a new section of rod was made, with a welded rather than threaded joint. This did not break, but at the end of the first 2000 hours, when the pump was re-assembled after inspection, a new section of rod was fitted in an alternative material supplied by the manufacturer. This section endured until the end of the 4000 hour test. We understand that the manufacturer now supplies rod made only from the alternative material, which we understand to be AISI 304 stainless steel.

During the test, it was necessary to tighten the gland in the pumpstand occasionally, to prevent leaks. However, it was necessary to install the pump in the tower with the obselete, upward-pointing spout. The current design uses a horizontal spout, so that leaks from the gland would be less likely to occur in normal installations.

In the final inspection, the valves showed signs of wear but the cylinder and foot valve were in good general condition. The pumpstand gland needed re-packing, but otherwise the pumpstand was in good order throughout.

7.2 Breakdown Incidence Failures are shown in **bold** type.



HOURS

651 Pump rod eye broken — replaced by rod with threaded joint.

Estimated amount of water pumped to breakdown..... 0.4 million litres

1377 Pump rod eye broken — replaced by rod with welded joint.

Estimated additional amount of water pumped to breakdown.. 0.4 million litres

2091 INSPECTION after 2000 HOURS

Pumpstand:	In good condition throughout.
Cylinder:	Piston lightly scratched and cylinder scored, but otherwise no significant wear.
Pump rod:	Section which broke at 651 and 1377 hours replaced by section in new material supplied by manufacturer.

4184 FINAL INSPECTION

Pumpstand:	Gland needs repacking; otherwise in good condition.
Cylinder:	Easy to extract: no sand-locking with this design. Piston lightly scratched and cylinder bore scored, but no significant change in diameters. Valves worn around seats but still serviceable.
Filter:	Not clogged but encrusted with sand and Kieselguhr: appeared to have been effective in minimising the quantity of solid contaminants entering pump.
Pump rods:	Contact areas polished in hooks and eyes, but little wear and no signs of cracking.

Estimated total amount of water pumped in 4000 hours... 2.4 million litres

	Volume Flow Tests at 45 m (litres)			Leakage Tests at 7 m (ml/min)
Cycles per minute	40	50	60	
New	0.24	0.24	0.24	None
After 2000 hours	0.26	0.30	0.31	None
After 4000 hours	0.24	0.25	0.24	None

7.3 Pump Performance after Endurance

7.3.1 Standing Start

HEAD	25 metres			45 metres		
Stroke (mm)	190			140		
Average pumping rate (revs/min)	33	36	43	33	38	44
Volume/rev (litres)	0.39	0.34	0.36	0.23	0.23	0.24
Volume/min (litres)	11	12	15	8	9	10
Work input/rev (J)	154	157	183	157	145	151
Power input (watts)	84	94	131	87	91	110
Efficiency (per cent)	54	53	48	65	71	69

7.3.2 Flying Start

HEAD	25 metres			45 metres		
Stroke (mm)	190			140		
Average pumping rate (revs/min)	40	49	60	40	47	61
Volume/rev (litres)	0.35	0.36	0.36	0.24	0.25	0.24
Volume/min (litres)	14	18	22	9	12	15
Work input/rev (J)	179	167	171	140	159	154
Power input (watts)	102	136	172	92	125	154
Efficiency (per cent)	56	53	52	75	69	71

The pump performance test results after endurance testing show a consistent reduction in the work input required per stroke, with a consequent improvement in overall pump efficiency. Since the piston has no seal, and no significant change in the dimensions of either the cylinder or piston was observed, this may be attributable to reduced friction in the well-head gland.

8. ABUSE TESTS

Refer to UNDP Project Management Report Number 3.

9. VERDICT

The steel rods of the current design are better than cable. The use of hook-and-eye connections is innovative and very convenient for installation and maintenance. However, the rod material must be chosen with care, and good quality control is essential in forming the hooks and eyes.

The design incorporates many useful innovations, including the ability to adjust the stroke length to compensate for water depth and/or local preference, and the elimination of seals in the piston. The pumpstand is very strong, but some children may find the inertia of the flywheel difficult to cope with.

Many parts of the pump are suitable for manufacture in developing countries, though rigorous quality control is essential in making the cylinder assembly. The pump is easier than most to maintain and repair.

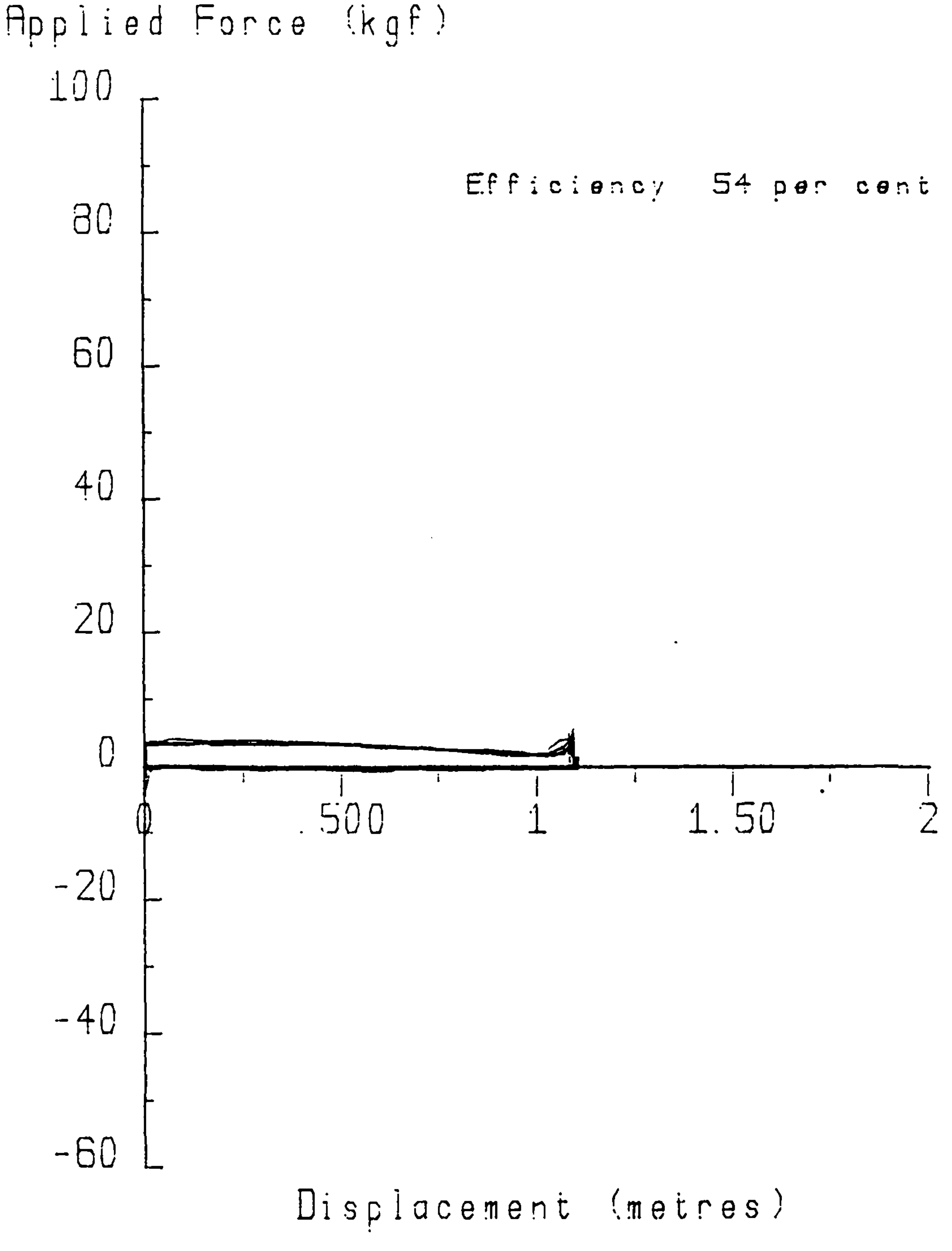
ANNEX A:

Examples of Force-Displacement Diagrams

PUMP PERFORMANCE TEST - GSW

Code FF400701

Water Head 7 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 2.9 kg in 10 cycles
Average flow rate .29 litres per cycle. 11.7 litres/minute
Total Work Done On Pump 370 joules in 10 cycles
Average work input rate 37 joules per cycle. 25 watts

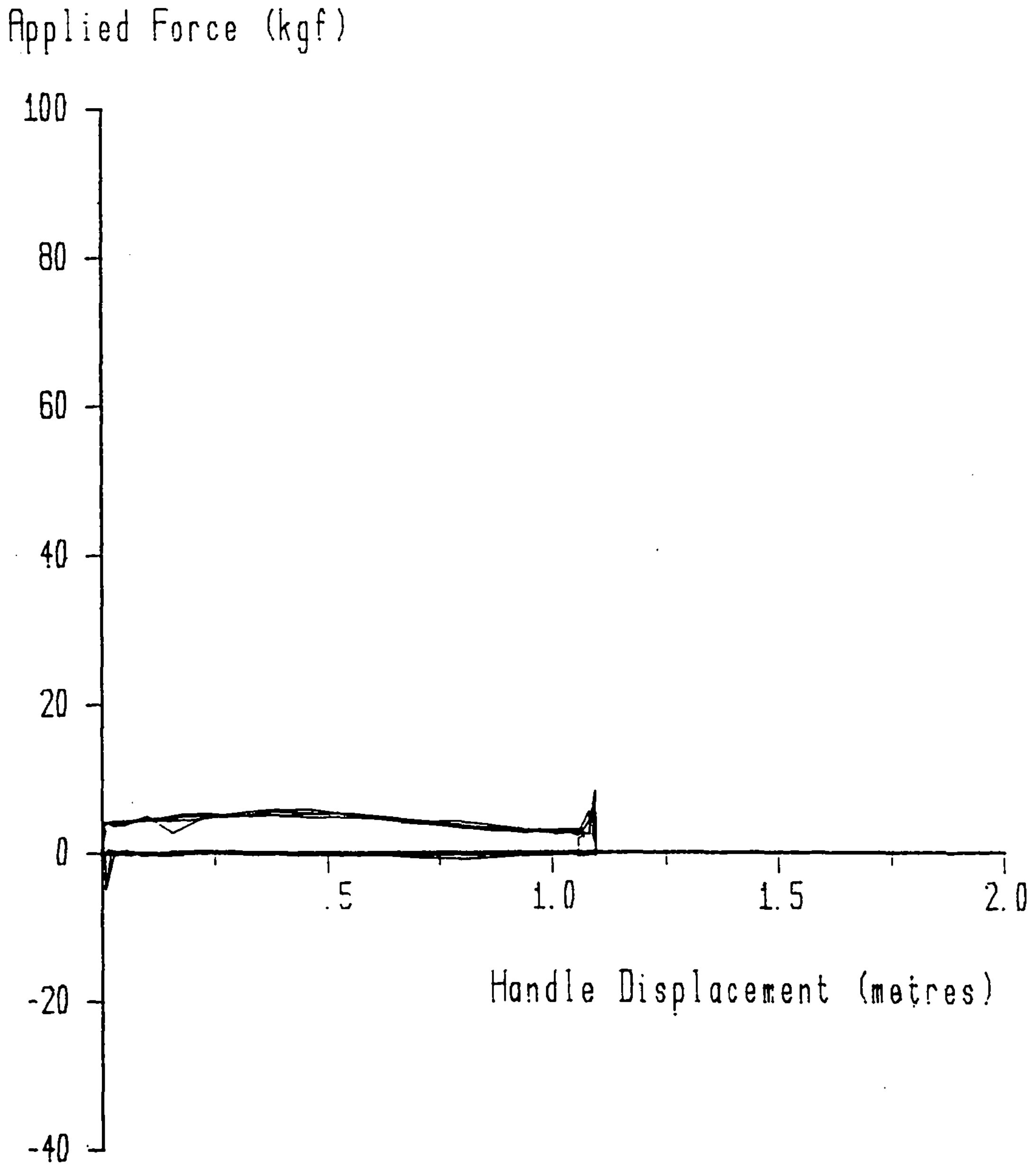


PUMP PERFORMANCE TEST after endurance - GSW

Code FF : GSW PUMP

Water Head 7 metres --- Pumping Rate 39 cycles/minute
Total Weight of Water Raised 2.9 kg in 10.0 cycles
Average Flow Rate .29 litres per cycle; 11.3 litres/minute
Total Work Done On Pump 495 joules in 10.0 cycles
Average Work Input Rate 50 joules per cycle; 33 watts

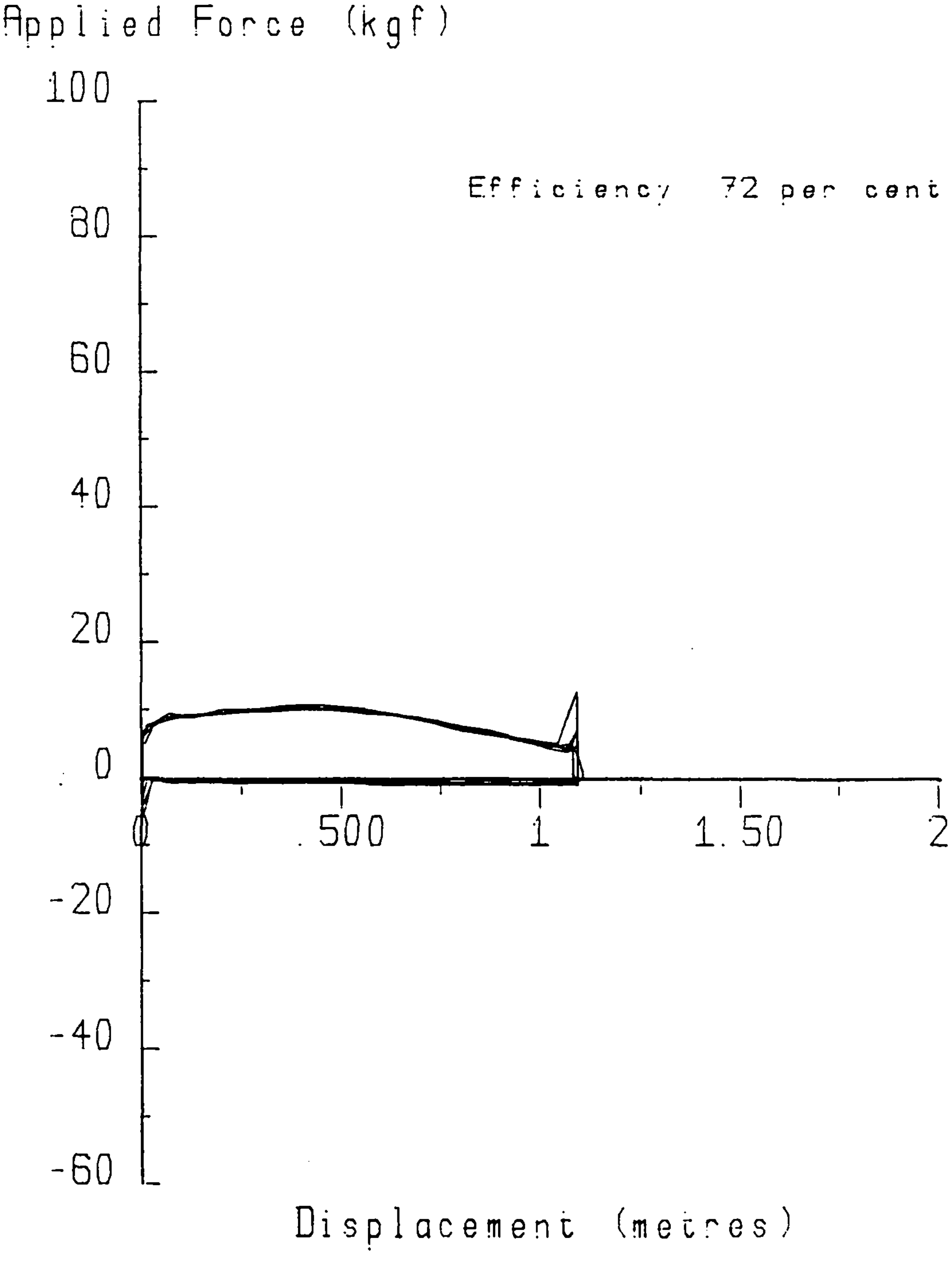
Efficiency 40 per cent



PUMP PERFORMANCE TEST - GSW

Code FF402501

Water Head 25 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 2.9 kg in 10 cycles
Average flow rate .29 litres per cycle. 11.7 litres/minute
Total Work Done On Pump 987 joules in 10 cycles
Average work input rate 99 joules per cycle. 66 watts



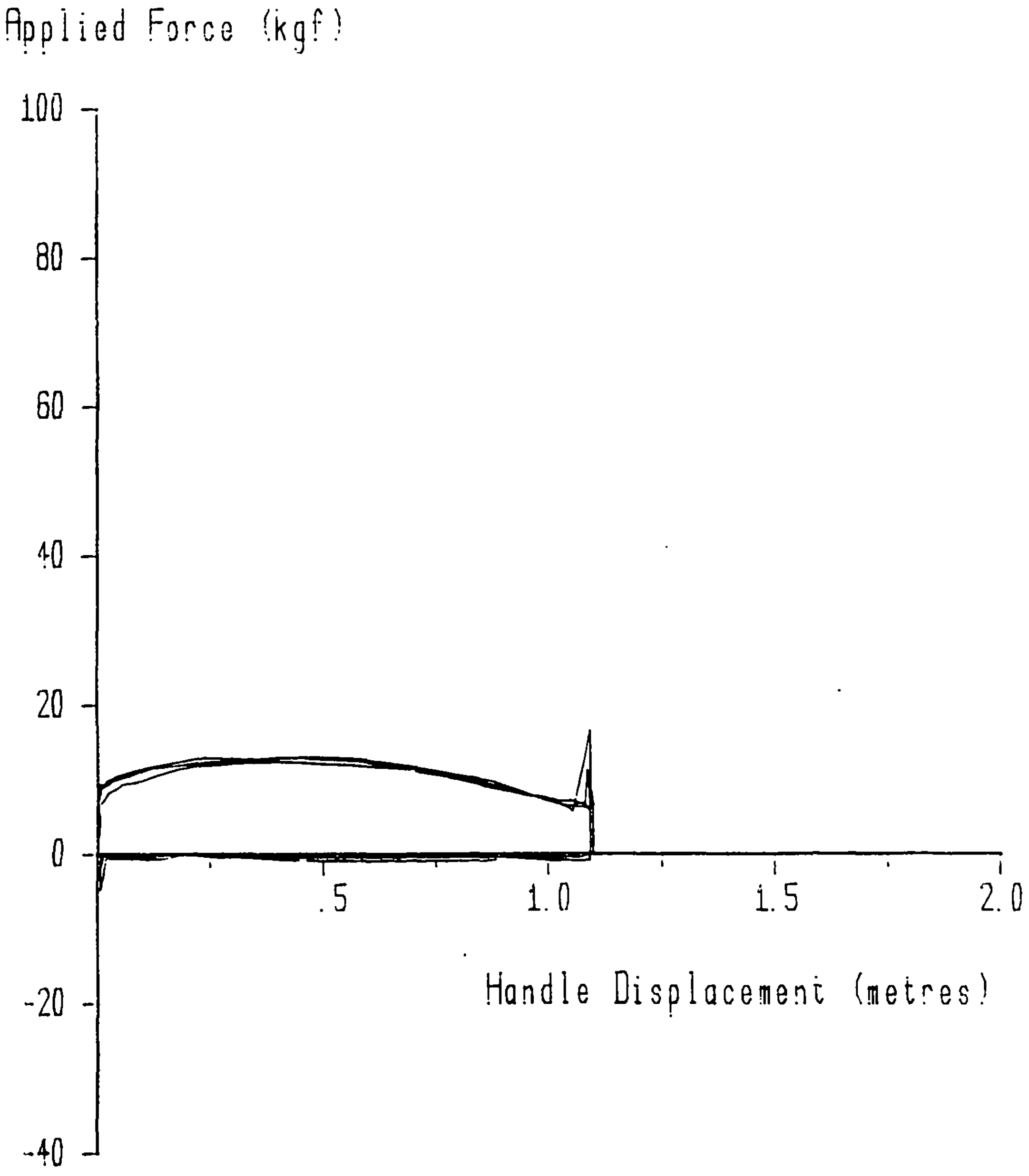
Efficiency 72 per cent

PUMP PERFORMANCE TEST after endurance - GSW

Code FF402501

Water Head 25 metres --- Pumping Rate 39 cycles/minute
Total Weight of Water Raised 2.9 kg in 10.0 cycles
Average Flow Rate .29 litres per cycle: 11.2 litres/minute
Total Work Done On Pump 1229 joules in 10.0 cycles
Average Work Input Rate 123 joules per cycle: 80 watts

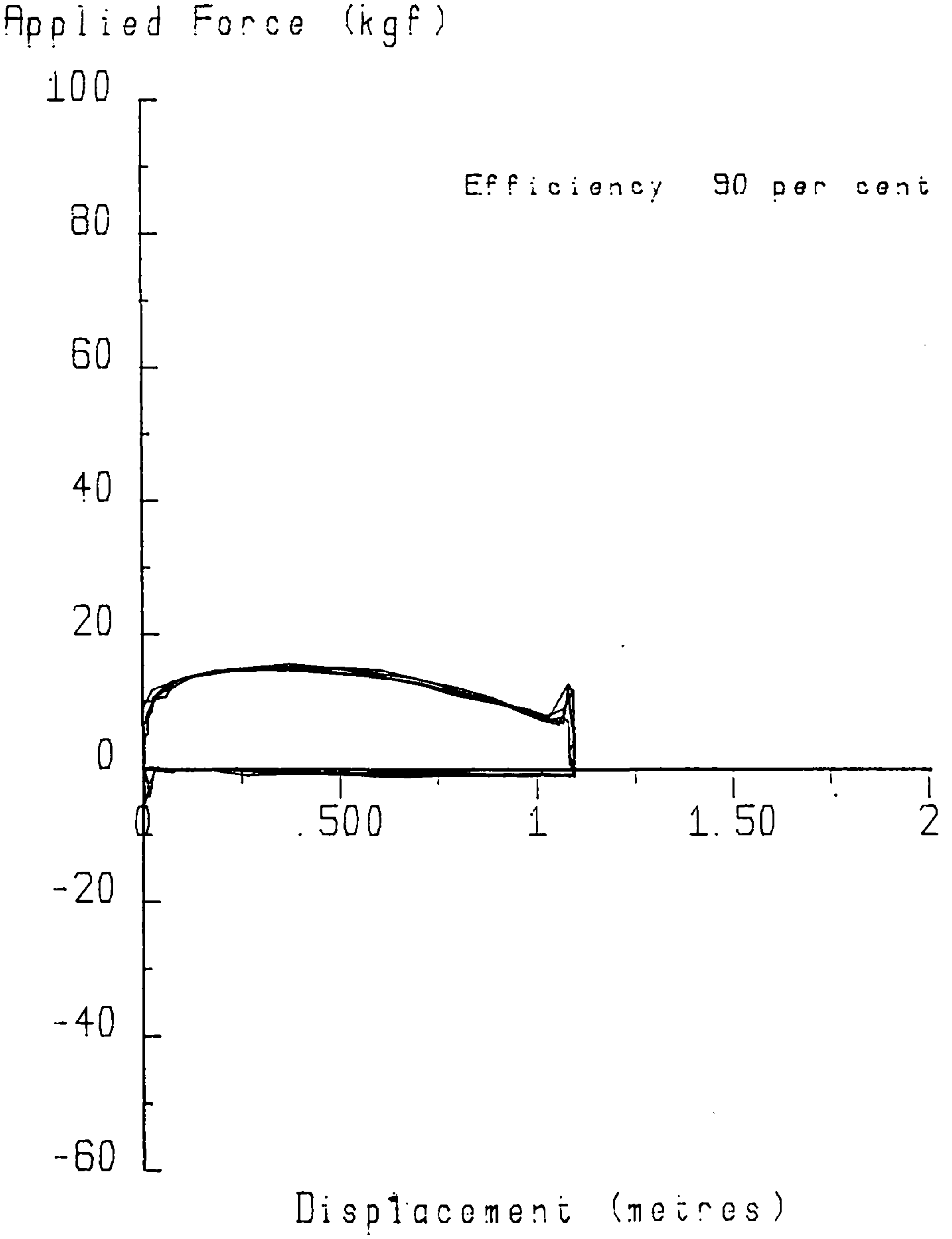
Efficiency 57 per cent



PUMP PERFORMANCE TEST - GSW

Code FF404501

Water Head 45 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 2.9 kg in 10 cycles
Average flow rate .29 litres per cycle. 11.6 litres/minute
Total Work Done On Pump 1425 joules in 10 cycles
Average work input rate 143 joules per cycle. 95 watts

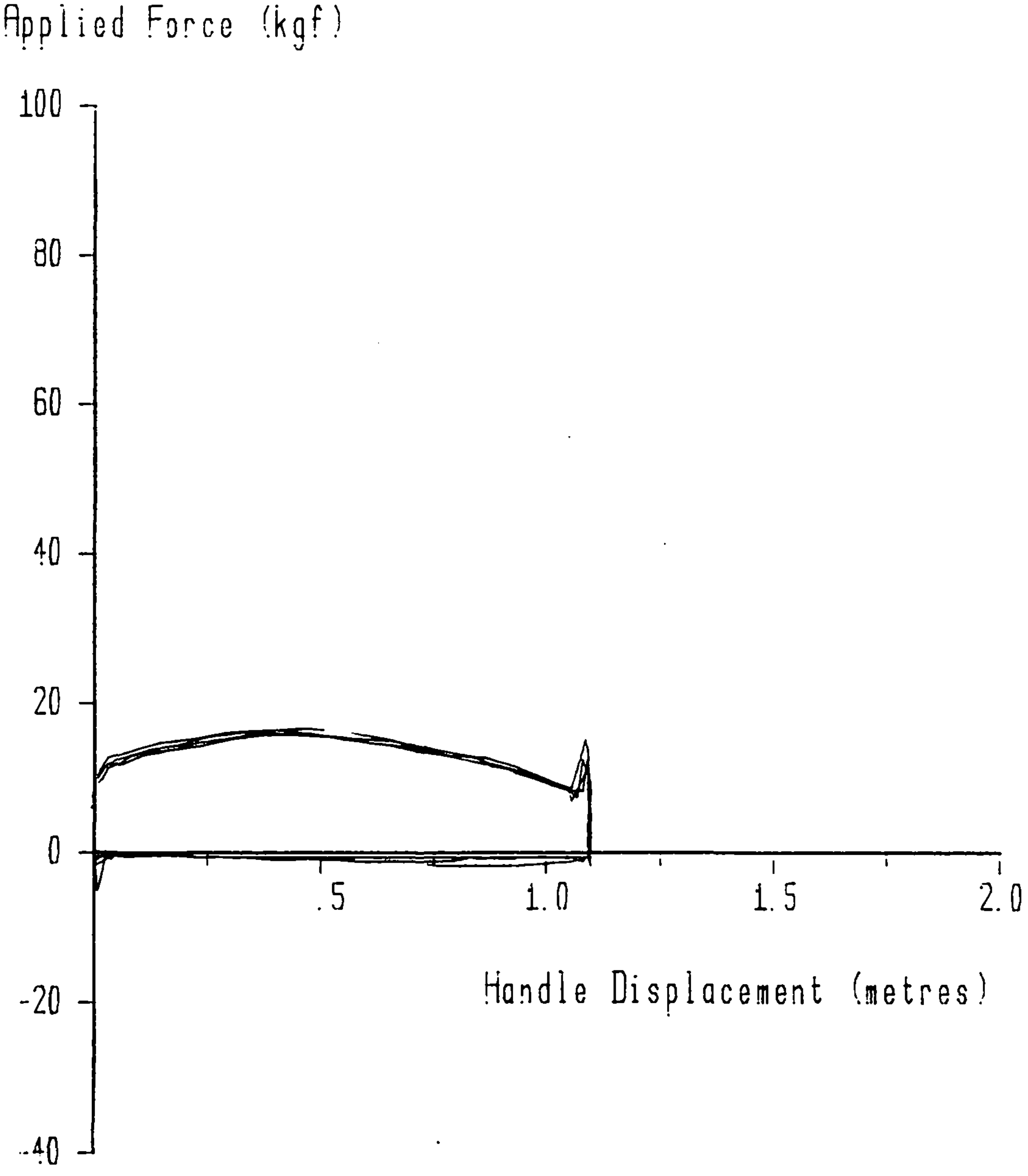


PUMP PERFORMANCE TEST after endurance - GSW

Code FF404501

Water Head 45 metres --- Pumping Rate 39 cycles/minute
Total Weight of Water Raised 2.9 kg in 10.0 cycles
Average Flow Rate .29 litres per cycle: 11.1 litres/minute
Total Work Done On Pump 1542 joules in 10.0 cycles
Average Work Input Rate 154 joules per cycle: 100 watts

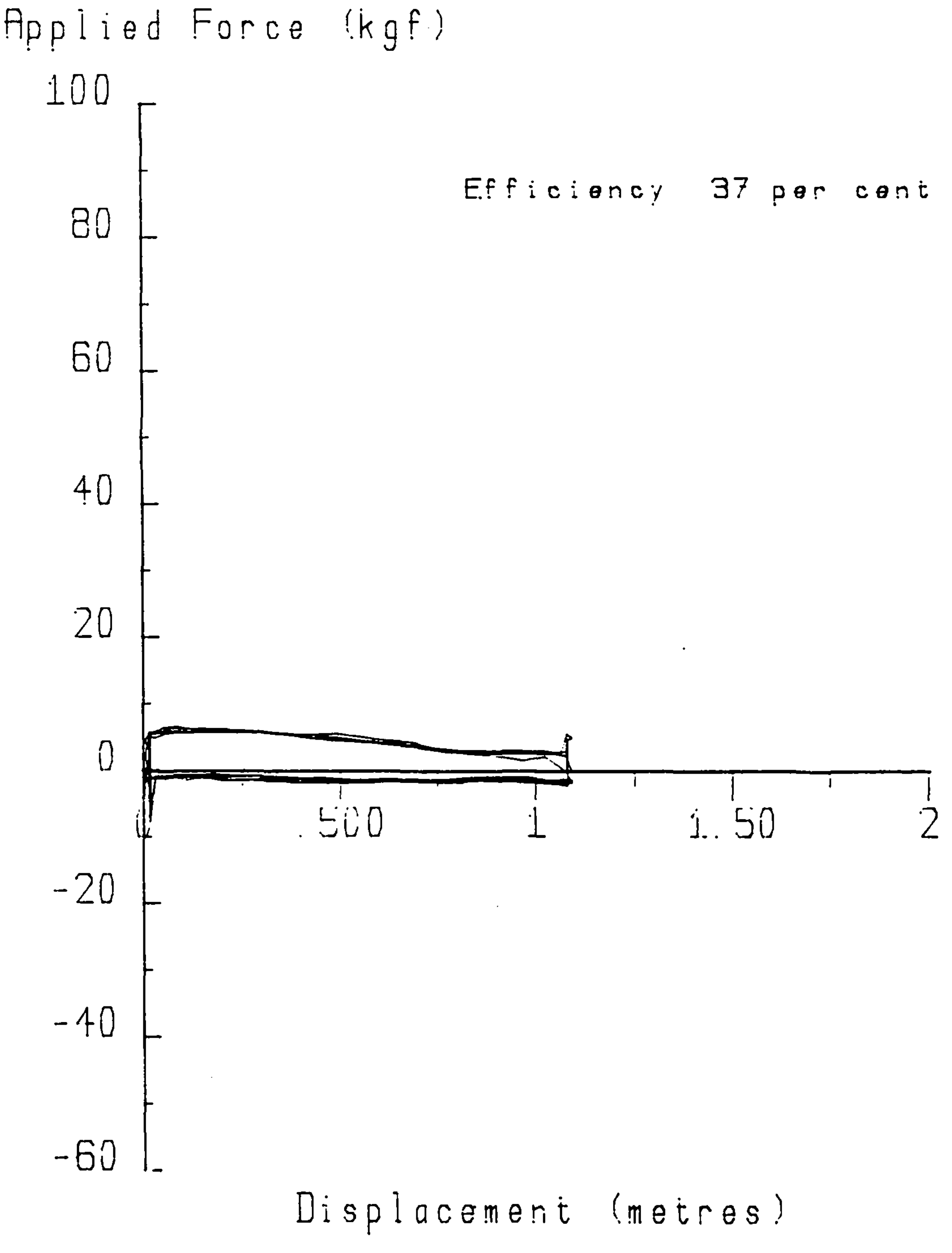
Efficiency 82 per cent



PUMP PERFORMANCE TEST - MONARCH

Code DD400701

Water Head 7 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 3.5 kg in 10 cycles
Average flow rate .35 litres per cycle. 14.2 litres/minute
Total Work Done On Pump 645 joules in 10 cycles
Average work input rate 64 joules per cycle. 43 watts



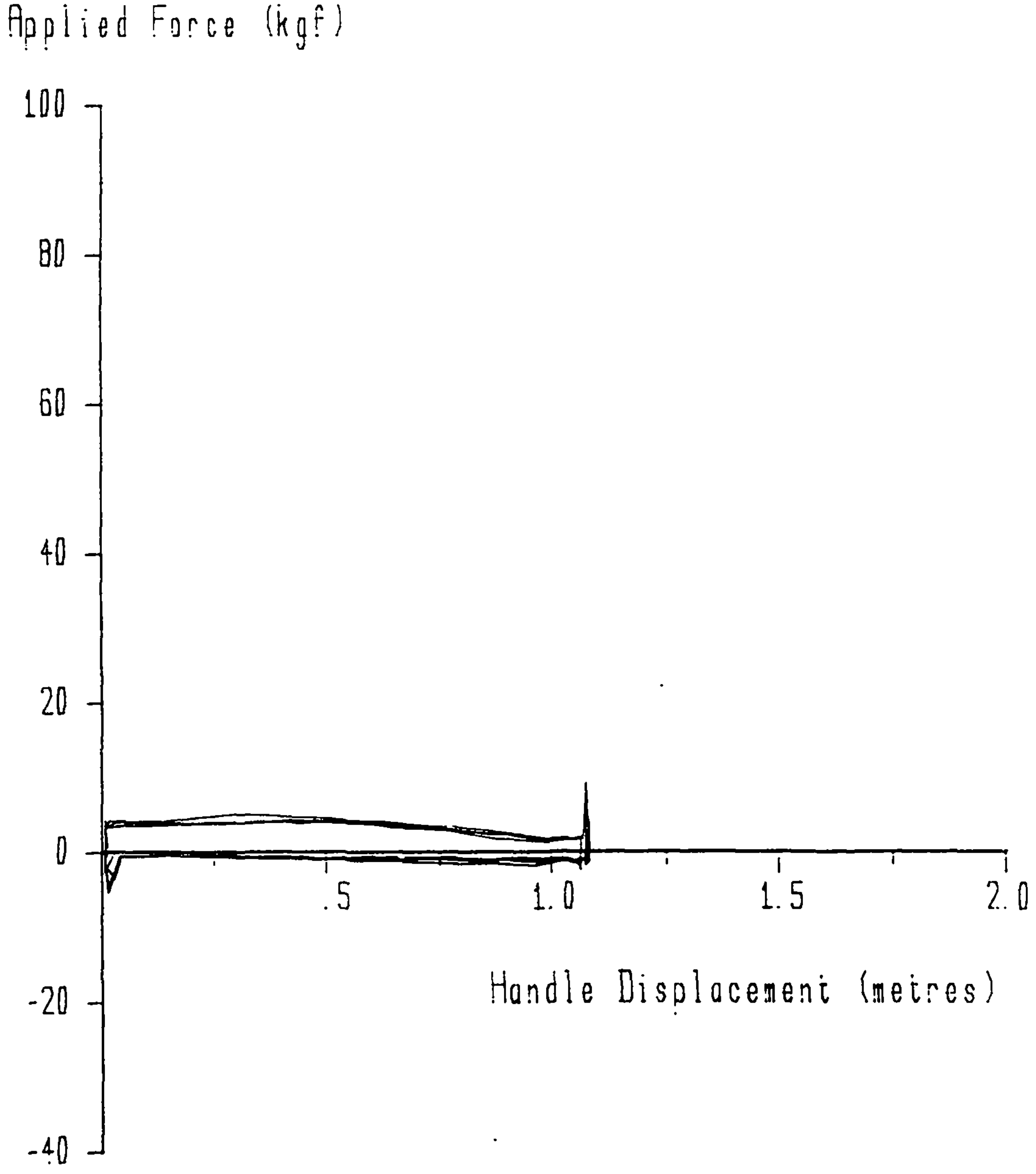
Efficiency 37 per cent

PUMP PERFORMANCE TEST after endurance - MONARCH

Code DD400701 400701

Water Head 7 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 3.3 kg in 10.0 cycles
Average Flow Rate .33 litres per cycle: 13.0 litres/minute
Total Work Done On Pump 451 joules in 10.0 cycles
Average Work Input Rate 45 joules per cycle: 30 watts

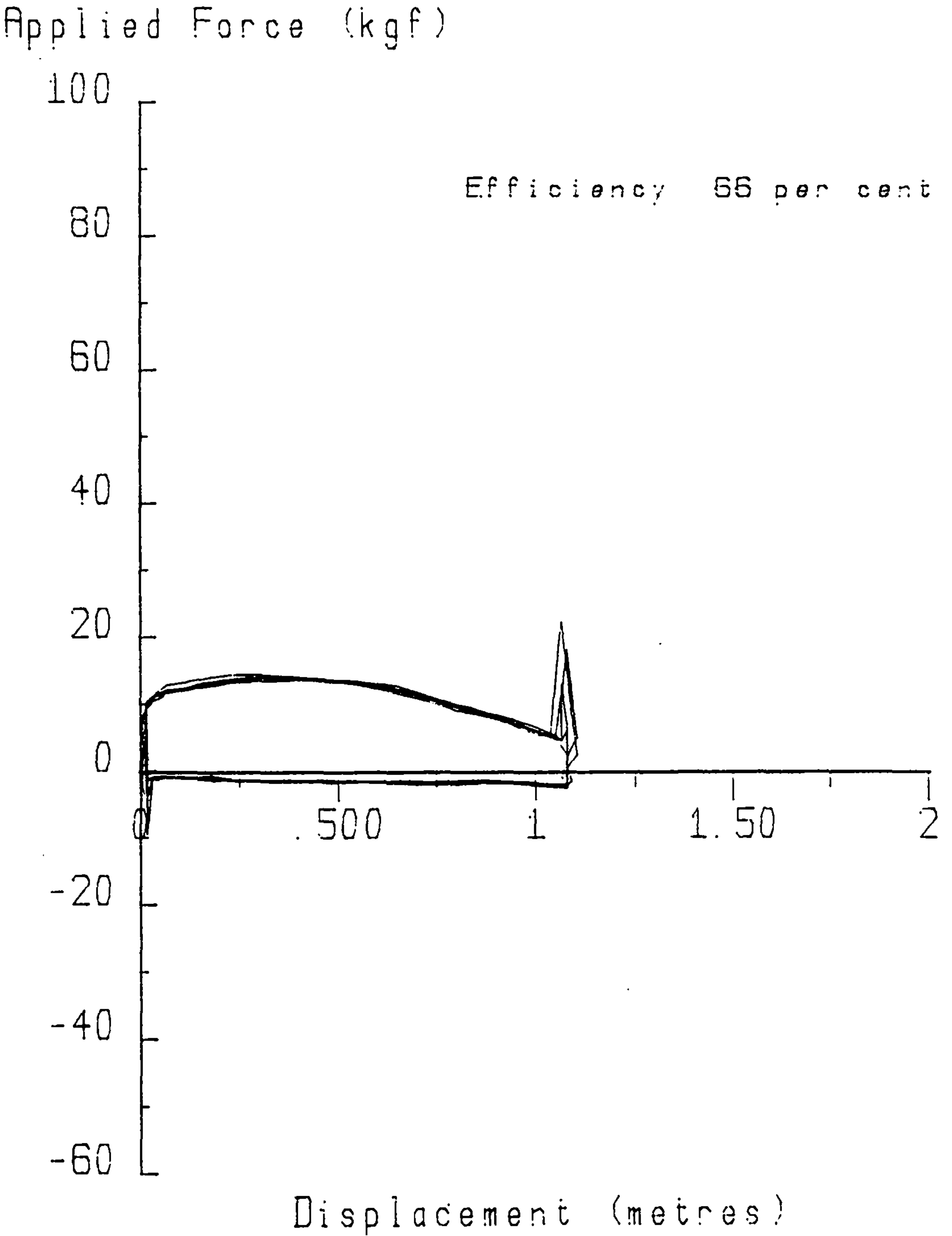
Efficiency 50 per cent



PUMP PERFORMANCE TEST - MONARCH

Code DD402501

Water Head 25 metres --- Pumping Rate 41 cycles/minute
Total Weight of Water Raised 3.6 kg in 10 cycles
Average flow rate .36 litres per cycle. 14.6 litres/minute
Total Work Done On Pump 1338 joules in 10 cycles
Average work input rate 134 joules per cycle. 91 watts

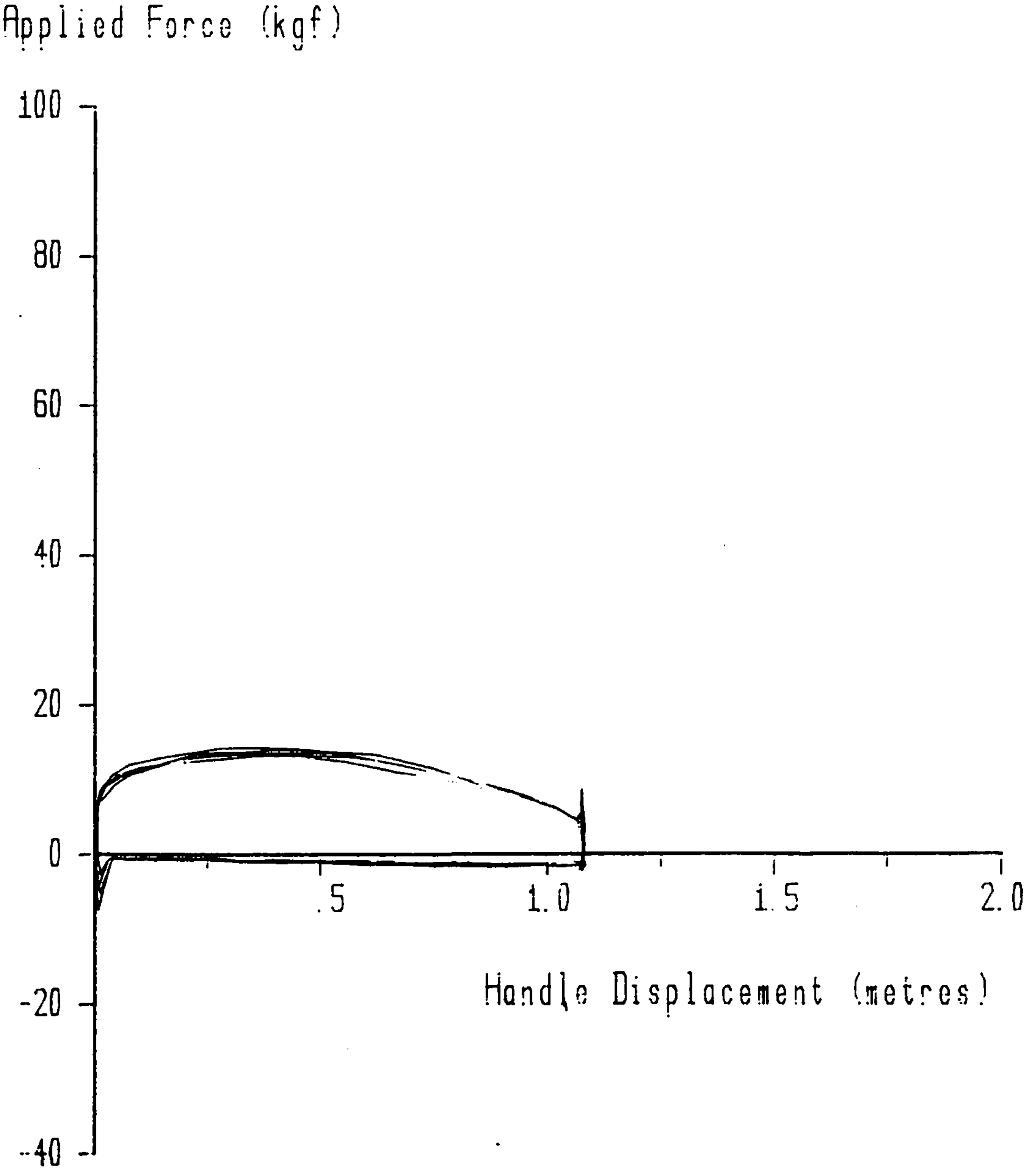


PUMP PERFORMANCE TEST after endurance - MONARCH

Code DD402501

Water Head 25 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 3.1 kg in 10.0 cycles
Average Flow Rate .31 litres per cycle: 12.6 litres/minute
Total Work Done On Pump 1273 joules in 10.0 cycles
Average Work Input Rate 127 joules per cycle: 85 watts

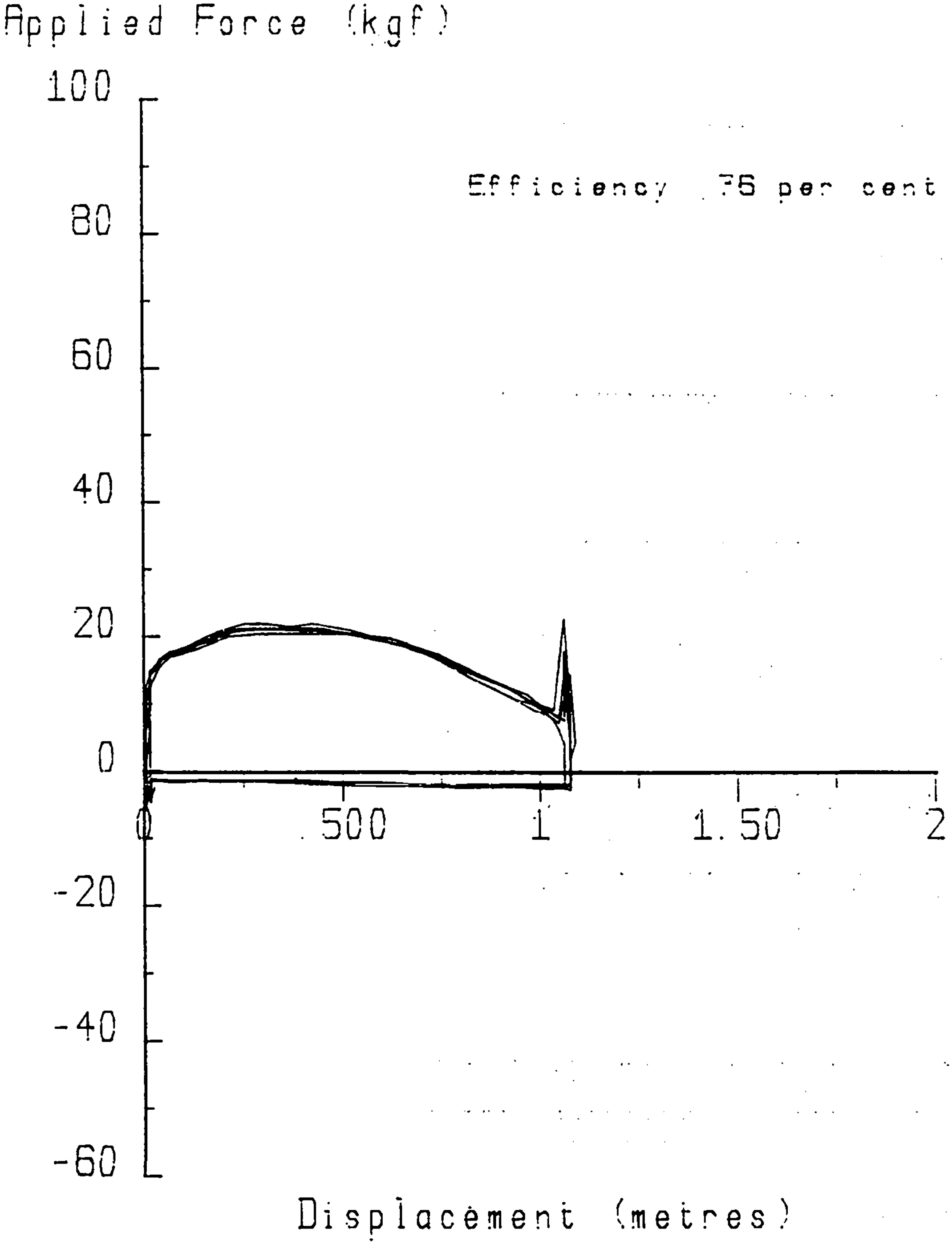
Efficiency 60 per cent



PUMP PERFORMANCE TEST - MONARCH

Code DD404501

Water Head 45 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 3.5 kg in 10 cycles
Average flow rate .35 litres per cycle. 14.0 litres/minute
Total Work Done On Pump 2067 joules in 10 cycles
Average work input rate 207 joules per cycle. 137 watts

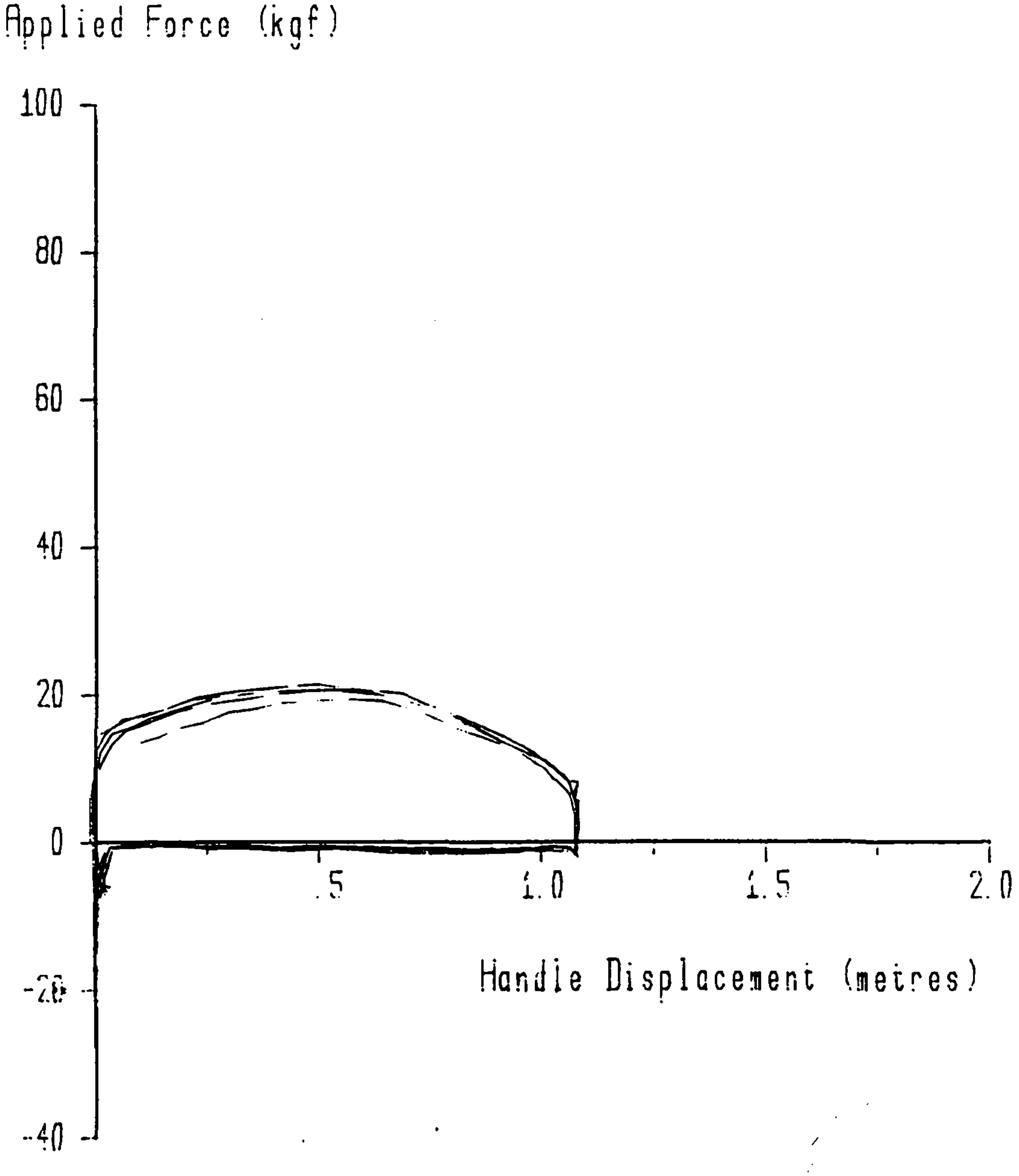


PUMP PERFORMANCE TEST after endurance - MONARCH

Code DD404501

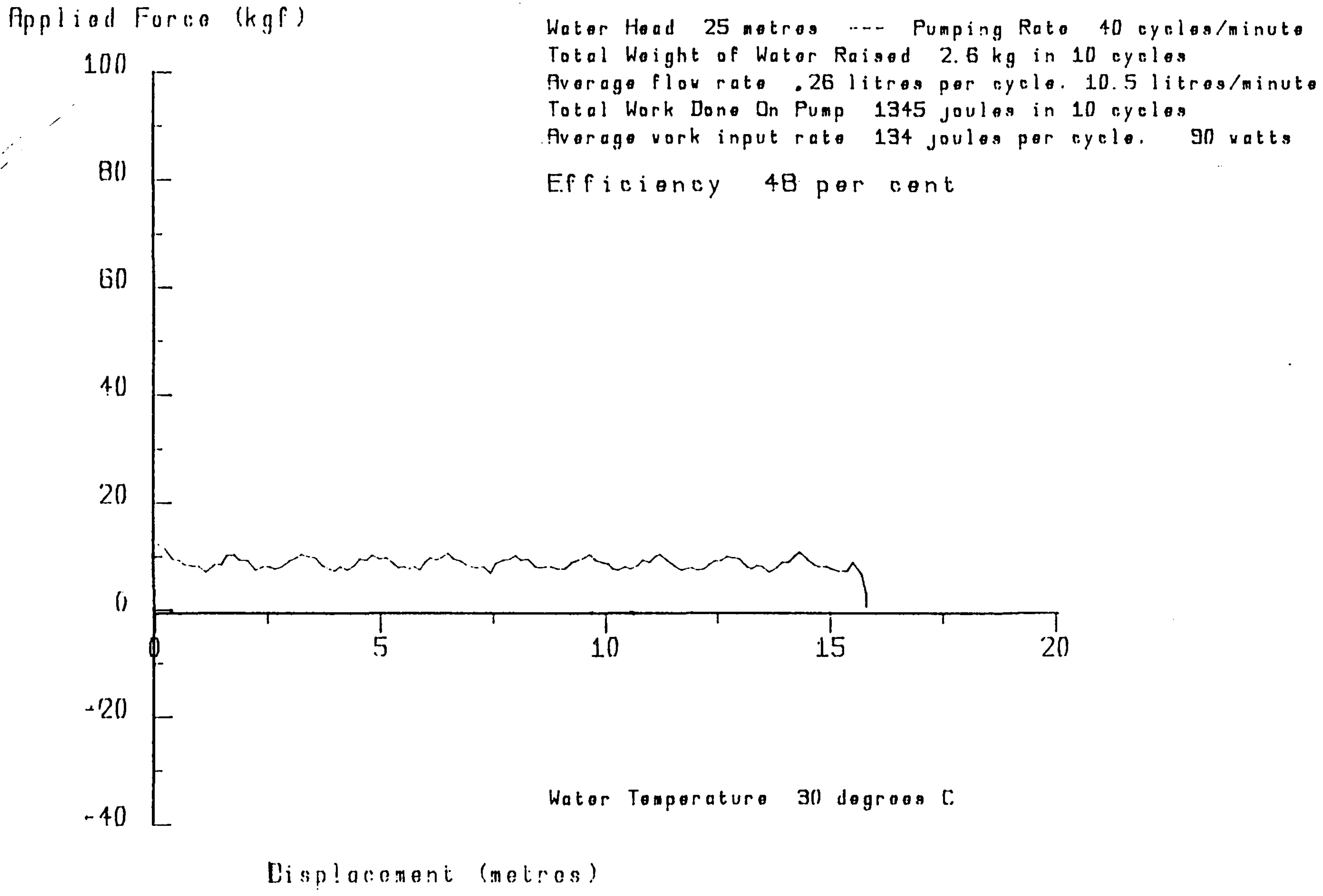
Water Head 45 metres --- Pumping Rate 39 cycles/minute
Total Weight of Water Raised 3.2 kg in 10.0 cycles
Average Flow Rate .32 litres per cycle; 12.5 litres/minute
Total Work Done On Pump 1879 joules in 10.0 cycles
Average Work Input Rate 188 joules per cycle: 124 watts

Efficiency 75 per cent



PUMP PERFORMANCE TEST - MONOLIFT

Code BB 2:1 Ratio



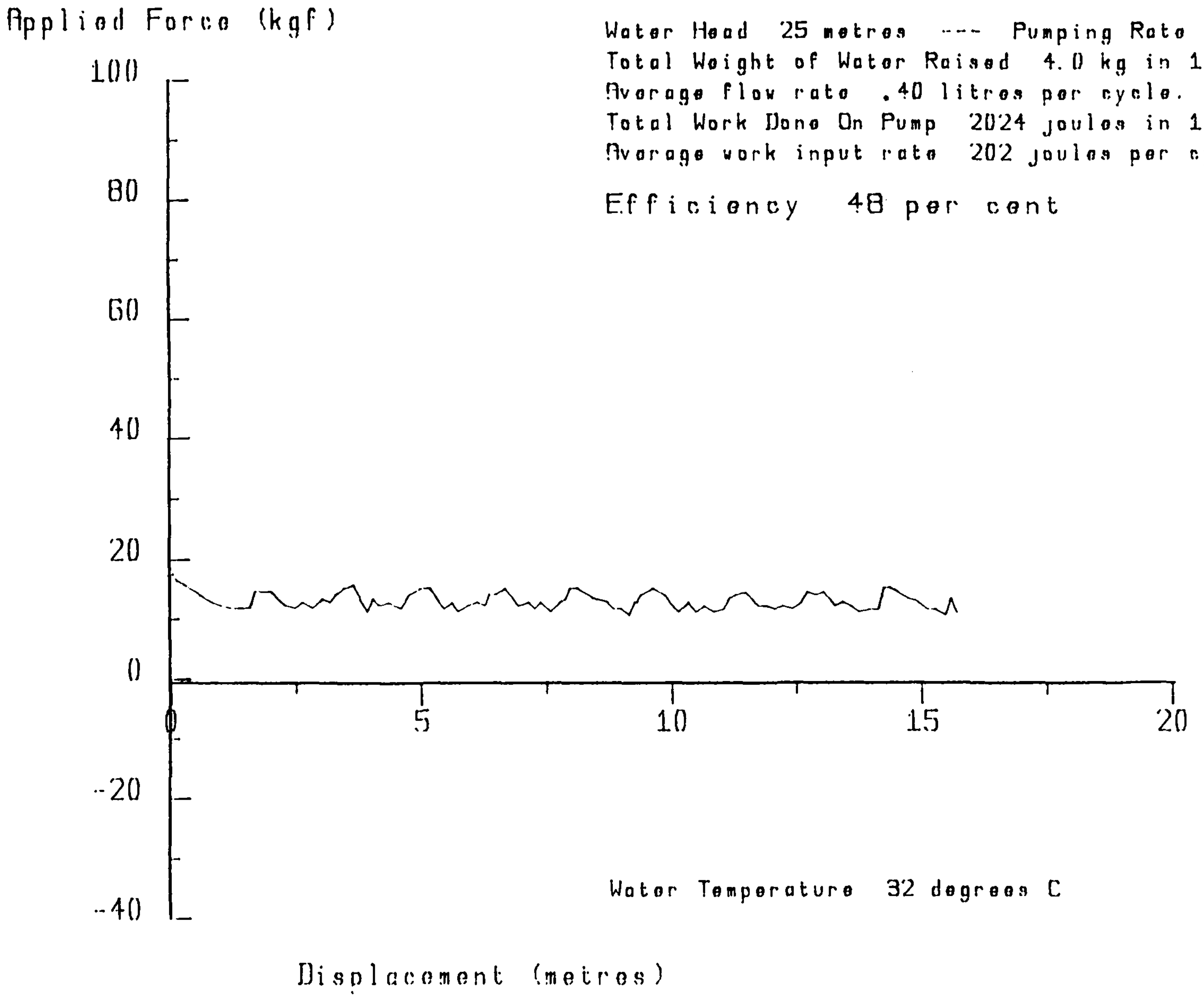
Water Head 25 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 2.6 kg in 10 cycles
Average flow rate .26 litres per cycle. 10.5 litres/minute
Total Work Done On Pump 1345 joules in 10 cycles
Average work input rate 134 joules per cycle. 90 watts

Efficiency 48 per cent

Water Temperature 30 degrees C

PUMP PERFORMANCE TEST - MONOLIFT

Code BB 3:1 Ratio



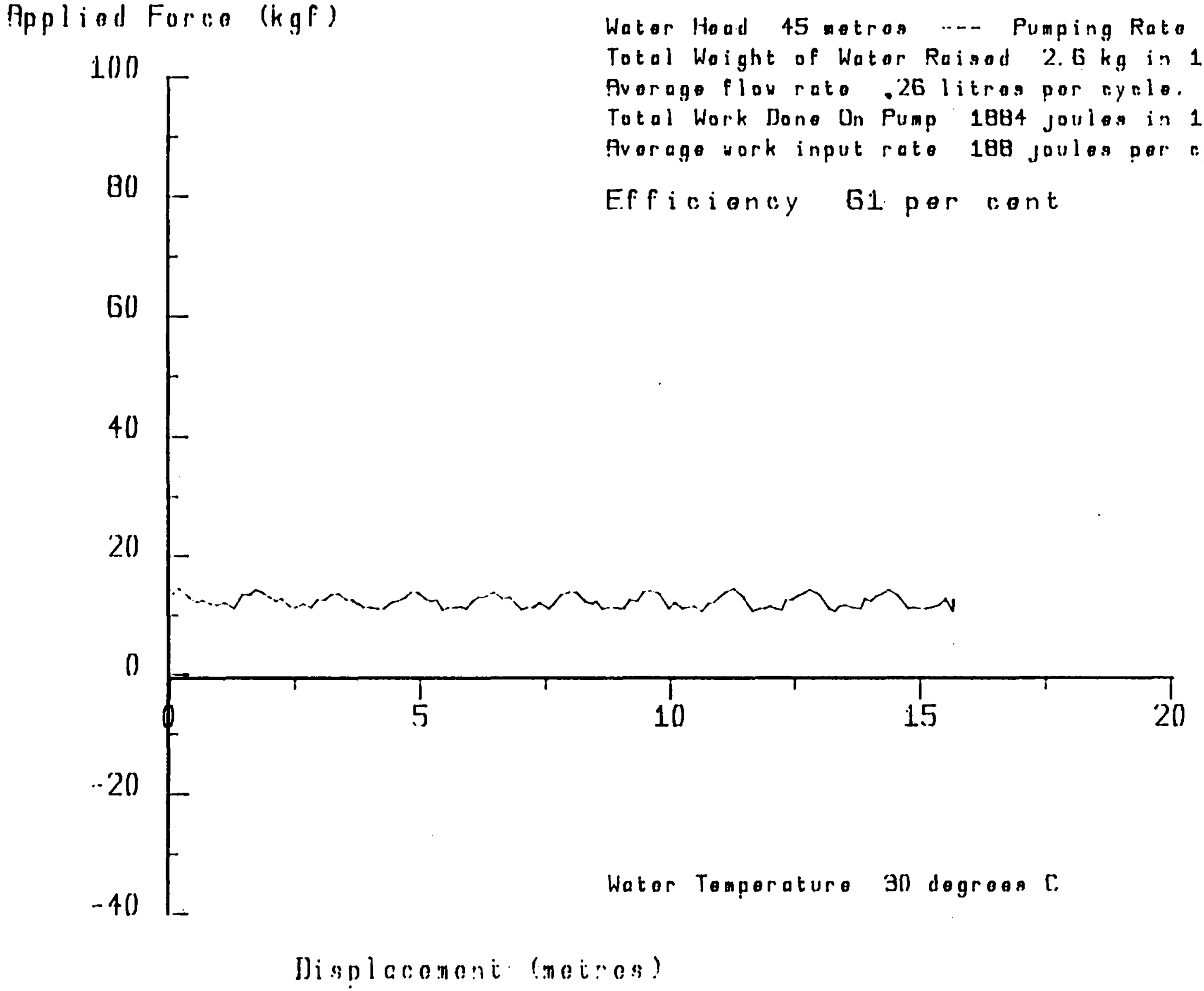
Water Head 25 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 4.0 kg in 10 cycles
Average flow rate .40 litres per cycle. 15.9 litres/minute
Total Work Done On Pump 2024 joules in 10 cycles
Average work input rate 202 joules per cycle. 135 watts

Efficiency 48 per cent

Water Temperature 32 degrees C

PUMP PERFORMANCE TEST - MONOLIFT

Code BB 2:1 Ratio



Water Head 45 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 2.6 kg in 10 cycles
Average flow rate .26 litres per cycle. 10.4 litres/minute
Total Work Done On Pump 1884 joules in 10 cycles
Average work input rate 188 joules per cycle. 125 watts

Efficiency 61 per cent

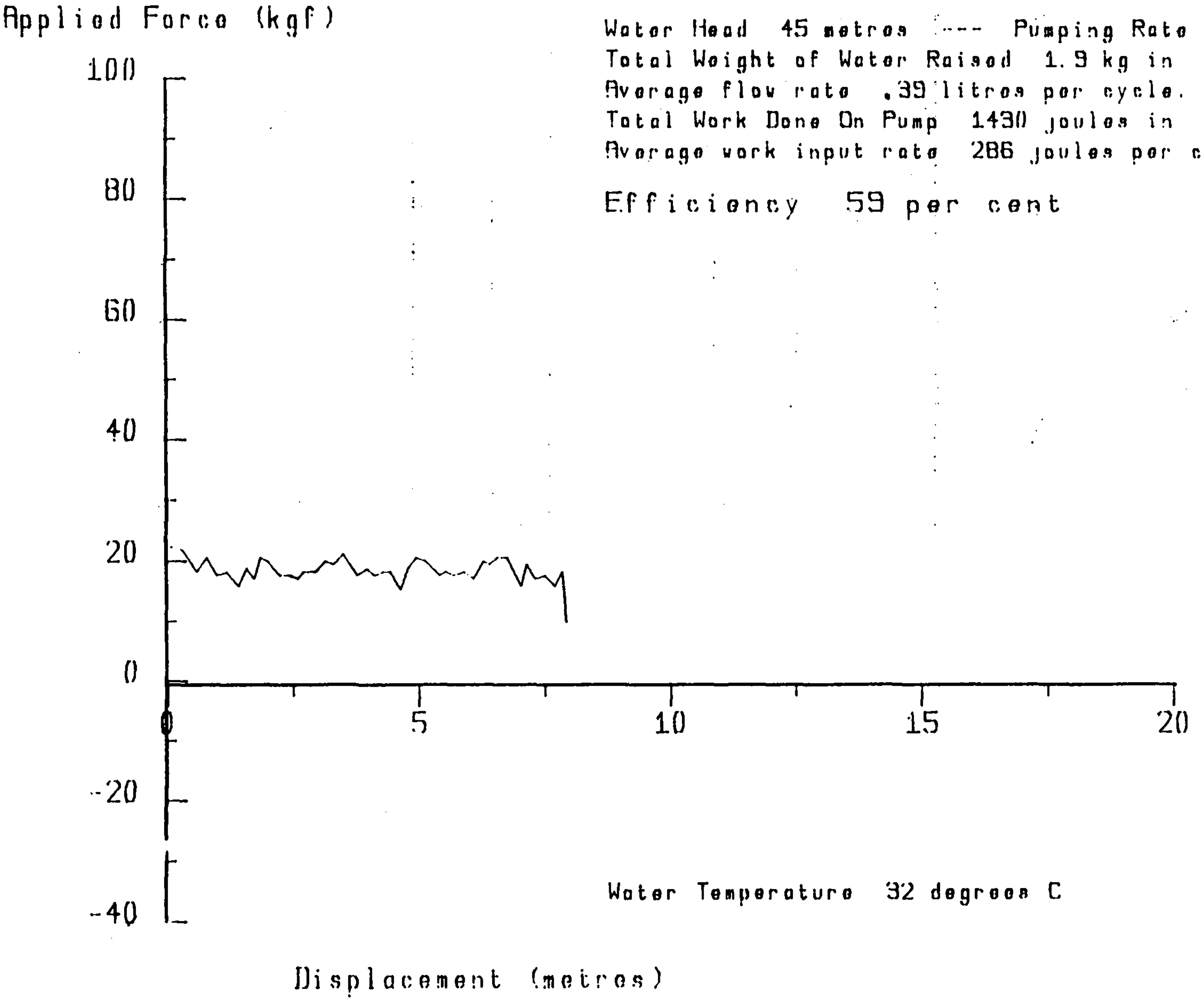
Water Temperature 30 degrees C

PUMP PERFORMANCE TEST - MONOLIFT

Code BB 3:1 Ratio

Water Head 45 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 1.9 kg in 5 cycles
Average flow rate .39 litres per cycle. 15.5 litres/minute
Total Work Done On Pump 1430 joules in 5 cycles
Average work input rate 286 joules per cycle. 191 watts

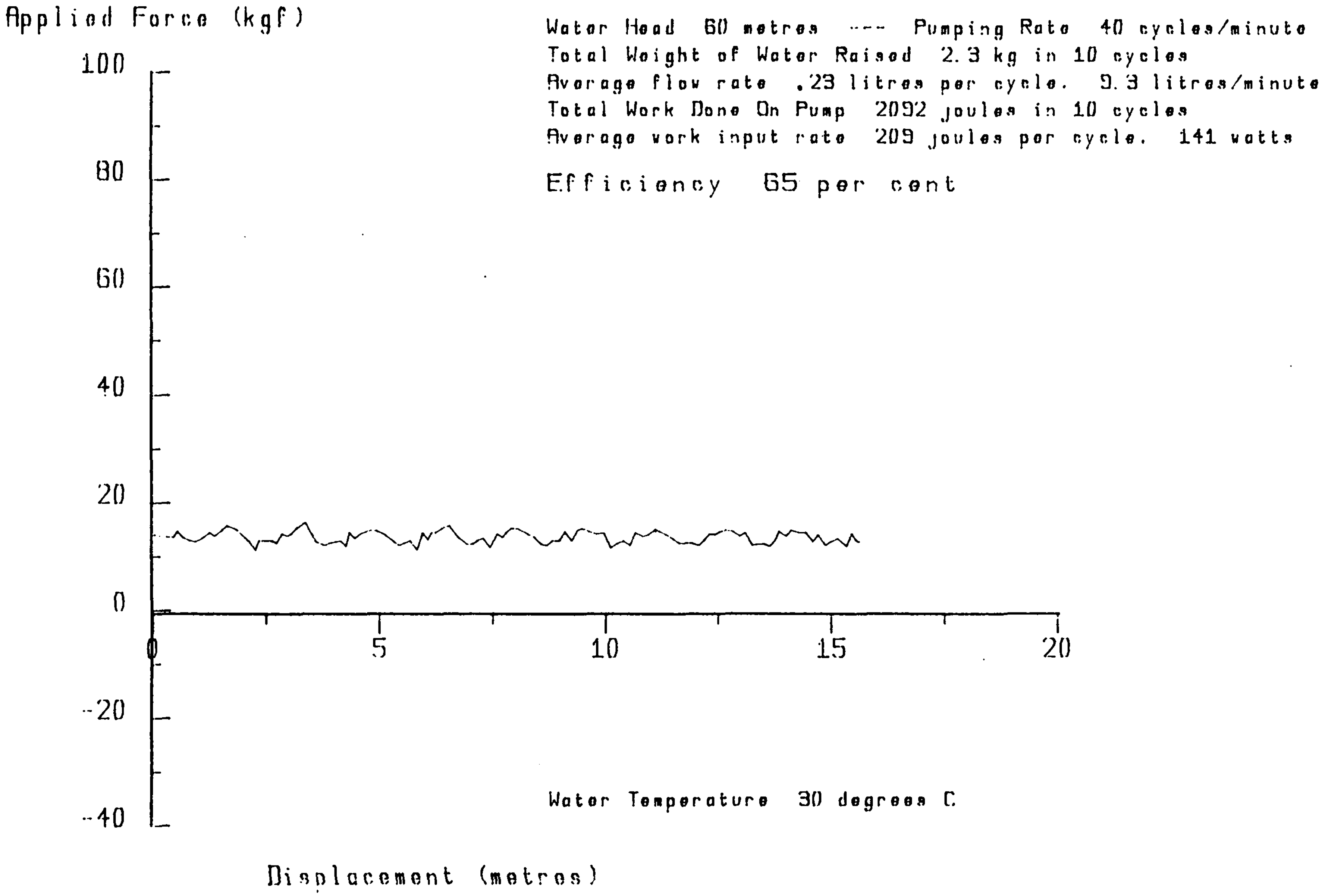
Efficiency 59 per cent



Water Temperature 32 degrees C

PUMP PERFORMANCE TEST - MONOLIFT

Code BB 2:1 Ratio



Water Head 60 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 2.3 kg in 10 cycles
Average flow rate .23 litres per cycle. 9.3 litres/minute
Total Work Done On Pump 2092 joules in 10 cycles
Average work input rate 209 joules per cycle. 141 watts

Efficiency 65 per cent

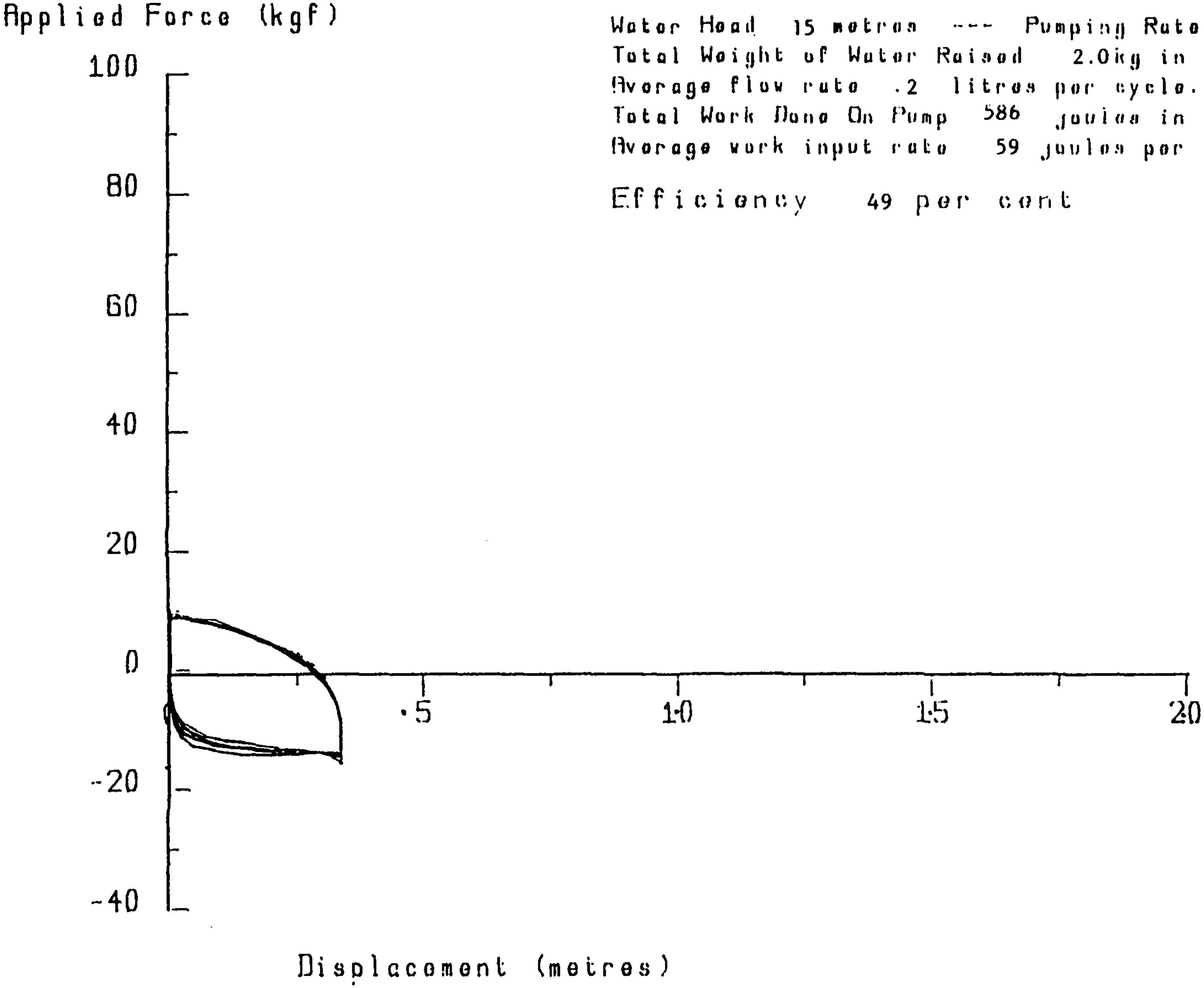
Water Temperature 30 degrees C

PUMP PERFORMANCE TEST - PEK

Code CC BOREHOLE

Water Head 15 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 2.0kg in 10 cycles
Average flow rate .2 litres per cycle. 7.8 litres/minute
Total Work Done On Pump 586 joules in 10 cycles
Average work input rate 59 joules per cycle. 39watts

Efficiency 49 per cent

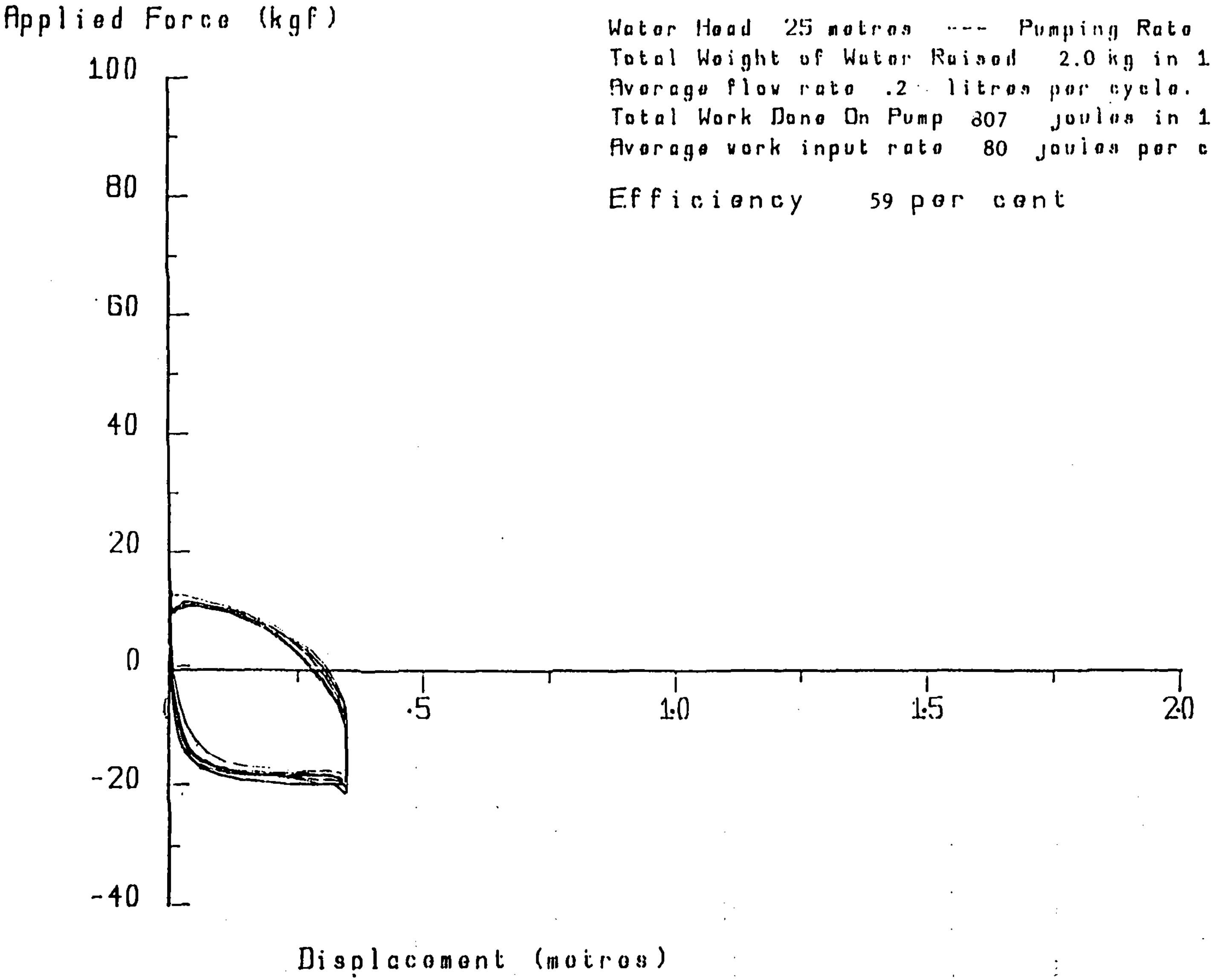


PUMP PERFORMANCE TEST - PEK

Code CC BOREHOLE

Water Head 25 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised 2.0 kg in 10 cycles
Average flow rate .2 litres per cycle. 7.8 litres/minute
Total Work Done On Pump 807 joules in 10 cycles
Average work input rate 80 joules per cycle. 53 watts

Efficiency 59 per cent

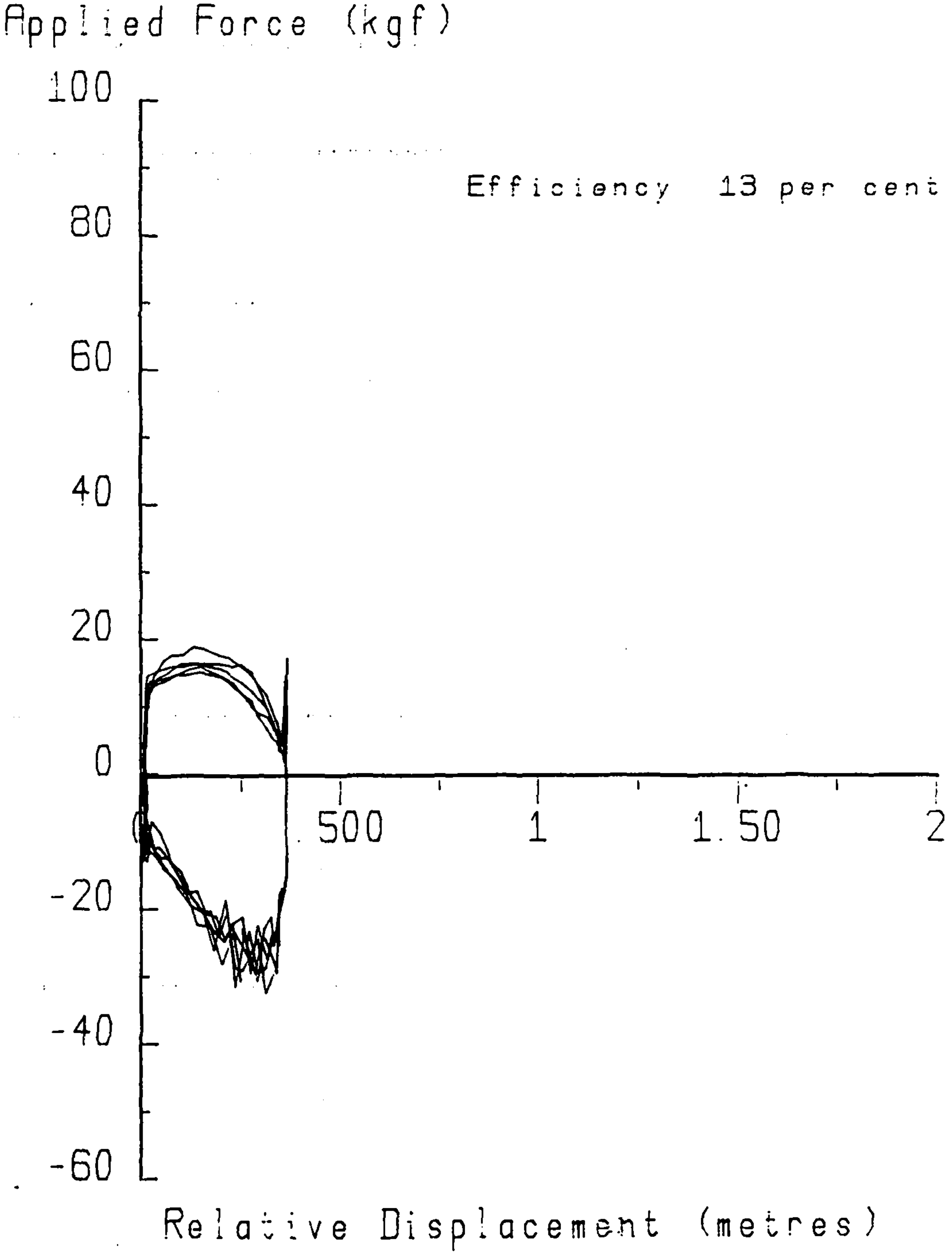


PUMP PERFORMANCE TEST - PEK

Code CC402501 BOREHOLE

after endurance

Water Head 25 metres --- Pumping Rate 40 cycles/minute
Total Weight of Water Raised .7 kg in 10 cycles
Average flow rate .07 litres per cycle. 2.9 litres/minute
Total Work Done On Pump 1326 joules in 10 cycles
Average work input rate 133 joules per cycle. 88 watts



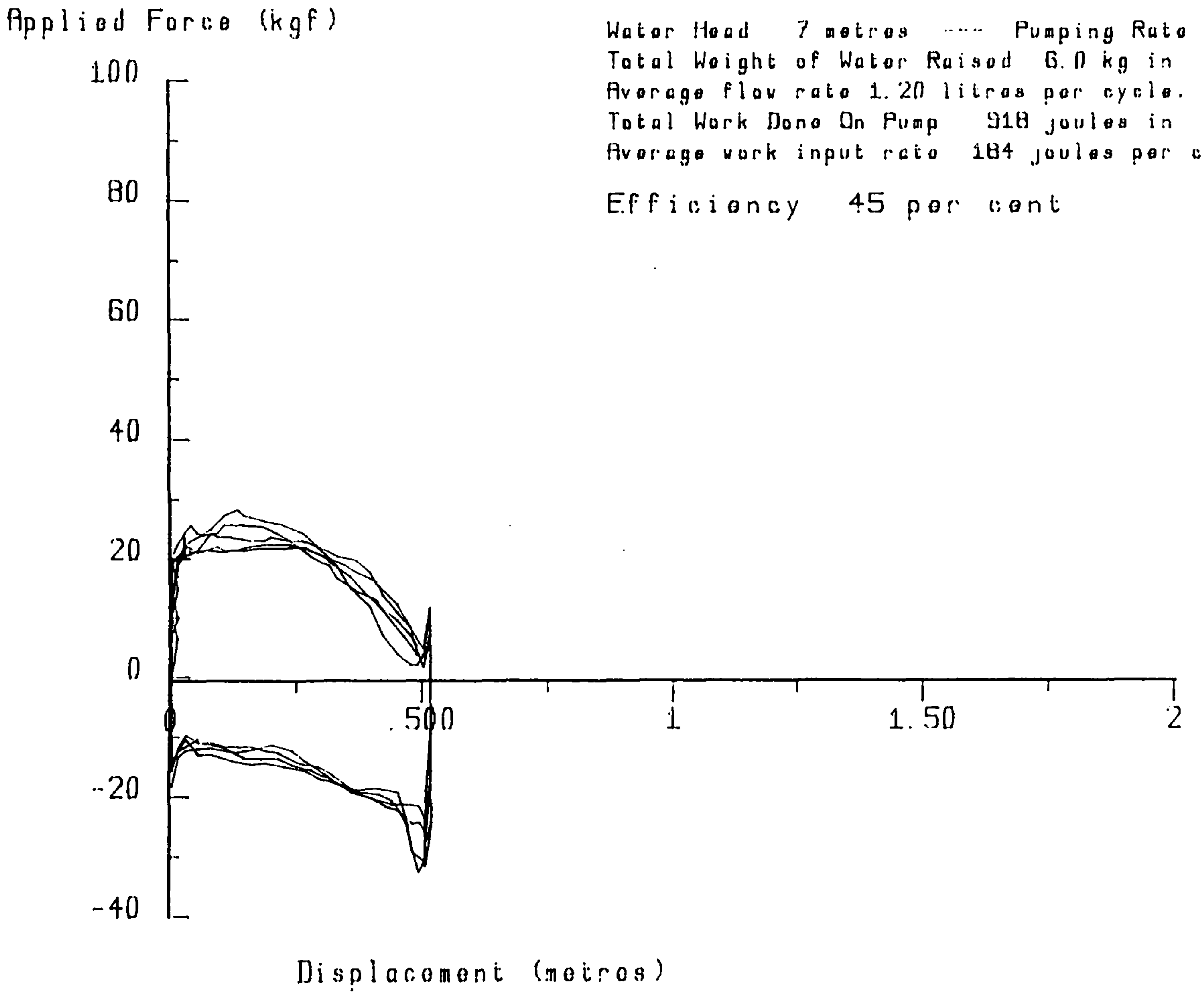
Efficiency 13 per cent

PUMP PERFORMANCE TEST

Code JJ Borehole Test TARA

Water Head 7 metres ---- Pumping Rate 30 cycles/minute
Total Weight of Water Raised 6.0 kg in 5 cycles
Average flow rate 1.20 litres per cycle. 35.8 litres/minute
Total Work Done On Pump 918 joules in 5 cycles
Average work input rate 184 joules per cycle. 91 watts

Efficiency 45 per cent

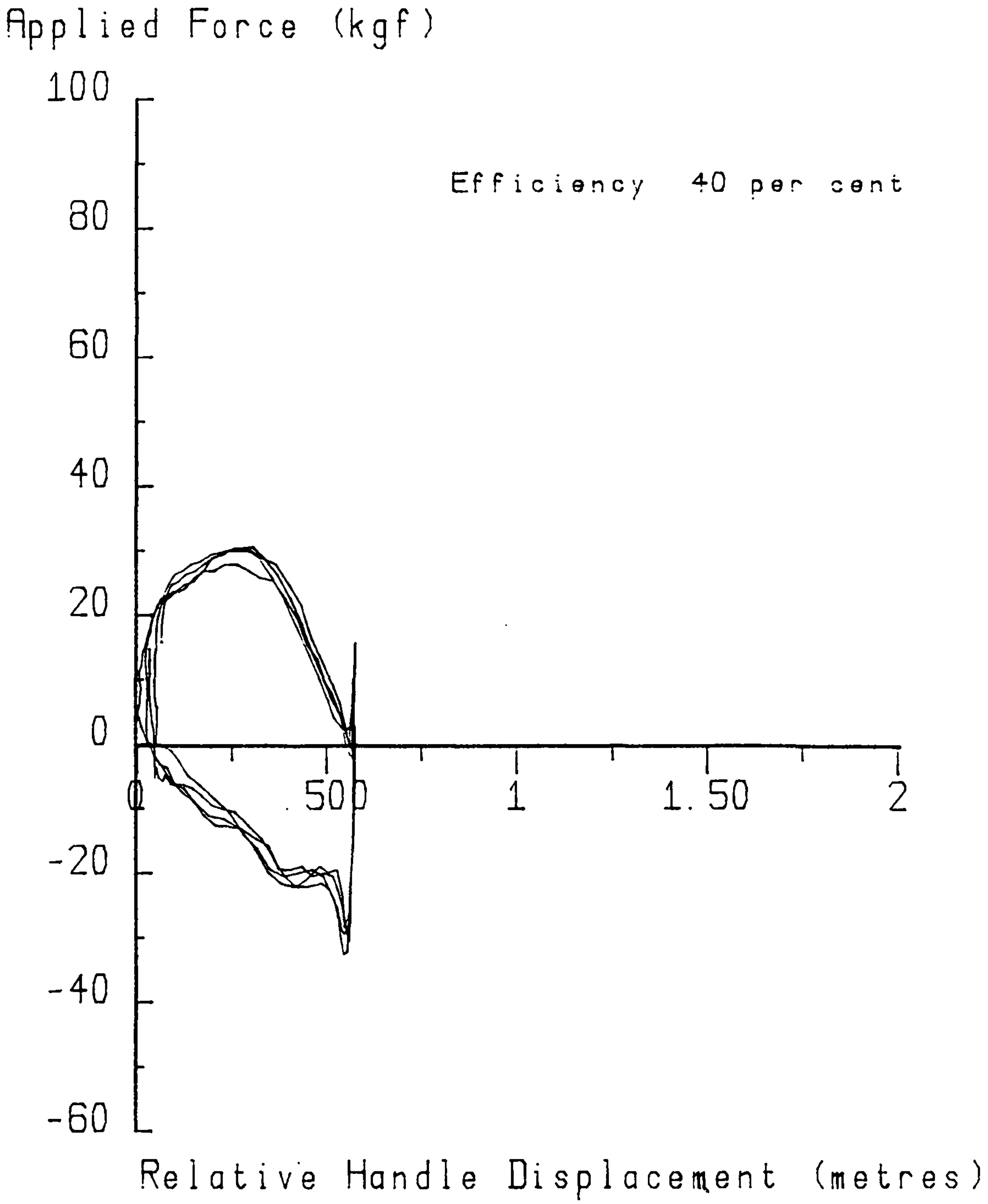


PUMP PERFORMANCE TEST

Code JJ3007B5 TARA BOREHOLE

after endurance

Water Head 7 metres --- Pumping Rate 30 cycles/minute
Total Weight of Water Raised 5.6 kg in 5 cycles
Average flow rate 1.11 litres per cycle. 33.3 litres/minute
Total Work Done On Pump 950 joules in 5 cycles
Average work input rate 190 joules per cycle. 95 watts

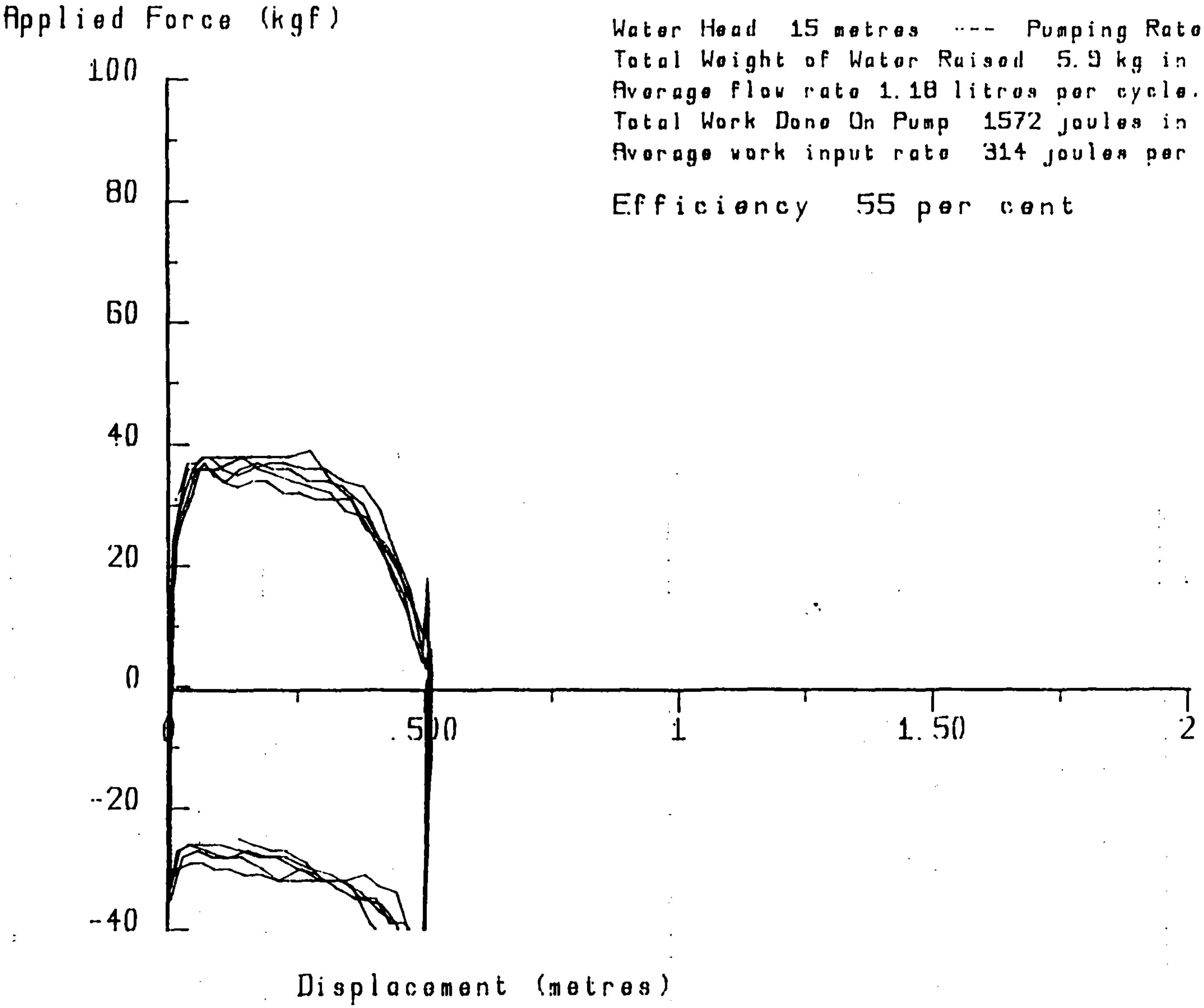


Efficiency 40 per cent

PUMP PERFORMANCE TEST

Code JJ Borehole Test 14-11-84

TARA



Water Head 15 metres --- Pumping Rate 24 cycles/minute
Total Weight of Water Raised 5.9 kg in 5 cycles
Average flow rate 1.18 litres per cycle. 27.9 litres/minute
Total Work Done On Pump 1572 joules in 5 cycles
Average work input rate 314 joules per cycle. 124 watts

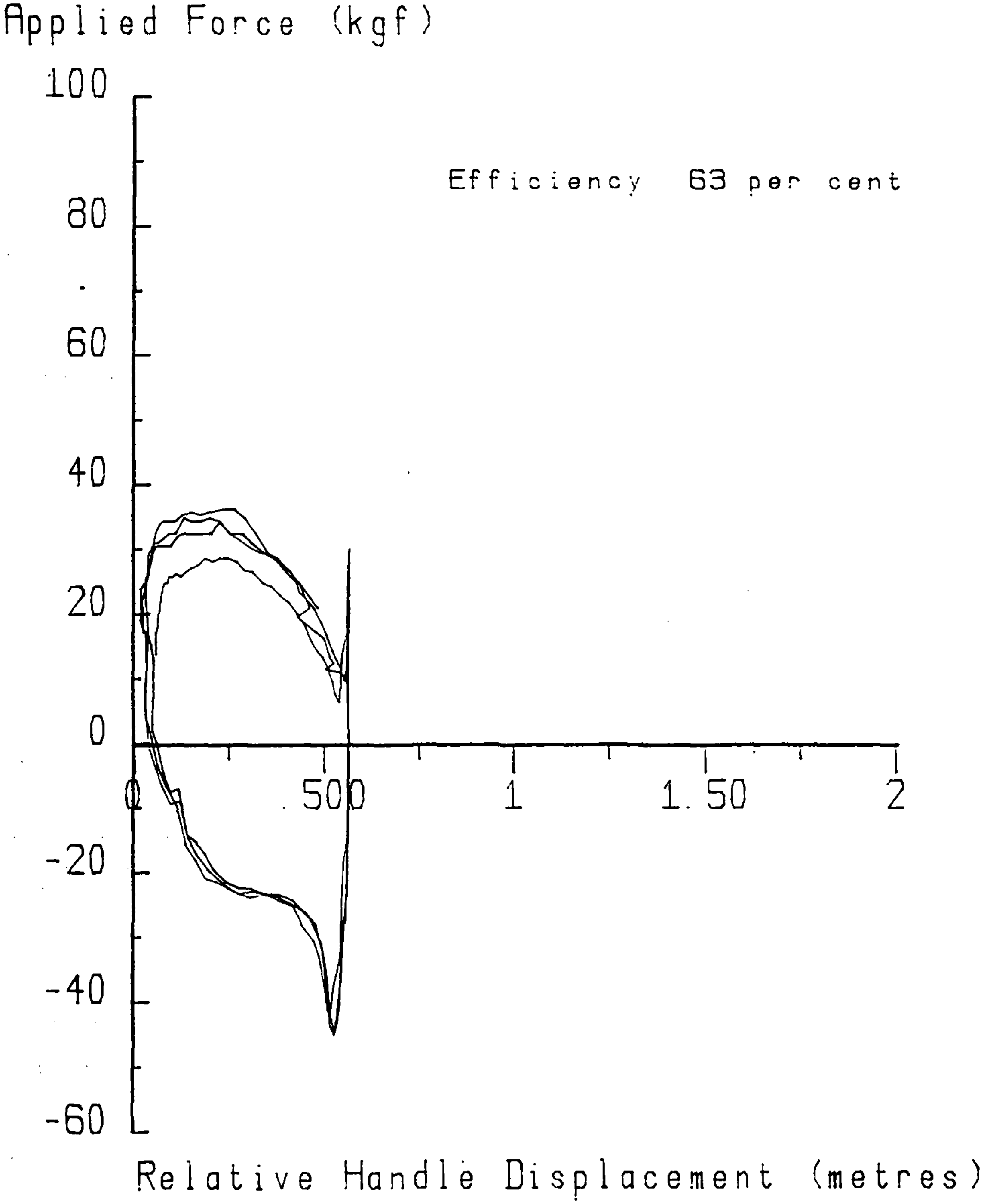
Efficiency 55 per cent

PUMP PERFORMANCE TEST

Code JJ2515B5 TARA BOREHOLE

after endurance

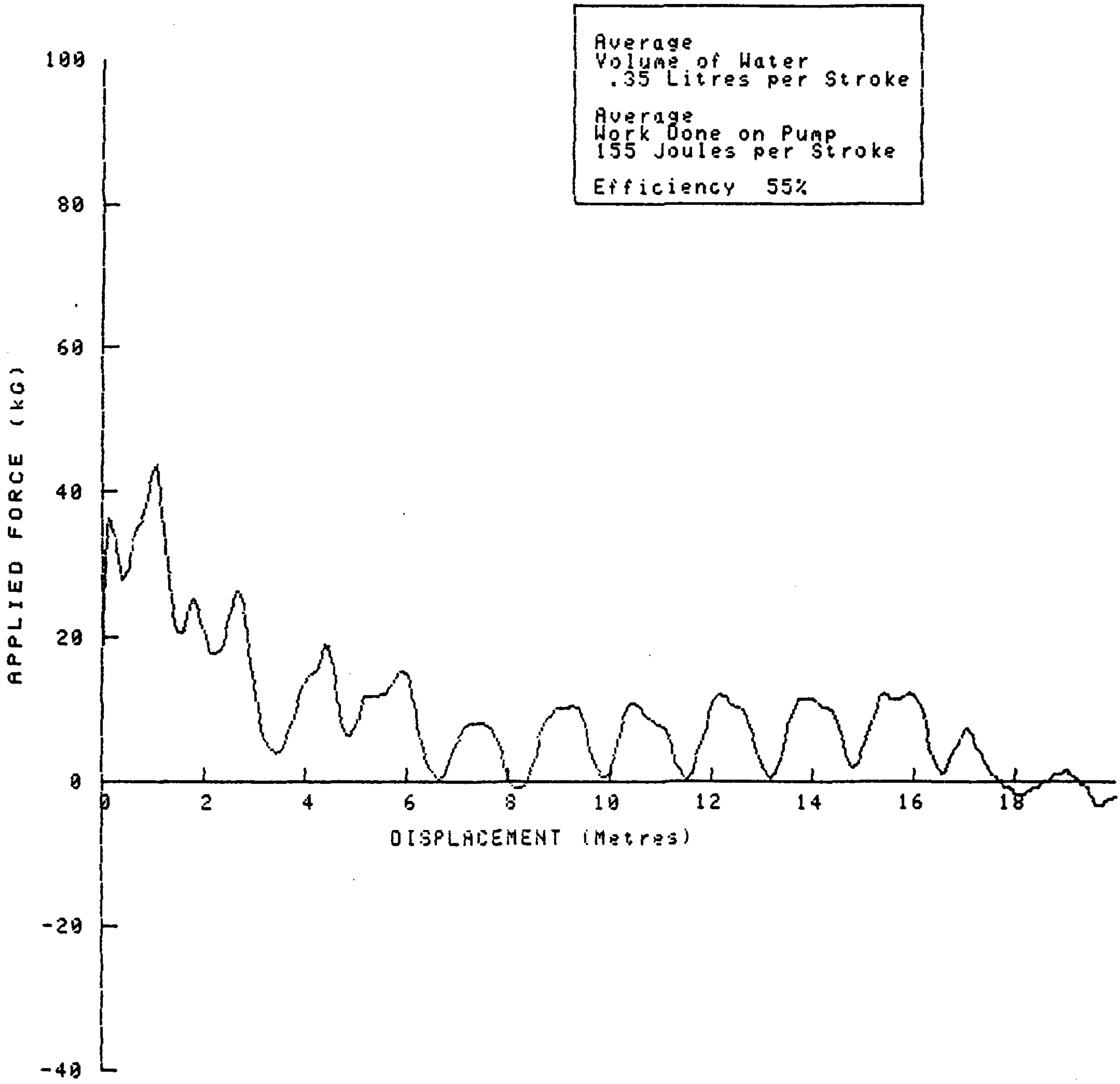
Water Head 15 metres --- Pumping Rate 27 cycles/minute
Total Weight of Water Raised 5.6 kg in 5 cycles
Average flow rate 1.12 litres per cycle. 30.4 litres/minute
Total Work Done On Pump 1313 joules in 5 cycles
Average work input rate 263 joules per cycle. 119 watts



PUMP PERFORMANCE : VOLANTA

CODE EY : BOREHOLE TEST : Standing Start

Water Head 25 Metres --- Pumping Rate 43 Strokes/Minute
Total Weight of Water Raised 4.4kG
12 Strokes/Revolutions
Total Work Done On Pump 1927 Joules. (Rate 110.3 Watts)


Average
Volume of Water
.35 Litres per Stroke

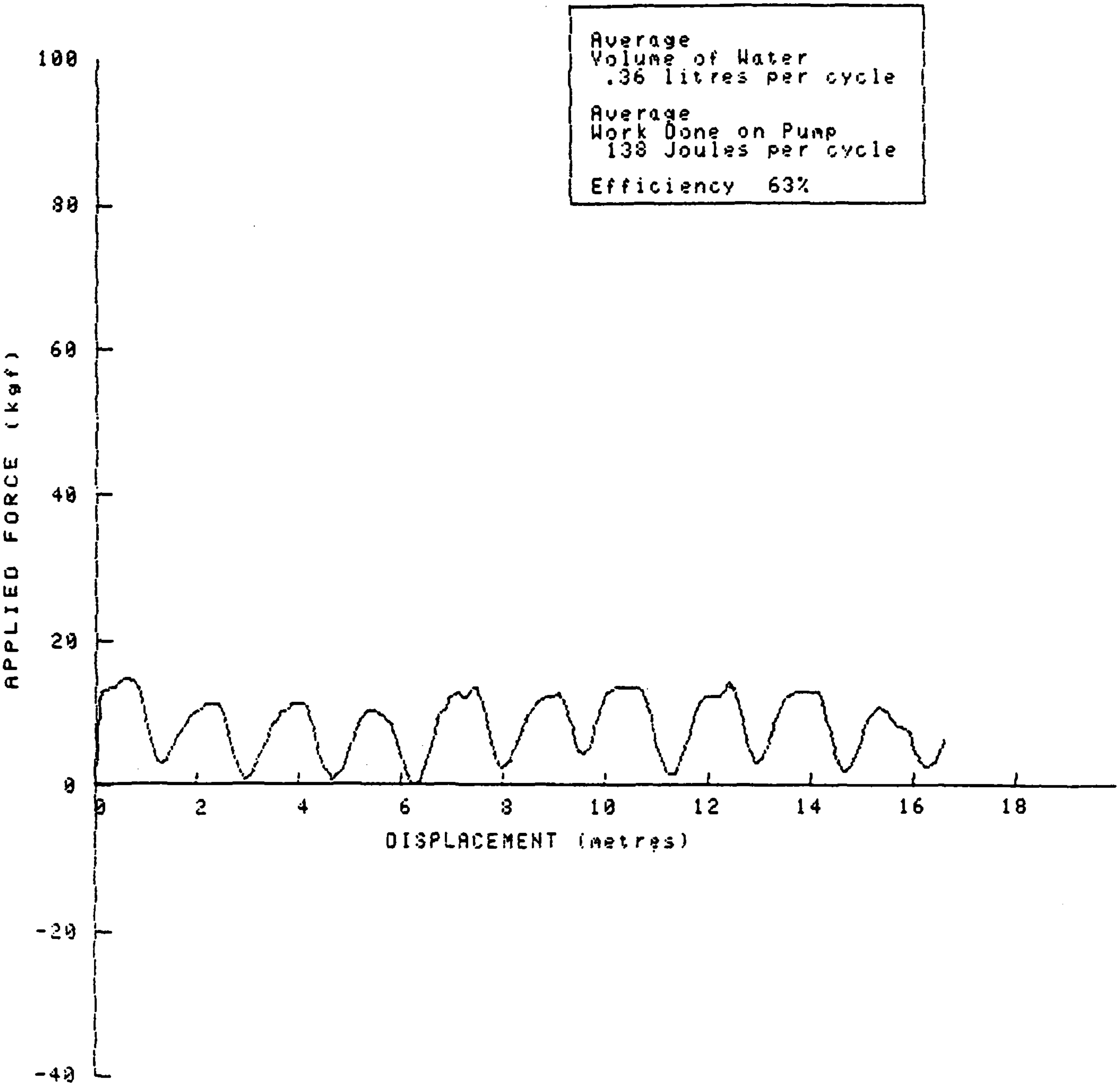
Average
Work Done on Pump
155 Joules per Stroke

Efficiency 55%

PUMP PERFORMANCE : VOLANTA

CODE EY : BOREHOLE TEST : Flying Start

Water Head 25 metres --- Pumping Rate 52 strokes/minute
Total Weight of Water Raised 3.6kg
10 Strokes/Revolutions
Total Work Done On Pump 1382 Joules. (Rate 118.8 watts)



Average
Volume of Water
.36 litres per cycle

Average
Work Done on Pump
138 Joules per cycle

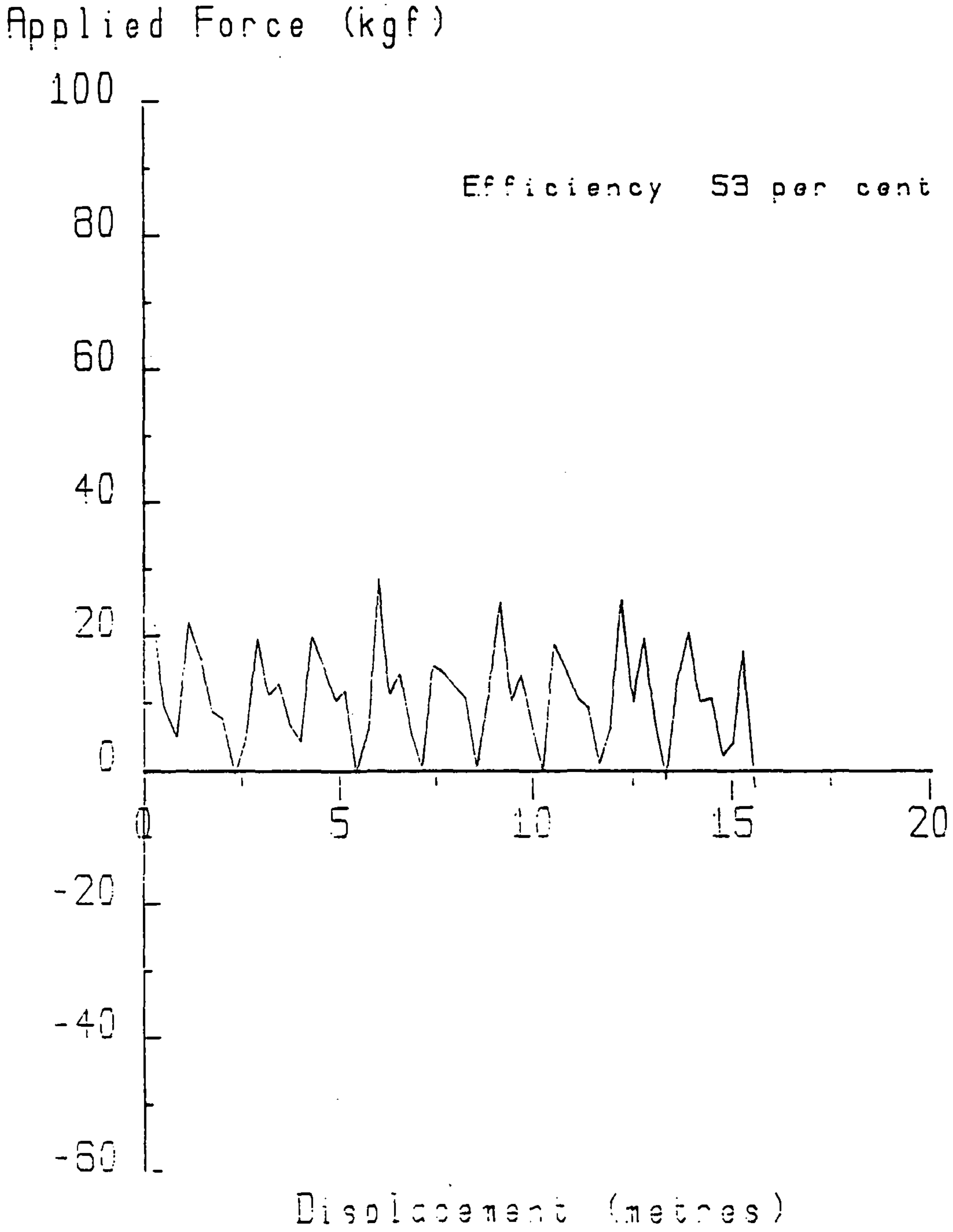
Efficiency 63%

PUMP PERFORMANCE TEST : VOLANTA

Code EE FLYING START

after endurance

Water Head 25 metres --- Pumping Rate 49 cycles/minute
Total Weight of Water Raised 3.6 kg in 10 cycles
Average Flow Rate .36 litres per cycle. 17.6 litres/minute
Total Work Done On Pump 1673 joules in 10 cycles
Average Work Input Rate 167 joules per cycle. 136 watts

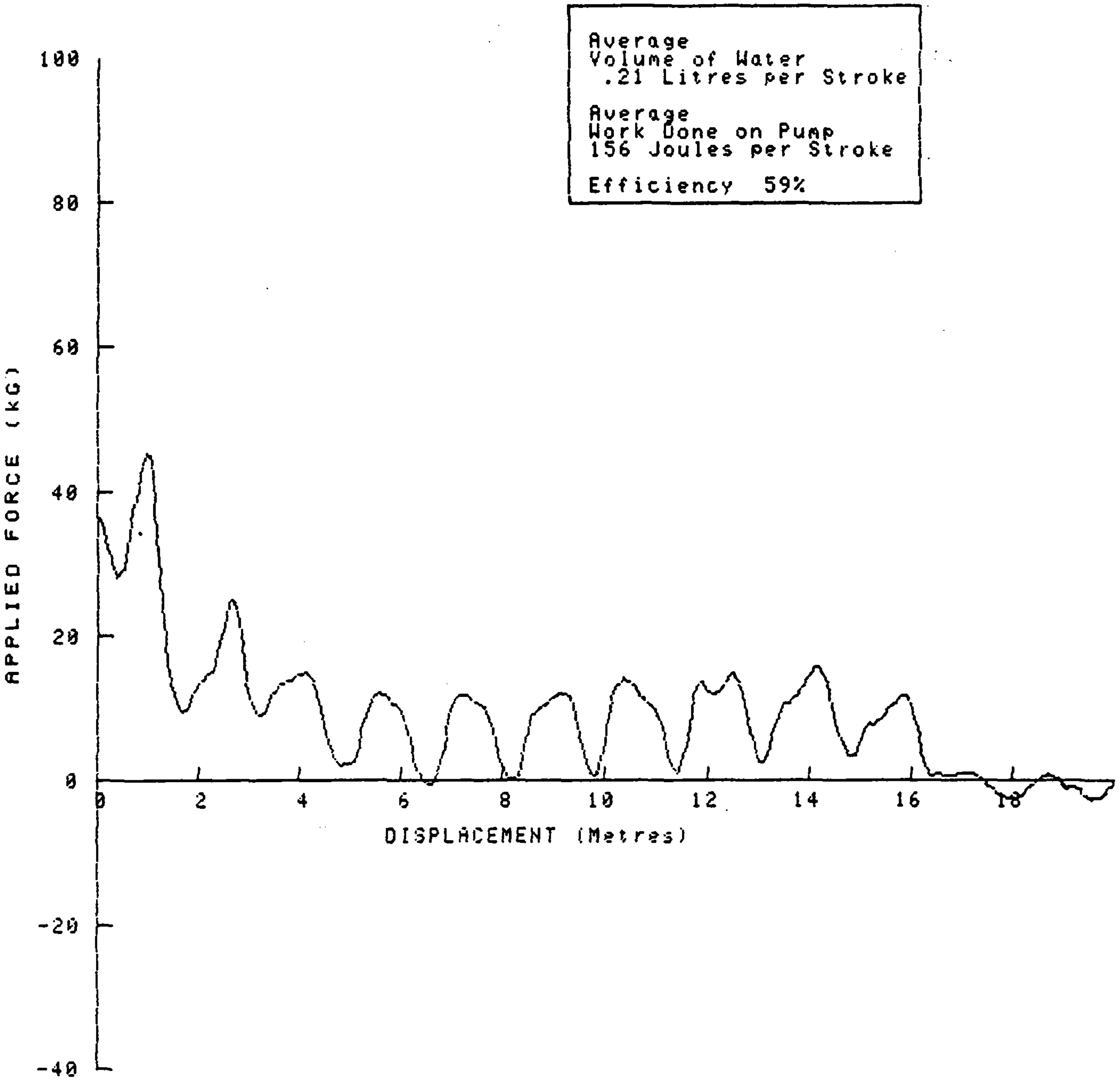


Efficiency 53 per cent

PUMP PERFORMANCE VOLANTA

CODE EY : BOREHOLE TEST : Standing Start

Water Head 45 Metres --- Pumping Rate 41 Strokes/Minute
Total Weight of Water Raised 2.6kG
12 Strokes/Revolutions
Total Work Done On Pump 1905 Joules. (Rate 105.6 Watts)



Average
Volume of Water
.21 Litres per Stroke

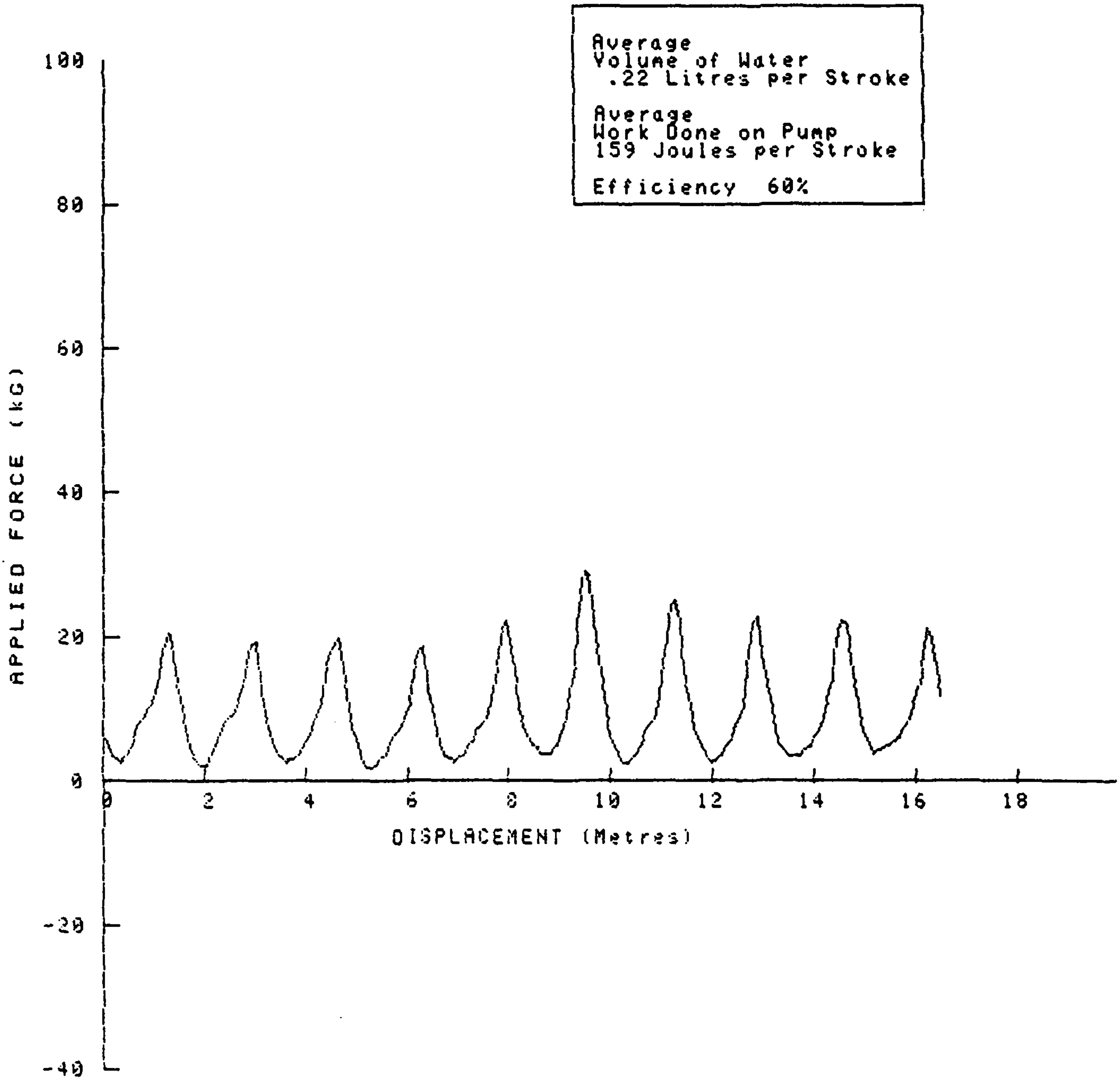
Average
Work Done on Pump
156 Joules per Stroke

Efficiency 59%

PUMP PERFORMANCE VOLANTA

CODE EY : BOREHOLE TEST : Flying Start

Water Head 45 Metres --- Pumping Rate 50 Strokes/Minute
Total Weight of Water Raised 2.2kG
10 Strokes/Revolutions
Total Work Done On Pump 1593 Joules. (Rate 133.9 Watts)



Average
Volume of Water
.22 Litres per Stroke

Average
Work Done on Pump
159 Joules per Stroke

Efficiency 60%

PUMP PERFORMANCE TEST : VOLANTA

Code EE FLYING START

after endurance

Water Head 45 metres --- Pumping Rate 47 cycles/minute
Total Weight of Water Raised 2.5 kg in 10 cycles
Average Flow Rate .25 litres per cycle. 11.7 litres/minute
Total Work Done On Pump 1591 joules in 10 cycles
Average Work Input Rate 159 joules per cycle. 125 watts