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LABORATORY TESTING OF HAND-OPERATED WATER PUMPS

WASH FIELD REPORT NO. 131

SEPTEMBER 1984

Prepared for:
Office of Health
Bureau for Science and Technology
U.S. Agency for International Development
Order of Technical Direction No. 69

WATER AND SANITATION FOR HEALTH PROJECT

WASH

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24 September 1984

Dr. John Austin
WASH Project Manager
USAID
Washington, D.C. 20523

Dear Dr. Austin:

On behalf of the WASH Project I am pleased to provide you with ten copies of a report on Laboratory Testing of Hand-Operated Water Pumps.

This is the final report by Dr. B.S. Dixit and P.W. Potts in which they describe their efforts to test 11 AID-type pumps from 16 countries as well as two rotary and two Malawi-type handpumps. This report describes the testing program that was followed, the results obtained and the resulting recommendations.

This assistance is the result of a request by S&T/H/WS on 19 November 1981. The work was undertaken by the WASH Project during the period 1981 to 1984 by means of Order of Technical Direction No. 69, authorized by the USAID Office of Health in Washington.

If you have any questions or comments regarding the findings or recommendations contained in this report we will be happy to discuss them.

Sincerely,

David Donaldson

David Donaldson
Acting Director
WASH Project

DBW:kk

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LABORATORY TESTING OF HAND-OPERATED WATER PUMPS

Prepared for the Office of Health
Bureau for Science and Technology
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under Order of Technical Direction No. 69

Prepared by:

B.S. Dixit
Phillip W. Potts

September 1984

Water and Sanitation for Health Project
Contract No. AID/DSPE-C-0080, Project No. 931-1176
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Washington, DC 20523

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ACKNOWLEDGEMENTS

The authors of this report wish to express their appreciation to several people for contributing to the handpump testing at the Georgia Institute of Technology. Mr. Ralph Preble, of the WASH Project office, Arlington, Virginia, did an excellent job in administering the project and coordinating it with AID/Washington. The Consumers' Association Testing and Research Laboratories at Harpenden, England, was most cooperative and helpful by sharing its experiences with Georgia Tech. Messrs. George Murdoch, Fernando Pareja-Gil, Terrence Moy, and James Larsen, all of Georgia Tech, contributed many hours during nights, weekends, and holidays to keep the testing facility running 24 hours a day, seven days a week.

EXECUTIVE SUMMARY

In December 1981, AID handpumps manufactured in Tunisia, Ecuador, the Dominican Republic, Honduras, and the Philippines were chosen by AID/Washington for laboratory durability and reliability testing. Later, in September 1983, AID handpumps manufactured in Haiti, Moyno rotary handpumps manufactured in the United States, Mono rotary handpumps manufactured in the United Kingdom, reciprocating handpumps manufactured in Malawi by Petroleum Services, and three types of foot valves were added to the testing. Also, one Malawi pump was to be tested with specially treated alkaline and acidic water.

This report presents the results of the testing of those pumps and foot valves. The testing was authorized under Order of Technical Direction (OTD) No. 69 by the Water and Sanitation for Health (WASH) Project, an AID/Washington centrally-funded program operated by Camp Dresser and McKee Inc., (CDM). CDM conducted the testing through the laboratory at the Georgia Institute of Technology.

During the handpump testing program, 15 pumps, including piston driven and rotary pumps from 11 different manufacturers were tested. These pumps were run for varying durations and some of them under different operating conditions. As mentioned above, tests were also conducted with respect to the performance of three foot valves.

All pumps of the AID design produced in the various countries, with the exception of the pumps from Haiti, appeared to be suitable for field use with minor design changes, if countries would provide extensive foundry technical assistance and maintain a tight quality control during the manufacturing and acceptance process. (The Haiti AID handpump was manufactured without technical assistance by the only foundry/machine shop known to project personnel to exist in Haiti, and this foundry/machine shop does not appear capable of producing a handpump of acceptable quality). It was found that the AID pumps tested in the laboratory generally could support intensive use over an extended period, <u>if responsible maintenance in the form of minor parts replacement and periodic lubrication of moving parts was provided</u>.

The Malawi handpumps were found to be of good manufacturing quality; they performed well throughout the testing even though one handpump had to have its main ball bearings replaced twice. Acidic water with a high chloride concentration of 3,000 parts per million did not appear to have any significant effect on pump components of the one pump exposed to the water during 5.0 million cycles (approximately 2,000 hours) of testing. (Only the pump head was from Malawi. The cylinder was of an AID-type design.)

The Moyno rotary handpump was of good manufacturing quality and generally performed well throughout 2.5 million revolutions of testing, although the rotor rod broke at 1.34 million revolutions. However, because of the short duration of testing it is recommended that additional testing under controlled conditions be conducted more fully to evaluate this pump's performance.

The Mono rotary handpump was tested for only 1.4 million revolutions, and therefore, no definite conclusions can be made with respect to its durability and reliability. However, it was observed that the manufacturing quality was quite good. As with the Moyno rotary handpump, it is recommended that additional testing under controlled conditions be conducted more fully to evaluate this pump's performance.

A commercially available brass foot valve from the Dominican Republic functioned throughout a test period of 6.2 million cycles. A plastic foot valve manufactured in the Dominican Republic separated due to joint failure at 1.4 million cycles and broke at 2.7 million cycles. A metal foot valve developed by the project operated for a total of 6.5 million cycles without any problems even though slight wear began to show at 5 million cycles.

The handpump testing described in this report has complemented earlier field data identifying improvements in handpumps for future rural water supply programs of developing countries. For instance: (1) Laboratory testing has confirmed field observations that a leather flapper-type foot valve, while inexpensive, is not as durable as other alternative valves and should be replaced with a metal design such as that used in the Philippine handpump program. (2) Laboratory testing with <u>one</u> of the Honduras shallow-well pumps has shown negligible wear of properly hardened pins and bushings despite a complete lack of lubrication for more than 6 million cycles. (3) Threaded connections, such as where the pump body screws into the pump base, should be minimized as much as possible.

It was also observed in the laboratory test program, which permitted direct comparisons of pumps from many sources, that there is a widespread variation in the quality of castings and machining of handpump components among the various handpump manufacturers throughout the world. Similar variation occurs in the hardening processes for pins and bushings and generally makes regular lubrication a critical factor in field performance of the current AID pump design.

As a result, even though the cast iron AID-type handpump has performed well in several developing countries during the past seven years, it is now recommended that AID examine such modifications as handpumps with sealed bearings (to eliminate the need for lubrication of moving parts) as possible improvements to the AID cast iron pump. Steel is one of the materials that should be considered for the pump body. It provides the advantages of uniform materials (e.g., commercially manufactured pipe, plate, and bar stock), simple fabrication (cutting, drilling, and welding), and reduced maintenance (especially lubrication) requirements.

Chapter 1

INTRODUCTION

1.1 General Background

The importance of water as a vital element for the sustenance of life and health of human beings has been recognized for thousands of years. Unfortunately, over one billion people in the world do not have access to safe drinking water at the present time. The urgency of changing this appalling situation led to the United Nations Water Conference in Mar del Plata, Argentina, in 1977, and subsequently, to the International Drinking Water Supply and Sanitation Decade (1981-1990), which has as its goal safe water and adequate sanitation for all by 1990.

In response to the Decade goals, a number of hand-operated water pump programs have been started in Africa, Latin America, and Southeast Asia. The basic principles of many handpump designs were known and utilized centuries ago mainly by small affluent groups or individual families. Within the last century, engine driven and electric pumps have also been developed and are in use to satisfy the demands of industry, agriculture, and public water supply in many countries of the world. However, for rural areas in less developed countries (LDCs), powered pumps are often not economically and technically feasible. The hand-operated pump, because of its simplicity and cost, still offers a practical solution for water supply in these countries, if its limitations are clearly understood and observed (i.e., it tends to be maintenance intensive, delivers low volumes of water, and works best when it is directly related to a family unit).

Many handpump programs have failed for a number of reasons. One major reason has been that the handpumps, incorporated as the basic element of the programs, were not able to withstand the stress and abuse that large user groups subjected them to. As this problem was recognized, a few international agencies providing aid to LDCs initiated programs to develop a handpump that could provide large user groups with reliable performance and service. One such program was initiated in the early 60's by the U.S. Agency for International Development (AID), which contracted Battelle Memorial Institute to develop a single-action, reciprocating, positive displacement design which is now referred to as the AID handpump.

1.2 Historical Field Programs

In September 1976, the Georgia Institute of Technology (GIT) was contracted by AID to select two countries for local manufacturing and field testing of the AID hand-operated water pump which had been earlier developed by Battelle. The scope of work included technical assistance to foundries and machine shops in manufacturing the pump and evaluating the field performance and acceptability of the handpump when heavily used. Nicaragua and Costa Rica were chosen as test countries. An initial study established the feasibility of local manufacture. Following manufacture of the AID handpump, field trials were conducted between January 1977 and September 1979. The AID handpump was determined to be reliable, sturdy, easily maintained, low in cost compared to imports, and capable of being manufactured in developing countries. As a result of the Nicaraguan and Costa Rican field tests, minor design modifications were recommended that proved successful in later local manufacturing and field testing programs.

Since 1978, GIT has been involved in other programs sponsored by AID to assist LDCs in their efforts to design, manufacture, and install hand-operated water pumps for their local needs. These countries include the Dominican Republic, Sri Lanka, and Indonesia. Since 1981, GIT has served as subcontractor for WASH's handpump effort in the Philippines, Tunisia, Honduras, Haiti, and Ecuador.

1.3 History of the Project

In 1981, AID handpumps manufactured in Tunisia, Ecuador, the Dominican Republic, Honduras, and the Philippines were chosen by AID/Washington for laboratory durability and reliability testing. The testing was authorized under Order of Technical Direction (OTD) No. 69 by the Water and Sanitation for Health (WASH) Project, an AID/Washington centrally-funded program operated by Camp Dresser and McKee Inc. (CDM). CDM, in turn, assigned the testing to GIT.

Authorization for WASH to proceed with the project was received in December 1981. Soon after the authorization was received, alternative conceptual designs for the test set-up were developed and studied for their technical feasibility, resource requirements, and costs. A protocol describing the test plan and manpower requirements was developed and presented at the WASH office in January 1982 where discussions were held and revisions to the plan were suggested. A revised test protocol was submitted in early February 1982 and approved by the WASH office March 4, 1982. At this point a subcontract was developed with GIT. One of the items to be carried on was the development of a handpump testing facility at GIT's Atlanta laboratory.

The project then moved to the procurement of space, manpower, electrical services, and the design of test stands and test procedures. In view of the magnitude of the dollar amount involved, outside vendors had to be selected through competitive bidding to build the first five test stands and their auxiliaries. Subsequent test stands were built by the GIT testing laboratory staff to speed up the progress of the project. Drawings for the head simulation valve were received from the Consumers' Association Testing and Research Laboratories in Harpenden, England. The head simulation valves were built at GIT's machine shop after some minor modifications. The springs for the head simulation valves were purchased locally. Concurrently, baseline measurements were made on the pumps as they were received.

The test protocol required that 10 test stands be built. By June 1982, five test stands were built, three of them equipped with head simulation valves for deep-well pumps. As of August 1982, five pumps (the Philippine shallow-well pump, the Philippine deep-well pump, the Honduras shallow-well pump, the Honduras deep-well pump, and the Tunisia deep-well pump) were under test when an AID/Washington representative, Mr. Victor Wehman, visited the test facility. A technical briefing regarding the progress of the tests was given by Dr. B. S. Dixit from GIT at a meeting held in the WASH office on September 14, 1982. At this briefing it was decided to continue testing the pumps up to 10 million cycles (the original protocol required that pumps be tested for 5 million cycles). Formal authorization to increase the testing to 10 million cycles was issued under the WASH Project in October 1982.

The testing on the pumps was designed to continue uninterrupted 24 hours a day, seven days a week. In January 1983, seven pumps were under test when a team of visitors from AID/Washington, the International Reference Centre for Community Water Supply, and CDM, namely, Mr. Eugene McJunkin, Mr. Ebbo Hofkes, and Mr. David Donaldson visited the test area. By then the Dominican Republic shallow-well pump, the Dominican Republic deep-well pump, and the Ecuador-Politechnica deep-well pump had been added to the program. The Haiti deep-well pump, which had been introduced earlier, was discontinued due to difficulties encountered with this pump (a report on the operation and testing on this pump is enclosed as Appendix F). An interim report on the progress of the project was prepared in February 1983 and submitted to the WASH office.

By the end of March 1983, testing on four pumps (the Honduras shallow-well pump, the Honduras deep-well pump, the Philippine shallow-well pump, and the Philippine deep-well pump) had been completed. Tests on the Tunisia deep-well pump, the Dominican Republic deep-well pump, the Dominican Republic shallow-well pump and the Ecuador-Politechnica deep-well pump were continuing, and efforts to install the Moyno rotary pump and to measure the force on the pump handles were also in progress. The design of the apparatus for the measurement of force on the pump handles was carried out by one of the associated divisions of the Engineering Experiment Station at GIT. By the middle of May 1983, the measurement of handle forces on all AID pumps had been completed. The testing was temporarily suspended on May 18, 1983, because of a lack of available funding for the WASH Project. The status of the testing at the time of its suspension was later submitted as a short report in August 1983.

Authorization to restart the testing was received on September 13, 1983. At that time, an AID-type handpump manufactured in Haiti, a Moyno rotary handpump manufactured in the United States, a Mono rotary handpump manufactured in the United Kingdom, two reciprocating handpumps manufactured in Malawi by Petroleum Services, and several types of foot valves were added to the testing. The changes in operation and protocol included in the September 1983 authorization for the resumption of testing, required modifications of the equipment to accommodate these additional pumps and to install a timing mechanism for the rotary pumps. The head simulation valves were tested and refitted to generate higher heads. However, because of the higher heads, frequent failures of the driving mechanism, the head simulation valves and the pump components of some of the pumps presented unforeseen difficulties in proceeding with the testing program as scheduled. In November 1983, a short interim report on the completed tests was sent to the WASH office, and later a letter stating the situation with respect to the difficulties of holding high heads was presented.

In January 1984, a final authorization including changes in the testing program was received, as stated in Section 2.3.

Chapter 2

OBJECTIVES

2.1 General Statement

Demonstration field programs to introduce the manufacture of the AID handpump have been carried out in a number of countries, and they have provided useful information on the local manufacturability and field performance of pumps in those countries. However, before 1981, laboratory testing of the AID handpumps manufactured in LDCs had been minimal; only two AID handpumps (from Indonesia and Honduras) had undergone testing at the Consumers' Association (CA) Testing and Research Laboratories at Harpenden, England. Therefore, in December 1981, in order to complement field data with laboratory test data, GIT was assigned under the WASH project to conduct durability and reliability tests on hand-operated pumps manufactured in the Dominican Republic, Ecuador, Honduras, the Philippines, and Tunisia. Later, handpumps manufactured in Haiti, the United States, the United Kingdom, and Malawi were added to the testing program.

The handpump testing program has involved 15 pumps of three different types manufactured in the United States, the United Kingdom and several LDCs. These pumps were tested for their durability, reliability, and performance under conditions of regular maintenance and lubrication, except in cases where lubrication was not necessary or for special studies. These special studies included the testing of three foot valves, testing a pump using brackish, acidic water, and running one pump without lubrication beyond the regular test period. The testing program has tried to couple field test results with those experienced in the laboratory.

The handpump testing at CA, the first laboratory to test a variety of handpumps under controlled conditions on a large scale, has included endurance testing, testing pumps without regularly lubricating them, design assessments of handpumps and their components, ergonomic studies, and user studies. While CA testing has not included field testing for comparing (correlating) results with those found in the laboratory, its work has influenced decision-makers around the world in choice of handpumps. Further, as a result of its cooperative attitude towards sharing information, CA staff has had a positive, contributory influence on the testing described in this report.

2.2 Objective of the Testing Program

The original objective, as presented in the Order of Technical Direction, was to determine the durability of AID handpumps manufactured in the Philippines, Ecuador, Tunisia, the Dominican Republic and Honduras through laboratory stress-testing. As testing developed, it became clear that the concept of durability was being understood by USAID to have two elements: 1) The wear resistance of the mechanical parts of the pump; and, 2) The ability of the pump unit to continue to deliver a fixed quantity of water over the long-term. The resulting testing looked at these two basic elements. In order to reach this objective, the first tasks undertaken were to develop conceptual designs for the test set-up and to establish testing procedures (protocol). The original objective was later expanded to include additional tests as described below. This report presents results of the testing program as they relate to the mechanical durability and long-term flaw characteristics of the various locally manufactured AID-type handpumps, the Mono, the Moyno and Malawi handpumps. The conclusion and recommendations of this report are directly related to these two elements.

2.3 Scope of Work

The testing protocol describing the full details of the scope of work of the laboratory testing program is presented in Appendix B. The main elements of this protocol are as follows:

- perform baseline measurements of the pump components that comprise the moving parts of the pump assembly,
- carry out periodic lubrication during testing,
- test at 40 pumping strokes (cycles) per minute,
- operate deep-well pumps at a simulated head of 100 ft.,
- test for 5.0 million cycles,
- periodically disassemble the pumps to take wear measurements and to examine for damage and relubricate prior to reassembly, and
- periodically test for foot valve leakage.

In October 1982, the above protocol was changed to increase the duration of testing from 5.0 million cycles to 10.0 million cycles. Another change in the program was made in September 1983. The main elements of these changes were as follows:

- the introduction of two new AID pumps from different manufacturers in Ecuador,
- the introduction of two rotary pumps, one from a United States manufacturer and one from a United Kingdom manufacturer,
- the introduction of two Malawi deep-well pumps,
- a change of simulated head from 100 ft. to 300 ft. for the new deep-well pumps,
- the addition of three different foot valves, and
- revision of the operating conditions for some of the pumps, such as use of water with a chloride concentration of 3,000 parts per million and a pH of 4.0 for one of the Malawi pumps.

On January 9, 1984, a final modification to the test program was issued in order to complete the project. This modification included the following:

- stop Moyno pump testing,
- stop Mono pump testing at the next breakdown,
- run the Dominican Republic deep-well pump until completion of 10.0 million cycles or up to the middle of February 1984 at a 300 ft. head,
- run the Ecuador-Tirado deep-well pump and the Ecuador-Metalurgica deep-well pump until the end of February 1984 at a 300 ft. head,
- continue running the Honduras shallow-well pump until failure or up to February 28, 1984, and
- shut the facility down on February 28, 1984.

Chapter 3

EQUIPMENT AND PROCEDURES

3.1 Test Equipment and Procedures

The test set-up and the testing procedures have varied among the pumps, depending on the type of design (reciprocating or rotary), the objectives relative to a particular pump or a group of pumps, and the changes in the project direction that became necessary during the course of the testing period. The following sections describe the test set-up and the general test procedures for the various pumps. Special experimental studies and variations from these general testing procedures will be described in separate sections.

3.2 Initial Test Program

The pneumatic drive described in the original protocol (see Appendix B), was changed to a mechanical drive for technical and cost considerations. This mechanical drive and the general set-up for testing the AID handpumps are shown in Figures 1 and 2. They consisted of a structural steel framework on which the pump was mounted and a driving mechanism consisting of an electric motor, a speed reducer, a crank, a connecting rod, and a fail-safe mechanism. The fail-safe mechanism shut the system down if the pump failed to deliver water, yet it permitted the pumps to run for 24 hours a day, seven days a week throughout the testing period if they were functioning properly. For simulating various well water depths below the head assembly of the deep-well pumps, a head simulation device designed by Consumers Association of England was used (see Figure 4 of Appendix B). A stroke (revolution) counter mounted near the crank wheel showed the cumulative number of cycles up to one million. After the completion of one million cycles, the counter reset itself automatically to zero. The instruments used for measuring the pump component dimensions included telescopic gauges, dial calipers, and micrometers. Other instruments, have been used when necessary -- for example, when comparing surface roughness.

A pump that was to be tested was unpacked and disassembled, care being taken not to damage the components. The dimensions of the components were measured and recorded. Any irregularities or defects in manufacturing were noted. The hardness values of the components were recorded where appropriate. After the initial measurements were completed, the pump components were made prior to or shortly after mounting the pump on the test stand. After the pump was mounted on the test stand, various steps were taken to minimize the vibration of the pump.

During the initial stages of the testing period the pump was allowed to run for 500,000 cycles (approximately). Then it was stopped for inspection of the components, such as valves, leather cups, etc. Since virtually no changes were noticed during the first scheduled inspection, the 500,000 cycle intervals were extended. Inspection and lubrication of the pumps during subsequent stages of the testing program were carried out at intervals of 1.8 million cycles, except where breakdowns offered opportunities for more frequent inspections. As indicated in Section 2.3 (Scope of Work), the overall duration of testing on each pump was eventually set at 10.0 million cycles.

At each scheduled inspection, the following measurements and observations were made (samples of data sheets are included in Appendix C and pump components are shown in Figures 3 and 4):

- diameters of pins -- rod end pin, handle pivot pin, and handle fulcrum pivot pin (at pump cap),
- internal diameters -- handle fulcrum bushings, handle bushings, pump cap bushings, rod end bushings, and sliding block bores,
- internal diameter of pump cylinder,
- wear of sliding surfaces -- sliding blocks and tracks,
- condition of leather cups and piston cage assembly,
- condition of suction (foot) valve and discharge (plunger) valve,
- leakage -- pump cylinder leakage, valve leakage, and pump base leakage, and
- observations of any other visible damage or changes.

Unusual events, such as the failure of a component or reduction in the flow rate were observed during the testing, and the causes of such events were studied and problems were corrected. Driving system failures were not recorded, since they were not related to the performance of the pumps. The flow rates of all pumps were measured at regular intervals ranging from 200,000 cycles. Sliding and rotating surfaces were lubricated with grease at regular intervals.

The deep-well pumps operated at heads of approximately 100 feet. For the shallow-well pumps, the suction head was limited by the height of the test stand and water level in the tank. The suction head varied between six and eight feet.

3.3 Modified Test Program

The testing program was modified in September 1983 to add two additional AID deep-well handpumps manufactured in Ecuador (the Ecuador-Tirado pump and the Ecuador-Metalurgica pump), two head sets for a Malawi-manufactured deep-well handpump with AID cylinders, and two rotary deep-well pumps (the Moyno and the Mono). The simulated head was increased from 100 to 300 feet. Three different foot valves were added to the program. Also, for one of the Malawi pumps, water to be used had to have a chloride concentration of 3,000 parts per million and a pH of 4.0.

3.3.1 Testing of AID Handpumps

The Ecuador-Politechnica pump, after having completed 5.0 million cycles, was withdrawn from testing during this stage of the program because Politechnica was no longer manufacturing AID handpumps, and the test stand was needed for testing other pumps. The Ecuador-Tirado pump was tested for 3.8 million cycles at heads ranging from 100 to 300 feet. The Ecuador-Metalurgica pump was tested for 2.6 million cycles at heads ranging from 100 to 300 feet. The test equipment and procedures were the same as those used for other AID pumps.

This stage of the program also included extending the operation of the Honduras shallow-well pump from 12 million to 18 million cycles without further lubrication.

3.3.2 Testing of Malawi Handpumps

The Malawi pumps differed in design from the AID pumps. However, it was possible to use the same test set-up that was used for AID deep-well pumps with slight modifications for mounting the pump on the test stand. Since these pumps were not supplied with cylinders, cylinders belonging to other AID pumps were used for the test run.

It was felt that the components most likely to wear or fail were the bearings, the axle, the handle, and/or the hanger (see Figure 5). These parts were carefully examined at the beginning of the test for possible defects, damage or irregularities. At approximately 2.5 million cycles, the pumps were disassembled and all components were re-examined. A final examination of the pump components was made at the end of the testing period.

The pumps operated at heads ranging from 100 to 300 feet, and the test period was 5.0 million cycles. Specially treated water containing 3,000 parts per million of chloride and maintained at a pH of 4.0 for acidity was used for one of the pumps to examine the effect of unusual concentrations of salt and acid on the pump components.

The following components and characteristics were observed as part of the test on these pumps (results of these tests are given in Chapter 4):

Components:

Pump head

Pump body
Axle
Hanger and top cover
Bearings
Handle
Threaded parts
Rising main
Rubber gaskets
Couplings

Characteristics:

Smoothness of operation
Failures
Damage to components
Force on handle
Unusual behavior

3.3.3 Testing of Moyno and Mono Rotary Pumps

The test set-up for the Moyno and Mono rotary pumps is shown in Figures 6 and 7. The driving mechanism consisted of an electric motor speed reducer provided with a sheave, a clutch, and a timer mechanism to provide on and off cycles. A V belt was connected to a pulley mounted on the pump drive shaft with the handle removed. The ratio of diameters of the driver and driven pulleys was designed to give a speed of 100 rpm for the rotor shaft of the pump. Head simulation valves were used to simulate heads of up to 300 feet. The fail-safe mechanism, a thermal overload switch, was provided within the system to protect the electric motor and the pump from undue damage.

The measurement of force and energy input to the pump was conducted by electrical means, as explained later in Appendix D.

The testing on these pumps included the examination of the pump components as they were received and at the end of the testing period. Due to changes in the objectives of the project, these pumps did not run for the full duration of the test. The Moyno pump was run for 2.5 million revolutions with 230,000 stops and the Mono pump was run for 1.3 million revolutions with 70,000 stops.

The components were examined as follows:

- examine the general condition of the pumps as they are received,
- visually examine the quality of the pump exterior and castings,
- visually examine the quality of the stator/rotor assembly,
- disassemble the gear box and measure the dimensions of the gears,
- check if there is any backlash in the gear assembly,
- examine the leak rate of the pumping assembly,
- measure the flow rate of the pump,
- measure the applied force or the input energy to the pump when operating at a handle speed of 50 rpm, and
- observe if there is unusual behavior, vibration, or noise during the operation of the pump.

Unfortunately, due to problems encountered with the driving systems and the pumps at the higher heads, the testing on these pumps had to be stopped before significant observations could be made (see Section 2.3, Scope of Work).

3.3.4 Force Measurement on Reciprocating Pumps

The forces on the handles of reciprocating pumps vary greatly during each cycle and simple conventional procedures for measuring forces do not provide realistic results. As a consequence, the Solid State Sciences Division of the Electromagnetics Laboratory at GIT's Engineering Experiment Station provided the testing effort with staff and equipment for the measurement procedure and the test set-up. Instrumentation equipment such as transducers and controllers were purchased from external vendors.

Figure 1

DEEP-WELL PUMP TEST SET-UP

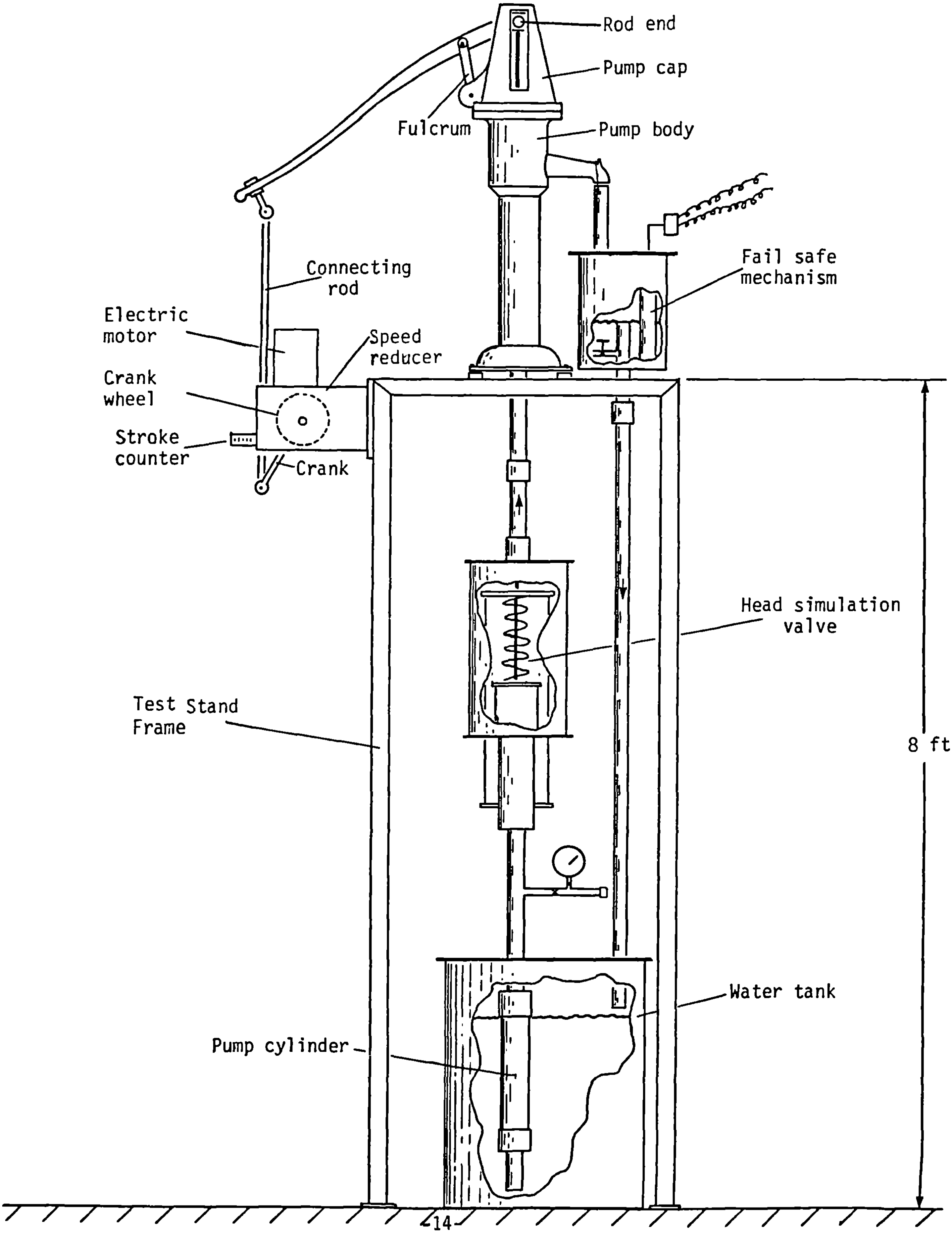
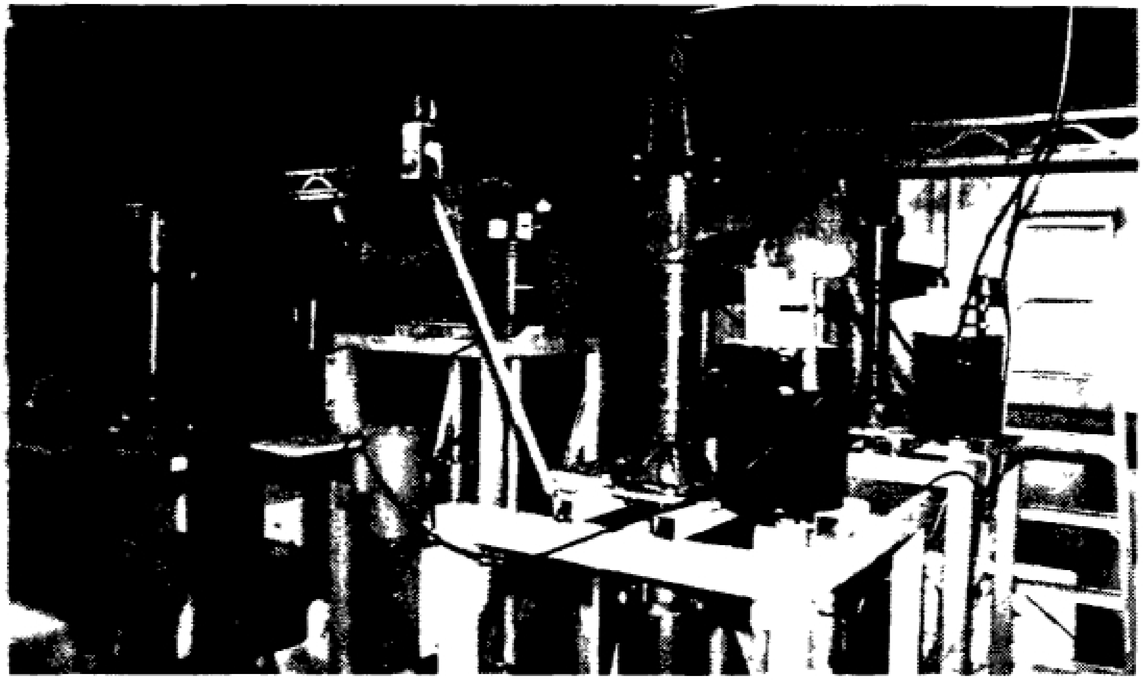
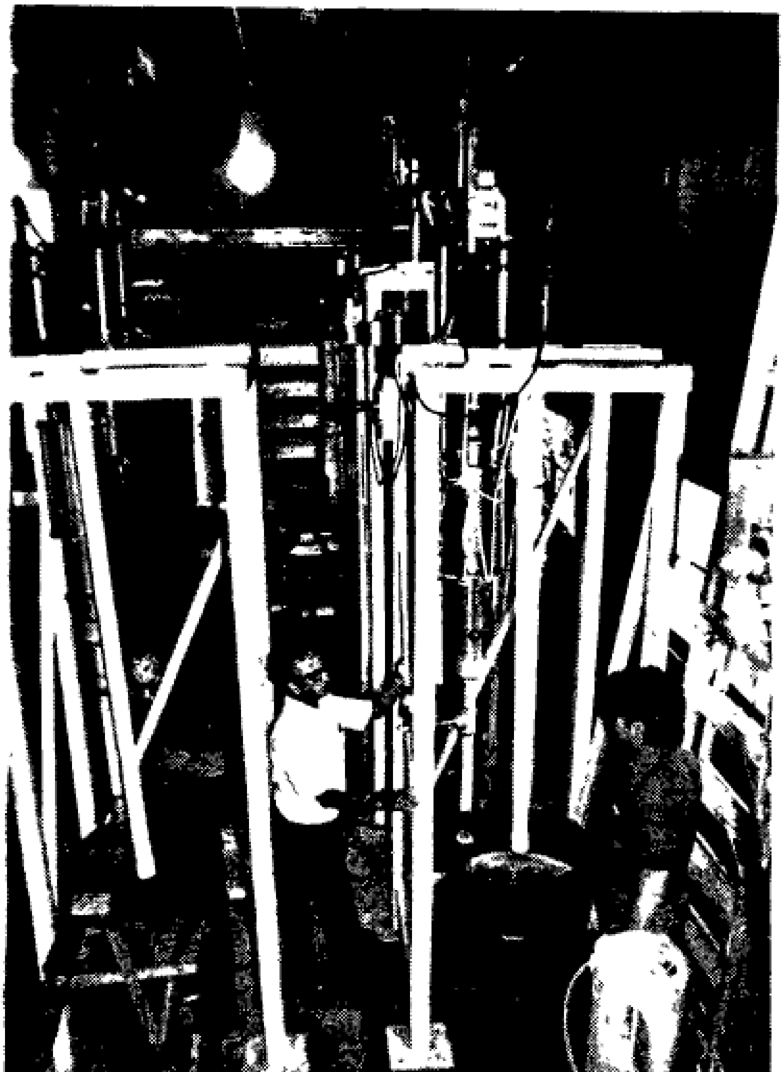


Figure 2

HAND PUMP TESTING FACILITY





AID HAND–OPERATED WATER PUMP
SHALLOW WELL

(For Wells less than 7-8 meters in depth)

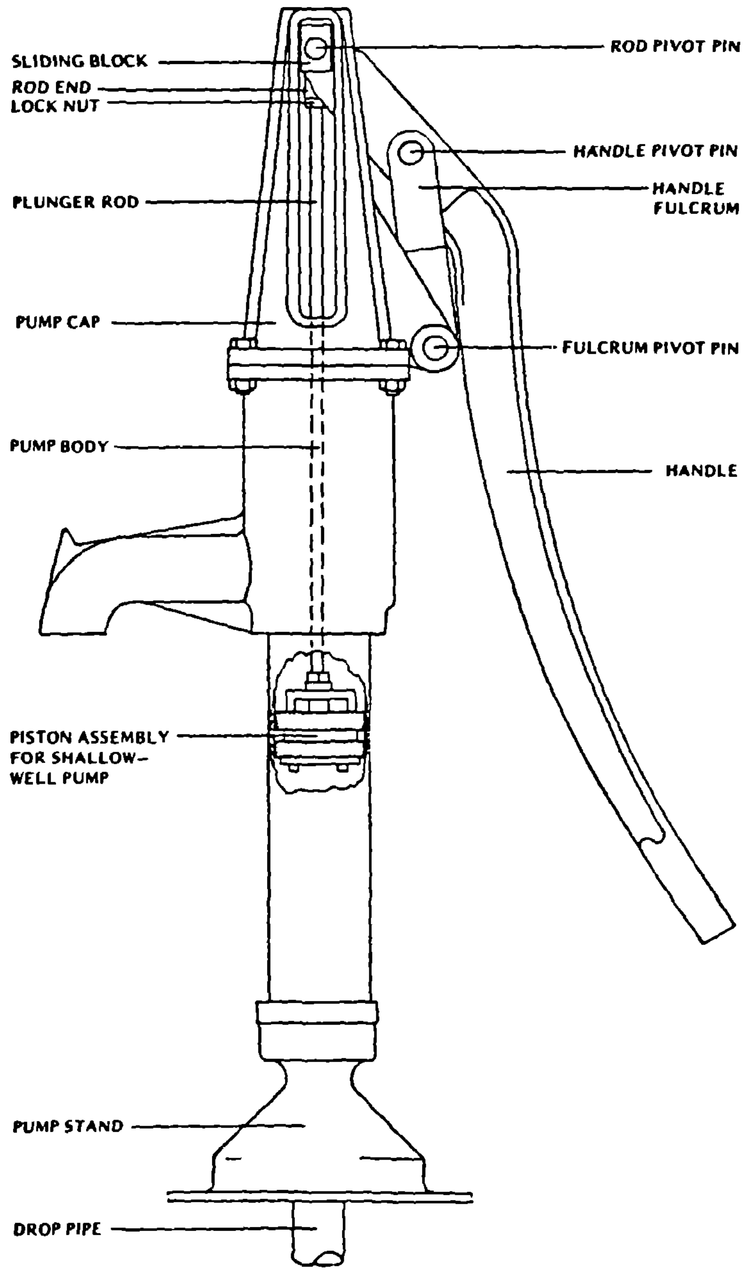


Figure 3

AID HAND–OPERATED WATER PUMP
DEEP WELL

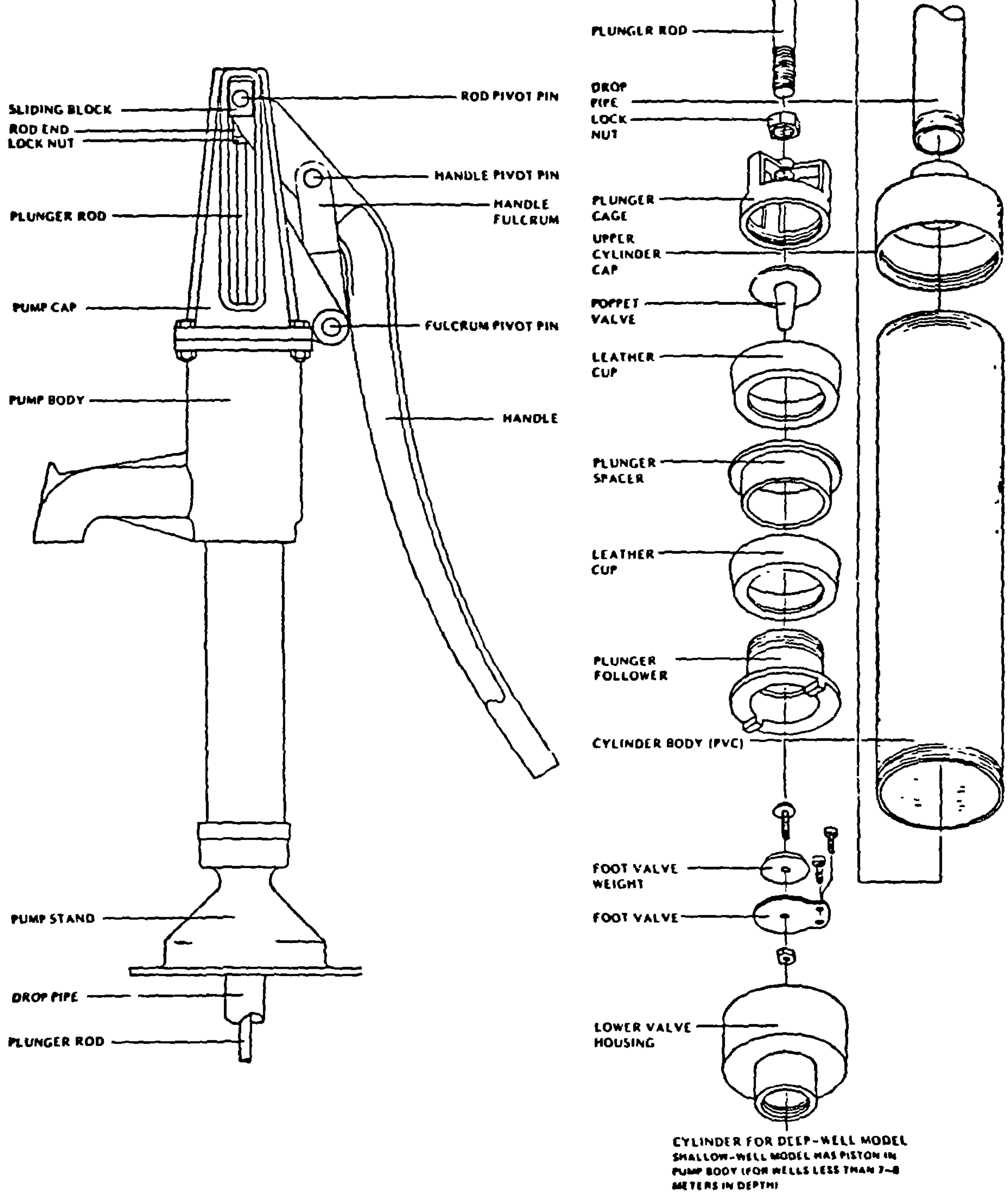
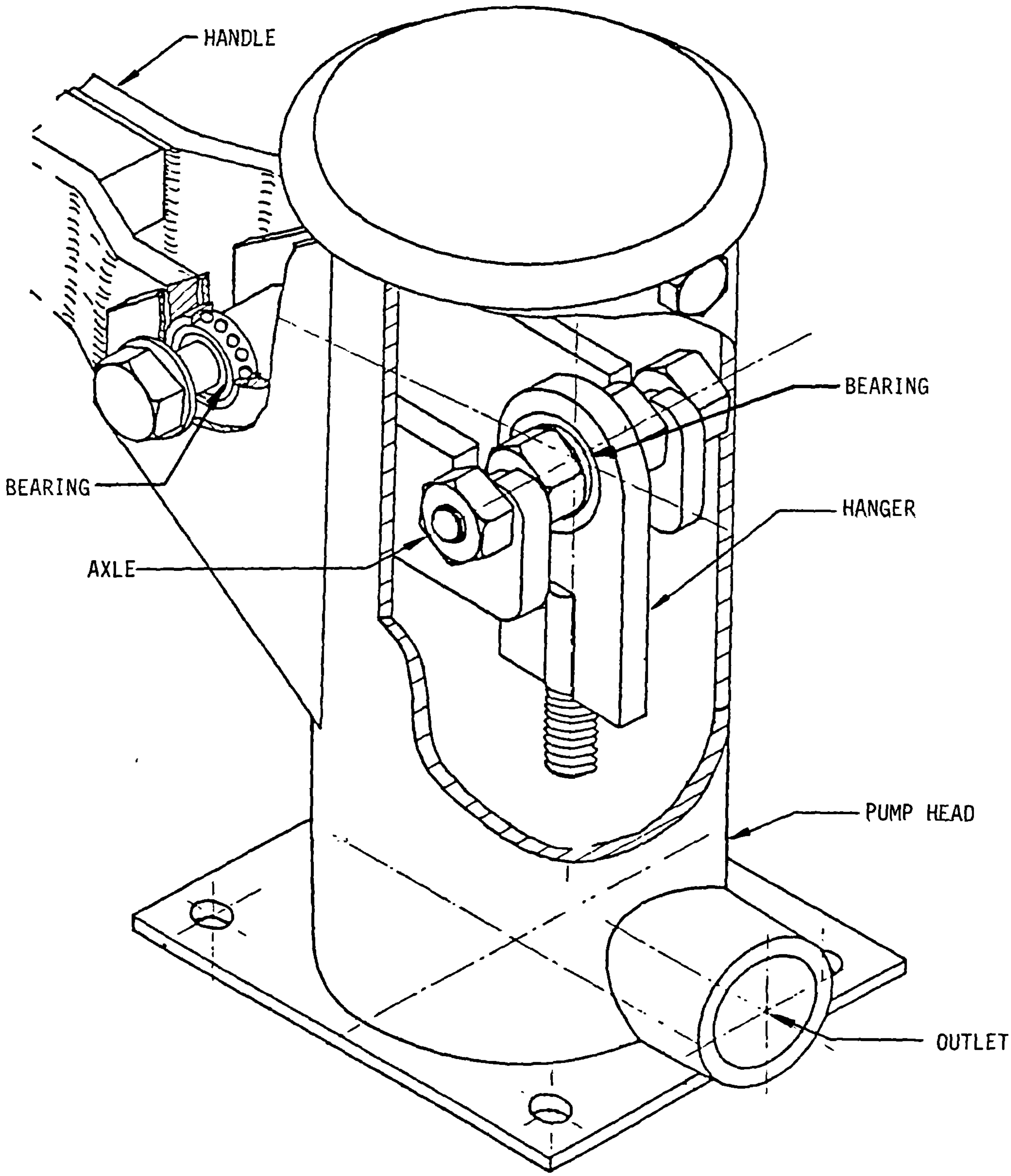


Figure 4

Figure 5

MALAWI PUMP



MOYNO PUMP TEST SET-UP

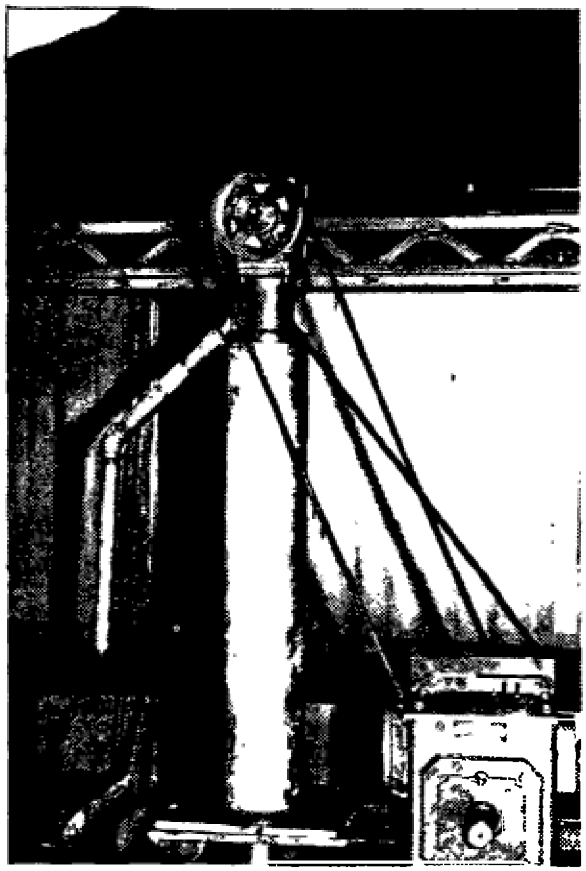


Figure 6

MONO PUMP TEST SET-UP

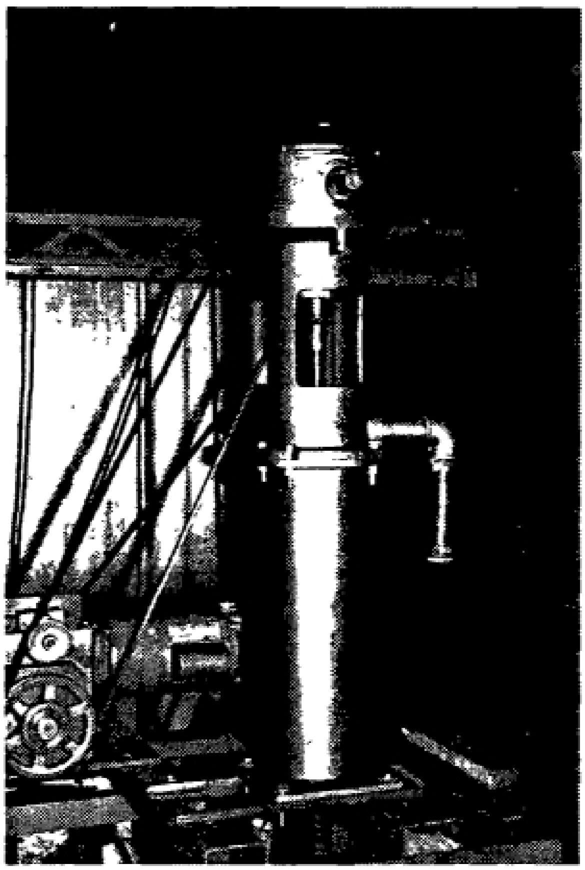


Figure 7

Chapter 4

LABORATORY TEST RESULTS

4.1 Introduction

During the handpump testing program, 15 pumps, including piston driven and rotary pumps from 11 different manufacturers were tested. The duration of this testing is summarized in Table 1. The description of each of these pumps, identified by the name of the manufacturer and/or the country and its type, has been included in Appendix A. These pumps were run for varying durations and some of them under different operating conditions. The test data obtained with respect to the wear of components such as pins, bushings, and sliding blocks are summarized in Appendix C. Observations regarding the operational performance of the various components of the pumps such as the foot valve, discharge valve, and the plunger are discussed below and summarized in Table 2 and Appendix E.

Additionally, special tests were conducted with respect to the performance of three foot valves, operation of the Honduras shallow-well pump without further lubrication from 12 million cycles to 18.2 million cycles (over 6 million cycles), and an endurance test on one of the Malawi pumps using treated water containing 3,000 parts per million of sodium chloride (NaCl) at a pH of 4.0. Observations with respect to these tests are discussed below.

4.2 AID Handpump Test Observations

1. Philippine Shallow-Well Pump (12.0 million cycles completed during testing)

   Wear of moving parts: Pins, bushings, sliding blocks, tracks showed negligible wear (less than 0.005 inch per 10 million cycles). See Appendix C.

   Plunger Cage Assembly: Remained in good condition* throughout the testing period.

   Leather Cups: Original leather cups were used throughout the test. Although they appeared soft and slightly worn at the end of the test, this did not affect the flow rate significantly (less than 10% - see below).

   Foot Valve: Metallic poppet-type; functioned smoothly during the test; was in good condition at the end of the test.

   Discharge Valve: Metallic poppet-type; functioned smoothly during the test; was in good condition at the end of the test period.

* "Good condition" (when used hereinafter) refers to visual inspection of the part revealed no evidence of wear and that the part appeared essentially like the original, unless otherwise noted. Good condition accompanied by a conditional note should be interpreted as a condition not affecting performance or continued use of that part.

Threaded Connections: Appeared to be in good condition; showed no leakage.

Cylinder: Was in good condition at the end of the test; there were tiny grooves made by foreign particles, but this did not affect the performance of the pump

Other: There were no failures of any kind during the test period.

Discharge Flow Rate: Remained steady throughout most of the test period; it decreased slightly (less than 10%) near the end of the test period when the leather cups became soft and slightly worn.

Force on Handle: See Appendix D.

2. Philippine Deep-Well Pump (11.9 million cycles completed during testing)

Wear of moving parts: Pins, bushings, sliding blocks showed negligible wear. See Appendix C.

Plunger Cage Assembly: Remained in good condition throughout the testing.

Leather Cups: One cup was replaced at the end of 10 million cycles; although both cups appeared soft and slightly worn at the end of the testing period, effect on flow rate was small (see below).

Foot Valve: Metallic poppet-type; functioned smoothly during the test; was in good condition at the end of the test.

Discharge Valve: Metallic poppet-type; functioned smoothly during the test.

Threaded Connections: Showed no leakage.

Cylinder: Showed no significant wear after 10.3 million cycles; appeared in good condition at the end of the test period.

Discharge Flow Rate: Remained steady throughout most of the test period; it decreased slightly (less than 10%) near the end of the test period when the leather cups became soft and slightly worn.

Force on Handle: See Appendix D.

3. Honduras Shallow-Well Pump (18.2 million cycles completed during testing)

Wear of moving parts: Pins, bushings, sliding blocks, tracks showed no significant wear, despite operation without lubrication for the final 6.2 million cycles. See Appendix C.

Plunger Cage Assembly: Was in good condition throughout the testing period.

Leather Cups: Were in good condition throughout testing period.

Foot Valve: Leather flapper valve was replaced twice during the testing period, once at 5.5 million cycles and the second time at 8.4 million cycles.

Discharge Valve: Metallic poppet-type; functioned smoothly throughout the testing period.

Threaded Connections: Appeared in good condition; showed no leakage.

Cylinder: The cylinder was in good condition at the end of the testing period.

Other: Other components such as pump body, base, threaded connections, fulcrum, and handle, did not suffer any damage or wear during the testing period.

Discharge Flow Rate: Remained steady throughout the test period except during periods when the flapper valve needed replacement.

Force on Handle: See Appendix D.

4. Honduras Deep-Well Pump (12.0 million cycles completed during testing)

Wear of moving parts: Pins, bushings, sliding blocks, and tracks showed negligible wear. See Appendix C.

Plunger Cage Assembly: Remained in good condition throughout the testing period.

Leather Cups: Remained in good condition throughout the testing period.

Foot Valve: The original leather flapper was replaced by another leather flapper valve during the testing at 6 million cycles; the second foot valve was, in turn, replaced by a rubber flapper valve at 9 million cycles which lasted throughout the remainder of the testing period.

Discharge Valve: Metallic poppet-type; functioned smoothly during the testing period.

Threaded Connections: Appeared in good condition; showed no leakage.

Cylinder: The cylinder remained in good condition throughout the test period.

Other: Other components, such as handle, fulcrum, pump body, base, pump rod and threaded connections, showed no damage or wear during the test.

Discharge flow rate: Remained normal throughout the test period.

Force on Handle: See Appendix D.

5. Tunisia Deep-Well Pump (10.0 million cycles completed during the testing)

Wear of moving parts: Pins, bushings, sliding blocks, and tracks showed negligible wear. See Appendix C.

Plunger Cage Assembly: Remained in good condition throughout the testing period.

Leather Cups: The leather cups remained in good condition throughout the major part of the test period; however, they appeared soft as the pump reached 7.8 million cycles. Leather cups commercially available in the United States were tried but were either oversized or undersized, because the cylinder was manufactured according to metric standards. The original leather cups were reinstalled at 8.25 million cycles and used for the remainder of the testing period.

Foot Valve: Metallic poppet-type; was in good condition throughout the test period.

Discharge Valve: Metallic poppet-type; was in good condition throughout the test period.

Threaded Connections: Appeared in good condition; showed no leakage.

Cylinder: The PVC cylinder developed a crack at 7.9 million cycles and was replaced. There was a leakage past the plastic cylinder ends at 0.8, 1.8, 6.9 and 8.2 million cycles due to failures of the sealant joints joining the cylinder to the cylinder end caps.

Other: The pump body, handle, fulcrum, and pump base remained in good condition throughout the test period. The PVC drop pipe connections (sealant joints) separated at the beginning of the test period and later at 3.37 and 9.4 million cycles.

Discharge Flow Rate: Remained steady throughout except when the leather cups needed replacement.

Force on Handle: See Appendix D.

6. Dominican Republic Deep-Well Pump (10.0 million cycles completed during testing)

This pump operated at a head of 100 ft. during the first 5 million cycles of the test period and at variable heads (100 to 300 ft.) during the second 5 million cycles, making a total of 10.0 million cycles of testing.

Wear of moving parts: Pins, bushings, sliding blocks showed negligible wear throughout the test period. See Appendix C.

Plunger Cage Assembly: Remained in good condition throughout the testing period.

Leather Cups: Leather cups were replaced at 2.9 million and 7.7 million cycles during the test period.

Foot Valve: Leather flapper valve did not suffer any damage or wear throughout the test period.

Discharge Valve: Cast iron poppet-type; was replaced after it progressively wore at the edge and some small portions chipped off. It was not closing the discharge bore completely and was replaced at 6.8 million cycles by another Dominican Republic pump discharge valve.

Cylinder: Was in good condition throughout the test period.

Other: The threaded components became loose frequently; the drop pipe near the pump base, the cylinder end, and the plunger rod became loose often. The plunger rod became loose at 0.3 million cycles and was broken at 1.02 million cycles; another plunger bent at 1.6 million cycles and was replaced; the cylinder came loose at 0.77 million cycles; and a sliding block dropped off after a cotter pin broke at 0.32 million cycles. Threading at the pump base was worn out partially and, as a precaution, the drop pipe was tightened periodically (seven times during the test period). This was possibly due to increased vibration at high heads as well as from poor machining of threads during manufacture.

Discharge Flow Rate: The discharge flow rate remained steady during the test period except when replacement of the leather cups or the discharge valve was required and at high heads during the final 5 million cycles of testing.

Force on Handle: See Appendix D.

7. Dominican Republic Shallow-Well Pump (10.0 million cycles completed during testing)

Wear of moving parts: Pins, bushings, sliding blocks showed negligible wear. See Appendix C.

Plunger Cage Assembly: Remained in good condition throughout the testing period.

Leather Cups: Remained in good condition throughout the testing period.

Foot Valve: Leather flapper valve was replaced at 9.4 million cycles. The valve was stiff and left gaps around the valve seat during operation. As a result, leakage past the valve was so great when the pump was not running that priming was required to restart the pump.

Discharge Valve: Cast iron poppet-type; functioned smoothly during the test period. Part of the valve showed a slight wear, but this did not affect the performance of the pump.

Cylinder: Remained in good condition throughout the test period; the flow rate was slightly lower compared to other cylinders of the same size.

Other: The pump body, handle and fulcrum did not show any wear or damage; however, the threading at the base of the body became loose seven times during testing. The bushings were loose from the start of the testing period.

Discharge Flow Rate: Remained steady throughout the test period except during a short period at the end of the test period when the flapper valve needed replacement.

Force on Handle: See Appendix D.

8. Ecuador-Politechnica Deep-Well Pump (5.0 million cycles completed during testing)

Wear of moving parts: Pins, bushings, sliding blocks showed negligible wear. See Appendix C.

Plunger Cage Assembly: Broke at 1.232 million cycles; it was repaired (welded together). The repaired plunger cage again broke at 4.77 million cycles and was replaced with a new assembly.

Leather Cups: Original leather cups appeared soft; however, flow rate was apparently not affected. The leather cups became twisted and were replaced at 1.232 and 4.7 million cycles.

Foot Valve: Leather flapper valve; functioned smoothly during the test; was in good condition at the end of the test.

Discharge Valve: Metallic poppet-type; functioned smoothly during the test; was in good condition at the end of the test period.

Threaded Connections: Appeared in good condition; showed no leakage.

Cylinder: Appeared to be in good condition throughout the test period.

Other: Other components such as the pump body, handle, fulcrum and pump base did not suffer visible wear or damage.

Discharge Flow Rate: Remained steady during the test period except during periods when the leather cups needed replacement.

Force on Handle: See Appendix D.

9. Ecuador-Tirado Deep-Well Pump (3.8 million cycles completed during testing)

Wear of moving parts: Pins, bushings, sliding blocks showed negligible wear. See Appendix C.

Plunger Cage Assembly: Appeared in good condition throughout the test period.

Leather Cups: Original leather cups appeared soft; in the initial stages, one of the cups became twisted due to high heads (290 ft.) and was replaced.

Foot Valve: Brass poppet valve; functioned smoothly during the test; was in good condition at the end of the test.

Discharge Valve: Metallic poppet-type; functioned smoothly during the test; was in good condition at the end of the test period.

Threaded Connections: Appeared in good condition; showed no leakage.

Cylinder: Appeared to be in good condition throughout the test period.

Other: Other components such as the pump body, handle, fulcrum, and pump base did not suffer any wear or damage.

Discharge Flow Rate: Remained steady during the test period except during periods when the leather cups needed replacement.

Force on handle: See Appendix D.

10. Ecuador-Metalurgica Deep-Well Pump (2.6 million cycles completed during testing)

Wear of moving parts: Pins, bushings, sliding blocks showed negligible wear. See Appendix C.

Plunger Cage Assembly: Appeared in good condition throughout the test period.

Leather Cups: Original leather cups appeared soft; one of the leather cups became twisted in the early stages and was replaced.

Foot Valve: Leather flapper valve was replaced at 0.5 million cycles; replaced valve functioned smoothly during the remainder of the test.

Discharge Valve: Metallic poppet-type; functioned smoothly during the test; was in good condition at the end of the test period.

Threaded Connections: Appeared in good condition; showed no leakage.

Cylinder: Appeared to be in good condition throughout the test period.

Other: Other components such as the pump body, handle, fulcrum, and pump base did not suffer any wear or damage.

Discharge Flow Rate: Remained steady during the test period except during periods when the leather cups needed replacement.

Force on handle: See Appendix D.

4.3 Malawi Handpump I Test Observations (5.0 million cycles completed during testing)

The first Malawi pump was run using tap water available in the testing laboratory. Since no cylinder was available with this particular pump, a Dominican Republic cylinder was used. There were no pins or bushings, as this pump uses sealed bearings at pivot points. All components were examined before the start, during the middle, and at the end of the test period.

At 1 million cycles one of the bearings broke and the pump stopped functioning. It was replaced by a American-made bearing. At the inspection time of 2.5 million cycles it was noticed that the replaced bearing was beginning to show rupture although the pump was still running. The bearing was again replaced. All other components functioned smoothly without any sign of wear or damage.

4.4 Malawi Handpump II Test Observations (5.0 million cycles completed during testing)

The second Malawi pump was tested using high-chloride, acidic water containing 3,000 parts per million of sodium chloride and held at a pH of 4.0. A cylinder from a Honduras deep-well pump was used. The head on the pump was held at approximately 280 feet during the initial period of testing. Difficulties were experienced in holding this high head which caused system failures quite often. As a result, the pump was run for most of the time at a 150 ft. head and part of the time at heads between 170 and 290 feet.

None of the components of the pump, including the bearings, showed any sign of damage or wear during the testing period. The treated water did not affect any of the components, even though the drop pipe, cylinder, pump rod, and other components tended to show rust. The rust was easily removed by using sand paper.

4.5 Moyno Rotary Pump Test Observations (2.5 million cycles completed during testing)

The Moyno rotary pump operated for a total of 2.5 million cycles at a head of 230 feet with 230,000 timed stops. The rotor rod broke at the coupling at 1.34 million cycles, the rod was rethreaded, and the pump restarted. Flow rate and force measurements (see Appendix D) were made periodically. The components of the pump, such as the gear box, the rotor, the stator and the foot valve, were examined before and after the test period. They were found to be in good condition. However, it is believed that this pump should be run for at least 5 million cycles before its performance can be analyzed.

4.6 Mono Rotary Pump Test Observations (1.4 million cycles completed during testing)

The Mono rotary pump operated for a total of 1.4 million cycles during the testing period. The rotor rod broke after 200,000 revolutions at heads of 280-290 ft. The bottom part of the rotor, approximately .25 inches, was cut by a machining action of the vane in the adapter section of the cylinder. It is believed that the rotor had slowly descended to the bottom of the cylinder due to slipping set screws and a cutting effect had caused a high torsional and bending load on the rotor shaft.

Flow rate and force measurements (see Appendix D) were made periodically. The pump components were examined before and after the test period. At the conclusion of the testing period the pump made a severe rubbing noise, the cause of which could not be traced even after the system was dismantled and the individual components examined.

4.7 Foot Valve Test Observations

As part of the effort to improve the design and operation of AID handpumps, the following three poppet-type foot valves were tested for their performance and stability:

- a commercially available brass foot valve sold in Dominican Republic hardware stores,
- a plastic foot valve designed and locally manufactured for the modified AID handpump (with PVC drop pipe/cylinder arrangement) in the Dominican Republic, and
- a metal foot valve developed at GIT and similar to that used for the Philippine AID handpump.

The commercially available brass foot valve from the Dominican Republic was installed in the Honduras shallow-well handpump. It performed well throughout a test period of 6.2 million cycles.

The plastic foot valve was installed as part of an AID deep-well handpump cylinder. At approximately 1.4 million cycles it dropped off due to joint failure. At 2.7 million cycles it was inadvertently broken while repairing a head simulation valve. No replacement was made since the testing period was nearing completion.

The metal foot valve developed at GIT was also installed as part of an AID deep-well handpump cylinder. It operated for a total of 6.5 million cycles without any problems even though slight wear began to show at 5 million cycles.

Table 1

HAND PUMP TEST DURATION

Name of the Pump	Cycles Completed at 6-8 ft. Head (millions)
Philippine shallow-well pump	12.0
Honduras shallow-well pump	18.2
Dominican Republic shallow-well pump	10.0

Name of the Pump	Cycles Completed at 100 ft. Head (millions)
Philippine deep-well pump	11.9
Honduras deep-well pump	12.0
Tunisia deep-well pump	10.0
Dominican Republic deep-well pump	5.0
Ecuador Politechnica deep-well pump	5.0
(Haiti deep-well pump test discontinued after 150,000 cycles)	

Name of the Pump	Cycles Completed at Variable Head (100-300 ft. head)
Ecuador Tirado deep-well pump	3.8
Ecuador Metalurgica deep-well pump	2.6
Dominican Republic deep-well pump	5.0
Malawi deep-well pump I	5.0
Malawi deep-well pump II (using high-chloride, acidic water)	5.0
Moyno rotary pump	2.5
Mono rotary pump	1.4

TABLE 2

PERFORMANCE OF PUMP

PUMP NAME	PUMP STROKE		THEORETICAL DISCHARGE AT 5" STROKE		ACTUAL DISCHARGE AT 5" STROKE		VOLUMETRIC EFFICIENCY PERCENT	AVERAGE FORCE ON HANDLE		
								Piston Upward Stroke	Piston Downward Stroke	
	in.	cm	gals/min	lit/min	gal/min	lit/min		kg	kg	Head, ft
1. Philippine Shallow-Well Pump	5"	12.7	6.69	25.31	6.40	24.2	95.7	1.9	4.0	5-6
2. Philippine Deep-Well Pump	5"	12.7	3.52	13.33	3.38	12.8	96.0	11.1	1.8	100
3. Honduras Shallow-Well Pump	5"	12.7	5.53	20.94	5.44	20.66	98.7	2.2	6.1	5-6
4. Honduras Deep-Well Pump	5"	12.7	5.54	20.97	5.39	20.4	97.2	26.0	3.1	100

TABLE 2 (CONTINUED)

PERFORMANCE OF PUMP

PUMP NAME	ACTUAL PUMP STROKE (TEST)		THEORETICAL DISCHARGE AT 5" STROKE		ACTUAL DISCHARGE AT 5" STROKE		VOLUMETRIC EFFICIENCY PERCENT	AVERAGE FORCE ON HANDLE		
								Piston Upward Stroke	Piston Downward Stroke	
	in.	cm	gals/min	lit/min	gal/min	lit/min		kg	kg	Head, ft
5. Tunisia Deep-Well Pump	5"	12.7	3.29	12.44	2.95	11.15	89.6	8.4	4.9	100
6. DR Deep-Well Pump	5"	12.7	5.40	20.41	4.81	18.2	89.2	27.6	3.5	100
7. DR Shallow-Well Pump	5"	12.7	5.38	20.31	4.81	18.2	89.6	4.8	6.1	56
8. Ecuador Politechnica Deep-Well Pump	5"	12.7	6.76	25.58	6.44	24.4	95.4	27.8	3.9	100

TABLE 2 (CONTINUED)

PERFORMANCE OF PUMP

PUMP NAME	PUMP STROKE		THEORETICAL DISCHARGE AT 5" STROKE		ACTUAL DISCHARGE AT 5" STROKE		VOLUMETRIC EFFICIENCY PERCENT	AVERAGE FORCE ON HANDLE		
								Piston Upward Stroke	Piston Downward Stroke	
	in.	cm	gals/min	lit/min	gal/min	lit/min		kg	kg	Head, ft
9. Ecuador Tirado Deep-Well Pump	5"	12.7	6.83	23.86	6.21	23.5	90.8	27.6 35.1	1.46 0.93	104 196
10. Ecuador Metalurgica Deep-Well Pump	5"	12.7	6.72	25.43	6.18	23.2	91.2	20.5 39.2	2.5 1.6	100 207
11. Malawi Deep-Well Pump I*	5.25	13.34	5.63	21.32	5.18	19.60	91.9	43.4 38.7	1.59 1.60	161 104
12. Malawi Deep-Well Pump II*	5.25	13.34	5.82	22.02	5.70	21.60	98.1	32.8 22.8	2.1 1.7	171 110

*Malawi pumps used AID cylinders; the stroke was slightly higher than for the AID pumps because of the design of the handle. The discharge and the volumetric efficiency given in the table would vary depending on the size of the cylinder used.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

With the exception of the Haiti AID handpump, all pumps of the AID design tested in this program appeared suitable for field use with minor design changes or tightening of quality control during the manufacturing process. (The Haiti AID handpump was manufactured without technical assistance by the only foundry/machine shop known by WASH Project personnel to exist in Haiti, and in the opinion of the field director, this foundry/machine shop does not appear to have the potential for producing a quality handpump.) the aid pumps tested in the laboratory generally were capable of supporting intensive use over an extended period, if responsible maintenance in the form of minor parts replacement and periodic lubrication of moving parts was provided.

As with all manufactured products, product cost competes with quality and some manufacturers turn out better quality than others. Later in this chapter suggestions for improvements in quality and reliability, through changes in the manufacturing process or design substitution of some pump parts, will be made for some of the pumps that were tested.

5.2 General Conclusions

Some of the results and conclusions originating with the laboratory testing and/or review of the various field programs were of a general nature pertinent to all handpumps. These were as follows:

- Periodic lubrication of moving parts reduces wear to negligible proportions over extended periods of time, even, in some cases, for pumps of poor manufacturing quality. (The period between greasings will depend on such field conditions as location, use rate and type of lubricant).

- PVC and ABS cylinders are durable and reliable for 10 million cycles (4,000 hours of operation) or more.

- Metal poppet-type foot valves are durable and reliable for 10 million cycles or more.

- Leather flapper-type foot valves, although inexpensive and simple in construction, require replacement on a more frequent basis (approximately every 5 million cycles or 2,000 hours) than the metal poppet-type foot valves.

- Leather cups are durable and reliable for 10 million cycles or more except in unusual cases such as where water has heavy concentrations of sand or silt.

- Acidic waters with chloride concentrations appear to have had very little effect on pump components such as valves, pistons, cylinders, and plunger rod during 5 million cycles of testing.

- Periodic maintenance and repairs, even for high quality handpumps, is necessary. Thus, a workable program to insure prompt pump repairs and continuing maintenance is important.

5.3 Conclusions and Recommendations - AID Handpumps

5.3.1 Philippine (Tri-Star) Shallow-Well Pump

Field experience with the Philippine (Tri-Star) shallow-well pumps has revealed no problems with the functioning or durability of the pump components, such as the metal poppet-type foot valve, plunger cage assembly, PVC-lined cylinder, pins, and bushings. This pump functioned in the laboratory for 12.0 million cycles (4,800 hours) with no problems with any of the components of the pump. Therefore, no recommendations are made for improving its design or manufacture.

5.3.2 Philippine (Tri-Star) Deep-Well Pump

Field experience with the Philippine (Tri-Star) deep-well pumps has revealed no problems with the functioning or durability of the pump components, such as the metal poppet-type foot valve, plunger cage assembly, PVC cylinder, pins, and bushings. This pump functioned in the laboratory for 11.9 million cycles (4,760 hours) with no problems with any of the components of the pump. Therefore, no recommendations are made for improving its design or manufacture.

5.3.3 Honduras (FUNYMAQ) Shallow-Well Pump

Field experience with the Honduras (FUNYMAQ) shallow-well pumps has indicated no major problems with the functioning or durability of the pump components except for the wearing of the leather flapper-type foot valve. Laboratory experience over 18.2 million cycles (7,280 hours) of testing has shown that the flapper valves have to be replaced during intervals of 1,160 hours (2.9 million cycles) and 2,200 hours (5.5 million cycles). Even though leather flapper valves are simple in design and easy to replace in shallow-well pumps, field and laboratory experience shows poppet-type foot valves to be more durable. On this basis, a poppet-type foot valve is recommended for the Honduras (FUNYMAQ) shallow-well pump.

5.3.4 Honduras (FUNYMAQ) Deep-Well Pump

Field experience with the Honduras (FUNYMAQ) deep-well pumps has indicated no major problems with the functioning or durability of the pump components except for the wearing of leather flapper-type foot valves and cups. In the laboratory, experience of over 12 million cycles (4,800 hours) of testing has shown that the flapper valves have to be replaced during intervals of 1,200 hours (3 million cycles) and 2,400 hours (6 million cycles). The leather cups lasted 4,800 hours (12 million cycles). Because of the difficulty of changing leather flapper valves in a deep-well pump it is recommended that the leather valves be replaced with more durable poppet-type foot valves in the Honduras (FUNYMAQ) deep-well pump.

5.3.5 Tunisia (Founderie Reunies) Deep-Well Pump

Field experience with the Tunisia (Founderie Reunies) deep-well pumps has shown major problems (see Appendix G) such as breakage of pump bases, metal and plastic foot valve leakage, separation of PVC drop pipe from the PVC cylinder and from the base of the pump, and a high rate of wear of pins and bushings because of grit from sand storms.

However, none of these field problems were experienced in the laboratory during 10.0 million cycles (4,000 hours) of testing except for separation of PVC connections. Laboratory measurements indicated no wear or damage of pins, bushings, the pump body, or the associated pump components. Even though the leather cups became soft at 7.8 million cycles (3,120 hours) they were used throughout the testing period except for 450,000 cycles (180 hours).

It is concluded that this pump can support intensive field and laboratory use with minor parts replacement and lubrication. However, it is recommended that the PVC drop pipe/cylinder arrangement be changed to a metal drop pipe and a cylinder of at least Schedule 80 specifications.

5.3.6 Dominican Republic (ETINCA) Deep-Well Pump

Field experience with the Dominican Republic (ETINCA) deep-well pump has shown major problems (see Appendix G). Major problems were also experienced during 10.0 million cycles (4,000 hours) of testing in the laboratory, such as the drop pipe becoming loose at the threaded portion of the pump base, of the plunger rod breaking, and the discharge poppet valve wearing out (see Section 4.1.1). It is concluded that this pump can withstand intensive use in the field and in the laboratory only if major technical assistance is provided to the manufacturer (ETINCA) for improving manufacturing quality.

5.3.7 Dominican Republic (ETINCA) Shallow-Well Pump

Field experience with the Dominican Republic (ETINCA) shallow-well pump has also shown major problems (see Appendix G). This pump functioned satisfactorily during 10.0 million cycles (4,000 hours) of testing in the laboratory except for a defective foot valve, which had to be replaced, even though overall manufacturing quality was far from desirable. The pump appears capable of intensive use if major technical assistance is provided to the manufacturer (ETINCA) for improving manufacturing quality.

5.3.8 Ecuador (Politechnica) Deep-Well Pump

The Ecuador (Politechnica) deep-well pumps have performed well in the field (see Appendix G) except for the leather flapper valves which were replaced with commercially available metal poppet-type foot valves from the United States. In the laboratory, this pump experienced problems during 5.0 million cycles (2,000 hours) of testing, such as the breakage of the plunger cage and the twisting of the leather cups (see Section 4.1.1). Minor technical assistance for the manufacturer is recommended.

5.3.9 Ecuador (Tirado) Deep-Well Pump

The Ecuador (Tirado) deep-well pump was tested for only 3.8 million cycles and no definitive conclusions can be reached at this time. All that can be said is that it performed well for 3.8 million cycles, except that one of the leather cups became twisted due to high heads. It is recommended that additional testing under controlled conditions be conducted more fully to evaluate this pump's performance.

5.3.10 Ecuador (Metalurgica) Deep-Well Pump

The Ecuador (Metalurgica) deep-well pump was tested for only 2.7 million cycles. No definitive conclusions can be reached at this time. The pump performed well for 2.7 million cycles except that a twisted leather cup had to be replaced. This malfunction was due to high heads and a defective leather flapper valve which should be replaced with a metal foot valve (such as that used in the Ecuador-Tirado deep-well pump). It is recommended that additional testing under controlled conditions be conducted more fully to evaluate this pump's performance.

5.4 Conclusions and Recommendations - Non-AID Handpumps

Malawi Handpumps: The two Malawi handpumps were of good manufacturing quality and operated for 5.0 million cycles of testing even though one had bearings replaced twice. Acidic water with a high chloride concentration of 3,000 parts per million during the test did not appear to have any significant effect on the pump components. Unfortunately, the manufacturer does not produce cylinders and pistons to go with the main body of the pump. The manufacturer should consider using bearings with a higher loading capacity and should choose one of the many reliable cylinder/piston arrangements available today for production and distribution along with the pump body.

Moyno Handpump: The Moyno pump was of good overall quality and functioned throughout 2.5 million revolutions of testing except for a rotor rod breaking at 1.34 million revolutions which appeared to be due to the rotor being too tight in the stator. The output of the pump (the discharge flow rate) could not be precisely compared with the performance data of the manufacturer because of different laboratory operating conditions. The tests were of short duration; therefore, it is recommended that additional testing under controlled conditions be conducted more fully to evaluate this pump's performance. Particular attention should be paid to the force required to operate this pump and other similarly designed rotary pumps, especially at higher heads.

Mono Handpump: The Mono pump was tested for only 1.4 million revolutions and, therefore, no definite conclusions could be made with respect to its durability and reliability. However, it was observed that the manufacturing quality of the pump components was quite good. It appeared to be sturdy and capable of withstanding rough usage. The rotor was made of brass, of a design that has now reportedly been modified. It was not possible to compare the performance of the pump with the performance data published by the manufacturer because of different laboratory operating conditions. Since the rotor broke at 200,000 revolutions it is recommended that further testing be carried out with the new modification for definitive conclusions and recommendations on reliability and durability.

5.5 Conclusions and Recommendations - Foot Valves

The leather flapper valve is not as durable as readily available, economical, alternative foot valves. To reduce maintenance requirements, the leather flapper-type foot valve should be replaced with a metal poppet-type foot valve of a design similar to that used in the Philippine pump or to the brass valve commercially available in the Dominican Republic.

5.6 Conclusions and Recommendations

The handpump testing described in this report complemented earlier field data identifying improvements in handpumps for future rural water supply programs of developing countries. For instance: (1) Laboratory testing has confirmed field observations that a leather flapper-type foot valve, while inexpensive, is not as durable as other alternative valves and should be replaced with a metal design like the one used in the Philippine handpump program. (2) Laboratory testing with one of the shallow-well pumps has shown negligible wear of properly hardened pins and bushings despite a complete lack of lubrication for more than 6 million cycles. (3) Threaded connections, such as where the pump body screws into the pump base, should be minimized as much as possible.

It was also observed in the laboratory test program, which permitted direct comparisons of pumps from many sources, that there is a widespread variation in the quality of castings and machining of handpump components among the various handpump manufacturers throughout the world. Similar variation occurs in the hardening process for pins and bushings and generally makes regular lubrication a critical factor in field performance of the current AID pump design.

A review of the problems encountered in the installation and operation of handpumps included in this testing program points to major issues such as the quality of castings and machining accuracy. Reports from the Consumers' Association Testing and Research Laboratories at Harpenden, England, with respect to the testing of handpumps, also lead to similar conclusions. Moreover, field performance and laboratory testing of the fabricated steel handpumps from Malawi indicate that steel fabricated pumps can perform well and may be easier to manufacture in less developed countries than cast iron pumps.

As a result, even though the cast iron AID handpump has performed well in several developing countries during the past seven years, it is recommended that AID consider testing one or more new designs with handpumps that use sealed bearings (to eliminate the need for lubrication of moving parts) as possible improvements to the AID cast iron pump. Sealed bearing pumps provide the advantages of uniform materials (e.g. commercially manufactured pipe, plate, and bar stock), simple fabrication (cutting, drilling, and welding), and reduced maintenance (especially lubrication) requirements.

APPENDIX A

Description of Pumps

DESCRIPTION OF PUMPS

General Statement

The pumps that were tested as part of this program can be classed into categories depending on the mode of operation and design as follows:

Shallow-well piston pumps
Deep-well piston pumps
Rotary pumps

In the handpump testing program, 15 pumps of 3 different types made by 11 manufacturers from the Dominican Republic, Ecuador, Haiti, Honduras, Malawi, Philippines, Tunisia, the United Kingdom and the United States were tested. They included the AID-design handpumps and several other designs.

AID-Design Handpump

The AID-design handpump (Figures 3 and 4) is a locally manufactured single-action, positive-displacement piston pump for community or multi-family use consisting of an above ground pump stand made of cast iron, drop pipe, and a PVC or PVC-lined pump cylinder containing a cast iron or brass piston or plunger assembly with leather cup seals. It can be mounted on tube wells or on a platform built over dug wells. It can be adapted for shallow wells as well as deep wells. The following AID pumps were tested:

Tri-Star shallow-well pump (Philippines)
Tri-Star deep-well pump (Philippines)
FUNYMAQ shallow-well pump (Honduras)
FUNYMAQ deep-well pump (Honduras)
ETINCA shallow-well pump (Dominican Republic)
ETINCA deep-well pump (Dominican Republic)
Founderie Reunies (FR) deep-well pump (Tunisia)
Politechnica deep-well pump (Ecuador)
Tirado deep-well pump (Ecuador)
Metalurgica deep-well pump (Ecuador)
Haiti deep-well pump (Haiti)

The principal dimensions and other mechanical features of all of the above except the Haiti pump (discontinued from testing) are included in Tables 3 through 5. Any special features with respect to any of the above pumps will be discussed in later sections on results.

Non-AID Handpumps

Malawi Handpump:

The Malawi handpump (Figure 8) was designed by officers of a UNDP based project in Lilongwe, Malawi and in conjunction with the Department of Lands, Valuation, and Water. The pump is designed as a single-acting, positive-displacement piston pump for community or multi-family use. Design of a piston-cylinder assembly was incomplete at the time of testing; therefore, an AID deep-well cylinder was used for the test. The pump head frame is called the pedestal and serves as the pump support. The upper section of the frame is called the pump head and contains a steel handle that pivots in sealed bearings. The drop pipe is connected to the pump with an adaptor plate that is clamped between the pump head and pedestal. Significant mechanical data are included in Tables 4 and 5.

Mono Rotary Pump:

The Mono rotary pump is manufactured by the Mono Pumps Ltd., of England, in one of its overseas companies. In principle, it consists of a helical shaped rotor, as shown in Figure 9, which turns inside a stator having a double helix cavity. Water is trapped inside the cavities and progressively forced upward towards the pump spout; this is a positive displacement pump. A pump of this design is commonly referred to as a progressive cavity pump. The specifications of the Mono pump are as follows:

Mechanical Specifications and Features:

Pump type:	Progressing cavity, crank operated
Pump height:	22 3/4 inches
Pump weight:	93.7 lbs.
Pump body:	Overall diameter = 13 1/2 inches
Pump handle:	Made of cast iron radius (crank radius): 10 inches
Pumping elements:	Stator: black natural rubber Rotor: chrome plated brass
Bevel gears:	Larger gear made of special plastic Smaller gear made of steel
Handle Speed to Rotor Speed ratio - 3:1	
Foot valve:	Poppet valve with strainer
Pump rod:	1/2 inches diameter (steel)
Drop pipe:	1 1/2 inches nominal, galvanized

Moyno rotary pump:

The Moyno rotary pump is manufactured in the United States by the Robbins and Myers company. The Moyno pump is a progressing cavity pump of similar design to the Mono of Figure 9. Like the Mono, it operates with a single screw-like helix rotor, turning eccentrically within a double helix stator, producing sealed cavities that are positive displacing and self priming. The dimensional specifications of the pump are as follows:

Specifications and Mechanical Features:

Pump type:	Progressing cavity, crank operated
Pump height:	42 7/16 inches
Pump weight:	100.3 lbs.
Pump stand:	Inside diameter = 5 1/2 inches fabricated from heavy steel plate and pipe
Pump handle:	Made of cast iron Radius of handle (crank radius): 12 1/4 inches

Gear box:	Has bevel gears located perpendicular to each other; machined and hardened bevel gears are mounted on a high strength steel shaft within a cast iron housing. Tapered roller bearings support the shaft; gear box is pre-packaged with long lasting grease.
Speed ratio of driven rotor shaft to crank handle:	2:1
Pumping elements:	Stator: rubber-like material Rotor: screw-like helix rotor made of steel which is chrome plated
Foot valve:	Poppet valve with strainer
Pump rod:	1/2 inch diameter steel rod
Drop pipe:	1 1/4 inch diameter galvanized pipe

MALAWI PUMP

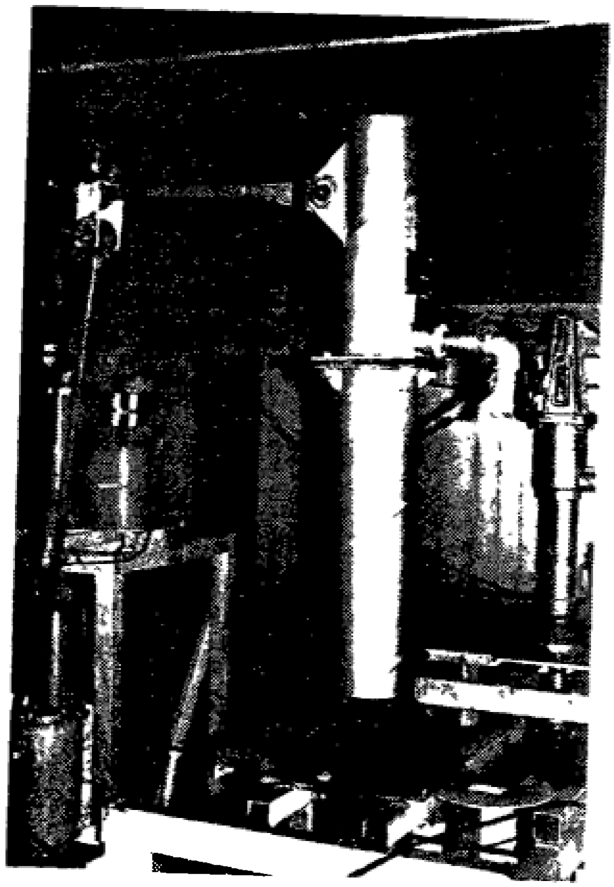
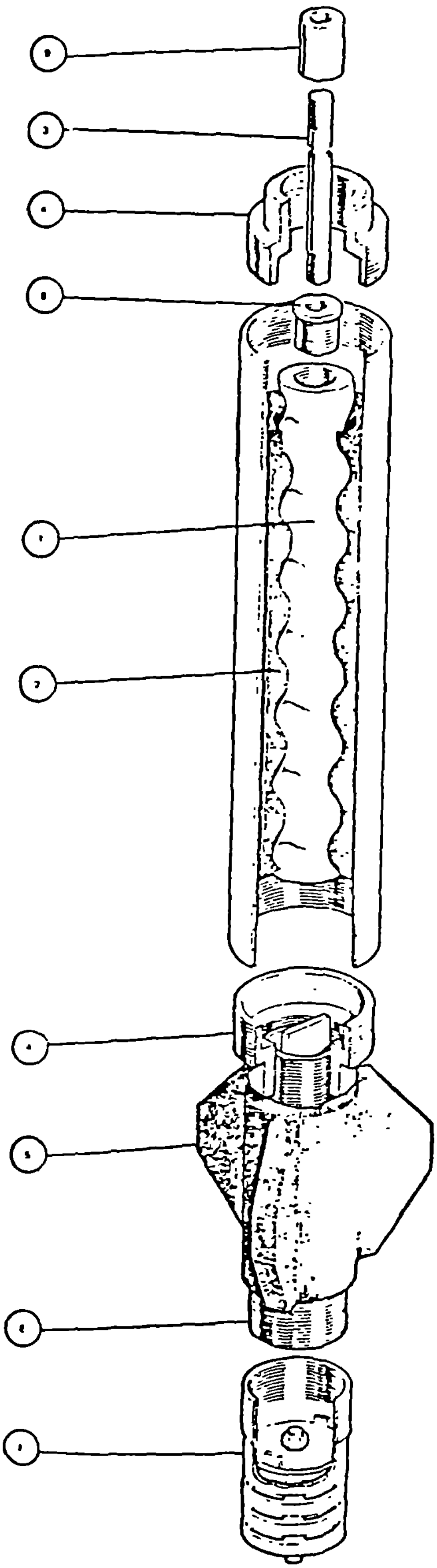


Figure 8

Figure 9

MONO ROTARY PUMP
ROTOR-STATOR ASSEMBLY



Item	Description
1	Rotor
2	Rubber Stator
3	Coupling Shaft
4	Stator Housing Adaptor
5	Stabilizer
6	Datum Pipe
7	Foot Valve and Strainer
8	Rotor Adaptor
9	Shaft Coupling
10	Intermediate Drive Shaft (N/S)

TABLE 3

PRINCIPAL DIMENSIONS AND WEIGHTS

PUMP NAME	PUMP (ASSEMBLED)			CYLINDER				DROP PIPE		PUMP ROD	
	TOTAL HEIGHT (INCHES)	TOTAL WEIGHT (LB)	TOTAL WEIGHT (KG)	TOTAL LENGTH (INCHES)	USABLE LENGTH (INCHES)	NOMINAL DIA. (INCHES)	WEIGHT (LB)	NOMINAL SIZE (INCHES)	WEIGHT (LB/FT)	SIZE DIA. (INCHES)	WEIGHT (LB/FT)
1.Philippine Shallow-Well Pump	40	85.0	38.4	14 1/2	7	3.00	NA	1 1/2	2.72	1/2	0.151
2.Philippine Deep-Well Pump	40	84.5	38.3	14 1/2	7	2.19	5.98	1 1/2	2.72	1/2	0.151
3.Honduras Shallow-Well Pump	40	112.0	51.0	14	7	2.75	NA	1 1/4	2.27	1/2	0.151
4. Honduras Deep-Well Pump	42	110.0	50.0	15	7	2.75	15.70	1 1/4	2.27	1/2	0.151

<u>NOTES</u>:

1. The weight of the cylinder includes that of the piston assembly also. In the case of shallow-well pumps the cylinder is a part of the pump body; therefore, its weight is not separately shown and is indicated as 'NA'. The Malawi deep-well pump (pump No. 11) was not supplied with a cylinder; therefore, the cylinder's dimensions and weight are indicated as 'NA'.

2. Usable length of cylinder is based on the maximum allowable stroke of the piston.

TABLE 3 (CONTINUED)

PRINCIPAL DIMENSIONS AND WEIGHTS

PUMP NAME	PUMP (ASSEMBLED)			CYLINDER				DROP PIPE		PUMP ROD	
	TOTAL HEIGHT (INCHES)	TOTAL WEIGHT (LB)	TOTAL WEIGHT (KG)	TOTAL LENGTH (INCHES)	USABLE LENGTH (INCHES)	NOMINAL DIA (INCHES)	WEIGHT (LB)	NOMINAL SIZE (INCHES)	WEIGHT (LB/FT)	SIZE DIA. (INCHES)	WEIGHT (LB/FT)
5. Tunisia Deep-Well Pump	42	100.1	45.4	19	7	2.12	4.4	2.12 PVC	1.25	1/2	0.151
6. DR Deep-Well Pump	41	89.3	40.5	14	7 1/8	2.75	22.1	1 1/4	2.27	7/16	0.115
7. DR Shallow-Well Pump	41	89.3	40.5	14	7	2.75	N/A	1 1/4	2.27	7/16	0.115
8. Ecuador Poli-Technica Deep-Well	43	105.8	48.0	14	6 1/2	3.00	9.0	1 1/2	2.72	1/2	0.151

TABLE 3 (CONTINUED)

PRINCIPAL DIMENSIONS AND WEIGHTS

PUMP NAME	PUMP (ASSEMBLED)			CYLINDER				DROP PIPE		PUMP ROD	
	TOTAL HEIGHT (INCHES)	TOTAL WEIGHT (LB)	TOTAL WEIGHT (KG)	TOTAL LENGTH (INCHES)	USABLE LENGTH (INCHES)	NOMINAL DIA. (INCHES)	WEIGHT (LB)	NOMINAL SIZE (INCHES)	WEIGHT (LB/FT)	SIZE DIA. (INCHES)	WEIGHT (LB/FT)
9. Ecuador Tirado Deep-Well Pump	41	88.2	40.0	14	6 1/2	3.00	9.0	1 1/4	2.27	1/2	0.151
10. Ecuador Metal-urgica Deep-Well Pump	42	84.5	38.3	14	6 1/2	3.00	9.0	1 1/2	2.72	7/16	0.115
11. Malawi Deep-Well Pump	60	110.3	50.0	NA	NA	NA	NA	2	5.08	5/8	0.237

TABLE 4

MECHANICAL DETAILS - STROKE, VOLUME FLOW

PUMP NAME	CYLINDER NOMINAL DIA. (INCHES)	CYLINDER VOLUME (CU. INCHES)	MAXIMUM POSSIBLE STROKE (INCHES)	MAXIMUM POSSIBLE DISCHARGE/STROKE (LITRES/STROKE)	THEORETICAL DISCHARGE VOLUME AT 5" STROKE (LITRES/STROKE)	PERCENT UTILIZATION AT 5" STROKE
1. Philippine Shallow-Well Pump	3.00	102.50	6 3/8	0.738	0.580	78.6
2. Philippine Deep-Well Pump	2.19	54.82	7 1/8	0.441	0.310	70.3
3. Honduras Shallow-Well Pump	2.75	83.15	7 1/8	0.694	0.487	70.2
4. Honduras Deep-Well Pump	2.75	83.15	7	0.681	0.487	71.5

NOTES:

1. Percent utilization at 5" stroke = $\frac{\text{theoretical discharge volume at 5" stroke}}{\text{maximum possible discharge/stroke}}$

TABLE 4 (CONTINUED)

MECHANICAL DETAILS - STROKE, VOLUME FLOW

PUMP NAME	CYLINDER NOMINAL DIA (INCHES)	CYLINDER VOLUME (CU. INCHES)	MAXIMUM POSSIBLE STROKE (INCHES)	MAXIMUM POSSIBLE DISCHARGE/STROKE (LITRES/STROKE)	THEORETICAL DISCHARGE VOLUME AT 5" STROKE (LITRES/STROKE)	PERCENT UTILIZATION OF CYLINDER AT 5" STROKE
5. Tunisia Deep-Well Pump	2.12	67.00	7	0.404	0.289	71.5
6. DR Deep-Well Pump	2.75	83.15	7 1/8	0.694	0.487	70.2
7. DR Shallow-Well Pump	2.75	83.15	6 7/8	0.669	0.487	72.8
8. Ecuador Poli-technica Deep-Well Pump	3.00	98.96	6 1/2	0.753	0.579	76.9

TABLE 4 (CONTINUED)

MECHANICAL DETAILS - STROKE, VOLUME FLOW

PUMP NAME	CYLINDER NOMINAL DIA (INCHES)	CYLINDER VOLUME (CU. INCHES)	MAXIMUM POSSIBLE STROKE (INCHES)	MAXIMUM POSSIBLE DISCHARGE/STROKE (LITRES/STROKE)	THEORETICAL DISCHARGE VOLUME AT 5" STROKE LITRES/STROKE	PERCENT UTILIZATION OF CYLINDER AT 5" STROKE
9. Ecuador Deep-Well Pump	3.00	98.96	6.625	0.767	0.579	75.5
10. Ecuador Metalurgica Deep-Well Pump	3.00	98.96	6.875	0.796	0.579	72.7
11. Malawi	NA	NA	7 1/2	NA	NA	NA

TABLE 5

MECHANICAL DETAILS OF COMPONENTS

PUMP NAME	COMPONENTS	MATERIAL	SURFACE FINISH	SIGNIFICANT DIMENSION OR FEATURE	OTHER INFORMATION
1. Philippine Shallow-Well Pump	Pump body	Cast iron	Painted		1. Pump handle, pump cap and fulcrum are provided with bushings
	Pump cap	Cast iron	Painted		
	Cylinder	PVC liner	Smooth inner surface		
	Handle	Cast iron	painted		
	Fulcrum	Cast iron	painted		
	Plunger cage	Brass casting	machined		
	Plunger rod	Steel	painted		2. PVC liner inside cast iron body
	Discharge valve	Brass	machined		
	Foot valve (suction)	Brass	machined	Poppet type valve	
	Pins	Steel	machined	Dia. = 0.625"	3. Plunger cage has machined surface for the valve seat
	Bushings	Steel	machined	I.D. = 0.625"	
	Cup seals (for piston)	Leather cups			4. Foot valve lined w/rubber
	Pump base	Cast iron	machined smooth and painted exterior		5. Pins were long bolts (hardened) with nuts

TABLE 5 (CONTINUED)

MECHANICAL DETAILS OF COMPONENTS

PUMP NAME	COMPONENTS	MATERIAL	SURFACE FINISH	SIGNIFICANT DIMENSION OR FEATURE	OTHER INFORMATION
2. Philippine Deep-Well Pump	Pump Body	Cast iron	painted		1. Pump cap, handle provided with bushings
	Pump cap	Cast iron	painted		
	Cylinder	PVC	Rough inner surface		
	Handle	Cast iron	painted		
	Fulcrum	Cast iron	painted		2. Plunger cage has machined surface for valve seat
	Plunger cage	Brass casting	machined		
	Plunger rod	Steel			
	Discharge Valve	Brass	machined	Poppet valve	
	Foot valve (suction)	Brass	machined	Poppet valve	3. Foot valve seat lined w/ rubber
	Pins	Steel	machined	Dia. = 0.625"	
	Bushings	Steel	machined	I.D. = 0.635	4. Pins were long bolts (hardened) with nuts
	Cup seals (for piston)	Leather cups			
	Pump base	Cast iron	machined smooth and painted exterior		

TABLE 5 (CONTINUED)

MECHANICAL DETAILS OF COMPONENTS

PUMP NAME	COMPONENTS	MATERIAL	SURFACE FINISH	SIGNIFICANT DIMENSION OR FEATURE	OTHER INFORMATION
3. Honduras Shallow-Well Pump	Pump body	Cast iron	Painted		1. Pump handle, pump cap and fulcrum are provided with bushings
	Pump cap	Cast iron	Painted		
	Cylinder	Cast iron	Lined with PVC - smooth		
	Handle	Cast iron	painted		
	Fulcrum	Cast iron	painted		
	Plunger cage	Brass casting	machined		2. Plunger cage has machined surface for the valve seat
	Plunger rod	Steel	painted		
	Discharge valve	Brass	machined	Poppet type valve	
	Foot valve (suction)	Leather loaded with weight		Leather flapper valve with a weight on it.	
	Pins	Steel	machined	Dia. = 0.625"	
	Bushings	Steel	machined	I.D. = 0.635"	
	Cup seals (for piston)	Leather cups			
	Pump base	Cast iron	machined smooth and painted exterior		

TABLE 5 (CONTINUED)

MECHANICAL DETAILS OF COMPONENTS

PUMP NAME	COMPONENTS	MATERIAL	SURFACE FINISH	SIGNIFICANT DIMENSION OR FEATURE	OTHER INFORMATION
4. Honduras Deep-Well Pump	Pump body	Cast iron	Painted		1. Pump handle, cap and fulcrum are provided with bushings
	Pump cap	Cast iron	Painted		
	Cylinder	PVC	Rough inner surface	PVC cylinder has cast iron cylinder end.	
	Handle	Cast iron	Painted		
	Fulcrum	Cast iron	Painted		
	Plunger cage	Brass casting	machined		
	Plunger rod	Steel	Painted		2. Plunger cage has machined surface for the valve seat
	Discharge valve	Brass	machined	Poppet type valve	
	Foot valve (suction)	Leather w/ a weight on it		Leather flapper valve with a weight on it.	
	Pins	Steel	machined	Dia. = 0.625"	
	Bushings	Steel	machined	I.D. = 0.625"	
	Cup seals (for piston)	Leather cups			
	Pump base	Cast iron machined	Machined smooth and painted exterior		

TABLE 5 (CONTINUED)

MECHANICAL DETAILS OF COMPONENTS

PUMP NAME	COMPONENTS	MATERIAL	SURFACE FINISH	SIGNIFICANT DIMENSION OR FEATURE	OTHER INFORMATION
5. Tunisia Deep-Well Pump	Pump body	Cast iron	painted		1. Pump cap, handle and fulcrum are provided with bushings
	Pump cap	Cast iron	painted		
	Cylinder	PVC	Rough inner surface	Small diameter and light weight	
	Handle	Cast iron	painted		
	Fulcrum	Cast iron	painted		
	Plunger cage	Brass casting	machined		
	Plunger rod	Steel			2. Plunger cage assembly has machined surface for the valve seat
	Discharge valve	Brass	machined	Poppet type	
	Foot valve (suction)	Brass	machined	Poppet type with strainer	
	Pins	Steel	machined	Dia. = 0.545"	
	Bushings	Steel	machined	I.D. = 0.555"	3. Foot valve is lined with rubber
	Drop pipe	PVC			
	Cup seals (for piston)	Leather cups			
	Pump base	Cast iron machined	machined smooth and painted exterior		4. The pump body and the base are welded to prevent leakage and loosening

TABLE 5 (CONTINUED)

MECHANICAL DETAILS OF COMPONENTS

PUMP NAME	COMPONENTS	MATERIAL	SURFACE FINISH	SIGNIFICANT DIMENSION OR FEATURE	OTHER INFORMATION
6. DR Deep-Well Pump	Pump body	Cast iron	Painted		1. Pump cap, handle and fulcrum are provided with bushings
	Pump cap	Cast iron	Painted		
	Cylinder	PVC lined	Rough inner surface		
	Handle	Cast iron	Painted		
	Fulcrum	Cast iron	painted		
	Plunger cage	Cast iron	machined		
	Plunger rod	Steel	Painted		2. Cylinder has PVC liner inside galvanized iron pipe
	Discharge valve	Cast iron	machined	Poppet type	
	Foot valve (suction)	Leather		Flapper type with a weight on it	
	Pins	Steel	Machined	Dia. = 0.625"	3. Plunger cage assembly has machined surface for the valve seat and is made of cast iron
	Bushings	Steel	Machined	I.D. = 0.640"	
	Cup seals (for piston)	Leather cups			
	Pump base	Cast iron machined	machined smooth and painted exterior		

TABLE 5 (CONTINUED)

MECHANICAL DETAILS OF COMPONENTS

PUMP NAME	COMPONENTS	MATERIAL	SURFACE FINISH	SIGNIFICANT DIMENSION OR FEATURE	OTHER INFORMATION
7. DR Shallow-Well Pump	Pump body	Cast iron	Painted		1. Pump cap, handle and fulcrum are provided with bushings
	Pump cap	Cast iron	Painted		
	Cylinder	PVC lined	Rough inner surface		
	Handle	Cast iron	Painted		
	Fulcrum	Cast iron	Painted		
	Plunger cage	Cast iron	machined		
	Plunger rod	Steel	Painted		2. Cylinder has PVC liner inside galvanized iron pipe
	Discharge valve	Cast iron	machined	Poppet type	
	Foot valve (suction)	Leather loaded with weight		Flapper valve with a weight on it	3. Plunger cage assembly has machined surface for the valve seat and is made of cast iron
	Pins	Steel	Machined	Dia. = 0.625"	
	Bushings	Steel	Machined	I.D. = 0.640"	
	Cup seals (for piston)	Leather cups			
	Pump base	Cast iron machined	machined smooth and painted exterior		

TABLE 5 (CONTINUED)

MECHANICAL DETAILS OF COMPONENTS

PUMP NAME	COMPONENTS	MATERIAL	SURFACE FINISH	SIGNIFICANT DIMENSION OR FEATURE	OTHER INFORMATION
8. Ecuador Poli- technica Deep- Well Pump	Pump body	Cast iron	Painted		1. Pump cap, handle and fulcrum are provided with bushings
	Pump cap	Cast iron	Painted		
	Cylinder	ABS (plastic)	Smooth inner surface		
	Handle	Cast iron	Painted		
	Fulcrum	Cast iron	Painted		
	Plunger cage	Brass casting	machined		
	Plunger rod	Steel	-		2. Cylinder has thin walls with cast iron end caps
	Discharge valve	Brass	machined	Poppet type	
	Foot valve (suction)	Leather		Flapper valve with a weight on it	
	Pins	Steel	machined	Dia. = 0.625"	3. Plunger cage assembly has machined sur- face for the valve seat
	Bushings	Steel	machined	I.D. = 0.635"	
	Drop pipe	Galvanized iron			
	Cup seals (for piston)	Leather cups			
	Pump base	Cast iron machined	machined smooth and painted exterior		

TABLE 5 (CONTINUED)

MECHANICAL DETAILS OF COMPONENTS

PUMP NAME	COMPONENTS	MATERIAL	SURFACE FINISH	SIGNIFICANT DIMENSION OR FEATURE	OTHER INFORMATION
9. Ecuador Tirado Deep-Well Pump	Pump body	Cast iron	Painted		1. Pump handle, pump cap and fulcrum are provided with bushings
	Pump cap	Cast iron	Painted		
	Cylinder	ABS (plastic)	Smooth inner surface		
	Handle	Cast iron	painted		
	Fulcrum	Cast iron	painted		
	Plunger cage	Brass casting	machined		2. Plunger cage has machined surface for the valve seat
	Plunger rod	Steel	painted		
	Discharge valve	Brass	machined	Poppet type valve	
	Foot valve (suction)	Brass	machined	Poppet type valve	3. Foot valve lined with rubber
	Pins	Steel	machined	Dia. = 0.625"	
	Bushings	Steel	machined	I.D. = 0.635"	
	Drop pipe	Galvanized			
	Cup seals (for piston)	Leather cups			
	Pump base	Cast iron machined	machined smooth and painted exterior		

TABLE 5 (CONTINUED)

MECHANICAL DETAILS OF COMPONENTS

PUMP NAME	COMPONENTS	MATERIAL	SURFACE FINISH	SIGNIFICANT DIMENSION OR FEATURE	OTHER INFORMATION
10. Ecuador Metalurgaica Deep-Well Pump	Pump body	Cast iron	Painted		1. Pump cap, handle and fulcrum are provided with bushings
	Pump cap	Cast iron	Painted		
	Cylinder	ABS	Smooth inner surface		
	Handle	Cast iron	Painted		
	Fulcrum	Cast iron	Painted		
	Plunger cage	Brass casting	machined		
	Plunger rod	Steel	Painted		
	Discharge valve	Brass	machined	Poppet type valve	
	Foot valve (suction)	Leather		Flapper type valve with weight on it	
	Pins	Steel	Machined	Dia. = 0.625"	2. Plunger cage assembly has machined surface for the valve seat
	Bushings	Steel	Machined	I.D. = 0.635"	
	Cup seals (for piston)	Leather cups			
	Pump base	Cast iron machined	Machined smooth and painted exterior		

APPENDIX B

AID Handpump Testing Protocol

AID HAND PUMP TESTING PROTOCOL

Objective

The objective of the testing described herein is to determine the durability and reliability of AID hand-operated water pumps from manufacturers in Tunisia, Ecuador, Dominican Republic, Honduras, and the Philippines to evaluate the general quality level. However, the test setup and procedures will be designed to test additional hand pumps as may be required in the future.

Quality Characteristics to be Observed

The quality characteristics to be observed and measured include the following:

- Wear, breakage, roundness, and dimensional changes of parts such as cylinders, pins, bushings, foot valve seat and flapper, check valve seat and poppet, cup seals, sliding blocks, and other moving parts. This includes Rockwell (R_C) hardness measurement of all pins, journals, and bushings.

- Flow rate of pumps over the test period at 40 strokes per minute at 100 feet of head (deep well pumps only).

- Leakage rate of foot valves over an 8-hour period.

- Applied force on the pump handle approximately six inches from the operator's end of the handle.

The above characteristics will be determined under ambient, indoor conditions for an extended period of time totalling 5×10^6 cycles. In order to record data from the above, a standard form will be designed for each component and kept in a project log book. Timers, counters, flow meters, telescoping gauges, micrometers, vernier dial-indicating calipers, Rockwell hardness testing equipment, air pressure gauges calibrated to read applied force on handles, and other laboratory instruments as required will be used for measurements.

Test Procedure and Methods

Pumps will be selected from accepted current production on a random basis without bias. Two pumps from each country will be installed on the test stand and tested for 5×10^6 cycles. The steps that will be taken during the test period follow below:

1. The pump will first be completely disassembled.
2. Baseline measurements will be recorded. These will include:

   A. Thread measurements on all threaded components.
   B. Visual quality of castings.

C. Visual quality of pump leathers.
D. Dimensional measurements:

1. Cylinder bore (i.d. at 90° intervals, top, middle, and bottom of plunger stroke).

2. Cup leathers (o.d. at 90° intervals with 0 force, assembled on piston, dry and water soaked)* .

3. Bushing bores (i.d. at 90° intervals, 1/4" from each end and middle).

4. Pin diameters (o.d. at 90° intervals 1/2" from each end and middle of any pin engagement area).

5. Surface roughness of bushings (i.d. at 90° entire length).

6. Surface roughness of pins (o.d. at 90° entire length).

7. Width of sliding blocks (top, middle, and bottom).

8. Surface roughness of sliding block contact faces.

9. Width of pump cap sliding block tracks (top, middle, and bottom of plunger stroke area).

10. Surface roughness of pump cap sliding block tracks (stroke area -- four surfaces).

11. Alignment of drilled holes in linkage system of pump cap, handle fulcrum, and handle. Measurements of parallelism and perpedicularity between the axes of the holes and the parts will also be made.

12. Hole to hole dimensions in pump cap, handle fulcrum, handle, pump body, and mounting flange.

13. Arc of handle during pumping cycle.

E. Leak rate of foot valve.

3. General purpose wheel bearing grease will be applied to all metal-to-metal moving parts and the pumps reassembled.

4. The pumps will be mounted on an indoor test stand under the following conditions:

A. The pumping rate will be set at 40 strokes per minute with the pumping force applied approximately six inches from the end of the pump handle.

B. The pump stroke will be five inches and will be limited to the middle section of the cylinder.

C. A pumping head of 100 feet will be simulated (deep well pumps only).

D. The pumps will be superficially lubricated every $.5 \times 10^6$ cycles with general purpose wheel bearing grease.

E. Water used for the test will be normal chlorinated water as obtained from the City of Atlanta water mains.

5. A photographic history will be kept of the testing program, including the test stand setup and all significant events during testing.

6. The pumps will be run continuously and the following performance data recorded at $.5 \times 10^6$ cycle intervals:

   A. Flow rate
   B. Applied force on handle
   C. Any unusual noise, vibration, or behavior.

7. The pumps will be disassembled at the end of approximately 0.5×10^6, 1.3×10^6, 2.6×10^6, 3.9×10^6, 5×10^6 cycles, and the following measurements made:

   A. Foot valve leak rate in ml/5 min (8-hour test)
   B. All dimensional measurements as listed previously in Step 2-D.

8. If the pumps fail during the testing period, they will be repaired using available replacement parts, and testing will be continued. Failure analysis will then be conducted on the failed component. Where castings break without an apparent flaw, they will be subjected to a metallurgical analysis upon authorization of the CDM/WASH manager.

9. After the completion of the test, a summary report including all acquired data, photographs, and test conclusions will be submitted.

Test Equipment

The test equipment will be set up to test pumps at heads of 100 to 120 feet. The Consumer Association Hand Pump Test protocol will be consulted to serve as a guide to testing procedures.

Initially, a single pump test setup will be designed and built, and the pump will run for 2 to 3 days to assist in the design of the automatic shut-off and safety equipment. Concurrently, the structural steel framework for the ten pump stands will be designed. After completing the preliminary testing of the first pump, the structural steel framework will be constructed and the ten pumps will be installed. The basic design concept is shown in Figures 1, 2, and 3. However, design improvements and details will be worked out while the project is in progress.

As shown in Figures 1 and 2, the handle of the pump will be operated by the piston rod of an air cylinder which is supplied with compressed air at 150 psi. The air cylinder is double acting and the reciprocating motion of the piston rod will be accomplished by means of a "shuttle valve" and two limit valves. The air pressure will be regulated by means of a "pressure regulator valve" and the speed of the piston will be controlled by flow control valves. The stroke can be adjusted by means of limit valves. A "head simulation valve" (Figure 4) or an alternative setup will be used to exert a constant head of 100 feet on the foot valve and other components.

"Fail-safe" devices will be installed in the system to instantly stop the test if a sudden failure of any of the hand pump or testing components occurs.

The cost estimate for the above test setup is $18,985.75 (See Page 5 for details).

Personnel

Georgia Tech Project Manager - 22 days management and coordination with WASH office.

Engineer - 22 days design, 3 days initial test, 12 days final testing, 30 days preparation of reports @ 3 days per pump (includes interim reports, log sheets, final report) = 67 days.

Technician - 30 days equipment construction, 3 days initial testing, 80 days final testing = 113 days.

Secretary - 22 days.

Total number of days for the project = 224 days.

Reports and Communications

A formal final report will be prepared in twenty-five (25) copies. All relevant information regarding test data, failure analysis, photographs, etc., will be presented through the WASH task manager to the AID program manager.

Any changes in test procedures or equipment as a result of the preliminary testing or other unforeseen causes, requested by Georgia Tech or directed by the WASH contractor, will be documented in writing.

However, informal verbal communications between the contractor and Georgia Tech personnel during the project period will be encouraged.

Cost of Equipment for Test Setup

Mead air cylinder w/cushions each end (2½" x 30" x 1" rod)	$ 311.00
Mead x 10 valve (shuttled)	63.00
2 pilot valves (LTV-75)	77.82
¼" flow controls JF-2	21.10
Stroke counter	35.00
Pressure regulator	18.74
Miscellaneous:	100.00
filter, air dryer, lubrication, safety attachments, hose, electrical, etc.	
	$ 626.66 per s
Cost for 10 sets	6,266.60
5 head simulation valves @ $850.00 each*(for 5 deep well pumps)	4,250.00
Structural steel frame work @ $1.00/lb for 4,672 lbs of steel	4,672.00
	$15,188.60

May have to add an additional 25% for expendables and other contingencies: $3,797.15

TOTAL APPROXIMATE COST - $18,985.75

*The approximate cost of manufacture, locally at Harpenden UK, as given by Mr. Ken Mills (CA Harpenden), is $750. We have added $100.00 for shipping and related charges. This is not a firm quote by CA, Harpenden.

PNEUMATIC DRIVING MECHANISM
FOR THE HAND PUMP

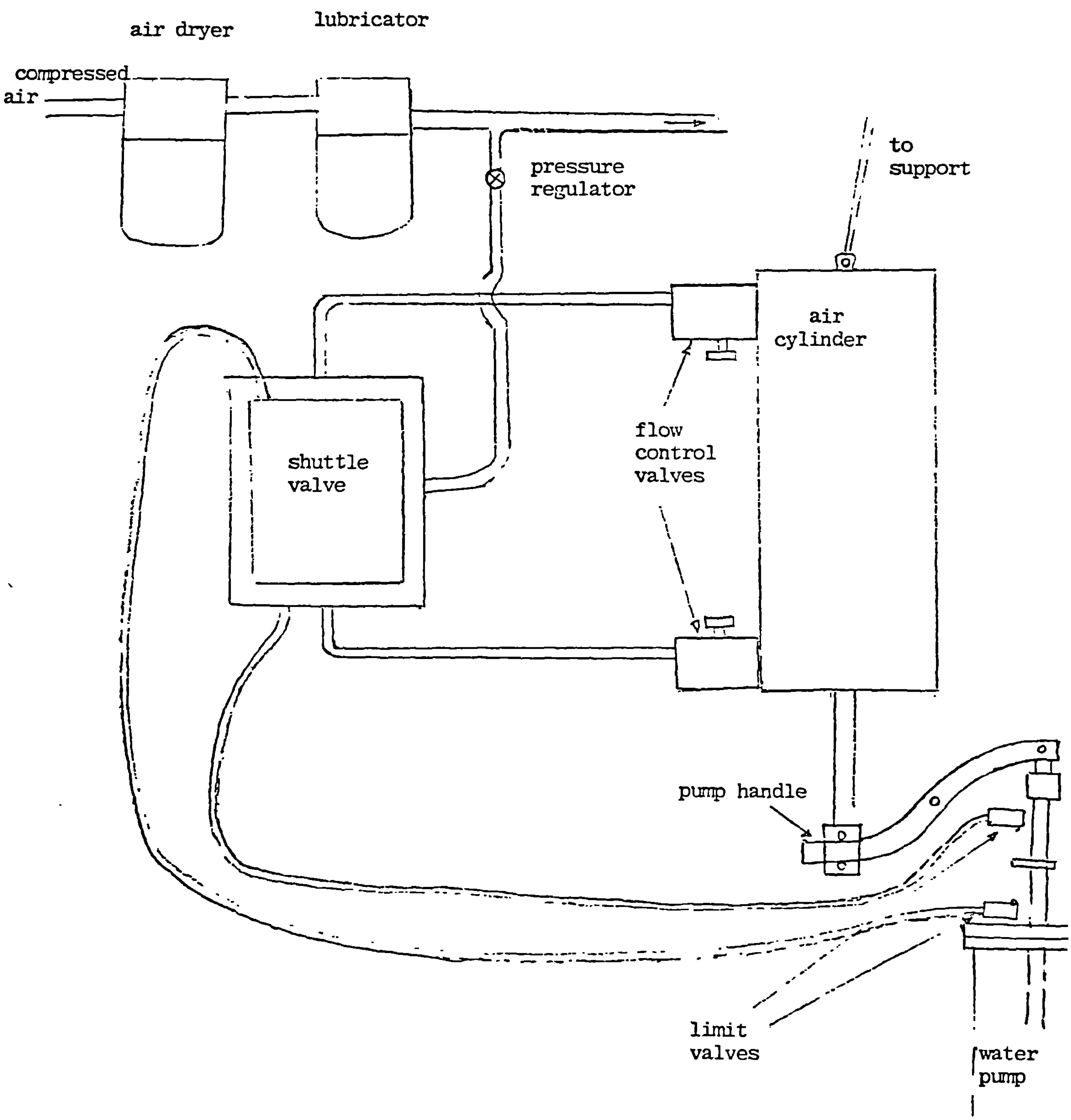


Fig.1

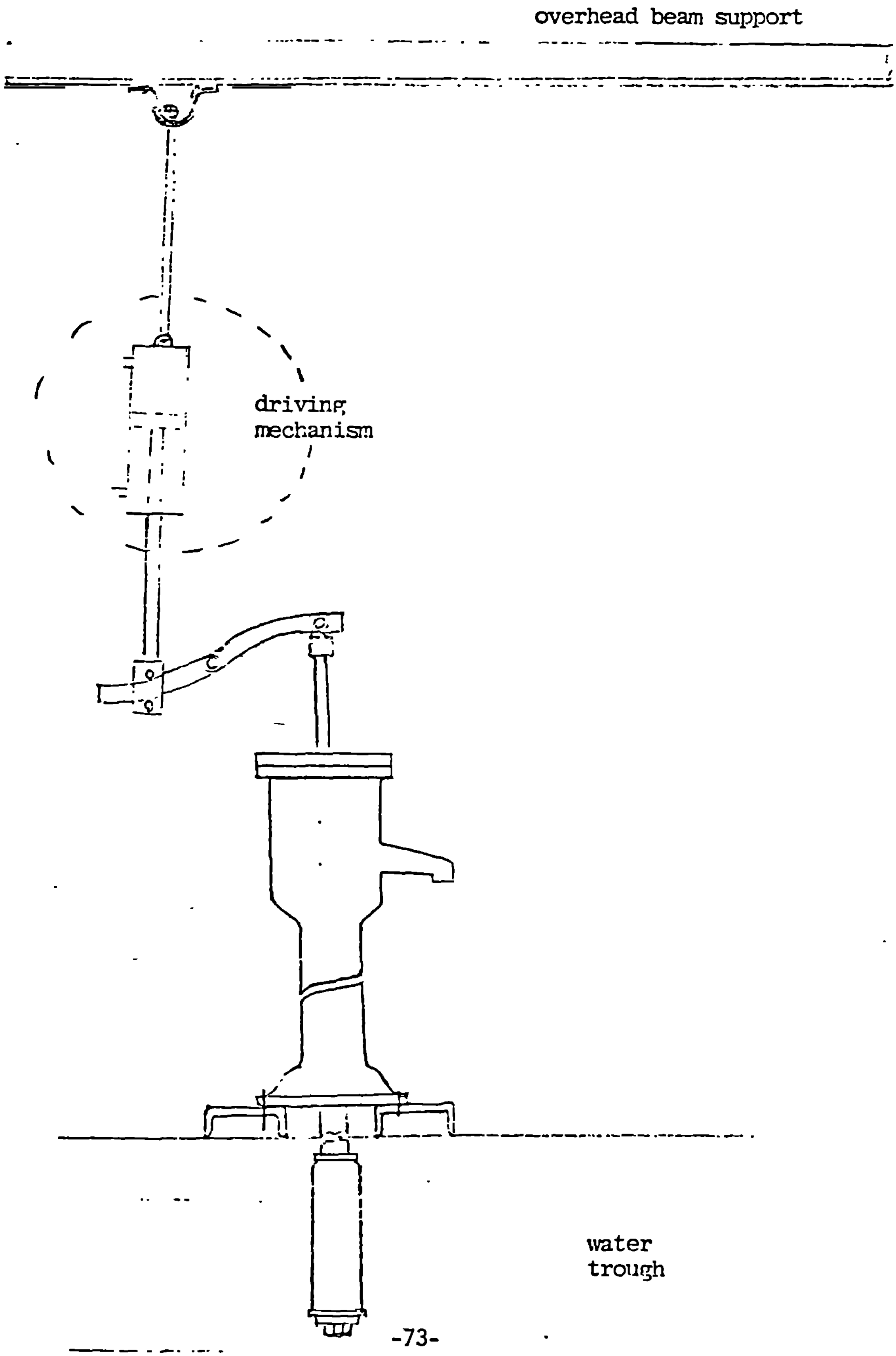


Fig.2

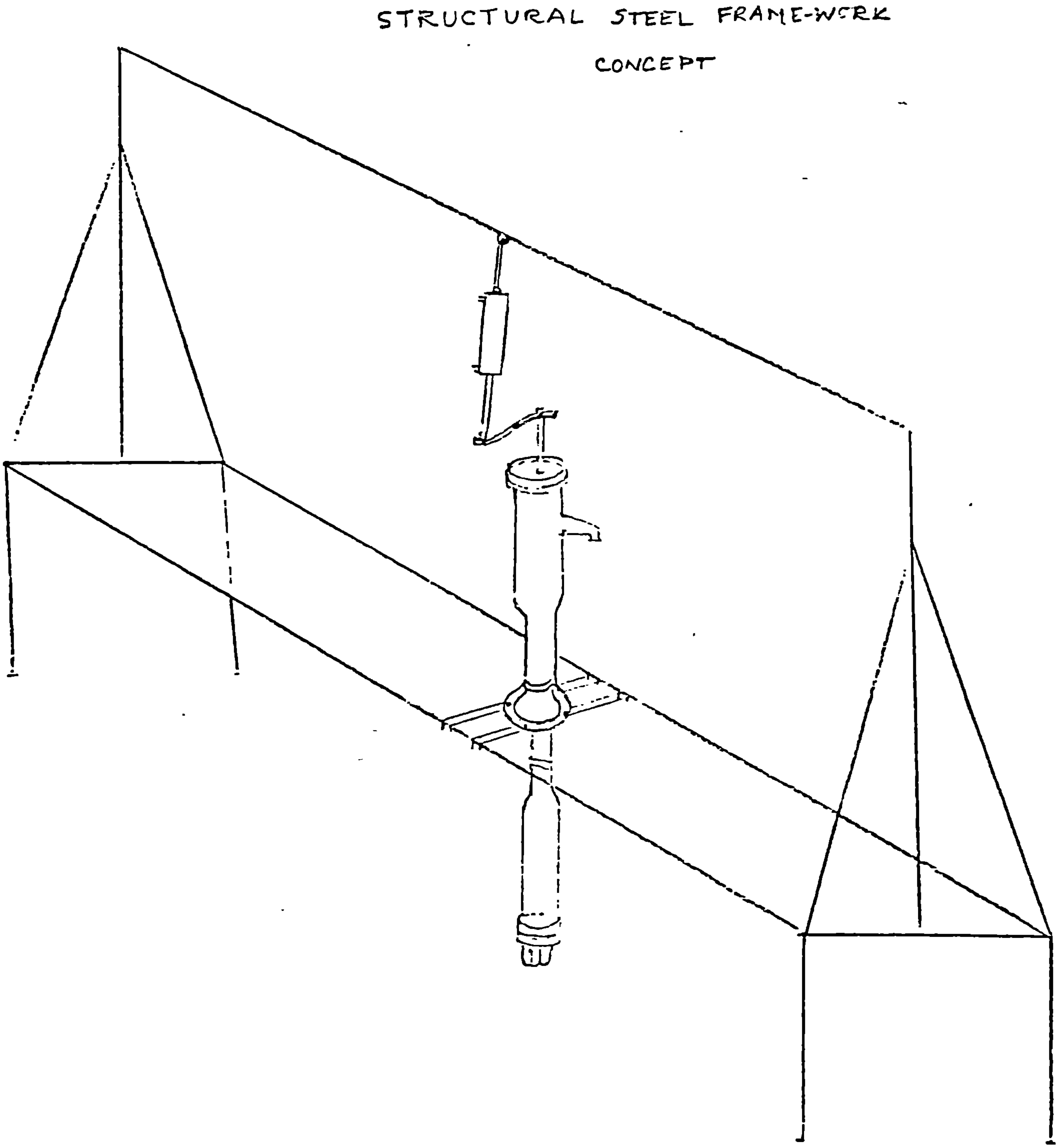
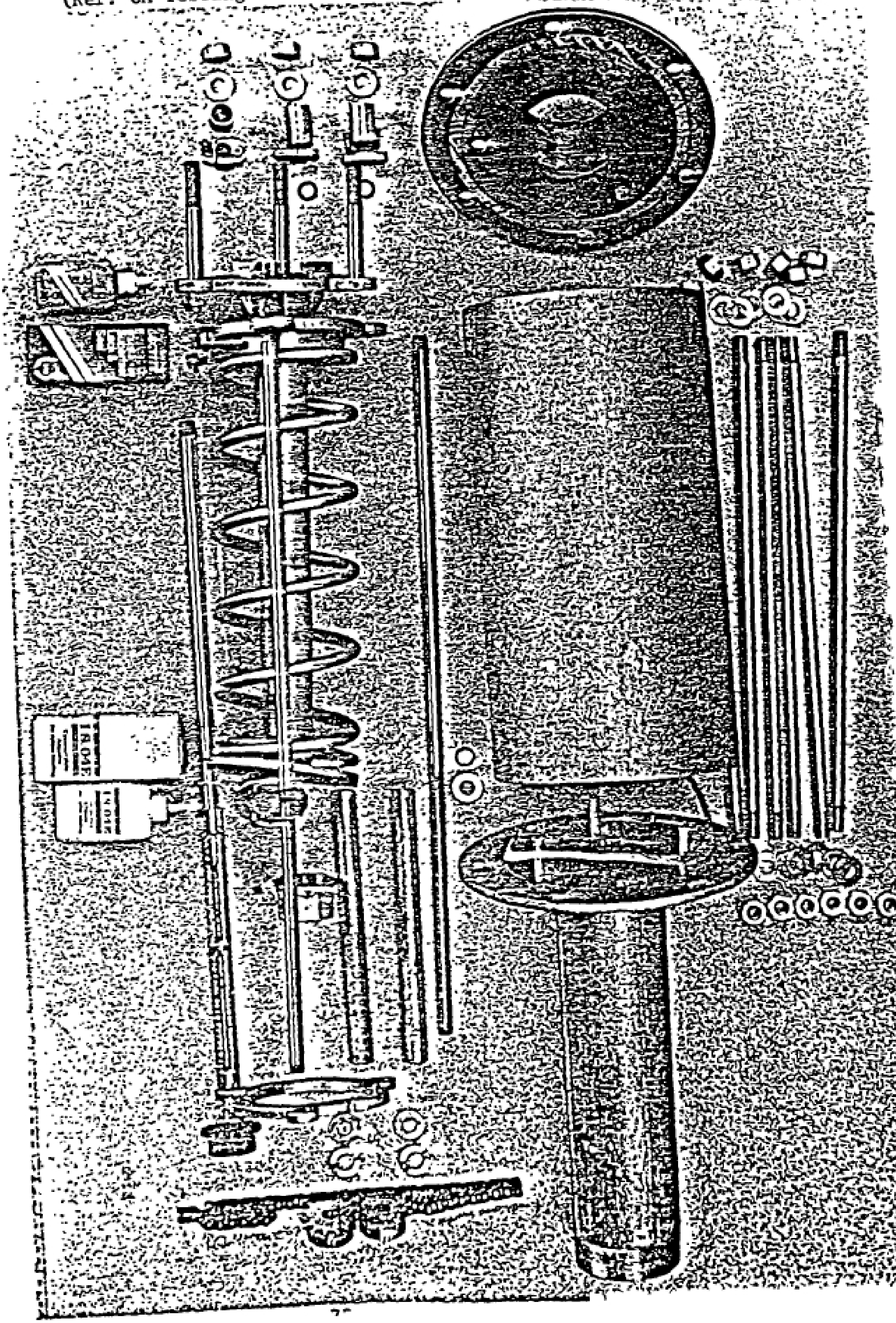


Fig. 3

Fig. 4

PHOTOGRAPH OF DISMANTLED HEAD SIMULATION VALVE

(Ref. CA Testing and Research, Harpenden Rice Laboratories)



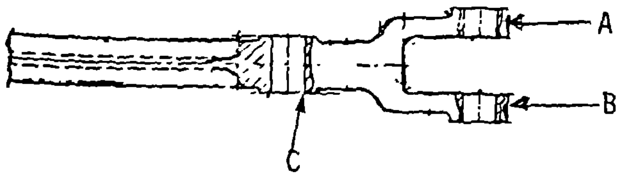
APPENDIX C

Wear Measurements

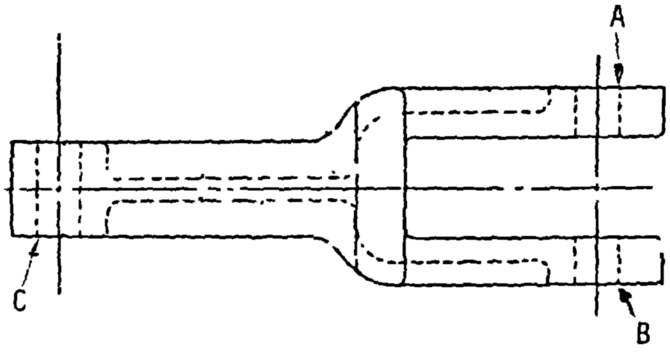
Note: All moving pump parts were relubricated at each inspection, except for the last six million cycles of the Honduras shallow well pump.

SYMBOLS FOR DATA SHEETS

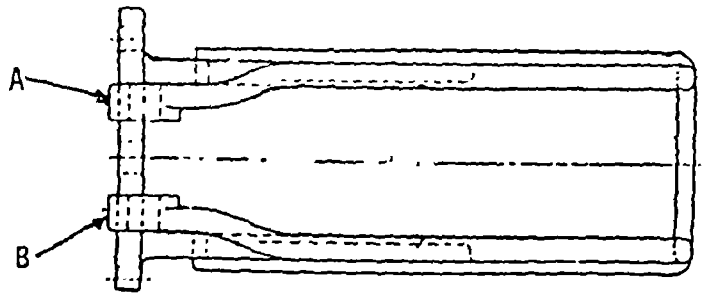
Handle Bushings:

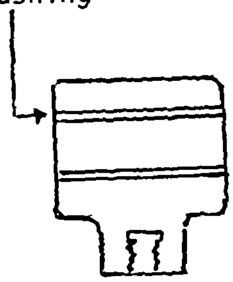


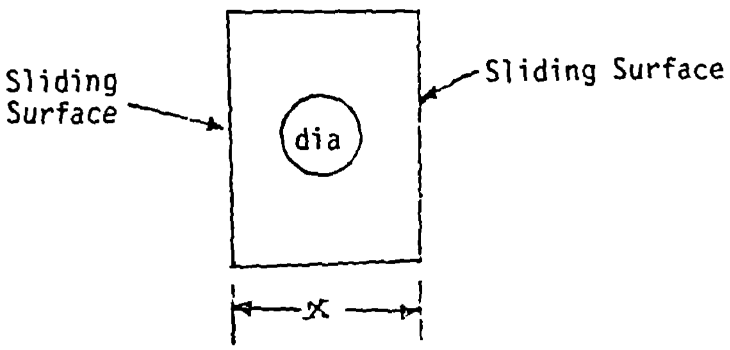
Fulcrum Bushings:



PUMP CAP BUSHINGS:







PHILIPPINE SHALLOW WELL PUMP

FULCRUM BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0.0	0.627	0.627	0.629
0.5	0.627	0.627	0.629
1.3	0.627	0.627	0.629
2.6	0.627	0.627	0.629
4.0	0.627	0.627	0.630
5.0	0.628	0.628	0.630
6.8	0.628	0.627	0.630
8.9	0.630	0.627	0.630
10.0	0.628	0.628	0.630

PHILIPPINE SHALLOW WELL PUMP

PUMP CAP & ROD END BUSHINGS

Cumulative Number of Cycles (Millions)	DIAMETER OF BUSHINGS - INCHES		
	A	B	(Rod End) C
0.0	0.630	0.626	0.634
0.5	0.630	0.626	0.634
1.3	0.630	0.626	0.634
2.6	0.6283	0.628	0.634
4.0	0.6286	0.627	0.634
5.0	0.631	0.628	0.635
6.83	0.630	0.627	0.634
8.9	0.630	0.627	0.635
10.0	0.630	0.627	0.6356

PHILIPPINE SHALLOW WELL PUMP

HANDLE BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHINGS - INCHES		
	A	B	C
0.0	0.649	0.639	0.639
0.5	0.649	0.639	0.639
1.3	0.650	0.640	0.640
2.6	0.651	0.6406	0.641
4.0	0.651	0.6415	0.643
5.0	0.650	0.642	0.643
6.8	0.649	0.642	0.6425
8.9	0.659	0.640	0.642
10.0	0.650	0.640	0.6435

PHILIPPINE SHALLOW WELL PUMP

PINS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER - INCHES		
	ROD END PIVOT	HANDLE PIVOT	FULCRUM PIVOT
0	0.621	0.618	0.618
0.5	0.621	0.618	0.618
1.3	0.621	0.618	0.618
2.6	0.621	0.617	0.617
4.0	0.620	0.617	0.617
5.0	0.6195	0.617	0.618
6.8	0.621	0.6175	0.6175
8.9	0.621	0.6175	0.6175
10.0	0.621	0.618	0.617

PHILIPPINE SHALLOW WELL PUMP

SLIDING BLOCKS

Cumulative Number of Cycles (Millions)	Block 1		Block 2	
	Dia - Inches	X (Inches)	Dia - Inches	X (Inches)
0	0.632	1.072	0.631	1.072
1.3	0.6327	1.072	0.631	1.072
2.6	0.633	1.072	0.633	1.072
4.0	0.6335	1.070	0.633	1.070
5.0	0.634	1.070-1.072	0.633	1.070-1.071
6.83	0.633	1.071-1.070	0.6338	1.070-1.071
8.90	0.633	1.070-1.072	0.634	1.070-1.070
10.00	0.6335	1.070-1.069	0.634	1.070

X = Thickness of block (distance between sliding surfaces)

PHILIPPINE SHALLOW WELL PUMP

CYLINDER

CUMULATIVE NUMBER OF CYCLES (Millions)	DIA-INCHES
0	3.0245
0.5	3.026
1.3	3.028
2.6	3.028
5.0	3.028
6.8	3.025
8.9	3.020
10.0	3.027

PHILIPPINE DEEP WELL PUMP

FULCRUM BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0.0	0.630	0.641	0.634
1.3	0.6307	0.642	0.635
2.6	0.630	0.641	0.635
3.96	0.6316	0.641	0.636
5.1	0.6326	0.6435	0.636
6.4	0.632	0.6415	0.636
8.5	0.630	0.6416	0.635
10.0	0.6318	0.6428	0.636

PHILIPPINE DEEP WELL PUMP

HANDLE BUSHINGS

Cumulative Number of Cycles (Millions)	Diameter of Bushings (inches)		
	A	B	C
0	0.6393	0.641	0.637
0.7	0.6403	0.6417	0.6365
2.6	0.6405	0.6415	0.637
3.96	0.640	0.642	0.6375
5.1	0.6413	0.6423	0.6398
6.4	0.6407	0.6423	0.6386
8.5	0.640	0.6410	0.637
10.0	0.6408	0.6423	0.639

PHILIPPINE DEEP WELL PUMP

PUMP CAP AND ROD END BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING (INCHES)		
	A	B	C
0.0	0.6363	0.6308	0.6387
0.7	0.638	0.630	0.638
1.3	0.639	0.6307	-
2.6	0.639	0.630	0.641
3.96	0.6405	0.630	0.641
5.1	0.6408	0.632	0.640
6.4	0.641	0.631	0.641
8.5	0.6395	0.630	0.6403
10.0	0.6397	0.631	0.6425

PHILIPPINE DEEP WELL PUMP

PINS

		DIAMETER - INCHES	
CUMULATIVE NUMBER OF CYCLES (MILLIONS)	ROD END PIVOT	HANDLE PIVOT	FULCRUM PIVOT
0	0.622	0.623	0.623
0.7	0.6215	0.622	0.621
1.3	0.621	0.622	0.621
2.6	0.621	0.6235	0.6207
3.96	0.6225	0.6225	0.6205
5.10	0.6215	0.623	0.6207
6.4	0.6215	0.6238	0.621
8.5	0.622	0.6215	0.620
10.0	0.622	0.620	0.622

PHILIPPINE DEEP WELL PUMP

SLIDING BLOCKS

Cumulative Number of Cycles (Millions)	Block 1		Block 2	
	Dia - Inches	X - Inches	Dia - Inches	X - Inches
0	0.627	1.072-1.078	0.629	1.078-1.079
0.7	0.632	1.070	0.6325	1.077
1.3	0.6316	1.070	0.6316	1.076
2.6	0.631	1.070	0.6316	1.077
3.96	0.629	1.070-1.071	0.6336	1.076-1.078
5.10	0.632		0.6346	
6.4	0.6315	1.070-1.071	0.6343	1.077-1.078
8.5	0.6315 0.6303	1.070-1.071 1.070-1.071	0.632 0.633	1.077-1.078 1.077-1.078
10.0	0.631	1.070-1.072	0.632	1.075-1.079

PHILIPPINE DEEP WELL PUMP

CYLINDER

CUMULATIVE NUMBER OF CYCLES (Millions)	DIA - INCHES
0	2.152
1.0	2.192
2.4	2.152
4.8	2.166
6.9	-
8.4	2.187
10.3	2.184

HONDURAS SHALLOW WELL PUMP

FULCRUM BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0	0.632	0.631	0.6317
0.5	0.633	0.633	0.632
1.3	0.634	0.633	0.633
2.6	0.630	0.631	0.630
4.0	0.634	0.633	0.632
5.0	0.634	0.633	0.633
6.8	0.6345	0.634	0.634
8.5	0.634	0.633	0.634
10.0	0.634	0.634	0.634
	(0.634)	(0.632)	(0.633)
18.2	0.633	0.632	0.633

HONDURAS SHALLOW WELL PUMP

PUMP CAP AND ROD END BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING (INCHES)		
	A	B	C
0.0	0.631	0.630	0.641
0.5	0.631	0.630	0.641
1.3	0.631	0.630	0.641
2.6	0.629	0.629	0.639
4.0	0.6315	0.630	0.643
5.0	0.632	0.631	0.643
6.8	0.632	0.631	-
8.5	0.630	0.630	0.643
10.0	0.631	0.631	0.6446
18.2	0.632	0.630	0.6415

HONDURAS SHALLOW WELL PUMP

HANDLE BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0	0.633	0.633	0.631
0.5	0.6325	0.633	0.6305
1.3	0.633	0.633	0.633
2.6	0.6315	0.6313	0.631
4.0	0.633	0.634	0.631
5.0	0.635	0.633	0.634
6.8	0.635	0.635	0.633
8.5	0.635	0.634	0.632
10.0	0.634	0.634	0.632
18.2	0.634	0.633	0.631

HONDURAS SHALLOW WELL PUMP

PINS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF PIN - INCHES		
	Rod End Pivot Pin	Handle Pivot Pin	Fulcrum Pivot Pin
0.0	0.6176	0.618	0.618
0.5	0.617	0.618	0.616
1.3	0.617	0.616	0.617
2.6	0.619	0.618	0.619
4.0	0.617	0.616	0.617
5.0	-	0.6163	0.616
6.8	0.617	0.616	0.617
8.6	0.618	0.6165	0.616
10.0	0.617 (0.617)	0.616 (0.6175)	0.6170 (0.617)
18.2	0.618	0.617	0.617

HONDURAS SHALLOW WELL PUMP

SLIDING BLOCKS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	BLOCK 1		BLOCK 2	
	DIA-INCHES	X-INCHES	DIA-INCHES	X-INCHES
0 (base line)	0.628	1.070	0.629	1.088
0.5				
1.3	0.630	1.065	0.630	1.075
2.6	0.628	1.065-1.072	0.628	1.080-1.091
4.0	0.630	0.065-1.070	0.630	1.082-1.090
5.0	0.631	1.064-1.067	0.630	1.078-1.093
6.8	0.631		0.631	
8.5	0.630	1.062-1.068	0.630	1.079-1.092
10.0	0.630	1.063-1.071	0.631	1.078-1.092
18.2	0.631		0.631	

HONDURAS SHALLOW WELL PUMP

CYLINDER

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER-INCHES
0	2.750
0.5	2.751
1.3	2.752
2.6	2.750
4.0	2.748
5.0	2.748
6.8	2.744
8.5	2.747
10.0	2.754

HONDURAS DEEP WELL PUMP

FULCRUM BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0	0.641	0.642	0.6383
0.5	0.6403	0.642	0.638
1.3	0.6405	0.642	0.639
2.6	0.641	0.644	0.639
3.9	0.6425	0.640	0.6396
5.0	0.6413	0.643	0.640
6.8	0.6416	0.643	0.6395
8.5	0.6415	0.643	0.6397
10.0	0.6417	0.643	0.640

HONDURAS DEEP WELL PUMP

PUMP CAP BUSHINGS AND ROD END BUSHING

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C (ROD END)
0	0.6383	0.639	0.643
0.5	0.6386	0.639	0.6435
1.3	0.637	0.637	0.6435
2.6	0.6375	0.639	0.6433
3.9	0.638	0.640	0.6435
5.0	0.638	0.639	0.6433
6.35	0.638	0.639	0.6438
8.5	0.638	0.639	0.6436
10.21	0.638	0.639	0.6447

HONDURAS DEEP WELL PUMP

HANDLE BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0 (baseline)	0.6433	0.644	0.645
0.5	0.6427	0.6425	0.645
1.3	0.646	0.645	0.648
2.6	0.6445	0.646	0.646
3.9	0.6458	0.6455	0.647
5.0	0.646	0.6453	0.645
6.35	0.6445	0.6453	0.647
8.5	0.6447	0.6447	0.6475
10.121	0.6447	0.6453	0.6473

HONDURAS DEEP WELL PUMP

PINS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF PIN - INCHES		
	Handle Pivot	Fulcrum Pivot	Rod End (Pivot)
0.0	0.6340	0.6338	0.6355
0.5	0.6340	0.6338	0.6355
1.3	0.632	0.633	0.634
2.6	0.633	0.633	0.6347
3.9	0.6333	0.6335	0.635
5.0	0.6323	0.6332	0.6347
6.35	0.6337	0.6335	0.6345
8.50	0.6335	0.633	0.63453
10.12	0.634	0.633	0.6350

HONDURAS DEEP WELL PUMP

SLIDING BLOCKS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	BLOCK 1		BLOCK 2	
	DIA-INCHES	X-INCHES	DIA-INCHES	X-INCHES
0	0.6397	1.144 1.145	0.638	1.154 1.155
0.5	0.638	1.143 1.147	0.638	1.156 1.157
1.3	0.6395	1.144	0.638	1.152
2.6	0.638	1.146 1.144	0.6395	1.154 1.156
3.9	0.6397	1.144 1.147	0.6387	1.154 1.157
5.0	0.6385	1.142 1.154	0.6397	1.153 1.157
6.4	0.6397		0.640	
8.5	0.638	1.144 1.146	0.638	1.154 1.156
10	0.640	1.141 1.144	0.6387	1.150 1.157

HONDURAS DEEP WELL PUMP

CYLINDER

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	AVERAGE DIAMETER OF CYLINDER (INCHES)
0.0	2.753
0.5	-
1.3	2.752
2.6	2.754
3.9	2.752
5.0	2.753
6.3	2.749
9.0	2.754
10.0	2.754

TUNISIAN DEEP WELL PUMP

FULCRUM BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHINGS (INCHES)		
	A	B	C
0	0.552	0.557	0.553
0.5	0.552	0.5567	0.553
1.5	0.551	0.561	0.553
3.3	0.551	0.555	0.552
4.9	0.5568	0.5566	0.553
6.9	0.551	0.5563	0.5533
8.2	0.551	0.557	0.552
10.0	0.552	0.559	0.553

TUNISIAN DEEP WELL PUMP

PUMP CAP AND ROD END BUSHINGS

CUMULATIVE NUMBER OF CYCLES	DIAMETER OF BUSHING - INCHES		
	A	B	ROD END C
0	0.553	0.5555	0.6353
0.5	0.555	0.5535	0.636
1.5	0.554	0.552	0.637
3.3	0.5548	0.5535	0.6355
4.9	0.5546	0.553	0.638
6.9	0.555	0.5523	0.637
8.2	0.5543	0.5536	0.637
10.0	0.553	0.556	0.637

TUNISIAN DEEP WELL PUMP

HANDLE BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHINGS (INCHES) A	B	C
0	0.553	0.553	0.555
0.5	0.553	0.553	0.555
1.5	0.553	0.553	0.555
3.3	0.553	0.551	0.5558
4.9	0.554	0.5528	0.554
6.9	0.553	0.551	0.555
8.2	0.552	0.553	0.5545
10.0	0.5546	0.553	0.556

TUNISIAN DEEP WELL PUMP

PINS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER - INCHES		
	ROD END PIVOT	HANDLE FULCRUM PIVOT	FULCRUM PUMPING PIVOT
0	0.545	0.5553	0.5456
0.5	0.5446	0.5456	0.5456
1.5	0.5445	0.5443	0.555
3.3	0.5448	0.5446	0.545
4.9	0.544	0.545	0.545
6.9	0.545	0.5446	0.545
8.2	0.5455	0.5443	0.545
10.0	0.5446	0.545	0.545

TUNISIAN DEEP WELL PUMP

SLIDING BLOCKS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	BLOCK 1		BLOCK 2	
	DIA INCHES	X INCHES	DIA INCHES	X INCHES
0	0.633	1.164-1.171	0.636	1.174-1.178
0.5	0.6336	1.194-1.196	0.6362	1.185-1.184
1.5	0.634		0.6365	
3.3	0.633	1.168-1.169	0.636	1.174-1.177
4.9	0.634		0.636	
6.9	0.634	1.166-1.169	0.636	1.174-1.179
8.2	0.633	1.165-1.169	0.636	1.174-1.179
10.0	0.634	1.164-1.169	0.6373	1.171-1.174

TUNISIAN DEEP WELL PUMP

CYLINDER

Initial diameter = 2.110 inches
Final diameter = 2.1145
(after 7.9 million cycles)

NOTE: The replaced cylinder was used for only 2.1 million cycles.

DR DEEP WELL PUMP

FULCRUM BUSHINGS

PHASE I - (100 ft. head)

Cumulative Number of Cycles (Millions)	Diameter of Bushings (inches)		
	A	B	C
0	0.636	0.638	0.653
1.6	0.636	0.6428	0.654
2.56	0.642	0.642	0.655
4.4	0.6436	0.643	0.652
5.0	0.644	0.643	0.653
PHASE II - (Variable head 100-300 ft.)			
5.0	0.644	0.643	0.653
6.8	0.643	0.6425	0.6545
7.8	0.642	0.6413	0.651
8.8	0.641	0.643	0.655
10.0	0.643	0.643	0.655

DR DEEP WELL PUMP

PUMP CAP AND ROD END BUSHINGS

PHASE I - (100 ft. head)

CUMULATIVE NUMBER OF CYCLES	DIAMETER OF BUSHING (INCHES)		
			ROD END
	A	B	C
0.0	0.641	0.642	0.642
1.6	0.641	0.6418	0.642
2.56	0.646	0.649	0.642
4.4	0.644	0.6506	0.642
5.0	0.644	0.651	0.6445
	PHASE II (100-300 ft. head)		
5.0	0.644	0.651	0.6445
6.8	0.641	0.651	0.6455
7.8	0.643	0.648	0.643
8.8	0.642	0.6526	0.6426
10.0	0.644	0.6425	0.646

DR DEEP WELL PUMP
HANDLE BUSHINGS
PHASE I (100 ft. head)

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHINGS - INCHES		
	A	B	CENTER C
0.0	0.683	0.638	0.639
1.6	0.683	0.638	0.641
2.56	0.683	0.637	0.639
4.40	0.686	0.637	0.641
5.0	0.686	0.637	0.641
	PHASE II (100-300 ft. head)		
5.0	0.686	0.639	0.641
6.8	0.6846	0.639	0.639
7.8	0.691	0.638	0.6385
8.8	0.685	0.638	0.642
10.0	0.686	0.6395	0.640

DR DEEP WELL PUMP

PINS
PHASE I (100 ft. head)

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER - INCHES		
	ROD END PIVOT	HANDLE FULCRUM PIVOT	FULCRUM PUMPING PIVOT
0.0	0.622	0.625	0.625
1.6	0.620	0.625	0.625
2.56	0.619	0.624	0.6238
4.30	0.620	0.6245	0.624
5.00	0.619-620	0.6245	0.6245
	PHASE II (100-300 ft. head)		
5.00	0.619	0.6245	0.6245
6.80	0.620	0.624	0.6245
7.80	0.618	0.6225	0.623
8.80	0.620	0.624	0.6246
10.00	0.6186	0.624	0.624

DR DEEP WELL PUMP

SLIDING BLOCKS
PHASE I (100 ft. head)

Cumulative Number of Cycles (Millions)	Block 1		Block 2	
	Dia - Inches	X - Inches	Dia - Inches	X-Inches
0.0	0.6365	1.207-228	0.641	1.236-.230
1.6	0.6425		0.643	
2.56	0.645	1.190-1.182	0.640	1.210-.205
4.4	0.645	1.226-1.185	0.640	1.203-1.211
	PHASE II (100-300 ft. head)			
5.0	0.646	1.188-1.222	0.641	
6.8	0.647		0.642	
7.8	0.6458		0.641	
8.6	0.6446		0.640	
10.0	0.646		0.641	

DR DEEP WELL PUMP

CYLINDER
PHASE I (100 ft. head)

CUMULATIVE NUMBER OF CYCLES (Millions)	DIA - INCHES
0	2.715
1.6	2.721
2.56	2.722
4.4	2.728
5.0	2.721
PHASE II (100-300 ft. head)	
5.0	2.714
6.8	2.722
7.8	2.7208
8.6	2.7225
10.0	2.728

*P.S. There are a number of longitudinal grooves in the cylinder; readings are some what approximate.

DR SHALLOW WELL PUMP

FULCRUM BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0	0.640	0.640	0.656
1.0	0.6403	0.6405	0.654
2.8	0.642	0.6406	0.656
4.3	0.641	0.640	0.6568
6.1	0.641	0.640	0.657
7.6	0.6408	0.6435	0.657
8.6	0.641	0.6428	0.656
10.0	0.6415	0.644	0.657

DR SHALLOW WELL PUMP

PUMP CAP BUSHINGS AND ROD END BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0	0.642	0.6415	0.642
1.0	0.640	0.6405	0.6435
2.8	0.641	0.642	0.644
4.3	0.641	0.642	0.6425
6.1	0.643	0.6421	0.6428
7.6	0.6438	0.6415	0.6428
8.6	0.641	0.6408	0.643
10.0	0.6436	0.642	0.6435

DR SHALLOW WELL PUMP

HANDLE BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0	0.644	0.6408	0.638
1.0	0.643	0.642	0.636
2.8	0.643	0.640	0.638
4.3	0.641	0.638	0.637
6.1	0.643	0.641	0.637
6.4	0.643	0.641	0.637
7.6	0.643	0.641	0.638
8.6	0.643	0.641	0.638
10.0	0.644	0.641	0.638

DR SHALLOW WELL PUMP

PINS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF PIN - INCHES		
	Fulcrum Pivot	Pump Cap (Bottom Pivot)	Rod End (Pivot)
0.0	0.625	0.625	0.625
1.0	0.625	0.625	0.625
2.8	0.6245	0.625	0.625
4.3	0.625	0.625	0.625
6.1	0.624	0.6245	0.624
6.4	0.6248	0.625	0.625
7.6	0.625	0.625	0.625
8.6	0.625	0.625	0.625
10.0	0.625	0.625	0.625

DR SHALLOW WELL PUMP

SLIDING BLOCKS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	BLOCK 1 DIA-INCHES	BLOCK 2 DIA-INCHES
0 (base line)	0.6438	0.642
1.0	0.6438	0.6435
2.8	0.6455	0.6443
4.3	0.6443	0.644
6.1	0.644	0.6433
6.4	0.646	0.646
7.6	0.645	0.645
8.6	0.645	0.647
10.0	0.6455	0.6455

DR SHALLOW WELL PUMP

CYLINDER

CUMULATIVE NUMBER OF CYCLES (Millions)	DIA - INCHES
0	2.706
1.0	2.709
2.8	2.710
4.3	2.714
6.1	2.716
7.6	2.710
8.6	2.715
10.0	2.707

ECUADOR POLITECHNICA

FULCRUM BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0	0.630	0.631	0.638
1.2	0.631	0.633	0.638
3.18	0.631	0.633	0.638
4.8	0.629	0.632	0.638
5.5	0.631	0.6335	0.639

ECUADOR POLITECHNICA

PUMP CAP AND ROD END BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING (INCHES)		
	A	B	C
0.0	0.642	0.633	0.6325
1.2	0.642	0.634	0.6328
3.18	0.642	0.631	0.6326
4.8	0.641	0.6333	0.6326
5.5	0.642	0.634	0.634

ECUADOR POLITECHNICA

HANDLE BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0	0.634	0.635	0.639
1.2	0.634	0.635	0.639
3.18	0.632	0.635	0.636
4.8	0.633	0.631	0.637
5.5	0.634	0.635	0.639

ECUADOR POLITECHNICA

PINS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF PIN - INCHES		
	Rod End Pivot Pin	Handle Pivot Pin	Fulcrum Pivot Pin
0.0	0.623	0.623	0.623
1.2	0.622	0.622	0.622
3.18	0.622	0.622	0.622
4.8	0.620	0.621	0.620
5.5	0.622	0.622	0.622

ECUADOR POLITECHNICA

SLIDING BLOCKS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	BLOCK 1 DIA - INCHES	BLOCK 2 DIA - INCHES
0 (base line)	0.638	0.639
1.2	0.638	0.640
3.18	0.639	0.6395
4.8	0.639	0.640
5.5	0.6395	0.6405

ECUADOR POLITECHNICA

CYLINDER

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIA - INCHES
0	3.041
1.2	3.063
3.18	3.044
4.8	3.061
5.5	3.069

ECUADOR TIRADO

FULCRUM BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0	0.630	0.627	0.6343
1.8	0.6305	0.628	0.634
3.2	0.631	0.628	0.635
3.8	0.632	0.628	0.634

ECUADOR TIRADO

PUMP CAP AND ROD END BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING (INCHES)		
	A	B	C
0.0	0.6293	0.630	0.624
1.8	0.6305	0.630	0.625
3.2	0.631	0.629	0.628
3.8	0.631	0.630	0.626

ECUADOR TIRADO

HANDLE BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0	0.632	0.632	0.625
1.8	0.632	0.632	0.6255
3.2	0.632	0.632	0.625
3.8	0.632	0.632	0.625

ECUADOR TIRADO

PINS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF PIN - INCHES		
	Rod End Pivot Pin	Handle Pivot Pin	Fulcrum Pivot Pin
0.0	0.6085	0.618	0.624
1.8	0.618	0.618	0.622
3.2	0.610	0.617	0.624
3.8	0.608	0.617	0.623

ECUADOR TIRADO

SLIDING BLOCKS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	BLOCK 1 DIA - INCHES	BLOCK 2 DIA - INCHES
0 (base line)	0.6465	0.6295
1.8	0.6463	0.6320
3.2	0.647	0.632
3.8	0.647	0.632

ECUADOR TIRADO

CYLINDER

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIA - INCHES
0	3.057
1.8	3.064
3.2	3.062
3.8	3.067

ECUADOR METALURGICA

FULCRUM BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0	0.639	0.640	0.6386
1.2	0.643	0.6455	0.643
2.6	0.644	0.646	0.642

HANDLE BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING - INCHES		
	A	B	C
0	0.641	0.636	0.639
1.2	0.644	0.6365	0.641
2.6	0.641	0.636	0.643

ECUADOR METALURGICA

PUMP CAP AND ROD END BUSHINGS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF BUSHING (INCHES)		
	A	B	C
0.0	0.637	0.636	0.643
1.2	0.637	0.6375	0.641
2.6	0.638	0.639	0.643
	0.639	0.639	0.643

ECUADOR METALURGICA

SLIDING BLOCKS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	BLOCK 1	BLOCK 2
	DIA - INCHES	DIA - INCHES
0 (base line)	0.635	0.637
1.2	0.635	0.636
2.6	0.635	0.638

PINS

CUMULATIVE NUMBER OF CYCLES (MILLIONS)	DIAMETER OF PIN - INCHES		
	Rod End Pivot Pin	Handle Pivot Pin	Fulcrum Pivot Pin
0.0	0.630	0.633	0.631
1.2	0.626	0.629	0.629
2.6	0.6287 (.6275)	0.623 (0.623)	0.625 (0.625)

APPENDIX D

Force Measurements on Pump Handles

Appendix D shows the test set-up for force measurements on the reciprocity and rotary pump and consists of a transducer mounted on the split section of the connecting rod and a linear slide potentiometer (pot) mounted at the pump cap. The transducer consists of a load cell containing strain gauge wire which serves as resistance 'R' of the bridge circuit (Figure 10). The strain resulting from the force in the handle causes a change in the electrical resistance of the wire which is directly proportional to the force. The output voltage of the bridge circuit serves as the input to the X-Y recorder.

The linear slide pot (Figure 11) consists of a resistance element provided with a movable contact 'C' which is connected to the piston rod. The resistance element is excited with a D.C. or A.C. voltage and the output voltage E_o is linearly proportional to the displacement of the piston 'X'. The output voltage also serves as an input to the X-Y recorder. Alternatively a rotary pot which records the angular displacement of the connecting rod can be used instead of a linear slide pot.

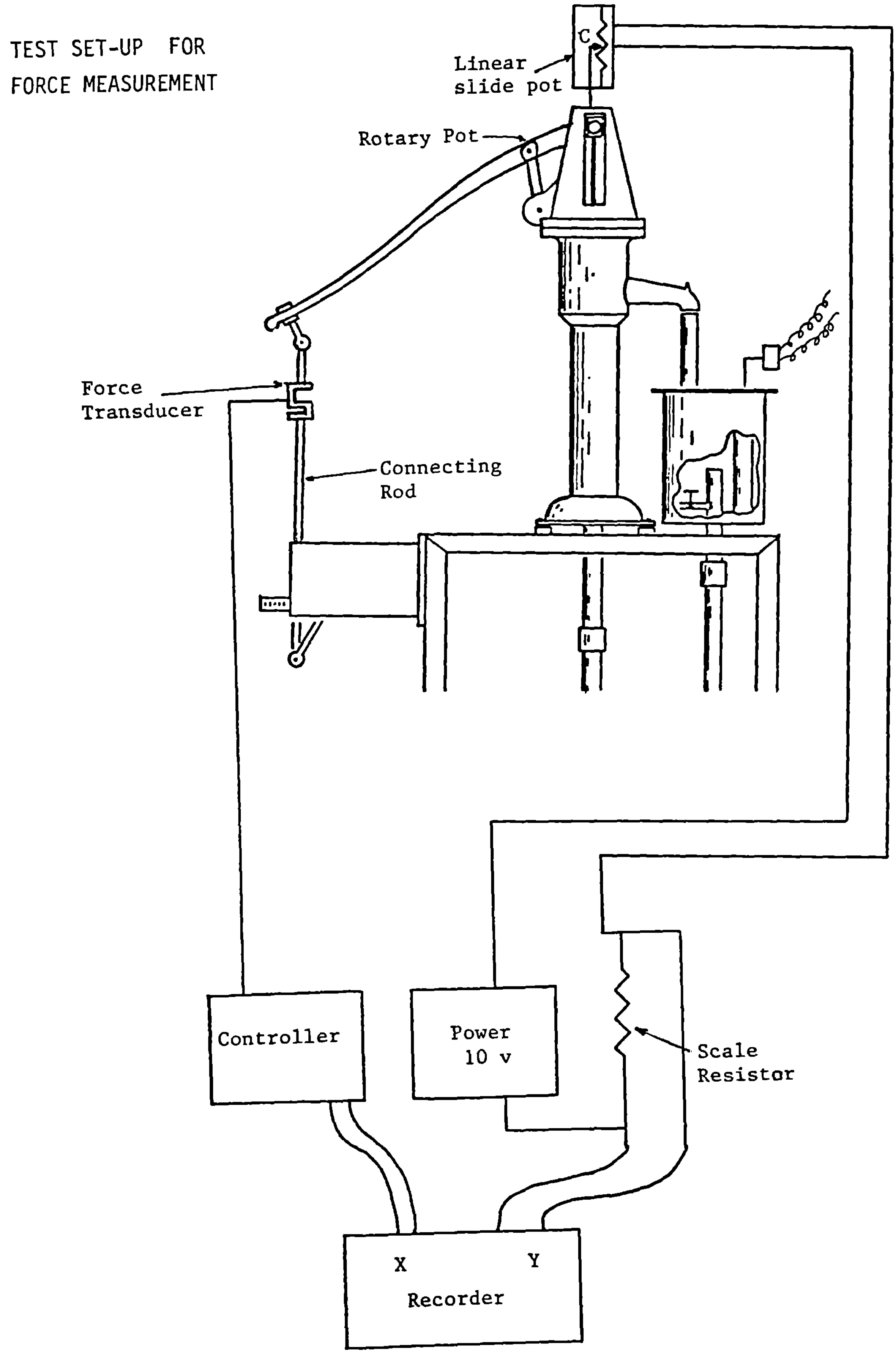
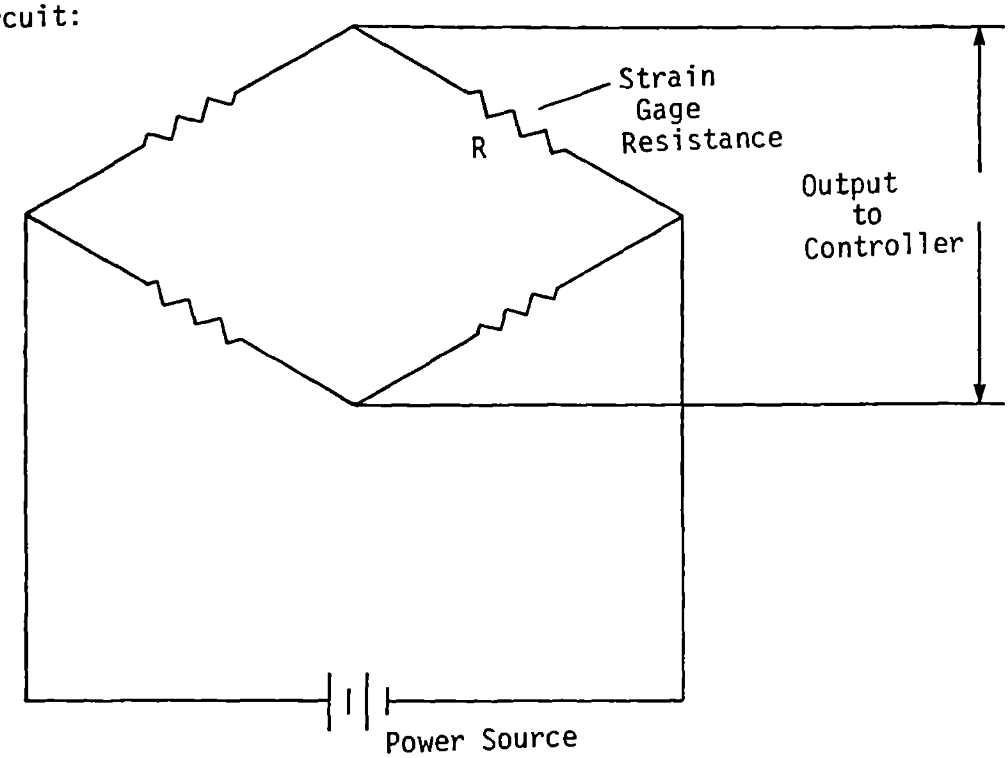

TEST SET-UP FOR
FORCE MEASUREMENT
C
Linear
slide pot
Rotary Pot
Force
Transducer
Connecting
Rod
Controller
Power
10 v
Scale
Resistor
X
Y
Recorder

Figure 10

FORCE MEASUREMENT

a) Bridge Circuit:



b) Linear Slide Pot:

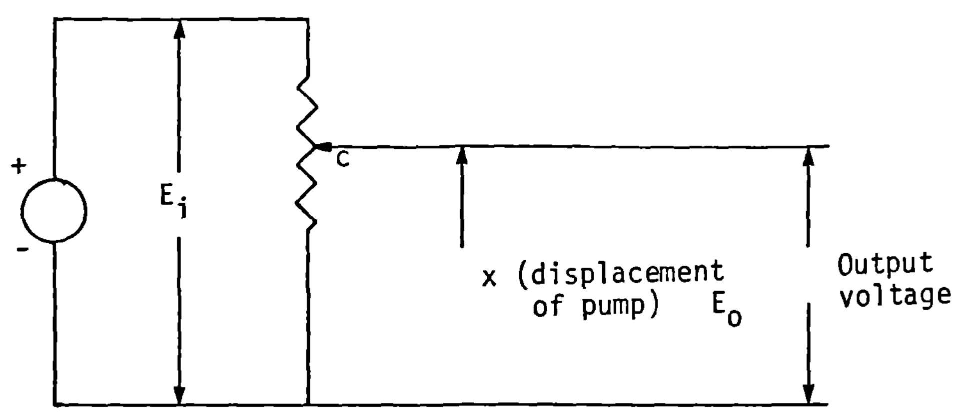


Figure 11

The method of measuring and recording the force can be explained with the aid of Figure 8. The effect of the force on the handle is transmitted to the transducer which sends electrical signals to the controller and from the controller to the X-Y recorder. Simultaneously, the displacement of the piston is transmitted to the linear slide pot, where it is converted to electrical signals that pass to the X-Y recorder through the scale resistor. The combination of these inputs is recorded as a plot of force versus displacement of piston on the X-Y recorder.

Typical values of force are included in Appendix D. It should be noted that laboratory testing included cylinders of a fixed diameter. However, field programs have the flexibility of reducing the diameter of the cylinder for deep wells if the force on the handle should turn out to be excessive for the operators of the pump. Reducing the diameter of the cylinder, in turn, reduces the force required at the handle for operating the pump. (Reducing the cylinder diameter, at the same time, reduces the outflow of the pump per stroke.)

4.3.5 Force Measurement on Rotary Pumps

The measurement of force on the handles of rotary pumps was performed during their operation by electrical means with their handles removed. The pumps were delivering water at a given head while operating at a handle speed of 50 RPM. The method of measurement can be explained as follows.

The power input to the pump system including the driving mechanism was first measured as E_1. Later, with the belt disconnected, the power input E_2 to the driving system only, that is, the electrical motor and the clutch-timer mechanism, was measured. The difference between the two inputs $E_1 - E_2$ would be the net power input 'P' to the pump. This reading is in kilowatts and can be converted to foot pounds. The force can be computed by using the arm length of the handle. A sample measurement and calculation is explained below.

Let P = net power input to the pump (obtained by electrical measurements)

1 kw = 1.341 h.p.
= 44251 ft-lb/min.

$P = T X 2 X \pi N$

where N = Rotational speed of the handle (RPM) = 50
T = Torque

In one of the measurements, P = 0.52 KW at a head of 230 feet
= 0.52 x 44251 ft-lb/min
= 23013 ft-lb/min

$23013 = T \times 2\pi (50)$

T = 73.25 lb-ft

T = F x r where F is the force on the handle

For the radius r of 1.0 foot (one-foot handle), the force would be 73.25 lbs. The force on each handle of the two-handle pump would be half this value, i.e. 36.62 lbs. (see Appendix D, Moyno pump at 1.7×10^6 cycles).

The forces on the handles of rotary pumps at high heads (138-290 feet), as shown in Appendix D, appear to be high, especially if the pumps are to be used by women and children. The rotary pumps (both Moyno and Mono) are also somewhat difficult to operate by one person because of the leaning stance required to reach both handles at the same time. This difficulty was confirmed when two laboratory test personnel operated the Moyno pump individually by hand at a 230-foot head. The maximum time of operation by a strong male was 1.75 minutes without resting, somewhat less than the effort required to fill a five-gallon water container. It appears that the use of rotary pumps on deep wells should be carefully reviewed for match with expected user populations.

ROTARY PUMP

FORCE ON EACH HANDLE
(Two Handle Pump)

PUMP NAME	TIME NUMBER OF CYCLE	HEAD FT	DISCHARGE FLOW RATE Lit/Min	AVERAGE FORCE ON HANDLE - LB
MOYNO	0.0	230	11.0	35.2
	0.7×10^6	230	11.1	35.2
	1.7×10^6	230	11.22	34.6
	2.24×10^6	184	11.3	33.2
		138	11.6	29.6
MONO	Start	290	8.346	43.97
	400,000	253	8.46	37.2
	1.0×10^6	138	11.60	35.5

NOTE: The two pumps should not be compared, because the crank radius and the operating conditions are different in each case.

FORCE ON HANDLE

DEEP WELL PUMPS

PUMP HEAD	HEAD FEET	Absolute Force on Handle - Kg Upward Motion of Handle			Absolute Force on Handle - Kg Downward Motion of Handle		
		MAX	MIN	AVG	MAX	MIN	AVG
1. Malawi Pump I	161 104	6 6	2.3 1.5	1.59 1.6	49.0 41.0	35.0 30.0	43.4 38.7
2. Malawi Pump II	173 110	7.6 7.0	2.1 1.7	1.75 2.28	36.0 28.3	26.0 15.0	32.8 22.8
3. Ecuador-Tirado	104 196	5.6 9.6	1.7 1.5	1.46 0.93	35.2 38.0	25.0 34.0	27.6 35.1
4. Ecuador-Metalurgica	100 207	5.5 3.5	2.5 1.6	0.55 0.86	24.0 47.5	17.3 5.0	20.5 39.2

FORCE ON HANDLE

DEEP WELL PUMPS
(100 FT HEAD)

PUMP NAME	Absolute Force on Handle - Kg Upward Motion of Handle			Absolute Force on Handle - Kg Downward Motion of Handle		
	MAX	MIN	AVG	MAX	MIN	AVG
1. Philippine Deep Well Pump	6.5	2.5	1.8	19.3	4.5	11.1
2. Honduras Deep Well Pump	11.8	1.7	3.1	30.9	0	26.0
3. Tunisian Deep Well Pump	23.5	2.0	4.9	17.1	12	8.4
4. DR Deep Well Pump	9.2	2.0	3.5	44.4	18	27.6
5. Ecuador-Politechnica Deep Well Pump	15.5	5	3.9	42.5	1	27.8

FORCE ON HANDLE

SHALLOW WELL PUMPS

PUMP NAME	Absolute Force on Handle - Kg Upward Motion of Handle			Absolute Force on Handle - Kg Downward Motion of Handle		
	MAX	MIN	AVG	MAX	MIN	AVG
1. Philippine Shallow Well Pump	7.7	0.8	4.0	3.9	0.6	1.9
2. Honduras Shallow Well Pump	8.6	3.5	6.1	6.8	2.2	2.2
3. DR Shallow Well Pump	9.86	2.64	6.1	5.8	1.36	1.8

APPENDIX E

Endurance Testing

APPENDIX E

ENDURANCE TESTING

PUMP NAME	MILLIONS OF CYCLES 0 1 2 3 4 5 6 7 8 9 10 11 12	Comments
1. Philippine Shallow-Well Pump(2)	No failures or repairs throughout the test period Final inspection	Pump condition equal to original at end of testing
2. Philippine Deep-Well Pump	See Note 2 for failures or repairs throughout the test period Final inspection	Pump condition equal to original at end of testing
3. Honduras Shallow-Well Pump	See Note 3 for failures throughout the test period Final inspection	Pump condition equal to original at end of testing
4. Honduras Deep-Well Pump	See Note 4 for failures throughout the test period Final inspection	Pump condition equal to original at end of testing

NOTE: (1) All pumps were lubricated at startup and relubricated at each inspection.

(2) The tests on all pumps were conducted under conditions of regular lubrication. In addition, the Honduras shallow-well pump (Pump 3) ran from 12 million cycles to 18.2 million cycles without lubrication.

(3) Final inspection on each pump was conducted after the completion of testing. However, the above pumps were allowed to run up to and beyond 12 million cycles depending on the circumstances and the need.

ENDURANCE TESTING

PUMP NAME	MILLIONS OF CYCLES 0 1 2 3 4 5 6 7 8 9 10 11 12	Comments
5. Tunisian Deep-Well Pump	See Note 5 for failures on repairs during test period Final Inspection	Pump condition equal to original at end of testing
6. DR Deep-Well Pump	See Note 6 for failures on repairs during test period Final Inspection	Pump condition equal to original at end of testing
7. DR Shallow-Well Pump	See Note 7 for failures on repairs during test period Final Inspection	Pump condition equal to original at end of testing
8. Ecuador Politechnica Deep-Well Pump	See Note 8 for failures on repairs during test period Final Inspection	Pump condition equal to original at end of testing

ENDURANCE TESTING

PUMP NAME	MILLIONS OF CYCLES 0 1 2 3 4 5 6 7 8 9 10 11 12	Comments
9. Ecuador Tirado Deep-Well Pump	See Note 9 for failures and repairs during test period Final Inspection	Pump condition equal to original at end of testing
10. Ecuador Metalurgica Deep-Well Pump	See Note 10 for failures and repairs during test period Final Inspection	Pump condition equal to original at end of testing
11. Malawi Deep-Well* Pump I	See Note 11 for failures and repairs during test period Final Inspection	Pump condition equal to original at end of testing
12. Malawi Deep-Well* Pump II	No failures or repairs throughout the test period Final Inspection	Pump condition equal to original at end of testing

*Neither of the Malawi Deep-Well pumps had their own cylinders; AID cylinders from other manufacturers were used; Malawi Pump I used chloride water with salt concentration of 3000 ppm and a pH of 4.0; Malawi Pump I used regular water available in Atlanta, Ga.

NOTE: Pumps 9 and 10 were not allowed to run for the full duration of the test time since the project came to an end in Feb. 1984; Pump No. 9 ran for 3.8 million cycles and Pump No. 10 ran for 2.6 million cycles.

ENDURANCE TESTING

PUMP NAME	MILLIONS OF CYCLES	
	0 1 2 3 4 5 6 7 8 9 10 11 12	Comments
13. Moyno Rotary Pump	See Note 13 for failures and repairs during test period Final Inspection	Pump condition equal to original at end of testing
14. Mono Rotary Pump	See Note 14 for failures and repairs during test period Final Inspection	Pump condition equal to original at end of testing

(See notes which follow on pump failures.)

ENDURANCE TESTING

Notes on Pump Failures:

Pump No. 1: There were no failures and no repairs with this pump during 10 million cycle testing; pump completed 12 million cycles.

Pump No. 2: One leather cup was replaced at end of 10 million cycles during final inspection; pump then completed 11.9 million cycles.

Pump No. 3: Leather flapper valve was replaced at 5.5 million and 8.4 million cycles during routine inspection; pump completed 18.2 million cycles, 6.2 million of which were without lubrication.

Pump No. 4: Leather flapper valve was replaced at 6.0 million and 9.0 million cycles during routine inspection; pump completed 12.0 million cycles.

Pump No. 5: The cylinder cracked at 7.92 million cycles; there were joints (sealant) of PVC pipe connection and cylinder end cap failures; pump completed 10 million cycles.

Pump No. 6: The plunger rod broke at 1.02 million cycles; a second plunger rod bent and was replaced at 1.6 million cycles; the leather cups were replaced twice; piston (discharge) valve replaced at 6.8 million cycles; there were frequent stops due to loosening of threaded connections at rod end, cylinder end cap, pump base threads, plunger rod; the pump completed 5 million cycles at 100 ft. head and 5 million cycles at 100-300 ft. head.

Pump No. 7: The pump required priming each time it was stopped due to flapper valve being stiff which was replaced at 9.4 million cycles; threaded connections came loose very often and needed tightening; it completed 10 million cycles without any components breaking.

ENDURANCE TESTING

Pump No. 8: Pump was run for 5 million cycles at 100 ft. head; the leather cups were twisted during operation and, as a result, created undue stress on the plunger to breakdown at 1.2 million cycles; the leather cups were also replaced at 4.7 million cycles (in addition to those replaced with the plunger rod at 1.2 million cycles); the plunger broke again at 4.7 million cycles; the cylinder was broken after 5 million cycles due to excessive wrenching by technician - not operational failure.

Pump No. 9: This pump completed 3.8 million cycles: The flow rate was reduced in the initial stages of testing due to the high heads which caused twisting of the leather cups; later on, one of the leather cups was replaced and the head was maintained at 165 ft; the pump functioned smoothly at this head.

Pump No. 10: This pump completed 2.6 million cycles; the flow rate was low due to high heads which caused twisting of leather cups which had to be replaced: leather flapper valve was replaced once at 0.5 million cycles.

Pump No. 11: This pump completed 5 million cycles; one of the ball bearings broke down at 1.0 million cycles and was replaced by a U.S. made bearing; the replaced bearing was found damaged at 2.5 million cycles and was replaced again.

Pump No. 12: There were no failures and no repairs with this pump during testing; pump completed 5.0 million cycles.

Pump No. 13: Rotor rod broke at 1.34 million cycles; pump completed 2.5 million cycles.

Pump No. 14: Rotor rod broke at 200,000 cycles at heads of 280-290 ft.; pump completed 1.4 million cycles.

APPENDIX F

Report on Haiti AID Handpump

Haiti Deep Well Pump - (Preliminary Assessment)

The following information and assessment is based on our experience with the Haiti deep-well pump during the testing period with respect to its durability and general performance. The principal components of the pump under our observation and the details of our study are summarized below:

CYLINDER:

material: PVC
observed internal diameter: 3.064" - 3.092
Comments: The internal surface was found to be uneven with ridges and depressions.

PINS AND BUSHINGS:

measured average diameters of pins: 0.605" - 0.635" (specifications = 0.625 + .003)
measured average diameter of bushings: 0.628" - 0.635" (specifications = 0.635 + .001)
Comments: Pins and bushings were observed to be soft and some were defective. The original average hardness values of pins and bushings were as follows (hardened to specifications before beginning testing):
Pins: 85 Rockwell B
Bushings: 74 Rockwell B

PUMP BODY AND COMPONENTS:

Comments: Cast iron components such as the pump body, the pump base, the pump cap, the fulcrum and the handle were observed to have blow holes - small and large.

PISTON CAGE ASSEMBLY:

The piston assembly was made of brass machined surfaces. Small blow holes were observed in several areas and the assembly appeared to be structurally weak.

TEST RUN:

The pump was assembled and started on 10/21/82 and the delivery head was set at slightly over 100 feet.

At 73,000 cycles there was a major pump failure due to a breakdown in the piston cage assembly (unusually excessive porosity). Other components such as the leather cups, the foot valve, etc., were in good condition. In comparison, we have had no similar failures or problems at such an early stage with other pumps that we have been testing. For instance, the Philippine and Honduran pumps have completed 10 million cycles without exhibiting such problems.

In order to assess the durability of other components, the piston assembly was replaced by another unit - not related to the Haiti pump - and the pump was allowed to run again. However at 142,000 cycles, severe leakage was observed where the pump body screws into the pump base. Our efforts to correct the leakage problem by chasing the threading and using joint sealers were not successful and at 150,000 cycles we found it would be impractical to correct the defects and restart the pump. To continue testing the pump would have also created a serious safety hazard to test personnel because of the possibility of the pump body becoming separated from the pump base and striking someone.

The water discharge rate of the pump during the testing period was 6.30 gallons per minute which can be considered satisfactory.

APPENDIX G

Supplemental Information from Manufacturing and Field Use Experience

SUPPLEMENTAL INFORMATION FROM MANUFACTURING AND FIELD USE EXPERIENCE

Nicaragua and Costa Rica were chosen as initial test countries for the AID handpump, as discussed in Section 1.3. This chapter presents an overview of the characteristics and results of subsequent programs where AID handpumps have been implemented.

Initial Manufacture and Use of the AID Handpump in the Dominican Republic (August 1978)

Handpump Program - Basic Description

Introduction of the AID design handpump into the Dominican Republic was initiated in August 1978 through USAID/Dominican Republic's Contract No. AID-517-423 with Georgia Tech. The handpump manufacturing and field testing component of this program included:

- feasibility study of potential for local manufacture of the AID handpump
- selection of manufacturers
- production of AID handpumps
- provision of drawings, prototypes, and continuous technical assistance throughout manufacturing
- local training in installation, maintenance and repair through field installations
- monitoring and evaluating performance of the handpumps installed in the field.

Project History - General

Action taken in carrying out the project included:

- selection of and technical assistance to Industria Troqueles y Diversos (INDUSTROQUEL), DR Betances No. 150, Santo Domingo, and Astilleros Navales Dominicanos, Santo Domingo, to manufacture 12 pumps and cylinders each
- completion of an installation crew training program with the installation of 21 pumps in the Cibao Valley near Santiago during December 1978 and January 1979
- monitoring the performance of pumps installed in the field and feeding back information to the manufacturers when tightening of quality controls was necessary

- determination of quality of water through chemical and bacteriological analysis

- delivery of a five-day task and performance based training workshop on chemical and bacteriological analysis of water for Santiago hospital technicians

- selection of and technical assistance to INDUSTROQUEL and Astilleros Navales Dominicanos to manufacture an additional 11 pumps each as prototypes to be shipped to other countries (under a separate contract between AID/Washington and Georgia Tech).

Review of Project Results

Project results and/or supplemental information from the field program applicable to improving the endurance and reliability of the AID handpump as manufactured by INDUSTROQUEL and Astilleros Navales Dominicanos are as follows:

- the AID handpumps produced by INDUSTROQUEL and Astilleros Navales Dominicanos performed well during a six-month monitoring period in the field even though they contained manufacturing deficiencies, especially in conforming to dimensional specifications

- the soundness of the modifications recommended during initial testing in Nicaragua and Costa Rica was confirmed.

Manufacture and Use of the AID Handpump in Indonesia (October 1978)

Handpump Program - Basic Description

Introduction of the AID design handpump into Indonesia by Georgia Tech was initiated in October 1978 after they had determined the feasibility of manufacturing the pump in-country the previous April. The manufacturing and handpump operational program was carried out under USAID contract (No. Asia-C-1366) and included:

- selection of manufacturers

- production of AID handpumps

- provision of drawings, prototypes and continuous technical assistance throughout manufacturing

- local training in installation, maintenance and repair through field installations

- area assessment and evaluation of the feasibility of local manufacture of the AID handpump in three Provincial Area Development Program project areas

- monitoring and evaluating performance of the handpumps installed in the field.

Project History - General

Action taken in carrying out the project included:

- selection of and technical assistance to P.T. Celco, Jl. Gatot Subroto 43A, Bandung, Indonesia for the manufacture of 230 AID handpumps

- selection of CARE/Bandung for (1) training village caretakers in the installation and maintenance of AID handpumps and (2) the establishment of and the training of local personnel for the operation of a field-based water quality analysis laboratory

- selection of the World Health Organization for an independent monitoring program covering 10 test sites near Jakarta, Indonesia

- selection of six Provincial Area Development Program project areas for local training in installation, maintenance and repair of pumps through field installations

- monitoring the peformance of pumps installed in the field and feeding back information to the manufacturers when tightening of quality control was necessary

- provision of well-stocked spare parts kits and maintenance tools kits to village leaders in the Bandung area where 35 pumps were installed.

New or Different Elements Related to Use

The main elements pertaining to pump use different from other programs were (1) the independent monitoring of pump performance by the World Health Organization and (2) the distribution of spare parts kits and maintenance tool kits to village leaders in the Bandung area.

Review of Project Results

Project results and/or supplemental information from the field program applicable to improving the endurance and reliability of the AID handpump as manufactured by P.T. Celco are as follows:

- the AID handpumps performed well in the Bandung area except for leather cups sometimes wearing out rather frequently due to extremely fine silt from volcanish ash in the well waters and leather flapper valves (foot valves) proving not to be reliable over a long period of time (longer than six months)

- the training of village caretakers by CARE in the Bandung area was most effective, as evidence by a random survey of installed handpumps in October 1982 which showed 90 percent of the pumps working and tool kits and spare parts kits properly stocked and maintained

- World Health Organization issued a favorable review of the AID handpump's performance with a recommendation that the leather foot valve be replaced with a valve of greater reliability

- installation, maintenance and repair of AID handpumps in the Provincial Area Development Program project areas did not go well because of a lack of available water-producing sites and a lack of coordination between Indonesia government officials in Jakarta and the remote areas of the Provincial Area Development Program

- there was a high degree of reluctance on the part of the pump manufacturer, P.T. Celco, to accept manufacturing techniques such as the use of jigs and fixtures.

Initial Manufacture and Use of the AID Handpump in Ecuador (June 1979)

Handpump Program - Basic Description

Introduction of the AID design handpump was initiated in June 1979 through USAID/Ecuador's Contract No. AID 518-451. The handpump manufacturing and field testing component of this program included:

- selection of manufacturers

- production of AID handpumps and cylinders

- provision of drawings, prototypes and continuous technical assistance throughout manufacturing

- local training in installation, maintenance and repair of pumps through field installations.

Project History - General

Action taken in carrying out the project included:

- selection of the National Politechnic School in Quito to manufacture 47 AID handpumps with technical assistance

- selection of Instituto Centroamericano de Investigacion y Tecnologia Industrial (ICAITI) as a Latin American counterpart because of its familiarity with local governments, private sectors, cultures and languages

- technical assistance and training in installation, maintenance and repair of AID handpumps for Ecuadorian Government, U.S. Peace Corps Volunteers and private volunteer organizations during field installation of National Polytechnic School pumps.

New or Different Elements Introduced in Manufacturing

Specific elements where manufacturing varied from other programs were:

- use of ABS injection molded plactic pump cylinders rather than PVC.

Review of Project Results

Project results and/or supplemental information from the field program applicable to improving the endurance and reliability of the AID handpump as manufactured in Ecuador are as follows:

- the AID handpump, including the ABS cylinder, performed well in the field with no major problems except for the leather flapper valves (the flapper valves were eventually replaced with commercially available metal poppet-type foot valves from the United States).

Manufacture and Use of the AID Handpump in Sri Lanka (October 1979)

Handpump Program - Basic Description

Introduction of the AID design handpump was initiated in October 1979 through USAID/Sri Lanka Contract No. AID-80-001. The handpump manufacturing and field testing component of this program included:

- determination of feasibility of locally manufacturing handpumps
- selection of manufacturers
- production of handpumps and cylinders
- provision of drawings, prototypes and continuous technical assistance throughout manufacturing
- implementation of handpump intallation, maintenance and repair training through field installation program
- assessment of the impact and effectiveness of the handpumps by monitoring and evaluating performance data, general user acceptance and water quality.

Project History - General

Action taken in carrying out this project included:

- identification of foundries and machine shops capable of producing AID handpumps
- selection of Somasiri Huller Manufactory, 112 Issibathara Mawatha, Colombo, Sri Lanka to manufacture the AID handpumps
- rendering of technical assistance in the production of 90 AID handpumps with emphasis on pump quality and interchangeability of parts
- installation of 79 pumps on 39 wells
- development of illustrated maintenance and repair manual in Sinhala, Tamil and English
- training of village caretaker at each site where handpumps were installed

- monitoring and evaluation of field installations, general user acceptance and water quality

- development and monitoring of a laboratory test program for handpumps at the Ceylon Institute for Scientific and Industrial Research (CISIR) to determine best alternative materials and specifications for such components as pivot pins, bushings, cups and flapper valves as well as overall durability of AID handpumps (see below).

Note: The Sri Lankan handpump program included the laboratory testing of AID handpumps by CISIR. As part of this program, two handpumps manufactured by Somasiri Huller Manufactory were tested for three months (approximately four million cycles) for "performance, wear and tear" according to procedures set forth by Georgia Tech field personnel. The physical test facility not only was useful to the handpump program in Sri Lanka, but was a basis for the procedures of the laboratory testing described in this report.

New or Different Elements Introduced in Manufacturing

Specific elements where manufacturing varied from earlier programs were:

- rubber instead of leather for the flapper valve as result of CISIR testing

- substitution of buffalo hide for cow hide for leather cups as result of CISIR testing.

New or Different Elements Related to Use

Sri Lanka was the first country where an illustrated maintenance and repair manual translated into the national languages was developed for the AID handpump and used in the training of village caretakers. It also was the first country to include a laboratory test to identify possible problems with the pumps before wide distribution into the field.

Review of Project Results

Project results and/or supplemental information from the field program applicable to improving the endurance and reliability of the AID handpump as manufactured by Somasiri Huller Manufactory were as follows:

- the AID handpump would perform well in the field if kept lubricated except for the flapper valve which tended to quickly wear out even when made from rubber

- maintenance of the AID handpump had not been effective because of infrastructure problems, especially a lack of funds to procure basic materials and supplies such as grease for lubricating pumps

- foreign objects had sometimes been put into the pumps through the spout and plunger rod hole, damaging the cylinder components

- the threaded joint at the base/pipe section had often come loose, causing loss of prime on shallow-well pumps.

From March 1 through March 8, 1984, a WASH consultant conducted a status review of the AID handpump program in Sri Lanka. Interviews were held with USAID/Sri Lanka, the United Nations Childrens Fund, the German Agency for Technical Assistance, Somasiri Huller Manufactory, and the Sri Lankan Ministry of Local Government, Housing and Construction because of their previous involvement in handpump programs. The consultant arrived at the same conclusions as listed above except that the rubber foot valve was not mentioned as a current problem. Additionally, several of those interviewed suggested that the AID handpump should be modified to allow extraction of the foot valve and piston assemblies through the base of the pump.

Manufacture and Use of the AID Handpump in Tunisia (September 1980)

Handpump Program - Basic Description

Introduction of the AID design handpump was initiated in September 1980 through USAID/Tunisia's Contract No. 664-725. The handpump manufacturing and field testing component of this program included:

- selection of manufacturers
- production of AID handpumps and cylinders
- provision of drawings, prototypes and continuous technical assistance throughout manufacturing
- local training in installation, maintenance and repair of pumps through field installation.

Subsequent to the above activities, OTD 63 authorized WASH in November 1981 to coordinate the field monitoring, adaptation and demonstration program for the locally manufactured AID handpump in Tunisia.

Project History - General

Action taken in carrying out the project included:

- selection of Founderies Reunies, Route de Sousse Km 5.5, Megrine, Tunisia to manufacture 40 AID handpumps and cylinders
- completion of an installation training program with the installation of 14 handpumps between April 1981 and September 1981
- selection of L'Ecole Nationale D'Ingenieurs de Tunis as a Tunisian counterpart to expedite (1) technical assistance to the manufacturer and (2) maintenance and repair of handpumps installed in the field.

New or Different Elements Introduced in Manufacturing

Specific elements where manufacturing varied from other programs were:

- adoption of a locally-made metal poppet-type foot valve and a plastic poppet-type foot valve made at the University of Maryland, both of which were later replaced with a metal poppet-type foot valve commercially available in the United States

- development of a 53 mm PVC drop pipe system that also served as a cylinder in order to pull the pump piston up through the drop pipe and pump base for changing of leather cups.

New or Different Elements Related to Use

The main element pertaining to pump use was the sometimes very strong opposition of communities to the covering of open wells and the installation of handpumps. This opposition also showed up in deliberate acts of vandalism to pumps installed in the field. L'Ecole Nationale D'Ingenieurs de Tunis representatives, being Tunisian, were somewhat successful in overcoming this cultural problem, but not completely.

Review of Project Results

Project results and/or supplemental information from the field program applicable to improving the endurance and reliability of the AID handpump as manufactured by Founderies Reunies are as follows:

- cast iron pump bases broke, a situation never before experienced (to resolve the problem, replacement bases were manufactured with four fins added for extra strength)

- metal and plastic poppet-type foot valves leaked at an unacceptable rate (this problem was resolved by using a metal poppet-type foot valve commercially available in the United States)

- pins and bushings wore at an unusually high rate even though manufactured to hardness specifications (because of grit from sand storms)

- the PVC drop pipe/cylinder arrangement proved not to be dependable and was prone to separate

- pumps became loose at the connection where the pump body screws into the pump stand (this problem was resolved by welding the two connections together)

- project personnel met strong opposition at times to the covering of open wells and the installation of hand pumps (on several occasions, breakage of pumps was suspected to have been from deliberate acts of vandalism due to this opposition to the pumps).

~~Subsequent Manufacture and Use of the AID Handpump in the Dominican Republic~~ (September 1980)

Handpump Program - Basic Description

Subsequent to the activities described in the beginning of this Appendix concerning the Dominican Republic AID handpump program, and through competitive bidding, Equipo Technico Industrial, C por A (ETINCA) in Santo Domingo was awarded a contract during March 1980 for the manufacture of 1,000 AID handpumps. ETINCA later was awarded another contract for 1,000 AID handpumps which was cancelled due to poor quality after approximately 400 pumps had been produced. Technical assistance for the manufacture of these handpumps was provided through WASH OTD Nos. 1 and 48.

New or Different Elements Introduced in Manufacturing

Specific elements where manufacturing varied from other programs were:

- adoption of a plastic foot valve for the second 1,000 pump order placed with ETINCA

- development of a PVC drop pipe/cylinder arrangement for the second 1,000 pump order placed with ETINCA (to allow the piston assembly to be pulled up through the base of the pump without having to remove the drop pipe and cylinder).

New or Different Elements Related to Use

The main elements pertaining to pump use was the introduction of a maintenance manual, the organization of a village-based maintenance program, planning the logistics of a spare parts system, and establishing a preventive maintenance program under OTD No. 48.

Review of Project Results

Project results and/or supplemental information from the field program applicable to improving the endurance and reliability of the AID handpump as manufactured by ETINCA are as follows:

- the first 1,000 handpumps produced by ETINCA have not performed well in the field due to poor castings, poor machining, loose pins and bushings, wearing of pins and bushings (pins and bushings have not met hardness specifications), the introduction of foreign objects into the pump through the spout and/or the plunger rod hole in the cap and, a lack of any operational local or national maintenance system.

- the 400 modified (with plastic foot valves and PVC drop pipe) handpumps manufactured by ETINCA have experienced the same problems as above along with a high rate (within two weeks in some cases) of separation of the PVC drop pipe and plastic foot valve.

Manufacture and Use of the AID Handpump in Honduras (May 1981)

Handpump Program - Basic Description

Introduction of the AID design handpumps was initiated in May 1981 through WASH OTD 29 after an earlier investigation in August 1980 showed local manufacture was feasible. Field installation, monitoring and evaluation of the handpumps was initiated in March 1982 through WASH OTD 85. The manufacturing component of this program included:

- selection of manufacturers
- production of AID design handpumps and cylinders
- provision of drawings, prototypes and continuous technical assistance throughout manufacturing
- installation, testing and evaluation of a limited number of AID handpumps for a demonstration effort
- development and field testing of a training manual to be used by the manufacturer to ensure quality control during pump fabrication
- development and field testing of a training manual for installation, operation and maintenance of the handpumps to be installed in the field.

Project History - General

Action taken in carrying out the project included:

- selection of Fundicion y Maquinado (FUNYMAQ), San Pedro Sula, Honduras to manufacture 150 pumps
- field installation of 50 pumps as a demonstration
- completion of region-wide training program with the installation of handpumps between March and October 1982
- provision of four regional one-day workshops for Ministry of Health officials and community caretakers in the installation, maintenance and repair of handpumps
- preparation of a manufacturing training manual for quality control which was completed under WASH OTD 82 for Ecuador
- preparation of a handpump installation, maintenance and repair manual which was completed under WASH OTD 82 for Ecuador.

New or Different Elements Introduced in Manufacturing

Specific elements where manufacturing varied from other programs were:

- introduction of more sophisticated jigs and fixtures to ensure the interchangeability of parts
- use of Schedule 120 PVC pipe for shallow-well cylinder liner and threaded deep-well cylinder rather than previously used Schedule 40.

New or Different Elements Related to Use

The main element pertaining to pump use was the introduction of a transparent demonstration cylinder to aid in maintenance and repair training of Honduran government health promoters and community caretakers.

Review of Project Results

Project results and/or supplemental information from the field program applicable to improving the endurance and reliability of the AID handpump as manufactured by FUNYMAQ are as follows:

- limited field reports showed no major problem areas except with wearing leather foot valves (deep-well pumps were retrofitted with U.S.-manufactured metal foot valves during latter stage of project) and cups.

Manufacture and Use of the AID Handpump in the Philippines (June 1981)

Handpump Program - Basic Description

Introduction of the AID design handpump was initiated in June 1981 through WASH OTD 40 after an earlier investigation in April 1979 showed local manufacture to be feasible. The handpump manufacturing and field testing component of this program included:

- selection of manufacturers
- production of AID handpumps and all-PVC deep-well cylinders
- provision of drawings, prototypes and continuous technical assistance throughout manufacturing
- local training in installation, maintenance and repair of pumps through field installations
- field installation of 10 pumps.

Project Hisory - General

Action taken in carrying out the project included:

- selection of Tri-Star Metal Industries, 210 Jabonoros St., Binondo, Manila to manufacture 250 pumps and 400 cylinders
- completion of an installation crew training program with the installation of 10 pumps between November 13, 1981 and December 3, 1981
- delivery of a four-day task and performance based training workshop for 90 waterworks technicians and engineers responsible for installation, maintenance and repair of handpumps.

New or Different Elements Introduced in Manufacturing

Specific elements where manufacturing varied from other programs were:

- adoption of a poppet-type foot valve for both shallow-well and deep-well design pumps to improve upon the poor performance of the leather flapper valve used in earlier programs

- development of a reduced diameter, all-PVC cylinder for use in three-inch well casings

- substitution of hardened bolts and nuts for the usual hardened pivot pins.

New or Different Elements Related to Use

The main element pertaining to pump use was the development of detailed instructions for installation, maintenance and repair of the AID pumps which became a major section of the Barangay Water Program Operations Manual.

Review of Project Results

Project results and/or supplemental information from the field program applicable to improving the endurance and reliability of the AID handpump as manufactured by Tri-Star Metal Industries are as follows:

- the AID handpump, including the poppet-type foot valve, the hardened bolts and nuts, and the all-PVC cylinder, performed well in the field with no major problems.

Manufacture and Use of the AID Handpump in Haiti (August 1981)

Handpump program - Basic Description

Introduction of the AID design hand pump was initiated in August 1981 through WASH OTD 46. The handpump manufacturing and field testing component of this program included:

- securing AID handpumps shipped from ETINCA, the AID handpump manufacturer located in Santo Domingo, Dominican Republic

- identification, selection and preparation of sites for installation of AID handpumps shipped from the Dominican Republic

- identification and development of a long-term maintenance system for the AID handpumps

- installation of the AID handpumps

- local training in installation, maintenance and repair

- provision of patterns and shop drawings to Founderie Nationale to assess its ability to manufacture AID handpumps

- procurement, shipment and installation of Moyno, Mono and Malawi handpumps for comparative field testing.

Project History - General

Action taken in carrying out the project included:

- completion of an installation, maintenance and repair crew training program for Atelier Ecole with the field installation of 16 AID handpumps, one Moyno handpump, two Mono handpumps and one Malawi handpump

- provision of patterns and shop drawings to Founderie Nationale
- assessment of Founderie Nationale as not having the capabilities for producing a quality AID Handpump

New or Different Elements Introduced in Manufacturing

Specific elements where manufacturing varied from other programs were:

- no technical assistance was given Founderie Nationale as this company did not appear to have the capabilities for producing a quality AID handpump.

New or Different Elements Related to Use

The main element pertaining to pump use was an unexpected introduction of extremely large user populations (200-400 families per site) which kept the pumps operating continuously 12-16 hours a day.

Review of Project Results

Project results and/or supplemental information from the field program applicable to improving the endurance and reliability of the AID handpump as manufactured by ETINCA in the Dominican Republic and Founderie Nationale in Haiti are as follows:

- AID handpumps manufactured by ETINCA have not held up well in the field because of extremely high numbers (2000-4000 people in some cases) of beneficiaries per pump and poor manufacturing (excessive porosity in the castings and poor machining)
- a small number of AID handpumps manufactured by Founderie Nationale and sold to the Baptist Convention in Haiti have not performed satisfactority due to poor manufacturing (excessive porosity in the castings and poor machining)
- the Moyno rotary handpump did not hold up well in the field and was removed from the field test after three breakages of the rotor rod within the first week after installation
- the Mono rotary handpumps and the Malawi reciprocating handpump have performed well in the field even though both Mono pumps required minor repairs shortly after installation.

Subsequent Manufacture and use of the AID Handpump in Ecuador (February 1982)

Handpump Program - Basic Description

Subsequent to the activities described previously in this appendix concerning the Ecuador AID handpump program, the decision was made by the Government of

Ecuador to use the AID handpump on a large-scale basis. This necessitated open, competitive bidding for the manufacture of the pumps. OTD No. 82 authorized Georgia Tech in February 1982 to carry out the following manufacturing and handpump installation operational program:

- assist USAID/Ecuador in selecting two Ecuadorian foundries for the manufacture of AID handpumps
- provide drawings, prototypes and continuous technical assistance throughout manufacturing
- provide local training in installation, maintenance and repair of handpumps
- develop an AID handpump local manufacturer quality control manual
- develop an installation, operation and maintenance handpump manual using a task and performance training approach
- attempt to develop an Ecuadorian counterpart to optimize supervision and quality control aspects
- continue field monitoring and evaluation of AID handpumps initially manufactured in Ecuador.

<u>Project History - General</u>

Action taken in carrying out the project included:

- selection of and technical assistance to Tirado Hermanos to manufacture 1,000 AID handpumps in Ambato, Ecuador and Metalurgica Ecuatoriana in Quito, Ecuador to manufacture 50 AID handpumps (Metalurgica Ecuatoriana was chosen in the event a second supplier should become necessary)
- delivery of a two-week task and performance based training workshop for 16 private volunteer organization representatives and U.S. Peace Corps volunteers who will assist in future installation, maintenance and repair of handpumps
- development of an AID handpump installation, operation and maintenance manual
- development of an AID handpump manufacturer quality control manual.

<u>New or Different Elements Introduced in Manufacturing</u>

Specific elements where manufacturing varied from other programs were:

- adoption of a poppet-type foot valve for the Tirado Hermanos pumps
- use of jigs and fixtures initially designed for the Honduran AID handpump program

- use of production gauges as part of the quality control program
- use of ABS injection molded pump cylinders where the threads were an integral part of the mold design.

New or Different Elements Related to Use

Handpump installation and field testing was excluded from this project. Thus, only limited information is available on the use of the pumps and their performance. It is, however, reported by the USAID Mission that 20 Metalurgica Ecuatoriana pumps have been recently installed by a private volunteer organization (Voz Andes). It is also reported that 25 of the Tirado Hermanos pumps have been recently installed by the Ecuadorian government's Ministry of Health.

Review of Project Results

The 20 Metalurgica Ecuatoriana and the 25 Tirado Hermanos pumps have been installed in the field for only a few months and no definitive conclusions can be reached as to their performance. However, no problems have been reported for the Tirado Hermanos pumps. Several (number unknown) Metalurgica Ecuatoriana pumps reportedly have leaked at the base where the pump body is screwed in.

Laboratory Testing as a Support to Field Testing

Laboratory testing, such as described here, provides information rapidly on the reliability and durability of a product. This information can then be used to refine a design or manufacturing process prior to widespread field testing and to predict maintenance requirements. The second stage, field testing, is used to further qualify the product design by exposing it to actual user conditions. Laboratory testing, generally,is continued during the field testing phase to constantly check correlation between field test results and laboratory test results. If field testing results contradict laboratory testing predictions of a product, laboratory testing procedures can then be modified to provide a higher degree of correlation between laboratory procedures and field test activities. However, in most cases, much of the AID handpump field testing preceded the laboratory testing. Nevertheless, the test laboratory is now in place and testing has been extremely worthwhile in complementing field data for a clearer picture of what must be done for a better handpump in future rural water supply programs of developing countries.

The handpump testing described in this report has complemented earlier field data identifying improvements in handpumps for future rural water supply programs of developing countries. For instance: (1) Laboratory testing has confirmed field observations that a leather flapper-type foot valve, while inexpensive, is not as durable as other alternative valves and should be replaced with a metal design such as that used in the Philippine handpump program. (2) Laboratory testing with one of the shallow-well pumps has shown negligible wear of properly hardened pins and bushings despite a complete lack of lubrication for more than 6 million cycles. (3) Threaded connections, such as where the pump body screws into the pump base, should be minimized as much as possible.

It was also observed in the laboratory test program, which permitted direct comparisons of pumps from many sources, that there has been a widespread variation in the quality of castings and machining of handpump components among the various handpump manufacturers throughout the world. Similar variation occurs in the hardening process for pins and bushings and generally makes regular lubrication a critical factor in field performance of the current AID pump design.

A review of the problems encountered in the installation and operation of handpumps included in this testing program leads to several major issues such as the quality of castings and machining accuracy. Reports from the Consumers' Association Testing and Research Laboratories at Harpenden, England with respect to the testing of handpumps also lead to similar conclusions. However, field and laboratory testing of the fabricated steel handpumps from Malawi indicate that steel fabricated pumps can perform well and should be easire to manufacture than cast iron pumps in less developed countries.

WASH